Control of Carbon Emissions and Energy Fiscal Reform in Spain

A Computable General Equilibrium Assessment

Ph.D. Thesis

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Me pongo el sol al hombro.

Y el mundo es amarillo.

Francisco Cabral

“*No soy de aquí, ni soy de allá*”

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Chapter 1

Introduction

1.1 Human activities and the climate change threat

This study presents a computable general equilibrium model to examine questions related to the interactions between the economy, the energy system and carbon emissions in Spain. More specifically, the investigation proposes to assess the potential impacts of different strategies to reduce carbon emissions[1] and improve energy efficiency in Spain over the medium term, with the objective of improving the analytical basis for the development of CO_2 emissions abatement policies[2]. As policy instruments, we consider fossil fuels taxes and final energy taxes, without prejudging which economic instrument should and would be used in Spain and in the EU, for controlling the impact of greenhouse gases and improving energy efficiency. Fossil fuels taxes are used as a proxy for 'carbon taxes', due to the linear relation between fossil fuels combustion and carbon dioxide emissions. Other major taxes are also targeted, under the constraint of public deficit neutral fiscal reforms. This allows to simulate the implementation of carbon taxes and energy taxes together with other tax policies, under the condition of constant public deficit to GDP ratio. The quantitative simulations presented in the study are based on a social accounting matrix (SAM) constructed for Spain in the year 2000. It therefore does not focus on the likely long term impacts on energy consumption and production patterns, nor on the specific short term impacts particular to the recent economic crisis.

Climate change has attracted a great deal of attention for years. There is an increasing scientific consensus that human activities do trigger climate changes and actual forecasts predict temperature increases that are likely to be beyond the adaptation potential of ecosystems. In its Fourth Assessment Report, the Intergovernmental Panel

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[1] We use the terms carbon emissions, carbon dioxide emissions and CO_2 emissions interchangeably.

[2] In this analysis, we restrict the impact of anthropogenic greenhouse-gases to carbon dioxide specifically.

on Climate Change (IPCC) of the United Nations Framework Convention on Climate Change (UNFCCC) states that warming of the climate system is “unequivocal”, as observed by the increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels. It also asserts that the probability that this is caused by natural climatic processes alone is less than 5%. For the IPCC, most of the observed increase in globally averaged temperatures since the mid-20th century is “very likely” due to the observed increase in anthropogenic greenhouse gas concentrations.

Human activities believed to be causing climate change result in emissions of four long-lived greenhouse gases (GHG): carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and halocarbons (a group of gases containing fluorine, chlorine or bromine). Global atmospheric concentrations of CO_2, CH_4 and N_2O have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values[3]. The IPCC calculates that, since 1750, the atmospheric carbon dioxide concentration has increased by more than 35% (from 280 parts per million, or ppm, to 379 ppm in 2005), while methane concentration has increased by 150% (from a pre-industrial value of about 715 ppb to 1774 ppb in 2005) and nitrous oxide concentration has increased by more than 15% (from a pre-industrial value of about 270 ppb to 319 ppb in 2005) [IPCC, 2007a]. The atmospheric concentration of carbon dioxide and methane in 2005 exceeded by far the natural range of the last 650,000 years (180 to 300 ppm for carbon dioxide and 320 to 790 ppb for methane), as determined from ice cores spanning many thousands of years. The IPCC notes that global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture.

Some concurrent explanations to the climate variability observed tend to question the significance to which atmospheric GHG have affected recent climate change. Among other theories, the cosmoclimatology theory, for example, asserts that galactic cosmic rays have more effect on the climate than anthropogenic GHG, trough variations in the intensity of the solar wind [Svensmark and Calder, 2007]. Regardless the merits of the concurrent theories, the current scientific concensus attributes, directly or indirectly, the current climate change in large part to human activities.

On current trends, the damage to the global climate could become catastrophic for some living species and largely irreversible [Solomon et al., 2009]: energy-related GHG

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[3] Halocarbons for example (halofluorocarbons, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride) are almost exclusively related to human activities, trough emission in industrial processes, and are not part of any natural cycle, such as the carbon cycle. They first appeared in the atmosphere in the 20th century and have thus increased from a near zero pre-industrial background concentration.

emissions will rise inexorably, pushing up average global temperature by as much as 6°C in the long term. Several countries (such as Spain, for example) are thought to be highly vulnerable to climate change, which could seriously affect the availability of their water supply, deteriorate their biodiversity and natural ecosystems, generating erosion, degrading the state of their coasts and presenting a threat to human health linked to rising temperatures and extreme weather events. To change this trajectory, a timely and ambitious programme of mitigation measures may be required.

Several studies have shown that, to stabilize global mean surface temperature, cumulative anthropogenic GHG emissions must be kept below a maximum upper limit. The goal of limiting the increase in global temperature to two degrees Celsius (2°C) above pre-industrial levels would for example require to reduce GHG emissions of 50% to 95% by 2050, compared to 1990 levels[4], thus indicating that future net anthropogenic emissions must approach zero[5]. Overshooting this threshold of maximum safe cumulative emissions, over a sustained period, implies a possibility of seeding irreversible catastrophic effects and no amount of emissions reduction will return the climate to within safe bounds for several ecosystems [Hansen et al., 2008]. The 2°C objective implies extensive cuts in GHG emissions trends. But the goal is not completely out of reach. It does mean however that much stronger efforts and ambitious policy commitments, costing notably more than what is currently done, will be required in the coming decades. In the long run, the sooner aggressive actions are taken to offset the effects of climate change, the less the overall cost to society would probably be.

To narrow the focus of our study, we concentrate exclusively on CO_2 emissions, among GHG emissions. The main reason to focus on CO_2 emissions is that it represents by far the most significant contributor of anthropogenic gases and the most long-lived gas[6]. In total, carbon dioxide makes up roughly 75% of global anthropogenic GHG emissions, while methane comes as a distant second, with 15% of all GHG emissions. Because carbon dioxide is the dominant component in GHG emissions, initiatives to offset climate change often strongly emphasize CO_2 emissions abatement. This is not to say that climate change efforts must focus exclusively on CO_2 emissions. It is rather an observation that any policy that does not have a strong CO_2-abatement

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[4] The IPCC's 2007 Fourth Assessment Report [IPCC, 2007a] states that temperature rises have around a 50:50 chance of being kept to within 2°C of preindustrial levels if atmospheric GHG concentrations are stabilized at around 450 ppm (parts per million; measured in CO_2-equivalent concentration). To achieve this stabilization, it was first suggested that developed country emissions would have to reduce their GHG emissions of 50% to 80% by 2050. However, more recent analyzes increased the required reductions for developed countries at 80% to 95% [Allison et al., 2009].

[5] See for example Broecker [2007], Raupach [2007], Matthews and Caldeira [2008], Allen et al. [2009], Meinshausen et al. [2009] and Solomon et al. [2009].

[6] Carbon dioxide emissions can remain in the atmosphere for 100 years or more, which implies long lags between changes in the level of emissions and changes in the stock of atmospheric GHG.

component will not effectively address the core of the climate change problem. A second reason is that estimations for the other GHG emissions (methane and nitrous oxide) must follow a bottom-up approach with a disaggregated description of the technologies used. Therefore, their estimation usually generates an important error margin due to the uncertainty related to the emission factors and sources. Estimations of carbon emissions are on the contrary much more precise and reliable given that they result at 98% from the combustion of fossil fuels and CO_2 emissions do not depend on the combustion technology.

As we discuss in the next chapter, anthropogenic CO_2 emissions have risen considerably during the last decades, putting Earth's ecosystems on a trajectory towards rapid climate change that is both dangerous and irreversible. Globally, human activity is responsible for the appropriation of 16 Gtonne of carbon per year from the biosphere, which corresponds to 25% of potential terrestrial net primary productivity[7] [Haberl et al., 2010]. Higher rates of appropriation will increase pressure on global ecosystems, exacerbating a situation that appears already unsustainable [Wackernagel et al., 2002]. If one of the reasons to the problem of global warming comes from excessive carbon levels in the atmosphere, due to anthropogenic emissions, the logical solution would be to halt this process and put the carbon back in the earth where it "belongs".

Mitigation strategies on CO_2 emissions are thus two-fold: on the one hand, draw down excess CO_2 from the atmosphere trough carbon capture and sequestration methods, and, on the other hand, strictly reduce the current pace of anthropogenic CO_2 emissions. With regard to carbon sequestration, soils could store for example more organic carbon in their surface layers via biological processes in agricultural and forestry activities and trough coherent land management practices[8]. Then again, massive cuts in anthropogenic CO_2 emissions require a far-reaching transformation of the global energy system that has to occur at a quick pace in order to have a real impact on energy demand and supply. In sum, a combination of environmental and energy policies.

The reason why energy policies are a critical target for reducing GHGs is straightforward: two thirds of the world's total anthropogenic GHG emissions are the results of energy production, transformation and consumption of fossil fuels. So, the

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[7] Human appropriation of net primary production is the aggregate impact of land use on biomass available each year in ecosystems. It represents a prominent measure of the human domination of the biosphere.

[8] Given the relative mass of carbon dioxide to carbon, each unit of mass of soil carbon removes 3.67 times the mass of CO_2, so that one additional ton of soil carbon removes 3.67 tons of CO_2 from the atmosphere. Hence, given that carbon represents approximately 50% of soil organic matter, carbon sequestration in soils, such as biochar, has the technical potential to make a non-trivial contribution to mitigating climate change at current levels of feedstock availability, while preserving biodiversity, ecosystem stability and food security [Woolf et al., 2010].

response to this challenge of sustainable development is also clear-cut: reducing anthropogenic emissions will ultimately requires a major 'decarbonisation' of the world energy sources, through major improvements in efficiency and rapid switching to renewables and other low-carbon energy sources and technologies, such as carbon capture and storage.

1.2 Initiatives adopted: Strengths and shortcomings

What has been done? The last two decades have witnessed significant steps forward in policy making, with the negotiation of important international agreements to alleviate climate change impact and eliminate inefficient fossil-fuel subsidies[9]. The United Nations Framework Convention on Climate Change (UNFCCC), signed by almost all countries and which came into effect in 1994, is commonly seen as the starting point for the international effort against climate change. The Kyoto Protocol of the UNFCCC adopted in 1997 [United Nations, 1997] has been by far the most comprehensive multinational effort to regulate the GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, complementing various national policies and measures enacted so far. The Protocol entered into force in February 2005, establishing legally binding objectives to the industrialised countries (Annex I countries) to curb collectively GHG emissions[10] by 5.2% by the 2008-2012 period relative to 1990. This objective is modulated among countries; being of 8% for the European Union, 6% for Japan and 0% for Russia for example.

Under three “flexible mechanisms”, such as emissions trading, the clean development mechanism and joint implementation, the Protocol aimed at encouraging greater international co-operation in development and application of CO_2 control strategies. Annex I countries can earn emission credits from financing emissions reduction projects in participating developing countries and economies in transition (EIT) countries. However, despite its ratification by 192 countries and one supranational union (the EU), the impact of the Protocol on reducing global emissions stays limited since not all major emitters are included in the legally binding reduction commitments. Most non-Annex I countries have signed the Protocol, but they do not face emissions targets. The United States, responsible for 36.1% of the 1990 emission levels of Annex I

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[9] In its 2011 *Clean Energy Progress Report*, the International Energy Agency found that fossil fuels currently attract $312bn in consumption subsidies, versus $57bn for renewable energy [IEA, 2011]

[10] The reductions in emissions apply to the four greenhouse gases (carbon dioxide, methane, nitrous oxide, sulfur hexafluoride) and two groups of gases, hydrofluorocarbons and perfluorocarbons, all converted into CO_2 equivalents. Emission limits do not include emissions by international aviation and shipping.

countries, did signed the Protocol (for a reduction objective of 7%) but never ratified it.

The 2009 UNFCCC Copenhagen Accord on climate change defined a collective and non-binding objective of limiting the increase in global temperature to 2°C above pre-industrial levels. Higher funding for low-carbon technologies, as part of fiscal stimulus packages, have also been increased while some commitments to eliminate fossil-fuel subsidies were proposed by the G-20 and APEC countries. Overall, some very positive steps have been taken and major policy commitments have been implemented during the last two decades, since the 1992 UNCED Rio Convention. But much more needs to be done to ensure that the transformation of the global energy system into a sustainable energy system happens quickly enough.

Overall, making GHG emissions a scarce resource within Annex I countries has been one of the major step forward resulting from the Protocol limit on the GHG emissions of Annex I countries. The valuation of carbon emissions as a tradable commodity has been the key driver for the development of emissions trading schemes (ETS). Without an established carbon emissions price, it would indeed be nearly impossible to create sustainable economic incentives for reducing emissions.

Who pays the bill? A hard dilemma... The Protocol ambition of stabilizing the CO_2 content of the atmosphere by sharply reducing carbon emissions worldwide is however far from being realized. Several factors tend to counteract these objectives: increasing world population, higher energy consumption per capita and more fossil fuels in the energy mix. Because of continuing population growth, projections forecast that, under a business as usual scenario, 1.4 billion people will not have access yet to electricity in 2030; while most of the growth in emissions over the next 20 years will occur in developing countries [IEA, 2006].

The International Energy Agency (IEA) has been warning for years about their trend projections of fossil fuels remaining the dominant energy sources in 2035, driving up energy-related GHG emissions through the projection period, albeit the rate of growth falls progressively. Despite some tangible improvement in the energy mix with respect to past trends, they expect a likely temperature rise of over 3.5°C in the long term, which the scientific community predicts will have unacceptable implications for the planet [IEA, 2010]. The current global efforts to reduce GHG emissions seem thus to fall short of what would be required to put the world onto a path to achieve the Copenhagen Accord's goal of limiting the global temperature increase to 2°C.

In the 2011 *Special Report on Renewable Energy Sources and Climate Change Mitigation*, the IPCC backs up the claim that renewable energy sources such as solar power, wind, biomass and hydropower could meet nearly 80% of the world's energy supplies by 2050 if governments pursue policies that harness their potential [IPCC, 2011]. Some first line organizations have drawn similar scenarios with a transition to a 95% sustainable global energy system by 2050 [Ecofys, 2011]. With a 2050 horizon, it seems in fact realistic to provide world wide energy for all purposes from wind, water, and sunlight. Barriers to the plan are primarily social, economic and political, not technological [Jacobson and Delucchi, 2010].

While the scientific community is reaching a general consensus on the necessity to reduce GHG emissions and transform the global energy system, it is true that the available methods for implementing abatement policies tend to represent a financial burden on society in the short term. And the payoff of aggressive abatement will likely not be seen for at least another generation. Furthermore, the lack of an international authority makes it hard to implement an efficient tax system to deal with GHG emissions and eliminate the potential free rider problem. Also, climate change and sustainable energy system are not the only concerns for the population and governments. Difficult decisions for policymakers are furthermore compounded during economic recessions. When public revenues fall, the response is often to consider the cheapest options to combat climate change, even tough such solutions are not the most effective in the long run.

Further steps to curb CO_2 emissions Time is always key. Making a meaningful difference to levels of global GHG emissions will require significant changes in several aspects of the world economies. We can roughly identify two major paths of change to respond to the twin challenges of climate change and energy security. First, on the supply side, an increase in energy efficiency, technology breakthroughs and a better energy mix. Second, on the demand side, an adaptation of fossil-fuel prices to some carbon penalties in order to affect fossil fuel demand.

On the nearest term, much of the improvements lie predominantly in energy efficiency, trough the use of more efficient appliances and energy savings in transport systems, buildings, industry (including coal-fired power plants) and energy end use. Energy efficiency not only should help reduce CO_2 emissions, but it could improve energy security of supply and foster economic growth, by lowering energy demand and stabilizing fossil fuel prices for example. The problem is that efficiency is not a free good, as consumers and firms will have to pay a cost for more energy efficient consumption and investment goods. Hence, technology breakthroughs remain crucial in cost-effective renewables, biofuels, fuel cells, energy transportation and carbon capture and storage.

Successful application of CO_2 control technologies depend not only on technical achievements, but also on the existence of an appropriate and clear financial and regulatory framework, designed to foster the development and implementation of the most suitable technological options. To improve energy efficiency and the use of energy-efficient technologies, a strategy of increasing the prices of energy sources (and not only the fossil energies) could also bring an important restructuring of the power generation sector and the heavy industry, even tough higher energy prices are of course a double-edged sword. The role of government policy action will be crucial, but to be significant, a broad support will need to come from governments, industry and the public at large.

The need for economic incentives: CO_2 emissions as a commodity Given the current fossil fuel reserves, and the absence of important resource constraints for decades to come (see estimates in chapter 2), fossil fuel prices on international markets should not suffer excessive upward pressures, except maybe for oil. And without shortage of fossil fuel resources, market prices will not be a sufficient incentive to restrain demand growth for fossil fuels and the related increase in GHG emissions. What could thus act as a strong stimulus to put the world on track to meet the goal of limiting temperature rise to 2°C?

Economic theory on external costs states that environmental damage associated with fuel use may generate substantial social welfare loss and misallocation of resources if these costs are not accounted for in market prices. The idea that control of global warming is costly is a misperception as it rests on the false assumption that the resource allocation of the world economy is efficient without mitigation measures. But, in the presence of such an externality, the world economy is not on its efficiency frontier. It is thus widely recognized that setting prices to internalize the costs associated with GHG emissions should be considered a cornerstone policy in climate change mitigation in market economies.

The economic logic of this policy is quite straightforward: by assigning an economic value to CO_2 emissions, they could be used to generate an income stream and a major incentive for reducing them would be created. Potentially, there are several types of broad policy instruments that could be used to do this. Emission trading systems are already being implemented in several countries, as it is the case for the European Emission Trading Scheme (EU-ETS). The other alternative are 'carbon taxes', a tax levied on CO_2 emissions, like the ones introduced in Finland, Sweden, Norway, Denmark, the Netherlands, Germany, the United Kingdom and Italy [Bosquet, 2000; Labandeira et al., 2008]. For both instruments, only large CO_2 emitters are usually targeted.

For the case of 'carbon taxes', their primary purpose is to reduce damage to the environment by increasing the costs of social costly actions, such as the use of fossil fuels that produce CO_2 trough carbon combustion. If the size of the taxes is adjusted to the monetary value of the environmental damage that the actions cause, firms and consumers will then be forced to take account of the effects of their actions on the environment. Under the strict condition that the revenue from such Pigouvian carbon taxes was sufficiently large to fund all government expenditures, the existing distortionary taxes could be completely removed and the economy would be undistorted by either taxation or environmental externalities.

The theory behind full cost pricing, however, cannot be easily applied. Such a taxation would require for example to integrate damage cost by differentiating tax rates according to the external damage costs of the different input fuels. And evaluation of precise external damage costs is not so straightforward. More importantly, there will probably always be other distortionary taxes in place, as environmental taxes would not be sufficient to finance expenditure levels of most governments. Therefore, in a "second best" real-life situation, it is more appropriate to consider carbon/energy taxes as reducing rather than entirely replacing other taxes. This implies to evaluate the complex interaction between carbon/energy taxes and other existing taxes. As these other taxes can sometimes be regarded as "distortionary" in the efficient functioning of markets, any reduction in their rates can result in efficiency improvement and thus generate a social benefit. For that reason, carbon/energy taxes may have the potential to generate two different benefits: providing environmental and energy efficiency improvements together together with an improvement in economic efficiency, by using the new government revenue to reduce other "distortionary" taxes in the tax system, maintaining unchanged the public revenues (or the ratio of public deficit to GDP).

Promoting a tax swap In this study, we examine the impact of several "fiscally neutral" tax initiatives that insure a constant ratio of public deficit to GDP. Instead of recycling carbon/energy tax revenues trough a lump-sum transfer to households, we consider alternative ways of shifting the tax burden, by using the fiscal revenues from carbon/energy taxes to compensate for the reduction in other distortionary tax rates. This would allow to investigate whether it is possible to curb CO_2 emissions and benefit at the same time from improving the economic efficiency of the fiscal system. This is the idea behind the "double dividend" hypothesis. More precisely, we consider some 'tax revenue-equivalent' *ex-ante* rebates in different existing taxes (VAT, income taxes, Social Security contributions) and finance the corresponding tax revenue loss by imposing new taxes on the energy and carbon content of energy inputs, such that we maintain *ex-post* a constant ratio of public deficit to GDP.

The discussion about the increase in energy efficiency and the concomitant CO_2 emissions reductions cannot be separated from the debate on the fiscal treatment of production factors. Firms will indeed operate substitution not only in favour of less carbon-intensive technologies, but also in favour of the production factors whose costs become relatively cheaper. In this case, for example, if reduction in labour costs more than compensates for the increase in energy prices, firms could face a total reduction in production costs. The emissions abatement and energy efficiency questions become thus particularly interesting when they get linked to measures targeting other policy priorities such as unemployment.

1.3 Methodological framework of the research

To take into account the macroeconomic closures and the ressources allocations mechanisms of the proposed tax reforms, the impact of these tax reforms will be simulated with a computable general equilibrium model (CGE), formulated as an Arrow-Debreu equilibrium model and written down as a mixed complementarity problem (MCP). This formulation presents the advantage to provide a stylized and consistent framework of the Spanish economy in the year 2000, to analyse the interactions of the main agents in the economy, assumed to be in general equilibrium (producers, consumers, government, foreign sector, etc.).

CGE modelling has become a standard tool for the analysis of the economy-wide impacts of policy measures on resource allocation and the associated implications for agents' incomes. The proposed modifications to the tax structure, trough their changes in relative prices and revenues, may indeed generate major impacts at the macroeconomic level (GDP and its components, employment, costs and prices, public finances and the balance of payments), sectoral level (industry's optimal mix of inputs, private and public consumption patterns), and on energy consumption and CO_2 emissions. Partial equilibrium framework studies do not offer a comprehensive interpretation of these larger macroeconomic impacts on an economy-wide system and its possible integration within a broader strategy of climate change policy. It results rather inappropriate to use partial equilibrium models to evaluate the fiscal cost of the above-mentioned policy measures, as their final impacts will differ from the direct or initial cost, to the extent that the taxable base itself changes as a consequence of these measures.

The usefulness of a CGE model, taking into account the main fiscal distortions, lies in its ability to evaluate the general-equilibrium effects of tax changes on the prices and quantities of goods and production factors; measure the subsequent effects on economic efficiency and the welfare of the households; and highlight how various economic parameters influence the effects of tax reform on relative prices and resources allocation. Constructing a general equilibrium model implies deriving demand and supply functions for goods and factor markets, as well as describing the macroeconomic closures of the economy as a whole. Many of those models are multi-sector models that analyse different issues from a single country or a multi-country perspective in economies with an extensive system of distortionary taxes.

The major contribution of this study lies in the implementation of a new CGE model for Spain, constructed specifically to analyse the impacts of an original tax policy promoted by the European authorities: the implementation of a joint tax on the energy content and carbon content of fossil fuels. To our knowledge, this tax policy hasn't been studied yet within a CGE model for Spain. To do so, this research develops two aspects that we consider crucial to assess the effects of an energy fiscal reform in Spain.

First, this study is based on a new social accounting matrix (SAM) constructed for Spain, with data corresponding to the year 2000. This SAM has been specifically designed to take into account the reactions of the economic agents to energy policy measures, by a careful disaggregation of economic activities and consumer goods. Derived from the SAM, the model presents a detailed specification of the energy use for production and consumption activities, allowing substitutions between energy inputs.

The database distinguishes some major features of the Spanish tax system, in order to capture important economic effects that could occur under an energy tax reform. It includes a variety of instruments of economic policy trough direct taxes, indirect taxes, Social Security contributions and transfers. A detailed tax structure of the Spanish economy can be of crucial importance in understanding how energy tax reforms actually work and affect economic outcomes, under second-best taxation. When data are available, the tax/subsidy items are differentiated by sector, production factor, consumption type or income source. We believe this distinction effort makes the new social accounting matrix a consistent information source on taxes and subsidies on products. All of these taxes, particularly when they are levied at different rates on different sectors, affect the relatives prices, which alter the the allocation of resources and the behaviours of the firms and the consumer. Tax burdens are shifted trough changes in supply and demand behaviours and thus trough changes in prices.

Second, the new static CGE model of a small and open economy is specifically developed to consider the links between energy use, the economy and the environment (carbon emissions). Around a standard theoretical framework, the model presents several specific characteristics which allow to take into consideration the interactions between energy policies and the existing fiscal system in Spain. So, the main variables of the Spanish fiscal system are initially reproduced within the model, allowing to evaluate the welfare impacts under a second-best perspective. In this case, the analysis of fiscal policies concentrates on the economic efficiency impacts of the tax reforms and does not consider distributional aspects.

These two aspects should help to capture the possible driving forces for curbing down CO_2 emissions in Spain and improve energy efficiency. The implementation of the model will help investigate whether a fiscal reform on energy use can influence the agents to modify their production and consumption patterns, and switch towards less energy intensive and carbon intensive activities.

The study is organised as follows. Chapter 2 provides the situation of CO_2 emissions on a world scale level and, more specifically, for Spain and other members of the European Union. Since the convergence and harmonisation of energy and fiscal policies represent a declared objective for the European Union countries, we try to present most statistics for Spain in comparison with the ones for the other members of the European Union. We describe some past and current paths within the Spanish energy market, and the related CO_2 emissions trends. To introduce the extent of the current tax policy related to climate change mitigation, we present first some general features of the Spanish tax system and how environmental taxes fit into that system. Under the hypothesis of the 'double dividend', we then propose the alternative policy scenarios to be simulated.

Chapter 3 offers an overview of the general equilibrium methodology and incorporates this work into the existing literature in energy tax reform, for Spain in particular. We also discuss the general features and key issues of the model and justify some of the most important assumptions. Chapter 4 presents the social accounting matrix constructed for the analysis and explains how to compute carbon emissions in the economy. Chapter 5 gives a complete description of the model, by providing specific equations for all the agents of the model and for the foreign sector. In this section, we describe also the specification of the labour market and the macroeconomic closure rules. Once defined the behavioural equations, chapter 6 identifies the equilibrium conditions of the model and the solution concept applied. We detail the calibration procedure and how to compute the carbon emissions tax. Subsequently, in chapter 7, the results of the policy scenarios simulations are presented. Some concluding remarks about the relevance of the results and the limitations of the model and methodology used are summarized in the last chapter.

Chapter 2

Emissions Control Policies in Spain and Europe

2.1 Global CO_2 emissions and the European policy

2.1.1 Fossil fuels: world supply and demand

Energy demand on the rise

Energy is the driving force behind the economy and the supply of energy is of course a prerequisite for its functioning. Since approximately 1850, global use of fossil fuels (coal, oil and gas) has increased to dominate energy supply. Primary energy consumption has increased worldwide by about 190% since 1965, 68% since 1980 and by 38% since 1990 (*figure* (2.1)). There was a continuous increase in oil and natural gas consumption while coal consumption had almost stagnated from 1987 to 2002. Then, from 2002 up to now, coal consumption started to augment consistently, owing to the sharp increase in Chinese coal demand.

In its World Energy Outlook 2010, the IEA presents detailed projections up to 2035 regarding energy demand, under three alternative scenarios[1] [IEA, 2010b]. Under all scenarios, global primary energy demand continues to grow (an average increase of around 35% between 2008 and 2035), but at a slower rate than in recent decades. Fossil fuels continue to be the main energy source, accounting for about 75% of the

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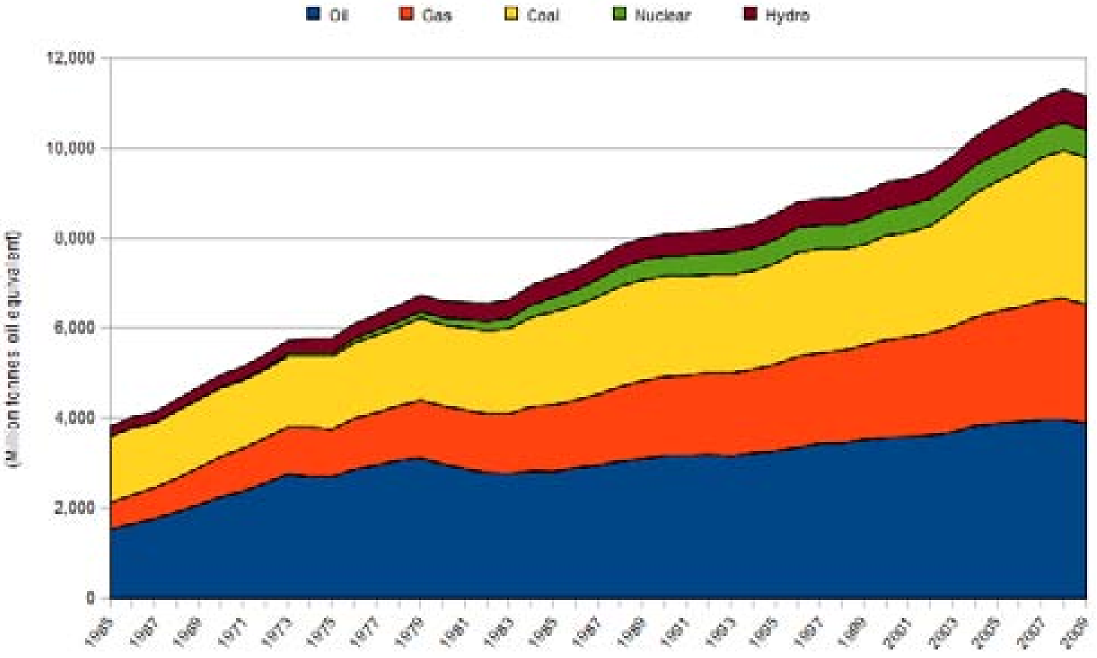
[1] These are the following:

- a *Current Policies Scenario*, as a baseline case in which only policies already formally adopted and implemented are taken into account;
- a *New Policies Scenario*, which assumes the introduction of new measures to implement the broad policy commitments already announced, such as national pledges to reduce GHG emissions and, in certain countries, plans to phase out fossil energy subsidies;
- third, the 450 Scenario, which sets out an energy pathway consistent with the goal of limiting the global increase in average temperature to 2°C (equivalent to a maximum concentration of GHG in the atmosphere of 450 parts per million of carbon-dioxide equivalent (ppm CO_2-eq)).

energy mix in 2035, compared to 88% of the world's energy needs in 2008. According to IEA estimates, in 2035, oil demand is up by 18%, coal demand is around 20% higher and natural gas increases by 44%. OECD countries increase their energy consumption by 14%, increasing even more their energy imports. But the most rapid growth in energy demand until 2035 should come from non-OECD countries, increasing energy consumption over 80% between 2007 and 2035, where population and economic growth are greater than in OECD countries and where the rate of migration from rural to urban areas is significantly higher. China alone, with its current per-capita energy use still only one-third of the OECD average, could account for some 30% of increased energy demand, making it the world's biggest energy consumer.

Figure 2.1: Primary energy consumption (million toe). World, 1965-2009.



Source: BP (2010) , *BP Statistical Review of World Energy, 2010 Edition.*

A look at the percentage share of primary energy consumption by fuel type for the years 1965-2009 (*figure* (2.2)) indicates that oil is the world's most important primary fuel, accounting currently for 35 % of the world's primary energy consumption[2]. Demand for oil will continue to grow, primarily owing to rapid growth in vehicle ownership in non OECD nations. Therefore, within energy markets, oil should probably remain the most important energy fuel for many years to come, even under the most optimistic forecasts about the pace of development of alternative energy technology.

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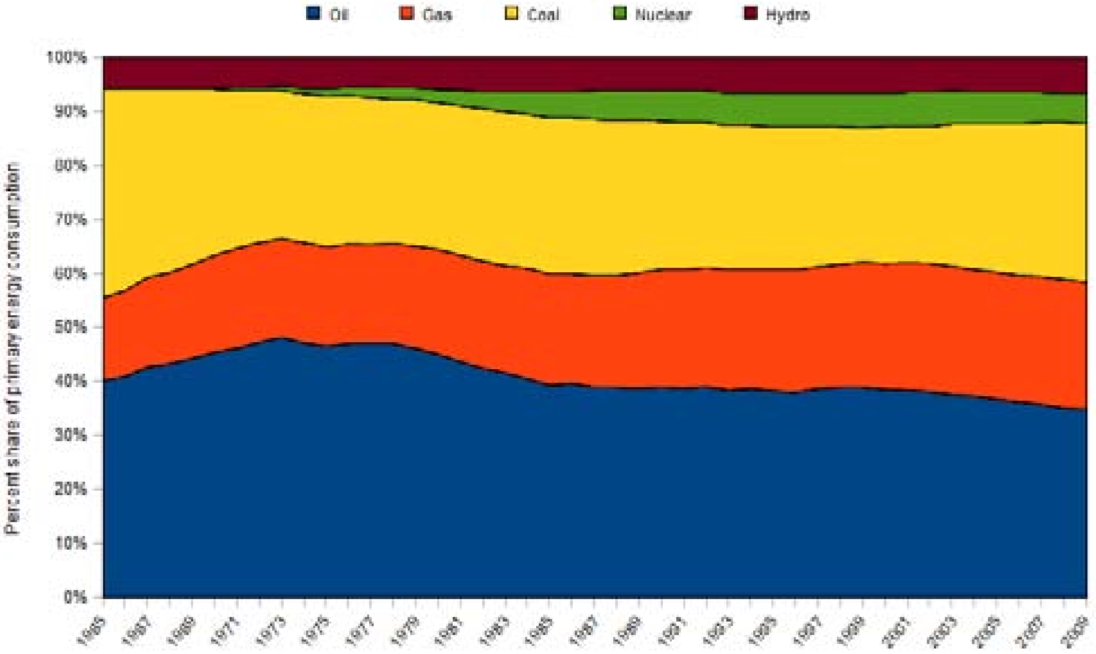
[2] Oil consumption data includes inland demand plus international aviation, marine bunkers and oil products consumed in the refining process. Consumption of fuel ethanol and biodiesel is also included.

According to this figure, coal shows the highest recent increase among the three fossil fuels, on a global basis. Also, given the current trends, it may take decades before renewables (included in the 'hydro' category) are able to provide a sizeable contribution to meeting energy demand.

Figure 2.2: Percent share of primary energy consumption. World, 1965-2009.



Source: BP (2010) , *BP Statistical Review of World Energy, 2010 Edition.*

Energy supply and proved reserves

Estimates of proved conventional oil reserves[3] ranged from about 1.2 to 1.3 trillion barrels at the end of 2009[4], having doubled since 1980 (see *figure* (2.3)). On the other hand, recoverable conventional oil resources (including initial proven and probable reserves from discovered fields, reserves growth and oil that has yet to be found) are estimated at 3.5 trillion barrels. In terms of production, only a third of this total, or 1.1 trillion barrels, has been used up to now [BP, 2010]. Taking into account the proved reserves for conventional oil and given the current pace of oil production, the maximum production of conventional oil (or "peak oil") would thus be estimated to occur around 2020. Thereafter production will start to decline[5].

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[3] Proved reserves of oil are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and geological conditions.

[4] Some uncertainties regarding the proper assessment of reserves in OPEC countries could lead to an upward bias in the estimation of the oil production potential.

[5] The term "peak oil" refers to the maximum rate of the production of oil in any area under consideration, recognizing that it is a finite natural resource, subject to depletion.

In addition to conventional oil reserves, non-conventional oil resources (oil sands and extra heavy oil), which have been barely developed to date, are also very large and amount to about one third of the conventional oil reserves. Almost half of these non-conventional oil resources are located in oil shales, which would involve high recovery costs and serious environmental problems[6]. Apart from the technological improvements to increase recovery rates in the current producing fields of conventional oil, its is expected that, after "peak oil", the non-conventional oil production will help to slow down the decline in oil supply rather than close the gap between demand and supply. Hence, taking into account the reserves of conventional and non-conventional oil resources together with the increasing quantities of NGL[7] from rising natural gas production, the "peak oil" may be reached 10 years later than 2020. Another way of presenting the situation of current reserves, is to use the 'reserves-to-production' (R/P) ratios, which represent the number of years that the remaining reserves would last if production were to continue at the previous year's rate. It is thus calculated by dividing remaining reserves at the end of the year by the production in that year. If oil production data includes crude oil, shale oil, oil sands and NGLs (an not biomass and coal derivatives), *figure* (2.3) shows that the current oil reserves would be sufficient to supply energy needs for the next 45 years, under the 2009 production rates.

Regarding natural gas, *figure* (2.2) shows that it accounts for about 24 % of the world's primary energy consumption in 2009. The world's natural gas resources are quite important, but, like oil, they are highly concentrated in a small number of countries and fields. More than half of the gas reserves are located in Russia, Iran and Qatar alone, while 25 fields alone hold also half of the reserves worldwide [BP, 2010]. Remaining proven reserves amount to more than 180 tcm, equal to around 60 years of current production. The constant R/P ratio since 1980 indicates that global reserves of conventional natural gas have increased at the same pace than production, as shown in *figure* (2.4). Hence, with respect to expected demand, natural gas should be available in sufficient quantities for several decades to come. Furthermore, the use of horizontal drilling in conjunction with hydraulic fracturing has greatly expanded the ability of producers to use the resources of "non-conventional" natural gas, or shale gas, from low permeability geologic formations, particularly shale formations [EIA,2011].

Coal accounted for around 30 % of the global primary energy consumption in 2009. While the size and location of reserves of oil and gas are limited, coal remains plentiful and widely distributed around the world. Proved reserves of coal are available in more

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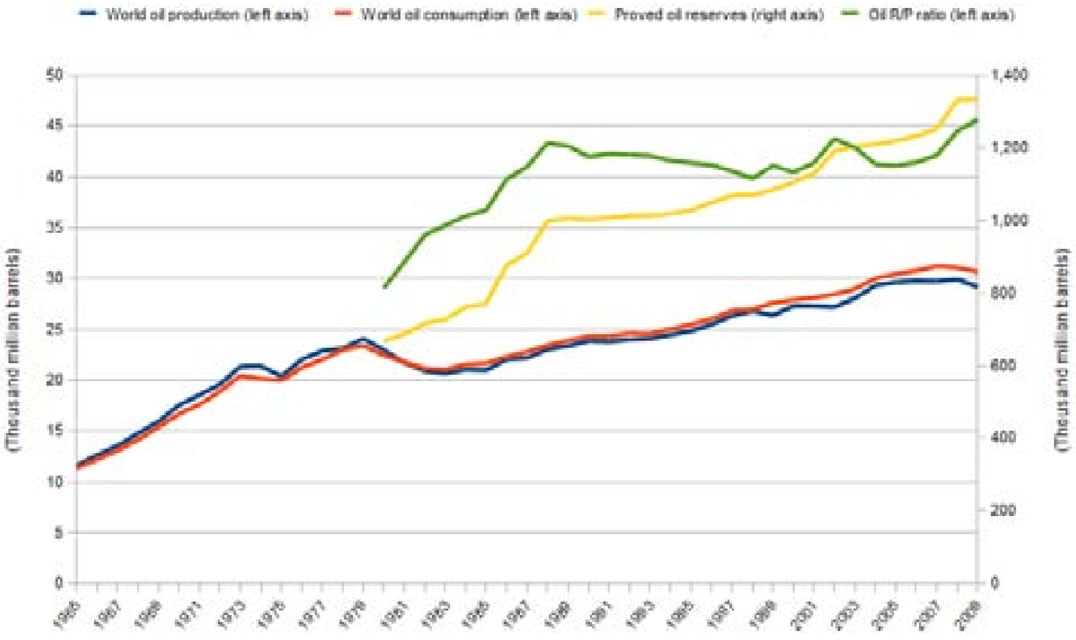
[6] These reserves are largely concentrated in Canada and Venezuela. It is calculated that between 1 and 2 trillion barrels of oil sands and extra-heavy oil may be ultimately recoverable economically [BP, 2010].

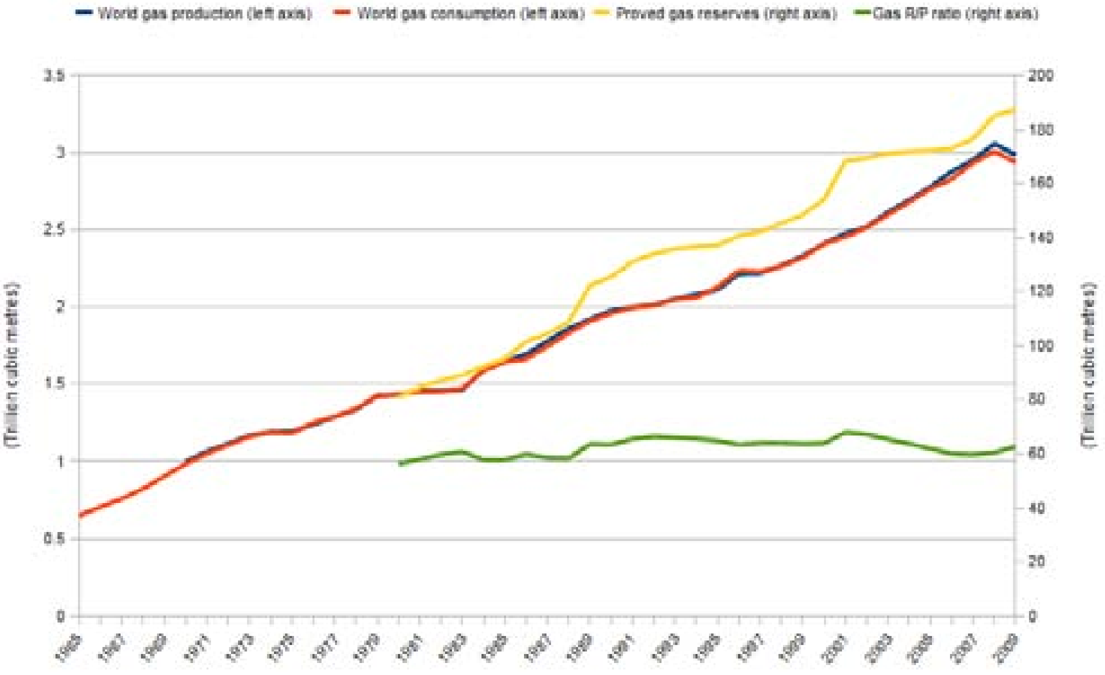
[7] NGL, or natural gas liquid, is the liquid content of natural gas, recovered separately when natural gas is extracted.

Figure 2.3: Oil: production, consumption and proved reserves. World, 1965-2009.



Source: BP (2010) , *BP Statistical Review of World Energy, 2010 Edition.*

Figure 2.4: Natural gas: production, consumption and proved reserves. World, 1965-2009.



Source: BP (2010) , *BP Statistical Review of World Energy, 2010 Edition.*

than 70 countries worldwide, and in each major world region[8] [BP, 2010]. With some

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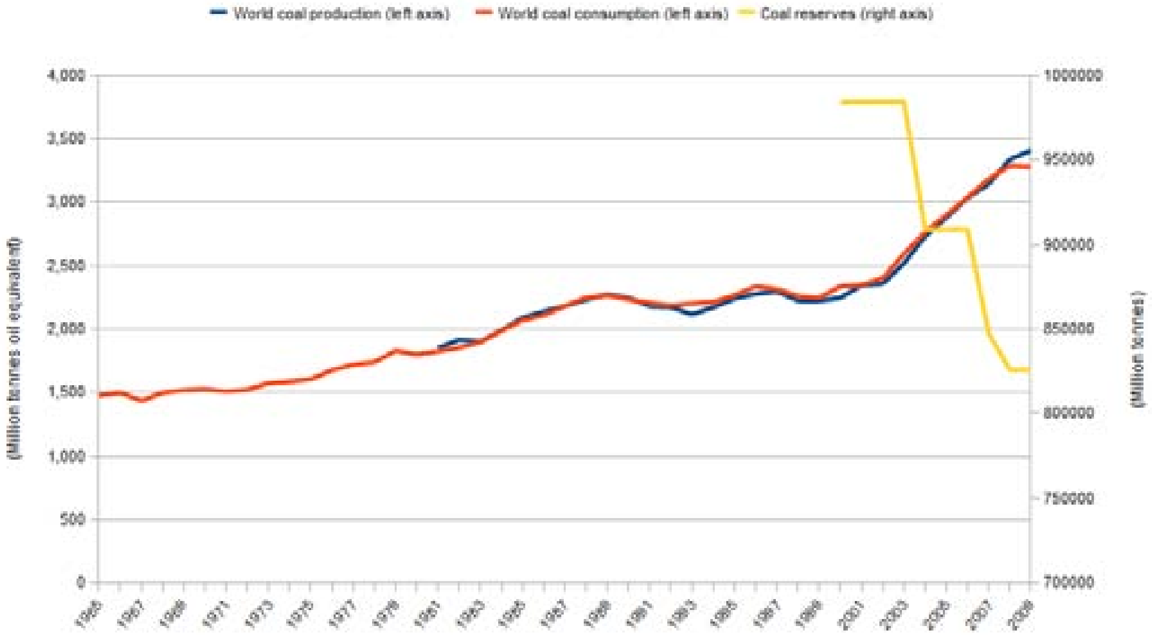
[8] Proved reserves of coal are considered to be those quantities that geological and engineering

825 billion tonnes of coal as currently recoverable, coal has the most favourable reserves to production ratio among the fossil fuel resources. The existing reserves of hard coal are sufficient for 120 years of production at the 2009 level, compared with 63 years for natural gas and 45 years for oil (see *figure* (2.6)). As OECD and non-OECD countries alike can be expected to continue using their abundant coal reserves, it seems clear that coal will continue to be a major source of the world energy mix, meeting expected future demand for many decades to come. But coal is also the most polluting fossil energy resource, in terms of CO_2 emissions. So, research will have to focus on solutions to reduce CO_2 emissions during coal burning, such as more efficient coal combustion technology, CO_2 capture and underground storage of carbon residuals.

Figure 2.5: Coal: production, consumption and proved reserves. World, 1965-2009.



Source: BP (2010) , *BP Statistical Review of World Energy, 2001 Edition to 2010 Edition.*

The question of fossil fuel prices

The surge in fossil prices in recent years, with the intermediary halt in 2008 owing to the global financial crisis, has been coupled with much greater short-term price volatility for natural gas and oil in particular. These price variations have highlighted just how sensitive prices are to short-term market imbalances, rising demand and production costs. But they have also alerted people to the ultimately finite nature of fossil fuel resources. It is indeed becoming increasingly apparent that the era of cheap oil is over.

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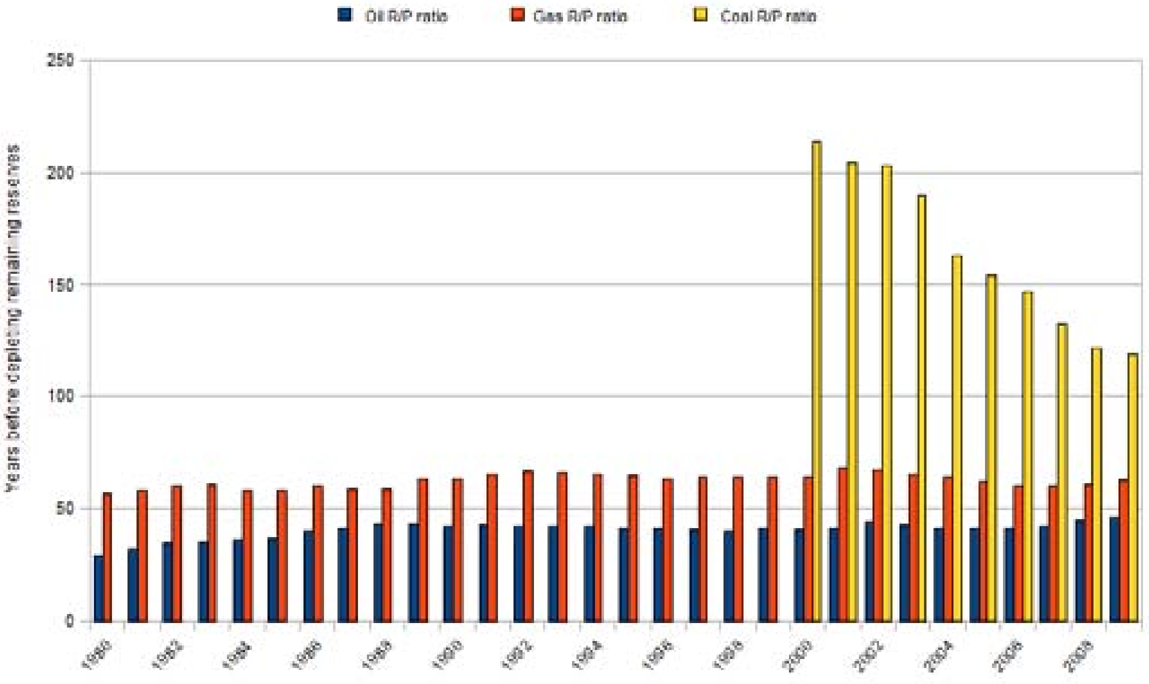
information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions.

Figure 2.6: Reserves to production ratios for fossil fuels. World, 1965-2009.



Source: BP (2010) , *BP Statistical Review of World Energy, 2001 Edition to 2010 Edition.*

On the other hand, being the most abundant fossil fuel, coal is expected to remain the most affordable fuel for power generation in many developing and industrialised countries for several decades. Its affordability and lack of price volatility are indeed underlining its key role as an energy source for the future.

High fossil fuel prices (oil and gas in particular) will of course raise credible economic possibilities for inter-fuel substitution. But, as we just described, statistics show that fossil fuels currently supplying the world's energy needs will remain in abundant supply for the coming decades. This will remain the case, in spite of anticipated cost increases, as the cheapest oil and gas reserves are depleted and extraction costs and transport distances increase for obtaining new supplies. For CO_2 emissions, the implicit conclusion is clear: if fossil fuel production peak will not be caused by resource constraints in the nearest future, then fossil fuel reserves may not be low enough to have a significant impact on prices, and thereby reducing demand and the subsequent CO_2 emissions from fuel combustion.

In order to reduce the demand for fossil fuels as soon as possible, authorities must act more vigorously than currently planned to encourage more efficient use of fossil fuels and the development of renewable energies. Also, they may reduce the demand for fossil fuels trough higher prices. If policymakers do just a little more than at present, we can expect an almost certain increase in fossil fuels demand, due in part to the growing weight of China, India, the Middle East and other non-OECD regions in energy markets. At the same time, supply costs will rise, vulnerability to supply disruptions will grow and the economic and environmental burdens of fossil fuels use should increase.

2.1.2 Trends in global CO_2 emissions

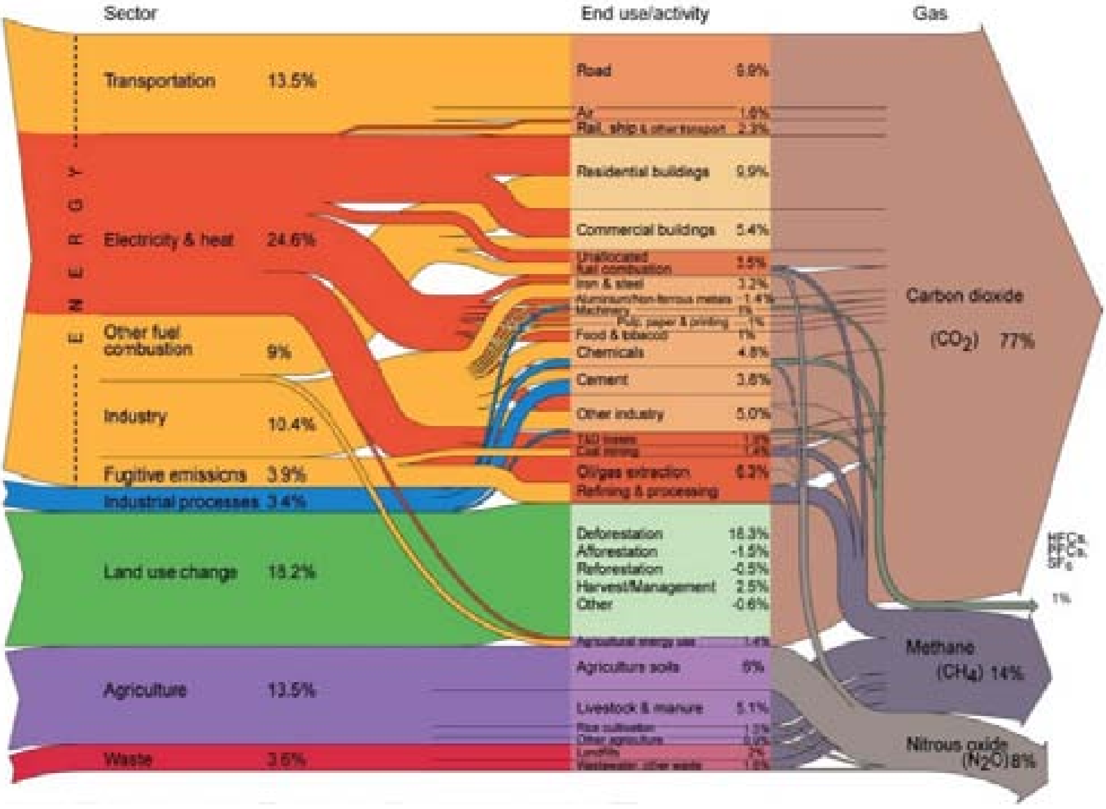
CO_2 emissions from fossil fuels combustion

Of all the human activities that produce greenhouse gases, energy-related activities are by far the most significant contributor to global emissions. In total, energy use accounts for roughly 60% of all anthropogenic greenhouse gases (and over 80% of the gases in Annex I countries), and these emissions come from all facets of the energy cycle, from production and transformation of fuels to energy handling and consumption. These greenhouse-gas emissions from the energy sector are largely dominated by the direct combustion of fuels. As a by product of the oxidation of carbon in fuels, carbon dioxide is the primary GHG produced by the energy cycle.

As shown in *figure* (2.7), CO_2 emissions represent by far the most significant contributor of anthropogenic gases. Smaller shares of GHG emissions come from land use change and deforestation, agriculture (specifically from the methane and nitrous oxide produced by domestic livestock production, enteric fermentation, manure, rice cultivation), wastewater handling and non-energy related industrial processes [IEA, 2010].

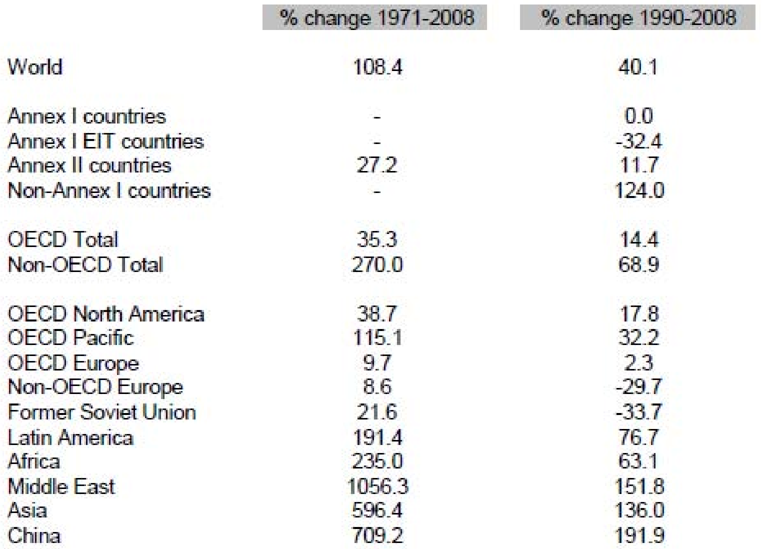
Between 1971 and 2008, global CO_2 emissions from fuel combustion doubled at the world scale level and increase by a 40% between 1990 and 2008, according to IEA data (*table* (2.1)). This exceptional increase in CO_2 emissions is due to an increase in consumption of the three fossil fuels (*figure* (2.8)). In 2008, of the total world carbon emissions from fuel combustion, 43% were produced from coal, 37% from oil and 20% from gas. However, as shown in *figure* (2.9), the proportional share of CO_2 emissions by fuel consumption indicates a tendency towards a greater use of coal and gas fuels at the world scale level. The decreasing share of carbon emissions from oil combustion is in that way a result of the growing use of coal and the penetration of gas in total primary energy supply. And these trends are expected to continue in the future, as coal is filling much of the ever increasing energy demand of the rapidly expanding economies with energy-intensive industrial production: countries such as China and India, with large coal reserves but limited reserves of other energy sources.

Figure 2.7: World greenhouse gas emissions by sector. Year 2000.



Source: World Resources Institute (2005), *Climate Analysis Indicator Tool (CAIT), Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*, December; Intergovernmental Panel on Climate Change, 1996 (data for 2000). Cartographer/ Designer: Riccardo Pravettoni, UNEP/GRID-Arendal.

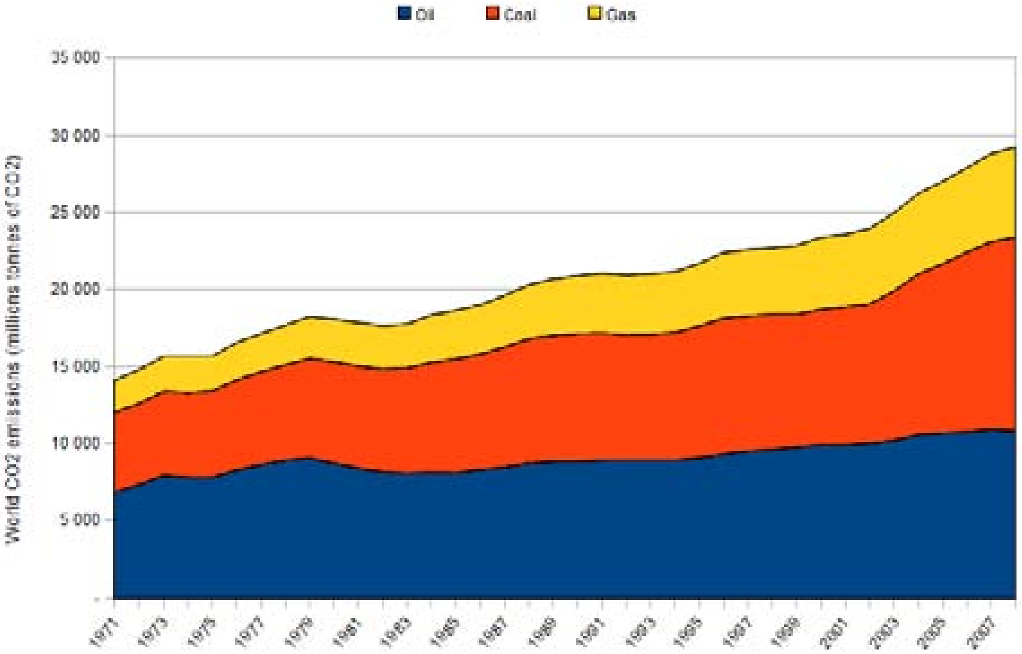
Table 2.1: CO_2 emissions by regions. Growth rates, 1971-2008.



	% change 1971-2008	% change 1990-2008
World	108.4	40.1
Annex I countries	-	0.0
Annex I EIT countries	-	-32.4
Annex II countries	27.2	11.7
Non-Annex I countries	-	124.0
OECD Total	35.3	14.4
Non-OECD Total	270.0	68.9
OECD North America	38.7	17.8
OECD Pacific	115.1	32.2
OECD Europe	9.7	2.3
Non-OECD Europe	8.6	-29.7
Former Soviet Union	21.6	-33.7
Latin America	191.4	76.7
Africa	235.0	63.1
Middle East	1056.3	151.8
Asia	596.4	136.0
China	709.2	191.9

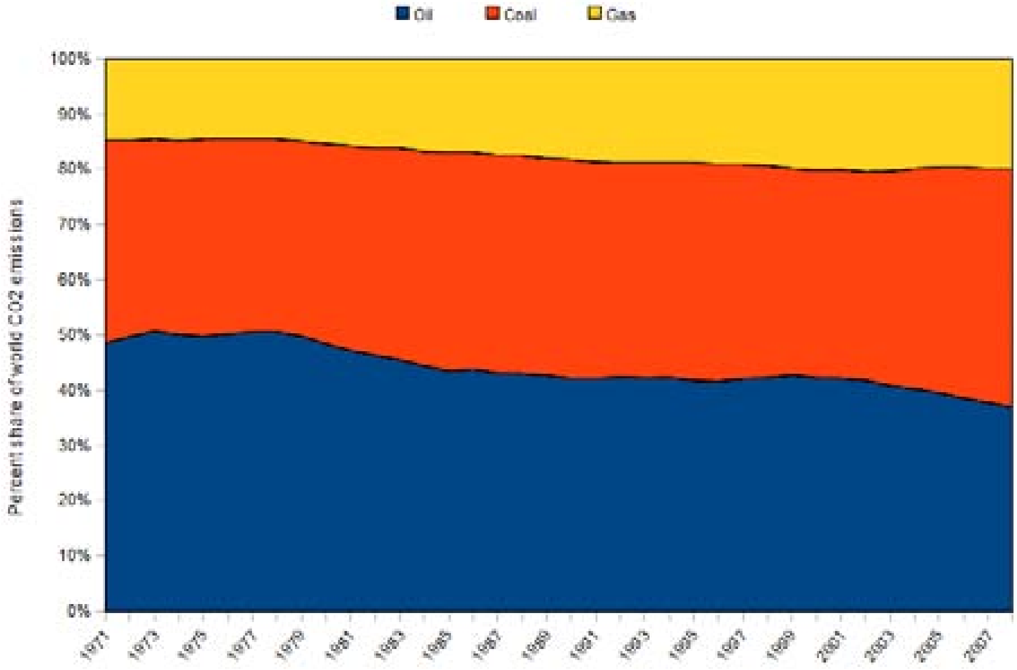
Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

Figure 2.8: World CO_2 emissions from fuel combustion. Years 1971-2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

Figure 2.9: Percent share of world CO_2 emissions from fuel combustion by fuel. Years 1971-2008.



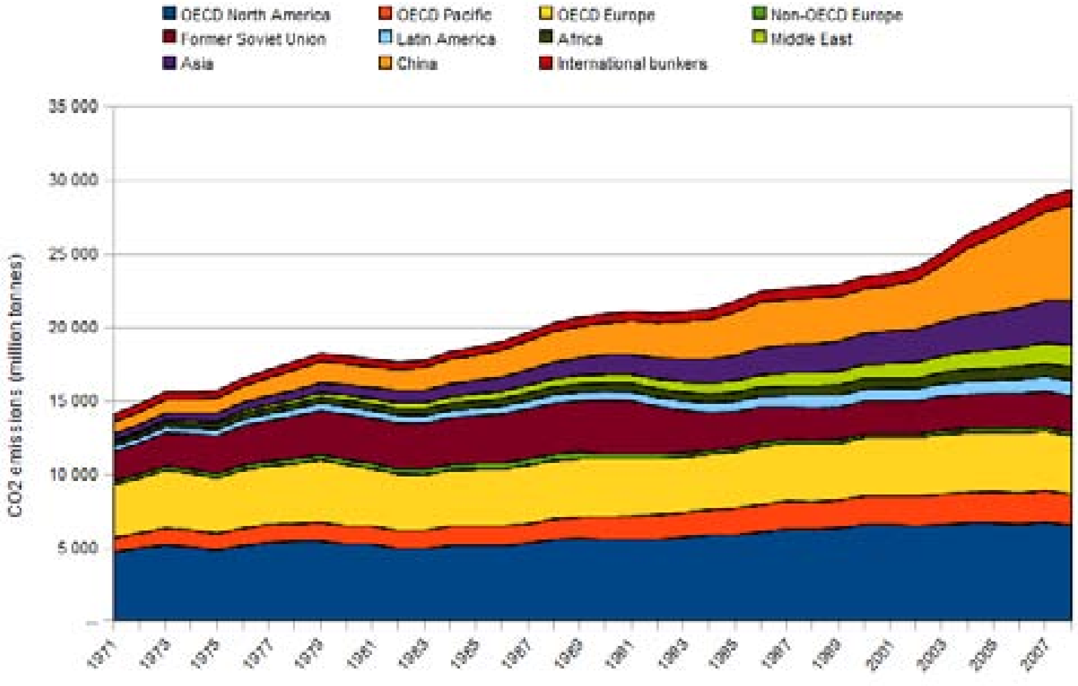
Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

CO_2 emissions by region

The evolution of CO_2 emissions from fuel combustion can also be disaggregated by macro-regions between 1971 and 2008, as shown in *Figure* (2.10). The share of CO_2

emissions in Annex I countries to the UNFCCC[9] progressively shrank, from 61% in 1971, 47% in 1990 and 37% in 2008. An historical turning point even happened in 2008 in that the emission levels of the Annex I countries felt below 1990 levels due to the economic contraction arising from the recession and high oil prices in 2008. But emission trends among Annex I countries were actually very different. These reductions (-0.007% growth between 1990 and 2008) took place above all within the Annex I EIT countries (-32%), whereas the 2008 emission levels for the Annex II countries were actually 12% above 1990 levels. Therefore the reduction in emissions for the EU-27 countries as a whole, during the last two decades, is largely due to this reduction in CO_2 emissions from Eastern European countries. In Russia and other non-OECD countries in Eastern Europe, total CO_2 emissions levels declined steadily from 1990, even if this trend was reversed in recent years. This was mainly the result of the structural changes in Eastern European economies, after the 1989 collapse of their centrally planned economies, generating a rapid decline in industrial productivity and the modernisation of several power plants.

Figure 2.10: World CO_2 emissions from fuel combustion by region. Years 1971-2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

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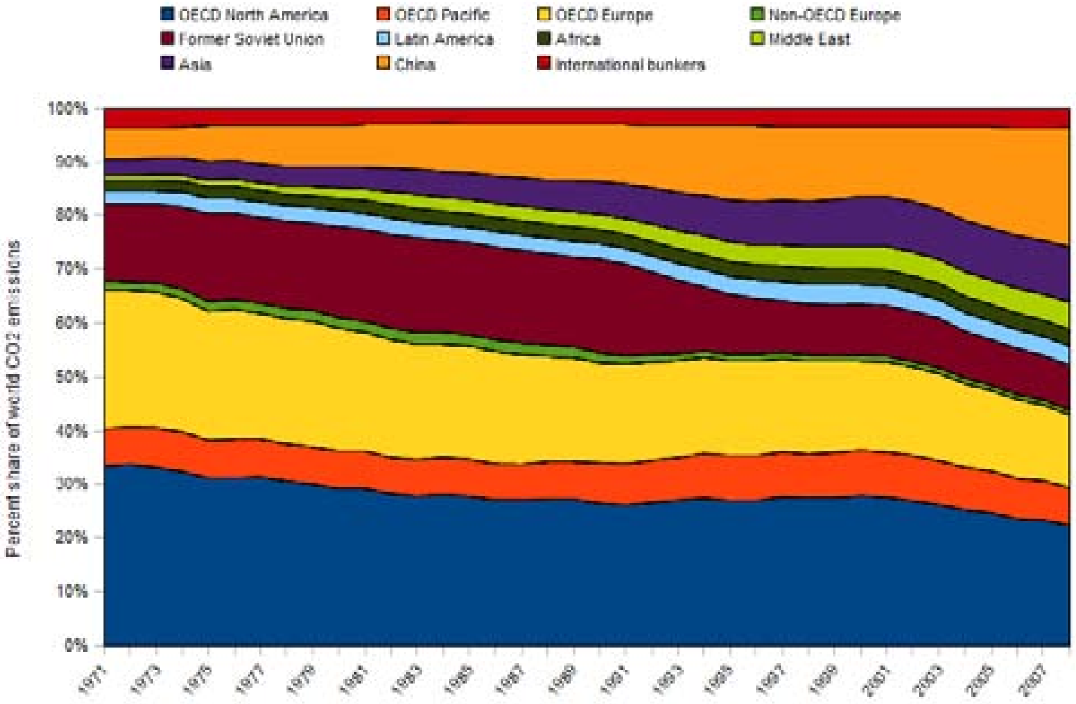
[9] The Annex I Parties to the 1992 UN Framework Convention on Climate Change (UNFCCC) represents the sum of the Annex I EIT countries (Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Russian Federation, Slovakia, Slovenia, Turkey and Ukraine) and the Annex II countries (Australia, Austria, Belgium, Canada, Denmark, European Union, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States of America), including the OECD members, except those that were considered economies in transition in 1992.

This reduction in emissions to 1990 levels which occurred in the Annex I countries must be put in contrast to the emissions growth in developing countries, or non-Annex I countries, as shown in *figure* (2.11), which gives the percent share of CO_2 emissions by regions over the years 1971-2008. While CO_2 emissions of the Annex I countries decreased by less than 1% over the years 1990-2008, CO_2 emissions from non-Annex I countries grew by 124%, including China (192%), the Middle East (152%), other Asia (136%), Latin America (77%) and Africa (63%). In line with a strong economic expansion, the growth in Asian emissions was particularly important in China and India.

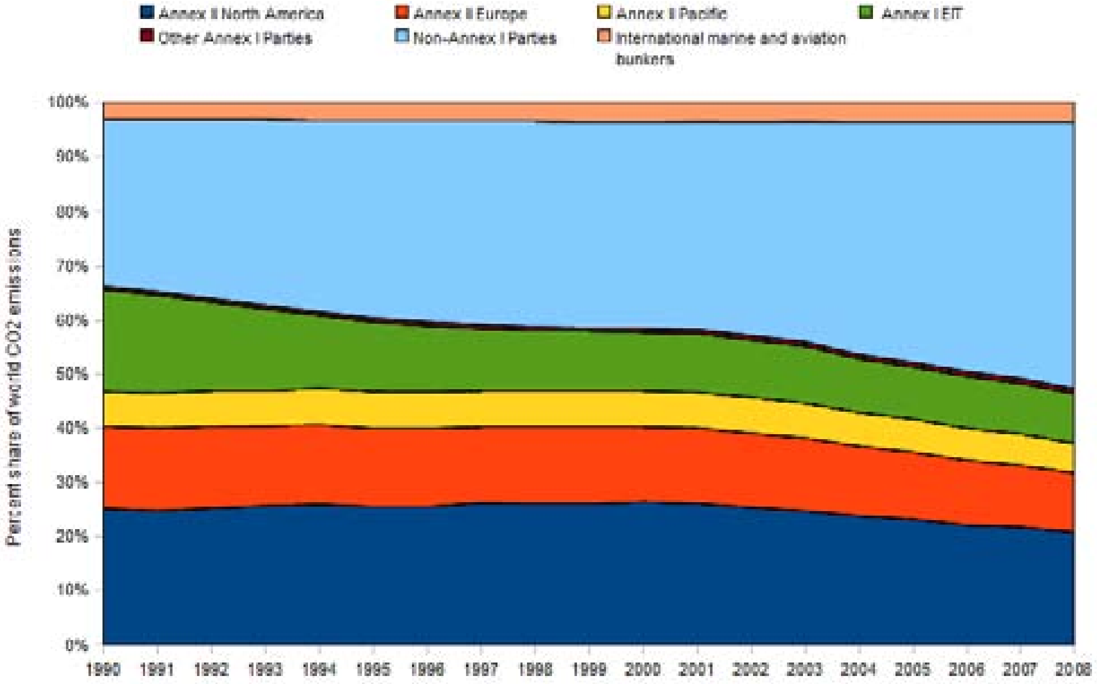
Figure 2.11: Percent share of world CO_2 emissions from fuel combustion by region. Years 1971-2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

Since the Industrial Revolution, the bulk of annual CO_2 emissions have originated from industrialised countries. However, according to the most recent statistical trends, this long period of dominance is about to end. Between 1971 and 2008, CO_2 emissions in the OECD countries rose by 35%, whereas, during the same time period, carbon emissions in non-OECD countries increased by 270%. As a result, the OECD's total share of global carbon emissions dropped almost constantly between 1971 and 2008, as can be seen in *figure* (2.11). Due to these diverging trends, for the first time in 2008, the aggregate emissions of non-Annex I countries were larger than those from the Annex I countries, as evidenced in *figure* (2.12). Given the size of some of the developing economies and the growth in their energy needs, it is probable they will continue generating important increase in emissions, at least under the current path of carbon emissions.

Figure 2.12: Percent share of world CO_2 emissions from fuel combustion by region. Years 1990-2008.

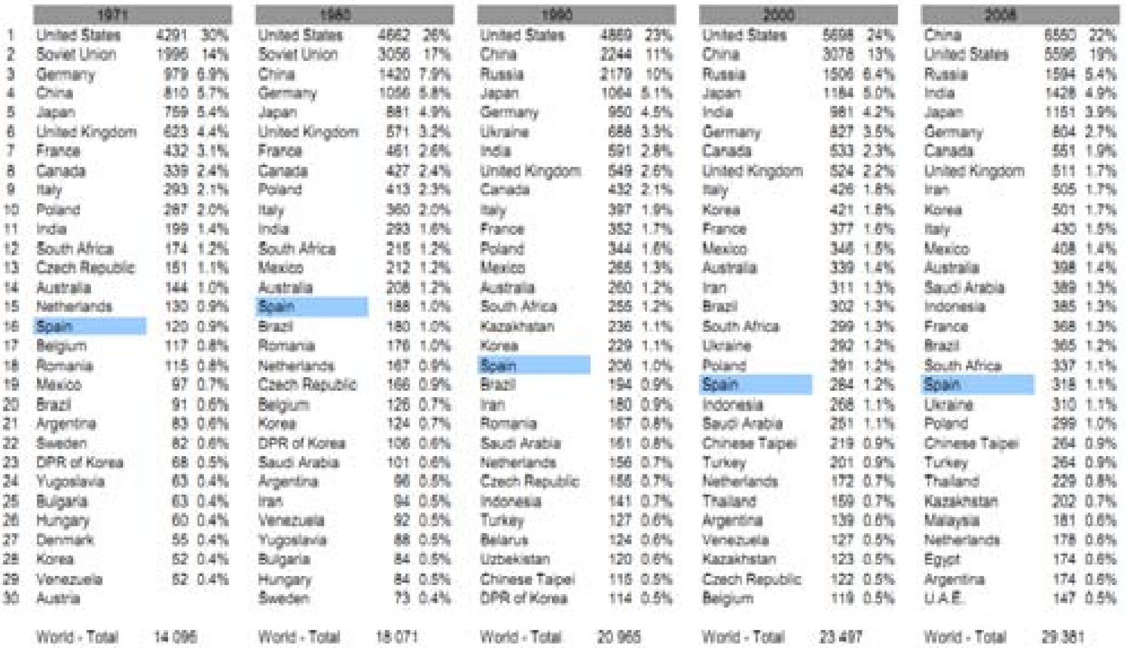


Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

At the European level, environmental record has been improving during the last three decades, as its total proportion of global emissions continued declining. It is probable that the EU, as a whole, will succeed toward meeting its emissions targets from the Kyoto Protocol. Overall, the EU-27's aggressive abatement goals are showing some success, even tough this reduction in emissions is also, to some extent, the consequence of significant emissions increases in other regions. In fact, western countries may have only managed to reduce emissions by relying on imports from emerging countries such as China. What these figures indicate therefore is that effective policies of energy use and emissions reduction will have to be taken by all regions, regardless of energy demand and infrastructure.

Regional differences in carbon emissions hide even larger differences among individual countries. *Table* (2.2) lists the thirty most polluting countries, in terms of carbon emissions, trough the years 1971-2008. Except for 2000, the two most polluting countries always produced more than 40% of world's carbon emissions. And in 2008, the five most polluting countries generated more than half of world's carbon emissions from fuel combustion, with the shares of China and the United States far surpassing those of all others. While the United States has historically been the major polluter, it is hard not to mention the growing importance of China in global energy markets and carbon emissions. Overall, China's carbon emissions from fuel combustion have increased seven fold during the years 1971-2008, and nearly tripled over the past two decades, going from 2.2 billion tons of emissions in 1990 to 6.5 billion tons in 2008. By comparison, US carbon emissions rose by 50% and 15% during the same periods. As suggested by data from IEA [IEA, 2010], China overtook the United States in 2007 to become the world's most polluting country in terms of carbon emissions from fuel combustion. While China energy use was only half that of the United States in 2000, its energy consumption during the last decade was more than four times greater than in the previous decade. But, to be fair, instead of absolute levels of carbon emissions per country, we should rather take into account the per capita emission levels across countries, underlining the important differences in energy use between countries. Because if the United States generated 19% of world carbon emissions in 2008, they accounted for only less than 5% of the world population. Whereas China, representing around 20% of the world population in 2008, generated an equivalent share of world emissions (22%). And India contributed less than 5% of the carbon emissions while accounting for 17% of world population.

Table 2.2: CO_2 emissions from fuel combustion (million tonnes of CO_2 and world percent share). Most polluting countries, 1971-2008.



	1971			1980			1990			2000			2008		
1	United States	4291	30%	United States	4662	26%	United States	4869	23%	United States	5698	24%	China	6550	22%
2	Soviet Union	1996	14%	Soviet Union	3056	17%	China	2244	11%	China	3078	13%	United States	5596	19%
3	Germany	979	6.9%	China	1420	7.9%	Russia	2179	10%	Russia	1506	6.4%	Russia	1594	5.4%
4	China	810	5.7%	Germany	1056	5.8%	Japan	1064	5.1%	Japan	1184	5.0%	India	1428	4.9%
5	Japan	759	5.4%	Japan	881	4.9%	Germany	950	4.5%	India	981	4.2%	Japan	1151	3.9%
6	United Kingdom	623	4.4%	United Kingdom	571	3.2%	Ukraine	688	3.3%	Germany	827	3.5%	Germany	804	2.7%
7	France	432	3.1%	France	461	2.6%	India	591	2.8%	Canada	533	2.3%	Canada	551	1.9%
8	Canada	339	2.4%	Canada	427	2.4%	United Kingdom	549	2.6%	United Kingdom	524	2.2%	United Kingdom	511	1.7%
9	Italy	293	2.1%	Poland	413	2.3%	Canada	432	2.1%	Italy	426	1.8%	Iran	505	1.7%
10	Poland	287	2.0%	Italy	360	2.0%	Italy	397	1.9%	Korea	421	1.8%	Korea	501	1.7%
11	India	199	1.4%	India	293	1.6%	France	352	1.7%	France	377	1.6%	Italy	430	1.5%
12	South Africa	174	1.2%	South Africa	215	1.2%	Poland	344	1.6%	Mexico	348	1.5%	Mexico	408	1.4%
13	Czech Republic	151	1.1%	Mexico	212	1.2%	Mexico	265	1.3%	Australia	339	1.4%	Australia	398	1.4%
14	Australia	144	1.0%	Australia	208	1.2%	Australia	260	1.2%	Iran	311	1.3%	Saudi Arabia	389	1.3%
15	Netherlands	130	0.9%	Spain	188	1.0%	South Africa	255	1.2%	Brazil	302	1.3%	Indonesia	385	1.3%
16	Spain	120	0.9%	Brazil	180	1.0%	Kazakhstan	236	1.1%	South Africa	299	1.3%	France	368	1.3%
17	Belgium	117	0.8%	Romania	176	1.0%	Korea	229	1.1%	Ukraine	292	1.2%	Brazil	365	1.2%
18	Romania	115	0.8%	Netherlands	167	0.9%	Spain	206	1.0%	Poland	291	1.2%	South Africa	337	1.1%
19	Mexico	97	0.7%	Czech Republic	166	0.9%	Brazil	194	0.9%	Spain	284	1.2%	Spain	318	1.1%
20	Brazil	91	0.6%	Belgium	126	0.7%	Iran	180	0.9%	Indonesia	268	1.1%	Ukraine	310	1.1%
21	Argentina	83	0.6%	Korea	124	0.7%	Romania	167	0.8%	Saudi Arabia	251	1.1%	Poland	299	1.0%
22	Sweden	82	0.6%	DPR of Korea	106	0.6%	Saudi Arabia	161	0.8%	Chinese Taipei	219	0.9%	Chinese Taipei	264	0.9%
23	DPR of Korea	68	0.5%	Saudi Arabia	101	0.6%	Netherlands	156	0.7%	Turkey	201	0.9%	Turkey	264	0.9%
24	Yugoslavia	63	0.4%	Argentina	96	0.5%	Czech Republic	155	0.7%	Netherlands	172	0.7%	Thailand	229	0.8%
25	Bulgaria	63	0.4%	Iran	94	0.5%	Indonesia	141	0.7%	Thailand	159	0.7%	Kazakhstan	202	0.7%
26	Hungary	60	0.4%	Venezuela	92	0.5%	Turkey	127	0.6%	Argentina	139	0.6%	Malaysia	181	0.6%
27	Denmark	55	0.4%	Yugoslavia	88	0.5%	Belarus	124	0.6%	Venezuela	127	0.5%	Netherlands	178	0.6%
28	Korea	52	0.4%	Bulgaria	84	0.5%	Uzbekistan	120	0.6%	Kazakhstan	123	0.5%	Egypt	174	0.6%
29	Venezuela	52	0.4%	Hungary	84	0.5%	Chinese Taipei	115	0.5%	Czech Republic	122	0.5%	Argentina	174	0.6%
30	Austria			Sweden	73	0.4%	DPR of Korea	114	0.5%	Belgium	119	0.5%	U.A.E.	147	0.5%
	World - Total	14 096		World - Total	18 071		World - Total	20 965		World - Total	23 497		World - Total	29 381	

Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

Table (2.3) takes into consideration a selected sample of 30 countries (the 30 most polluting countries in year 2008 from *table* (2.2)) and shows their per-capita carbon emissions levels trough the years 1971-2008. Comparing the per capita emissions levels of the five largest emitters countries (China, the United States, the Russian Federation, India and Japan) shows substantial divergence, ranging from 1.25 tonne CO_2/capita for India to 18.4 tonne CO_2/capita for the United States. As expected, OECD countries emit far larger amounts of CO_2 per capita than the world average. But new trends emerge for some rapidly expanding economies such as China and India. While countries such as United States, Germany, United Kingdom and France decreased their per capita emissions levels over the period 1971-2008, most of the non-OECD countries increased substantially their levels, contributing massively to the 17% increase of global per capita emissions over the same period.

Thus, the dramatic increase in China and India's emissions recently must be put in perspective: the per capita emissions level in the United States was still almost four times higher than Chinese levels and 15 times higher than in India. While newly industrialized countries, such as China and India, still have lower per-capita carbon emissions , it is expected that their energy consumption level per inhabitant, and the related per-capita carbon emissions level, will continue to rise significantly from their current level, due to the demand for higher standards of living and comfort trough the use of cars, air conditioning or refrigerators for example [IEA, 2010].

Table 2.3: CO_2 emissions from fuel combustion per inhabitant (tonnes CO_2 / capita). Selected countries, 2008.

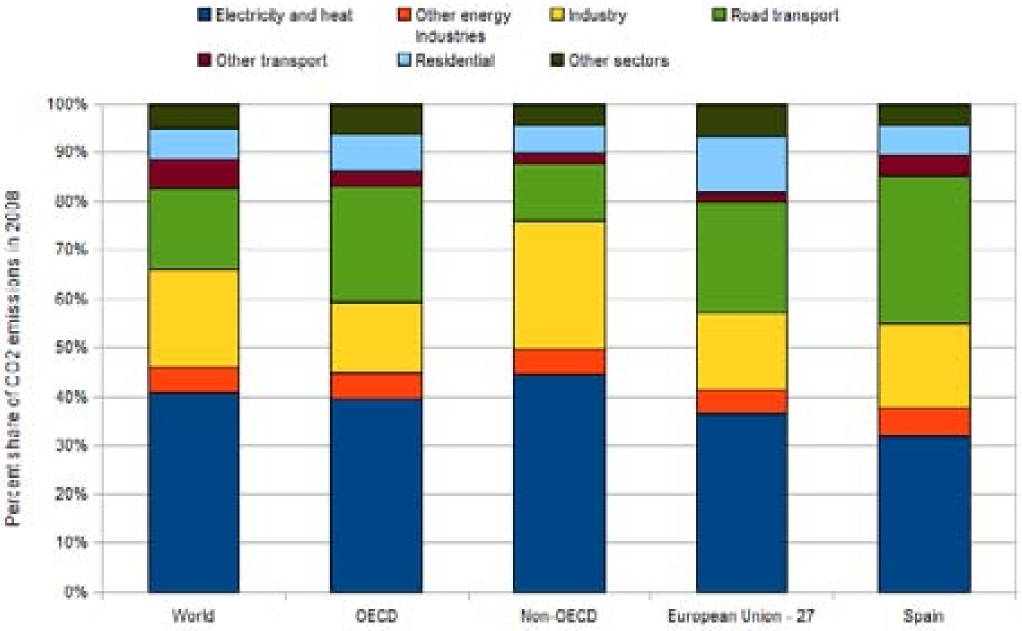
	1971		1980		1990		2000		2008	
1	United States	20.66	United States	20.47	United Arab Emirates	27.64	United Arab Emirates	26.50	United Arab Emirates	32.77
2	Canada	15.46	United Arab Emirates	18.79	United States	19.46	United States	20.19	Australia	18.48
3	Germany	12.49	Canada	17.41	Canada	16.61	Australia	17.88	United States	18.38
4	United Kingdom	11.15	Australia	14.05	Australia	15.15	Canada	17.38	Canada	16.53
5	Australia	10.92	Germany	13.48	Russian Federation	14.72	Saudi Arabia	12.15	Saudi Arabia	15.79
6	Netherlands	9.82	Netherlands	11.78	Germany	11.98	Netherlands	10.81	Chinese Taipei	11.53
7	United Arab Emirates	9.20	Poland	11.61	Netherlands	10.43	Russian Federation	10.27	Russian Federation	11.24
8	Poland	8.74	Russian Federation	11.49	Saudi Arabia	9.85	Germany	10.06	Netherlands	10.62
9	France	8.24	Saudi Arabia	10.66	United Kingdom	9.60	Chinese Taipei	9.89	Korea	10.31
10	Russian Federation	8.15	United Kingdom	10.14	Poland	9.04	Japan	9.33	Germany	9.79
11	South Africa	7.59	France	8.37	Japan	8.61	Korea	8.96	Japan	9.02
12	Japan	7.23	South Africa	7.78	South Africa	7.24	United Kingdom	8.89	United Kingdom	8.32
13	Italy	5.42	Japan	7.52	Italy	7.01	Poland	7.62	Poland	7.84
14	Spain	3.49	Italy	6.38	France	6.06	Italy	7.48	Italy	7.18
15	Argentina	3.41	Spain	4.89	Chinese Taipei	5.65	Spain	7.05	Islamic Rep. of Iran	7.02
16	Saudi Arabia	2.22	Chinese Taipei	4.04	Korea	5.35	South Africa	6.78	Spain	6.97
17	Chinese Taipei	2.08	Argentina	3.41	Spain	5.28	France	6.21	South Africa	6.93
18	Mexico	1.96	Korea	3.26	Islamic Rep. of Iran	3.31	Islamic Rep. of Iran	4.86	Malaysia	6.70
19	Korea	1.58	Mexico	3.23	Mexico	3.26	Malaysia	4.77	France	5.74
20	Islamic Rep. of Iran	1.50	Islamic Rep. of Iran	2.40	Argentina	3.08	Argentina	3.77	China	4.92
21	Colombia	1.15	Malaysia	1.76	Malaysia	2.70	Mexico	3.52	Argentina	4.36
22	Turkey	1.14	Turkey	1.60	Turkey	2.30	Turkey	3.12	Mexico	3.83
23	Malaysia	1.14	Algeria	1.61	Algeria	2.04	Thailand	2.58	Turkey	3.71
24	China	0.96	Brazil	1.48	China	1.97	China	2.42	Thailand	3.41
25	Brazil	0.90	China	1.44	Thailand	1.39	Algeria	2.05	Algeria	2.56
26	Algeria	0.81	Colombia	1.34	Egypt	1.37	Brazil	1.73	Egypt	2.13
27	Egypt	0.56	Egypt	0.95	Colombia	1.36	Egypt	1.57	Brazil	1.90
28	Thailand	0.46	Thailand	0.72	Brazil	1.30	Colombia	1.47	Indonesia	1.69
29	India	0.36	Indonesia	0.47	Indonesia	0.79	Indonesia	1.30	Colombia	1.36
30	Indonesia	0.21	India	0.43	India	0.75	India	0.97	India	1.25
	World	3.75	World	4.07	World	3.98	World	3.87	World	4.39
	OECD Total	10.59	OECD Total	11.06	OECD Total	10.59	OECD Total	11.07	OECD Total	10.61
	Non-OECD Total	1.48	Non-OECD Total	1.87	Non-OECD Total	2.20	Non-OECD Total	2.06	Non-OECD Total	2.86

Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

CO_2 emissions by sector

If anthropogenic carbon emissions are produced from a variety of sources, it is well known that a major contributor is the fossil fuel-fired power generation sector. Other major industries that are heavy users of energy and emitters of carbon emissions include oil refining, chemical manufacturing, cement manufacture and metallurgy. To shed some light on the percent share of carbon emissions from fuel combustion by economic sectors, *figure*(2.13) shows data for the year 2008 regarding Spain and different regions.

Figure 2.13: Percent share of CO_2 emissions from fuel combustion by sectors. Year 2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

As it appears, two sectors (electricity and heat generation and transport) produced two-thirds of world carbon emissions in 2008. By far, the most polluting sector was electricity and heat generation, responsible of more than 40% of the world carbon emissions that year. A major reason is the extensive reliance on coal, the most carbon-intensive of fossil fuels, as an energy source as confirmed by *figure* (2.8)[10]. As a consequence, in the non-OECD economies, the amount of electricity and heat-related emissions is quite high relative to the amount of electricity produced, in comparison to the levels of emissions and electricity output in OECD countries. However, due to the lower level of electricity consumption in the non-OECD economies, these countries also present a lower value of electricity-related emissions per capita. Again, to

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[10] In countries such as Australia, China, India, Poland and South Africa for example, between 70% and 95% of their electricity and heat are produced through the combustion of coal [IEA, 2010].

reduce the emission intensity of this sector, there is no doubt that the energy mix to generate electricity and heat will be crucial, as the relevance of non-emitting sources, such as renewables and nuclear, is already well known. The impact of transport, the second most polluting sector, with 22% of global CO_2 emissions in 2008, is particularly important in Spain, representing 34% of carbon emissions that year.

Non-OECD countries present some specificities with respect to the other aggregates. First, it shows a particularly high contribution of the electricity and heat generation sector, probably due to the extensive use of coal as an energy source. This makes the amount of electricity-related emissions to stay currently quite high relative to the more industrialized countries. Second, the second most polluting sector is not the transport sector, but the industry sector. Carbon emissions from the industry are also particular in the way that, unlike for most sectors of the economy, carbon emissions are not always related to energy use. They may be the consequence of other industrial processes, as it is the case with the cement production, metallurgy or chemical and petrochemical products, all using consequent amounts of carbon fossils as primary inputs.

The future of GHG emissions

As the world's population expands together with a higher world emissions per capita, the current prospect is for the world's energy demands and carbon emissions to continue to grow. As discussed above, one of the main contributors to increasing carbon emissions in the non-OECD countries is electricity production. The IEA forecasts that world electricity demand will continue to grow more strongly than any other final form of energy, by 2.2% per year between 2008 and 2035 [IEA, 2010]. From this increase, 80% should come from non-OECD countries, with China tripling its electricity demand between 2008 and 2035. This should allow China to generate, over the next 15 years, the capacity equivalent to the current total installed capacity of the United States. As we know, coal-fired generation is a major energy source for electricity generation in the newly industrialised economies and should therefore keep playing an important role in the coming decades. But, globally, this increase in coal-fired generation in non-OECD regions could be offset by a fall of its use in OECD countries.

The growing demand in some rapidly expanding economies, all of which are in non-OECD regions, will dramatically change future emissions trends. There is thus a call for all countries, and not just the industrialised ones, to address the effects of GHG emissions on global climate change. New technologies development and the implementation of economic policies to curb carbon emissions are two important steps in this endeavour. With regards to technology, it seems important to foster the production of clean energy technologies as well as technologies that can help reduce the amount of GHG already in the atmosphere. In the power sector, a shift to nuclear power, renewables and other low-carbon technologies could significantly reduce the amount of CO_2 emitted. Economic policies include carbon markets and fiscal policies, as discussed in the next section.

2.1.3 The European Emission Trading Scheme (EU-ETS)

To formulate effective and efficient economic policies, we should first consider the well known problem of environmental externalities generated by emissions of GHG. Since nobody owns the assimilating capacity of the atmosphere, emissions of GHG are considered as cost free and unrestricted. Those who emit only consider their private benefits and private costs and do not take into account the public benefits of the atmosphere and the public costs inflicted on the global society. These negative costs correspond to the reduction in the quality of the services provided by the atmosphere and the related effects on global climate. A public good, i.e. the atmosphere, is damaged and a public bad, i.e. climate change, is created.

Two kinds of economic policy instruments are usually considered to achieve control of GHG emissions efficiently. The best known is a tax on GHG emissions, but this instrument has met a lot of resistance up to now. On the other hand, recently, emission permits trading has generated a lot of interest from academics and policy makers. An emissions trading system (ETS) is a market-based mechanism that allows one liable entity (responsible for emissions, such as individual enterprise or commercial organisation), with emissions below an agreed cap value, to sell or pass on its excess credits to a second party. Trading of allowances establishes a market price for emissions and promotes least-cost actions to meet efficiently the cap. In a permits market, balancing would take place between the marginal costs of reducing emissions and the price of the permit, such that the total cost of the system would be minimised.

This concept of ETS is not particular to CO_2 emissions. Similar schemes, for SO_2 trading for example, have been implemented for a number of years in different places. But, although the challenge of climate change is a global one, the use of market mechanisms to control emissions has so far been overwhelmingly local in nature. Many countries and regions are attempting to launch carbon markets in order to fulfill their Kyoto commitments or their own national emissions reduction targets. In the European Union, the largest scheme in operation is the Europe's Emission Trading Scheme (EU-ETS), the world's most developed carbon emission allowances market. Its development can be presented in three phases.

During the first pilot phase, lasting from 2005 to 2007, the EU ETS was concentrating initially on emissions from some major polluters sectors from the first 15

Member States that participate to the "8%" joint reduction target. Totalling over 12,000 installations and covering approximately 40% of the EU's total CO_2 emissions in 2005, these major contributors to GHG included the ones involved in the production and processing of ferrous metals, mineral industry (including cement, glass and ceramic production) or pulp and paper. The ETS included also directly the energy production sectors such as oil refineries, coke ovens and combustion installations with a rated thermal input higher than 20MW. Organisations with excess emission credits were able to trade these on to other agents in need of them, under the threat of being applied a penalty charge for not meeting their emission targets. The market was however difficult to operate, as evidenced by the fall in the price per tonne of CO_2 from a peak of €30 in April 2006 to €0.10 per tonne of CO_2 in September 2007.

The second phase (2008-2012) has been focused on improving the functionality of the market for GHG emission permits, in order to confirm the EU-ETS as the major pillar for the Post-Kyoto climate policy within the EU. The EU-ETS is also now directly linked to Norway's proper ETS and Iceland and Liechtenstein were included too, enlarging its international implementation.

After 2012, entering the third phase, others important economic sectors should be added to the ETS, such as the aviation sector. This could have important impact on the certificates demand, due to the large and increasingly important emissions of that sector. Ultimately, the objective could be to include all GHG and all economic sectors within the scheme. Due to its commitment to control GHG emissions trough its international ETS, the development of clean energy technologies and energy supply diversification, the European Union has been showing some success toward meeting its emissions targets since the implementation of the Kyoto Protocol. This is also part of the reason why the proportion of Europe's total CO_2 emissions are limited and declined to 14% of total global CO_2 emissions in 2008, as shown in *figure* (2.11). And this share is expected to decrease even more in the next decades as newly industrialized countries contribute increasingly more to world CO_2 emissions.

2.1.4 The debate on carbon emissions taxes in the EU

From the beginning of the nineties, the European Commission has advocated for an energy tax harmonization between EU members, promoting in the same way an increase in fossil fuel prices in order to impact on their consumption and reach a more efficient use of energy.

In 1992, the European Commission defined a directive proposal (COM 92/226 final, Council Directive 92/81/EEC and Council Directive 92/82/EEC) for the harmonisation of the structure of excise duties on mineral oils[11] and for the introduction of a European CO_2/energy tax on the fossil fuels, with the proposed tax burden adjusted to the energy content and the carbon content of the fuel[12] [European Commission, 1992]. This Council Directive proposal for a Community-wide tax on carbon dioxide emissions and energy on the fossil fuels had thus a double objective, as reflected by the 50/50 share of the proposed tax between energy content and carbon content of the fuels. Part of the burden of the tax was aimed at stabilizing CO_2 emissions by 2000 at their 1990 level (the carbon content share), while the other half of the tax burden was focused on general energy saving (the energy content share).

The tax harmonisation represented minimum taxation levels across EU member countries to be levied at a national level and not at the EU level, as a particular source of revenue. The proposal was also seen as part of a broader fiscal reform. Indeed, the tax policy was intended to be “fiscally neutral” for the government, such that the revenue raised with the CO_2/energy tax could be used to reduce other taxes. The main idea was to shift the general burden of taxation from labour taxes (especially non-wage labour costs) to taxes on the use of resources; a policy otherwise known as the “double dividend”.

This proposal could not be considered as a full harmonization of fossil fuel taxation. Indeed, different Member States introduced numerous exemptions or reductions for specific sectors (i.e. the most energy-intensive industrial sectors) and specific policy considerations (i.e. condition of tax setting reciprocity from main OECD competitors), setting more than one hundred special provisions in the 15 Member States.

Overall, this proposal of energy tax reform met strong resistance from several Member States due to considerations of national fiscal sovereignty. And given that tax issues decisions require an unanimous agreement in the EU to be validated, the proposal failed to be accepted. This first attempt was thus revised (COM/95/172 final), under the same general proposition of fuel taxes harmonisation, but allowing this time the member states to fix the tax rates independently during a transition period, in order to reach defined target rates [European Commission, 1995]. Exemptions for various industries were also allowed. Due to the constant blockage of some member countries, the new directive proposal was finally abandoned.

In 1997, in another attempt, the European Commission presented a new Directive proposal on the restructuring of the Community framework for the taxation of energy

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[11] All Member States were required to apply an excise duty to mineral oils used as motor fuels or heating fuels, subject to certain exemptions.

[12] As the carbon content of fossil fuels was assumed to be related to the CO_2 emissions generated from combustion.

products, focused again on reducing distortions on energy products among Member States and coming closer to a fiscal structure accommodating environmental impacts [European Commission, 1997]. In contrast to the 1992 CO_2/energy tax proposal, the 1997 proposal did not include a carbon component, but consisted of a framework of tax rates increases in different steps, extending the minimum rate system for mineral oils to other energy products, including electricity. But again, non-unanimity led to abandon the proposal.

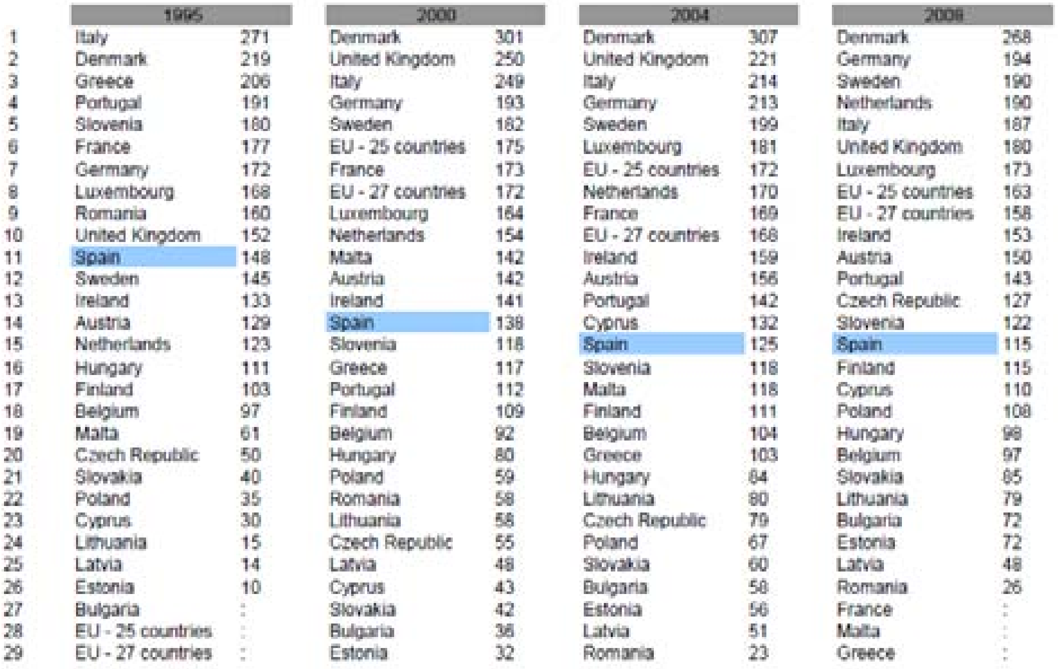
Several years later, after these series of attempts to establish a comprehensive system of energy taxation in Europe and a long process of discussion, the Council of the European Union finally adopted in October 2003 the Directive 2003/96/EC, restructuring the Community framework for the taxation of energy products and electricity [European Commission, 2003].

Presented as an important requirement for both the proper functioning of the internal market and the coherence of energy, transport and environment policies in Europe, the Directive widened the scope of the EU's minimum tax levels for mineral oils to all energy products including coal, natural gas and electricity; but under some conditions however. Only energy products used as fuels or heat generation were subject to taxes, not the ones used for other purposes (raw materials, chemical reductions or metallurgical processes), nor crude oil. And while electricity input was taxed, the energy carriers as inputs to electricity generation were not. Article 5 recognised also that Member states could apply differentiated energy tax rates due to energy product quality, energy consumption levels, and public/industry/non-industry use of energy.

Article 7 of the Directive stated that, from 2004, a minimal tax rate on motor fuels had to be fixed and that European Parliament would be entitled to decide on minimum levels of tax for gas oil not later than January 2012. Also, trough an amendment of April 2004 by the EU's Council of Ministers, general and Member specific exemptions, such as transitional periods, were introduced. The EU accession countries were allowed to temporarily apply country specific exemptions or lower rates of excise duty, but up to 2012 as a maximum.

As given by *table* (2.4), the current situation shows a diversified implicit tax rate on energy among the 27 EU Member countries. It demonstrates that certain countries (such as Denmark, Germany, Sweden, Netherlands, etc.) have chosen to increase energy taxes higher than others.

Table 2.4: Implicit tax rate on energy (Energy taxes in Euro per ton of oil equivalent). Deflated, base year = 2000. EU 27 countries, 1995-2008.



	1995		2000		2004		2008	
1	Italy	271	Denmark	301	Denmark	307	Denmark	268
2	Denmark	219	United Kingdom	250	United Kingdom	221	Germany	194
3	Greece	206	Italy	249	Italy	214	Sweden	190
4	Portugal	191	Germany	193	Germany	213	Netherlands	190
5	Slovenia	180	Sweden	182	Sweden	199	Italy	187
6	France	177	EU - 25 countries	175	Luxembourg	181	United Kingdom	180
7	Germany	172	France	173	EU - 25 countries	172	Luxembourg	173
8	Luxembourg	168	EU - 27 countries	172	Netherlands	170	EU - 25 countries	163
9	Romania	160	Luxembourg	164	France	169	EU - 27 countries	158
10	United Kingdom	152	Netherlands	154	EU - 27 countries	168	Ireland	153
11	Spain	148	Malta	142	Ireland	159	Austria	150
12	Sweden	145	Austria	142	Austria	156	Portugal	143
13	Ireland	133	Ireland	141	Portugal	142	Czech Republic	127
14	Austria	129	Spain	138	Cyprus	132	Slovenia	122
15	Netherlands	123	Slovenia	118	Spain	125	Spain	115
16	Hungary	111	Greece	117	Slovenia	118	Finland	115
17	Finland	103	Portugal	112	Malta	118	Cyprus	110
18	Belgium	97	Finland	109	Finland	111	Poland	108
19	Malta	61	Belgium	92	Belgium	104	Hungary	98
20	Czech Republic	50	Hungary	80	Greece	103	Belgium	97
21	Slovakia	40	Poland	59	Hungary	84	Slovakia	85
22	Poland	35	Romania	58	Lithuania	80	Lithuania	79
23	Cyprus	30	Lithuania	58	Czech Republic	79	Bulgaria	72
24	Lithuania	15	Czech Republic	55	Poland	67	Estonia	72
25	Latvia	14	Latvia	48	Slovakia	60	Latvia	48
26	Estonia	10	Cyprus	43	Bulgaria	58	Romania	26
27	Bulgaria	:	Slovakia	42	Estonia	56	France	:
28	EU - 25 countries	:	Bulgaria	36	Latvia	51	Malta	:
29	EU - 27 countries	:	Estonia	32	Romania	23	Greece	:

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

2.1.5 The Europe 2020 strategy

In 2007, the European Union stepped up its energy and climate change ambitions to a new level. With the Kyoto Protocol set to expire in 2012, the international community is looking to implement a comprehensive and effective strategy to deal with climate change in the post-Kyoto world, with the underlined objective of limiting the increase in global average temperature to no more than two degrees Celsius above pre-industrial levels.

Based on several communications by the European Commission on an Energy and Climate Policy for Europe, the European Parliament and Council agreed in December 2008 the Decision 406/2009/EC on new climate and energy targets to be met by 2020 and establishing the legal framework for emissions trading, starting from 2013. Known as the "Climate Action and Renewable Energy" package or the "Europe 2020 strategy", it came into law in June 2009.

This climate and energy package seeks to reduce further EU's GHG emissions and increase its energy security while strengthening its competitiveness. In order to become this energy-efficient and low carbon economy, the 27 Member States of the European Union decided to set three wide targets to be met by 2020, known as the "20-20-20" targets. First, a GHG emission reduction of 20% by 2020 compared to 2005 levels, and an objective for a 30% reduction by 2020 subject to the conclusion of a comprehensive international climate change agreement. Second, the use of renewable energy sources to at least 20% of gross final energy demand in the EU by 2020, including a 10% share of renewables in transport for each Member State. And third, a 20% reduction in primary energy use compared with baseline projected levels, to be achieved by improving energy efficiency.

The first target, a decrease of EU's GHG emissions by 20% by 2020, compared to 1990 levels, has different sectoral implementations. On the one hand, all the sectors included in the EU-ETS should be constrained to reduce their emissions by 21% compared to 2005 levels. A single EU-wide cap on emission allowances is set to operate from 2013 and should be cut annually, reducing progressively the number of allowances available to ETS installations. Also, there will be a gradual shift from free allocation of allowances to auctioning (including a probable full auctioning for the power generation sector) and a greater coverage of sectors and GHG into the ETS. On the other hand, all Member States have agreed country-specific GHG emission limits in 2020 compared to 2005 for sectors not covered by the ETS (e.g. transport, housing, agriculture and waste), on the basis of a GDP per capita distribution key. On average, this should lead to a 10% reduction below 2005 levels (Council Decision 2009/406/EC). An overall objective of a 10% reduction by 2020 from 2005 levels has been set and national targets for limiting or reducing emissions have been established (Council Decision 2009/406/EC). Spain, with a 10% reduction target, is matching the overall objective for the EU.

The possibility of increasing the EU's emissions reduction target to 30% by 2020 has also been suggested, but subject to the condition that other major emitting countries in the developed and developing worlds contribute also to their fair share of efforts, under a global UN climate agreement[13]. Opting for the 30% reduction by 2020 would put the EU on target to reduce GHG emissions by 80-95% in 2050 compared to 1990. The same reduction level that is considered as the threshold level for keeping global warming below 2°C compared to pre-industrial levels.

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[13] Fairness in effort could be discussed under criteria such as per capita emissions in the sectors concerned with diffuse pollution and emissions by production unit in industrial sectors.

2.2 Energy demand and CO_2 emissions in Spain

2.2.1 Energy demand

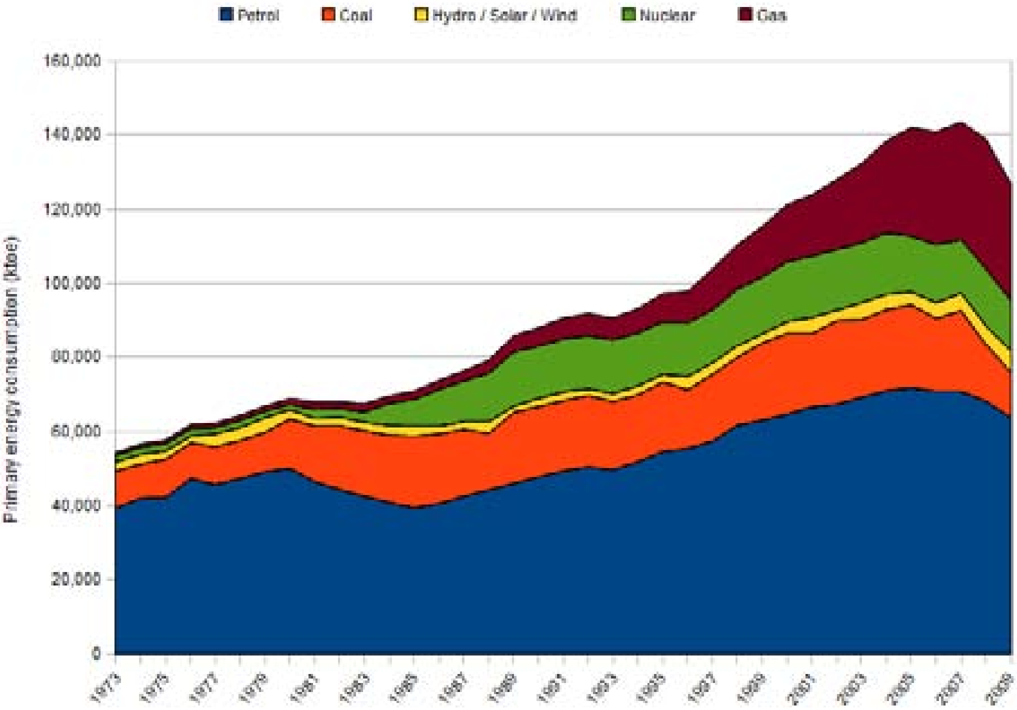
Primary energy demand

The primary energy demand, or gross inland energy consumption (GIC), reflects total energy consumption and sums up primary energy production and net energy imports (plus recovered products and variations of stocks), corresponding to the addition of final consumption, distribution losses, transformation losses and statistical differences. It is calculated as the sum of the gross inland consumption of five energy types (coal, oil, natural gas, nuclear and renewable energy sources) and represents the total energy demand necessary to satisfy inland consumption within the national territory.

The growth pattern of gross inland consumption for Spain is described in *figure* (2.14). From 1973 to 2009, total GIC increases from 54,145 kilotons of oil equivalent (ktoe) to 125,810 ktoe, i.e. +132%. The Spanish primary energy consumption changed fundamentally during the 1990s. Energy demand grew rapidly, together with the economy. Also, the electricity, gas and oil markets started to be liberalised. After a continuous drop during the first half of the '80s, oil consumption as a primary energy source has kept increasing until 2008, when, like coal, it has suffered a new reversal. The vast majority of this oil had to be imported, both from OPEC and non-OPEC countries, due to low domestic oil production levels. Coal consumption increases consistently in the '80s, after the technological developments in the '60s and '70s to enable Spain to burn the country's low quality coal reserves, mainly used for electricity generation. A striking feature is obviously the increase in natural gas consumption, with a constant upward trend until 2009. The 2007-2009 economic crisis marked a significant reversal in primary energy demand growth rate trend. Whether it will represent a long-term inflexion point in terms of the energy intensity of the economy, and a concomitant reduction of GHG emissions, is to be determined.

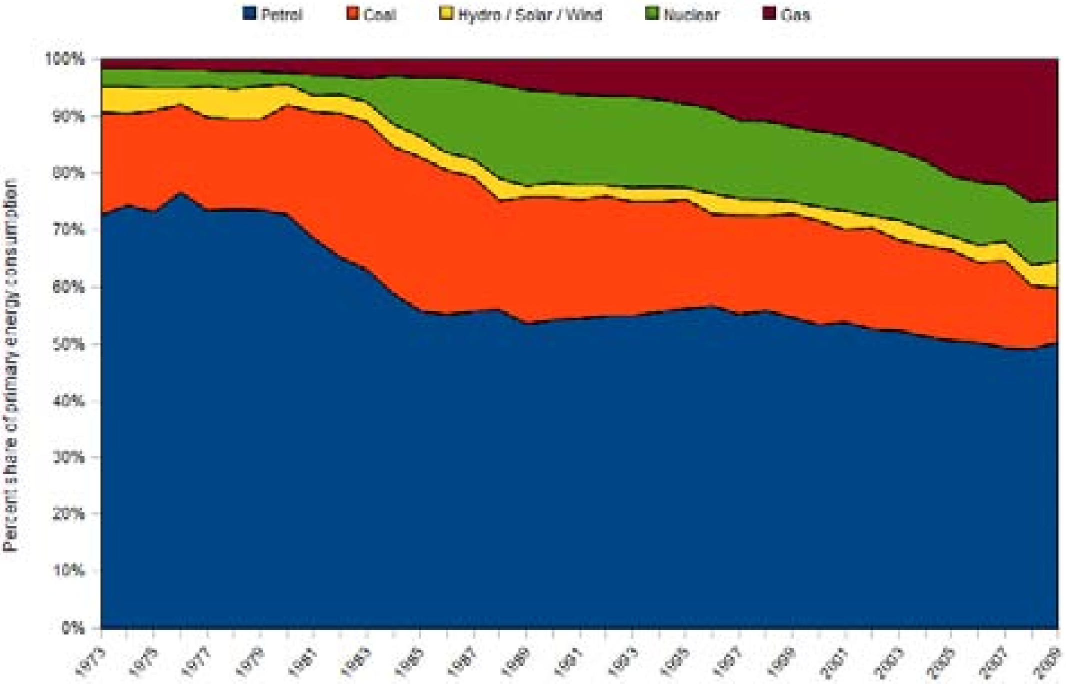
To examine the relative importance of each fuel more carefully, *figure* (2.15) describes the evolution of the relative weight of each energy source in the domestic total primary energy demand. Throughout the period 1973-2009, we can observe a gradual decline in the GIC of petroleum products and solid fuels, while increasing amounts of nuclear energy, renewable energy sources and, most of all, natural gas are consumed. Petrol looses a consequent part of its relative weight, from a share of 73% in 1973, it falls down to 50% in 2009. Coal energy shares this loss: its part in GIC dives by almost 100%, from 18.2% in 1973 to 9.6% at the end of the period. If the relative share of hydroelectric and other renewable energies remains fairly constant, it is the nuclear energy and, above all, natural gas that manage to pick up the lost shares.

Figure 2.14: Primary energy consumption (ktoe). Spain, 1973-2009.



Source: Foro Nuclear (2010), *Energía 2010*, Madrid: Foro Nuclear.

Figure 2.15: Percent share of primary energy consumption by energy source. Spain, 1973-2009.



Source: Foro Nuclear (2010), *Energía 2010*, Madrid: Foro Nuclear.

Primary energy produced by nuclear plants expanded from 3% to 11%, but is expected to decrease slightly over the coming years[14]. Nuclear power in Spain is an important energy resource which covers about 30% of total electricity generation and contributes to the diversification of energy supply. Natural gas increased from 1.5% to 25% share, resulting from the growing use of natural gas in electricity generation from combined cycle plants, with energy output exceeding 50%, compared to 37% for conventional thermal plants [Unesa, 2010]. For several uses, such as heating, natural gas is becoming the fuel of choice because it is more versatile than coal or oil and can be used in 90% of energy applications. This trend in natural gas use indicates also a move away from the most polluting fossil fuels. Hopefully, it should play a key role in Spain's compliance with Kyoto Protocol requirements.

The GIC of a country will vary with respect to the availability of natural resources for primary energy production and the structure of its energy system. In this regard, it must be recognised that Spain has low fossil fuel reserves as shown in *figure* (2.16). It can be seen that primary energy self-sufficiency is very modest, with domestic oil and natural gas production not exceeding 1% of GIC. Spain has become increasingly dependent on imports, especially with respect to natural gas and petrol: nearly all the required crude oil and gas has to be imported. Due to the small amounts of domestic production and reserves, Spain could become even more dependent on the import of fossil fuels in the future. Compared to other European countries, Spain shows also one of the highest energy dependency rate, expressing the extent to which an economy relies upon imports in order to meet its energy needs. The relative percentages, calculated as net imports divided by the sum of GIC plus bunkers, are shown in *table* (2.5). With domestic energy resources covering only 20% of 2008 total primary energy supply, diversification of fuels and their supply sources is an important aspect of Spanish energy policy.

Because Spain has few fossil fuel resources at its disposal, the increase in fossil fuel consumption depicted in *figure* (2.14) translates into more energy imports. As an indication, *table* (2.6) compares the percentage change of net imports of primary energy for the 27 EU countries. Spain appears to be among the countries with the highest increase in net imports of primary energy, with respect to the 1997 base year. Natural gas imports have probably played a key role in this significant increase, due to the fact that domestic gas production is almost non-existent and gas is the fuel that has increased the most recently in Spain.

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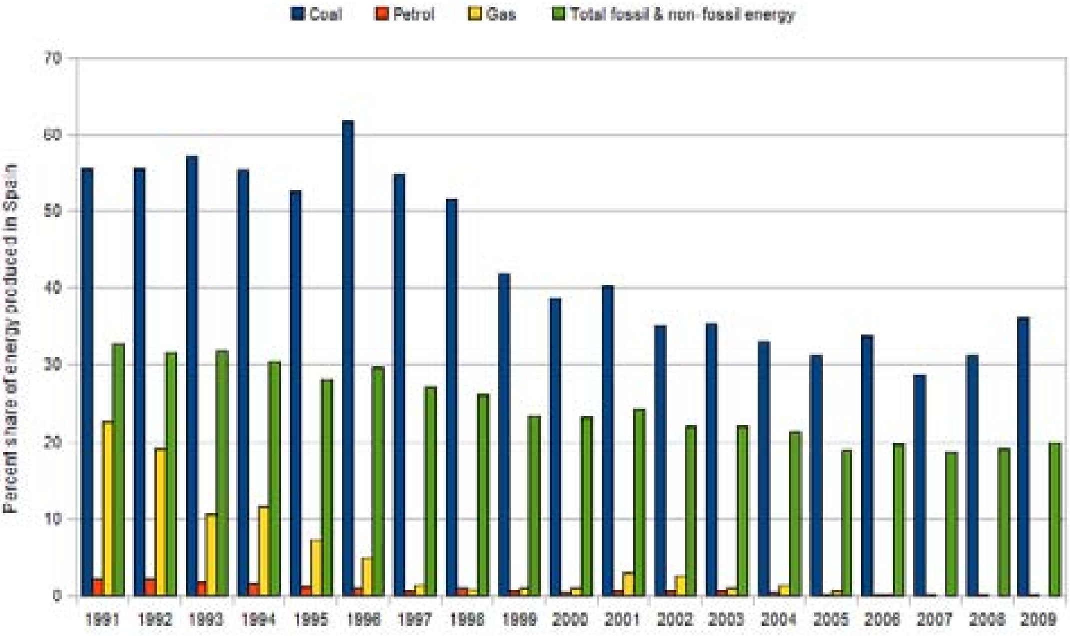
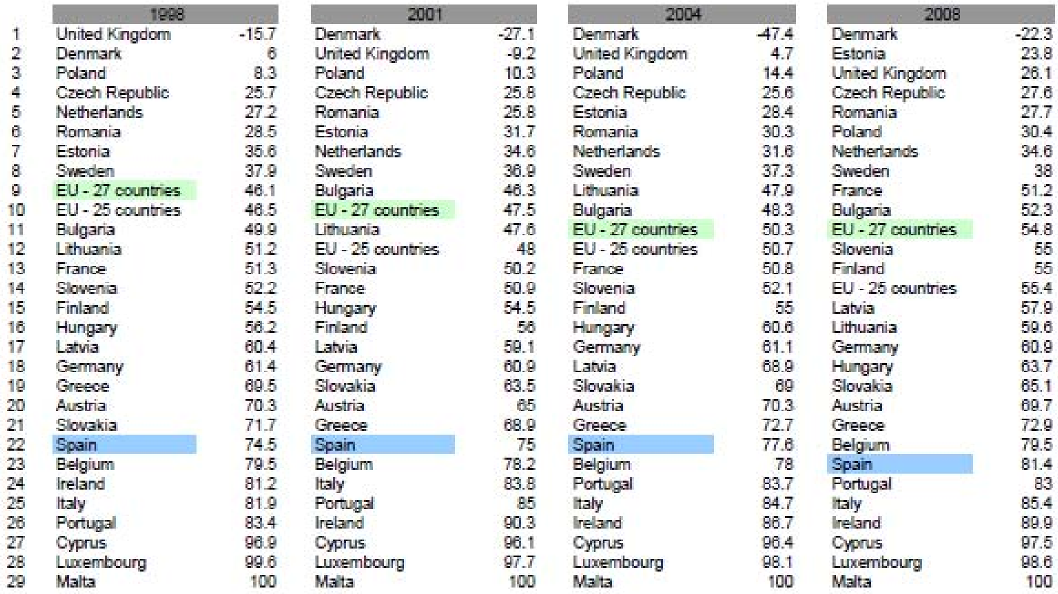
[14] The increase of nuclear capacity is restricted to small production increases of existing units

Figure 2.16: Energy produced in Spain (self-sufficiency). Spain, 1991-2009.



Source: INE (2011), *Energy. Annual main results. Series 1991-2009*, Madrid: INE.

Table 2.5: Energy dependency ratios (imports / GIC). EU 27 countries, 1998-2008.



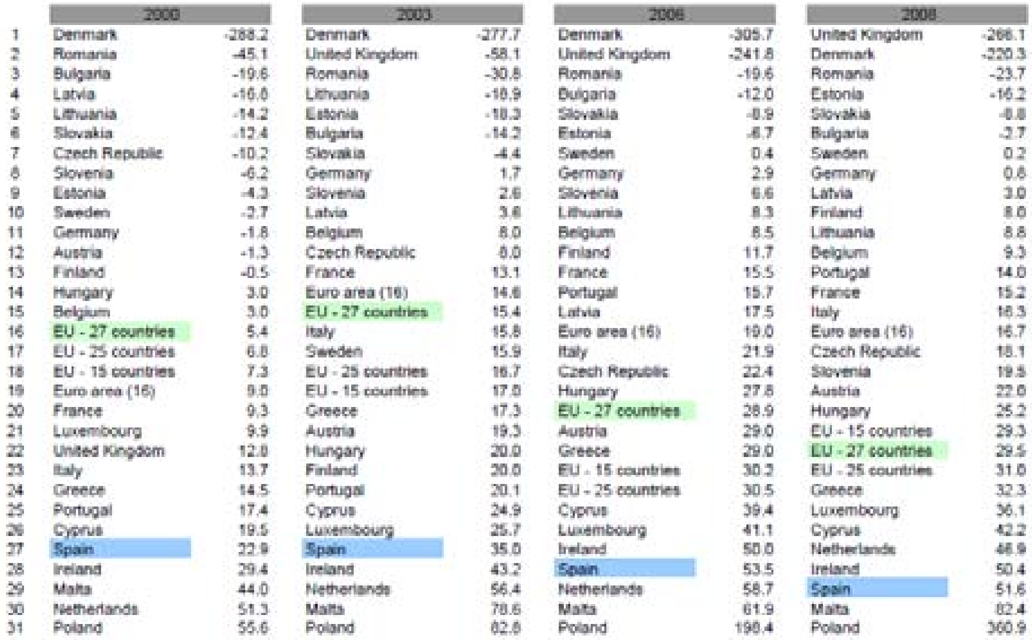
	1998		2001		2004		2008	
1	United Kingdom	-15.7	Denmark	-27.1	Denmark	-47.4	Denmark	-22.3
2	Denmark	6	United Kingdom	-9.2	United Kingdom	4.7	Estonia	23.8
3	Poland	8.3	Poland	10.3	Poland	14.4	United Kingdom	26.1
4	Czech Republic	25.7	Czech Republic	25.8	Czech Republic	25.6	Czech Republic	27.6
5	Netherlands	27.2	Romania	25.8	Estonia	28.4	Romania	27.7
6	Romania	28.5	Estonia	31.7	Romania	30.3	Poland	30.4
7	Estonia	35.6	Netherlands	34.6	Netherlands	31.6	Netherlands	34.6
8	Sweden	37.9	Sweden	36.9	Sweden	37.3	Sweden	38
9	EU - 27 countries	46.1	Bulgaria	46.3	Lithuania	47.9	France	51.2
10	EU - 25 countries	46.5	EU - 27 countries	47.5	Bulgaria	48.3	Bulgaria	52.3
11	Bulgaria	49.9	Lithuania	47.6	EU - 27 countries	50.3	EU - 27 countries	54.8
12	Lithuania	51.2	EU - 25 countries	48	EU - 25 countries	50.7	Slovenia	55
13	France	51.3	Slovenia	50.2	France	50.8	Finland	55
14	Slovenia	52.2	France	50.9	Slovenia	52.1	EU - 25 countries	55.4
15	Finland	54.5	Hungary	54.5	Finland	55	Latvia	57.9
16	Hungary	56.2	Finland	56	Hungary	60.6	Lithuania	59.6
17	Latvia	60.4	Latvia	59.1	Germany	61.1	Germany	60.9
18	Germany	61.4	Germany	60.9	Latvia	68.9	Hungary	63.7
19	Greece	69.5	Slovakia	63.5	Slovakia	69	Slovakia	65.1
20	Austria	70.3	Austria	65	Austria	70.3	Austria	69.7
21	Slovakia	71.7	Greece	68.9	Greece	72.7	Greece	72.9
22	Spain	74.5	Spain	75	Spain	77.6	Belgium	79.5
23	Belgium	79.5	Belgium	78.2	Belgium	78	Spain	81.4
24	Ireland	81.2	Italy	83.8	Portugal	83.7	Portugal	83
25	Italy	81.9	Portugal	85	Italy	84.7	Italy	85.4
26	Portugal	83.4	Ireland	90.3	Ireland	86.7	Ireland	89.9
27	Cyprus	96.9	Cyprus	96.1	Cyprus	96.4	Cyprus	97.5
28	Luxembourg	99.6	Luxembourg	97.7	Luxembourg	98.1	Luxembourg	98.6
29	Malta	100	Malta	100	Malta	100	Malta	100

Source: Eurostat (2011), *Energy Statistics*, Luxembourg: Eurostat.

Energy intensity

Improvements in energy efficiency (a 20% reduction in primary energy use compared with baseline projected levels) are one of the three targets of the EU Climate Action

Table 2.6: Percentage change of net imports of primary energy. Base year = 1997. EU 27 countries, 1997-2008.



	2000		2003		2006		2008	
1	Denmark	-288.2	Denmark	-277.7	Denmark	-305.7	United Kingdom	-266.1
2	Romania	-45.1	United Kingdom	-58.1	United Kingdom	-241.8	Denmark	-220.3
3	Bulgaria	-19.6	Romania	-30.8	Romania	-19.6	Romania	-23.7
4	Latvia	-16.6	Lithuania	-18.9	Bulgaria	-12.0	Estonia	-16.2
5	Lithuania	-14.2	Estonia	-18.3	Slovakia	-8.9	Slovakia	-6.8
6	Slovakia	-12.4	Bulgaria	-14.2	Estonia	-6.7	Bulgaria	-3.7
7	Czech Republic	-10.2	Slovakia	-4.4	Sweden	0.4	Sweden	0.2
8	Slovenia	-6.2	Germany	1.7	Germany	2.9	Germany	0.8
9	Estonia	-4.3	Slovenia	2.6	Slovenia	6.6	Latvia	3.0
10	Sweden	-2.7	Latvia	3.6	Lithuania	8.3	Finland	8.0
11	Germany	-1.8	Belgium	8.0	Belgium	8.5	Lithuania	8.8
12	Austria	-1.3	Czech Republic	8.0	Finland	11.7	Belgium	9.3
13	Finland	-0.5	France	13.1	France	15.5	Portugal	14.0
14	Hungary	3.0	Euro area (16)	14.6	Portugal	15.7	France	15.2
15	Belgium	3.0	EU - 27 countries	15.4	Latvia	17.5	Italy	16.3
16	EU - 27 countries	5.4	Italy	15.8	Euro area (16)	19.0	Euro area (16)	16.7
17	EU - 25 countries	6.8	Sweden	15.9	Italy	21.9	Czech Republic	18.1
18	EU - 15 countries	7.3	EU - 25 countries	16.7	Czech Republic	22.4	Slovenia	19.5
19	Euro area (16)	9.0	EU - 15 countries	17.0	Hungary	27.8	Austria	22.0
20	France	9.3	Greece	17.3	EU - 27 countries	28.9	Hungary	25.2
21	Luxembourg	9.9	Austria	19.3	Austria	29.0	EU - 15 countries	29.3
22	United Kingdom	12.8	Hungary	20.0	Greece	29.0	EU - 27 countries	29.5
23	Italy	13.7	Finland	20.0	EU - 15 countries	30.2	EU - 25 countries	31.0
24	Greece	14.5	Portugal	20.1	EU - 25 countries	30.5	Greece	32.3
25	Portugal	17.4	Cyprus	24.9	Cyprus	39.4	Luxembourg	36.1
26	Cyprus	19.5	Luxembourg	25.7	Luxembourg	41.1	Cyprus	42.2
27	Spain	22.9	Spain	35.0	Ireland	50.0	Netherlands	46.9
28	Ireland	29.4	Ireland	43.2	Spain	53.5	Ireland	50.4
29	Malta	44.0	Netherlands	56.4	Netherlands	58.7	Spain	51.6
30	Netherlands	51.3	Malta	78.6	Malta	61.9	Malta	82.4
31	Poland	55.6	Poland	82.8	Poland	198.4	Poland	360.9

Source: Eurostat (2011), *Energy Statistics*, Luxembourg: Eurostat.

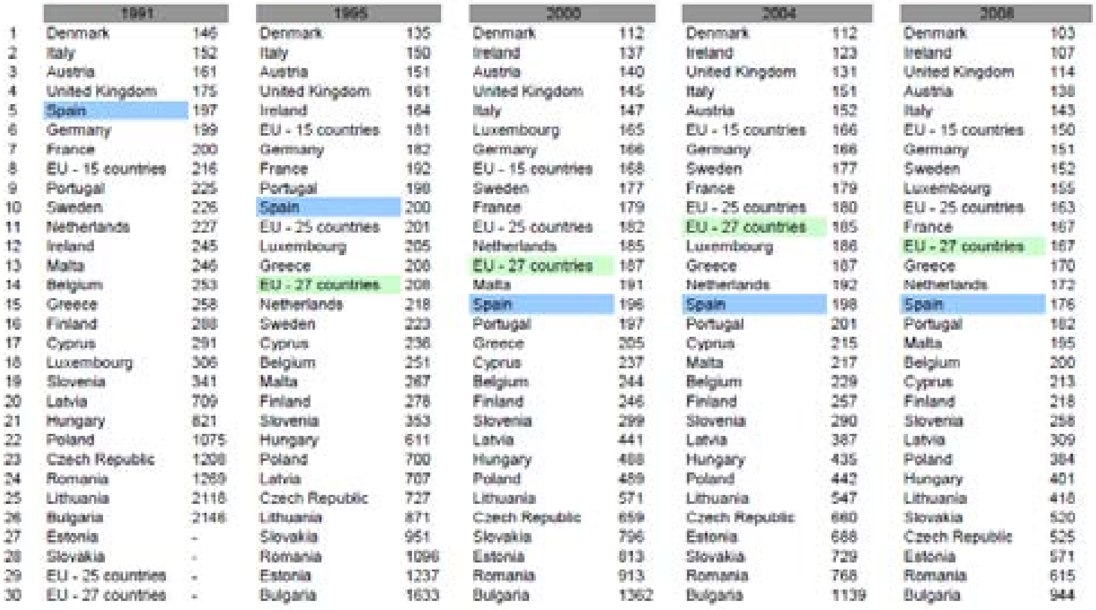
and Renewable Energy package. The levels of energy intensity, a measure of an economy's energy efficiency, are shown in *table* (2.7) for the EU 27 countries along the years 1991-2008. It is determined by the ratio between the gross inland consumption of energy and the real gross domestic product for a given calendar year (kg of oil equivalent per 1000 Euro).

Overall, the most energy-intensive Member States were East-Europan economies and Baltic economies, such as Bulgaria, Romania, Estonia or Slovakia. This is mostly due to their economic structures, as economies characterized by traditional and heavy industries, such as steel-making, will, a priori, have considerably higher energy use than post-industrial economies with large service sectors. Nevertheless, these economies have realised substantial energy savings during the last two decades, as the amount of energy required to produce a unit of economic output has more than halved in most cases.

To a higher or lesser degree, improvements in energy intensity have been made in almost every EU country. With a notable exception up to 2005: Spain. Energy intensity in the country was kept unchanged from 1991 to 2004. So, while the energy intensity average for EU-25 or EU-15 countries was in a constant downtrend, improvements in energy intensity have only been perceptible since 2005 (*figure* (2.17)).

By comparing primary energy demand, primary energy consumption intensity and

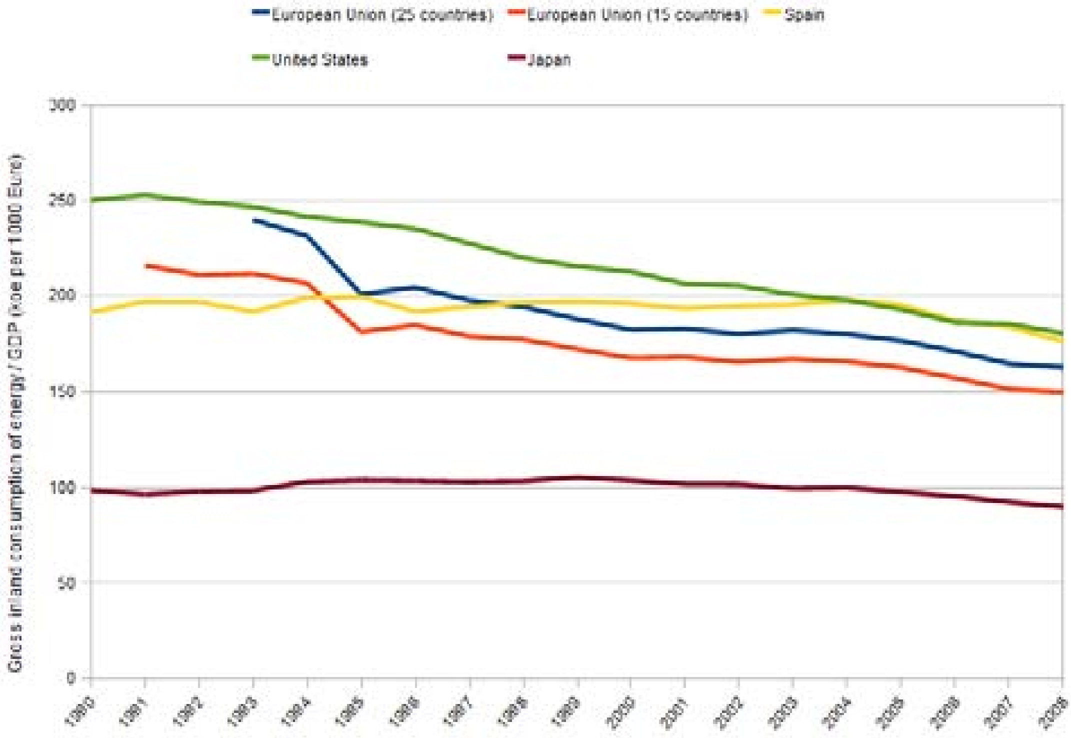
Table 2.7: Energy intensity (koe per 1000 Euro). EU 27 countries, 1991-2008.



	1991		1995		2000		2004		2008	
1	Denmark	146	Denmark	135	Denmark	112	Denmark	112	Denmark	103
2	Italy	152	Italy	150	Ireland	137	Ireland	123	Ireland	107
3	Austria	161	Austria	151	Austria	140	United Kingdom	131	United Kingdom	114
4	United Kingdom	175	United Kingdom	161	United Kingdom	145	Italy	151	Austria	138
5	Spain	197	Ireland	164	Italy	147	Austria	152	Italy	143
6	Germany	199	EU - 15 countries	181	Luxembourg	165	EU - 15 countries	166	EU - 15 countries	150
7	France	200	Germany	182	Germany	166	Germany	166	Germany	151
8	EU - 15 countries	216	France	192	EU - 15 countries	168	Sweden	177	Sweden	152
9	Portugal	225	Portugal	198	Sweden	177	France	179	Luxembourg	155
10	Sweden	226	Spain	200	France	179	EU - 25 countries	180	EU - 25 countries	163
11	Netherlands	227	EU - 25 countries	201	EU - 25 countries	182	EU - 27 countries	185	France	167
12	Ireland	245	Luxembourg	205	Netherlands	185	Luxembourg	186	EU - 27 countries	167
13	Malta	246	Greece	206	EU - 27 countries	187	Greece	187	Greece	170
14	Belgium	253	EU - 27 countries	208	Malta	191	Netherlands	192	Netherlands	172
15	Greece	258	Netherlands	218	Spain	196	Spain	198	Spain	176
16	Finland	288	Sweden	223	Portugal	197	Portugal	201	Portugal	182
17	Cyprus	291	Cyprus	236	Greece	205	Cyprus	215	Malta	195
18	Luxembourg	306	Belgium	251	Cyprus	237	Malta	217	Belgium	200
19	Slovenia	341	Malta	267	Belgium	244	Belgium	229	Cyprus	213
20	Latvia	709	Finland	278	Finland	246	Finland	257	Finland	218
21	Hungary	821	Slovenia	353	Slovenia	299	Slovenia	290	Slovenia	258
22	Poland	1075	Hungary	611	Latvia	441	Latvia	387	Latvia	309
23	Czech Republic	1208	Poland	700	Hungary	488	Hungary	435	Poland	384
24	Romania	1269	Latvia	707	Poland	489	Poland	442	Hungary	401
25	Lithuania	2118	Czech Republic	727	Lithuania	571	Lithuania	547	Lithuania	418
26	Bulgaria	2146	Lithuania	871	Czech Republic	659	Czech Republic	660	Slovakia	520
27	Estonia	-	Slovakia	951	Slovakia	796	Estonia	688	Czech Republic	525
28	Slovakia	-	Romania	1096	Estonia	813	Slovakia	729	Estonia	571
29	EU - 25 countries	-	Estonia	1237	Romania	913	Romania	768	Romania	615
30	EU - 27 countries	-	Bulgaria	1633	Bulgaria	1362	Bulgaria	1139	Bulgaria	944

Source: Eurostat (2011), *Energy Statistics*, Luxembourg: Eurostat.

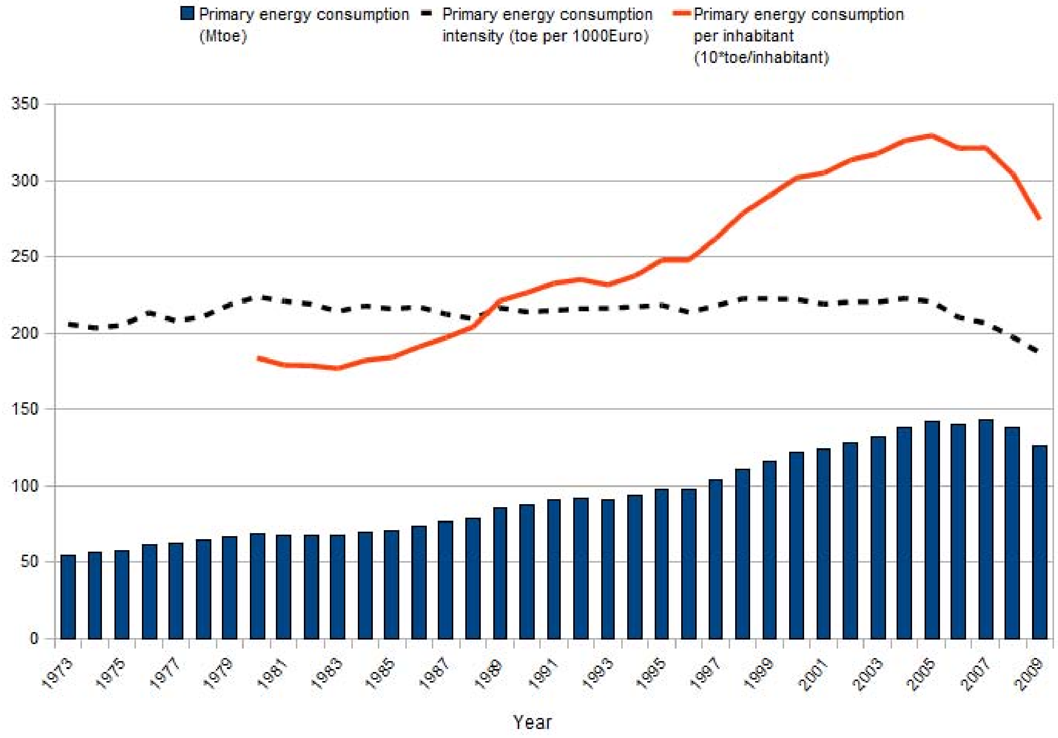
Figure 2.17: Energy intensity (koe per 1000 Euro). Spain, 1990-2008.



Source: Eurostat (2011), *Energy Statistics*, Luxembourg: Eurostat.

primary energy consumption per inhabitant, we can get a clearer picture of the energy efficiency effort in Spain. Data for primary energy consumption per inhabitant show a similar trend to primary energy consumption and confirm, on a per capita basis, the downward trend in primary energy consumption intensity, starting from 2005. This could be due to the introduction of higher-performance fuels and technologies to the power generation mix for example, as *figure* (2.15) shows a clear decrease in coal demand and, on the contrary, a higher use of gas and nuclear energies.

Figure 2.18: Primary energy consumption intensity and primary energy consumption per inhabitant. Spain, 1973-2009.



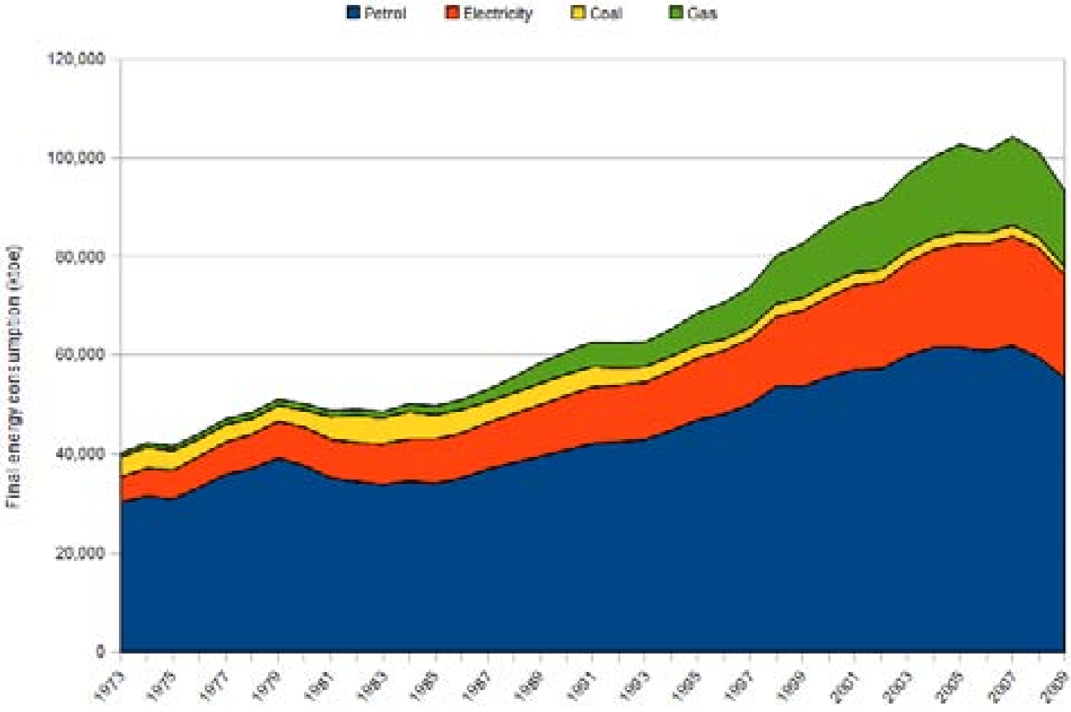
Source: Foro Nuclear (2010), *Energía 2010*, Madrid: Foro Nuclear.

Final energy demand

Final energy consumption represents the total energy consumed by end users, such as households and economic sectors such as agriculture, industry and the tertiary sector. It excludes energy used by the energy sector itself. *Figure* (2.19) shows the percentage of final energy consumption for different energy sources (coal, petrol, gas and electricity) over the years 1973-2009 in Spain.

As for primary energy demand, the negative impact of the 2007-2009 economic crisis has reversed the upward trend in final energy consumption. Unsurprisingly, fossil fuels represent the vast majority of energy consumption. And while oil is by

Figure 2.19: Final energy consumption (ktoe). Spain, 1973-2009.



Source: Foro Nuclear (2010), *Energía 2010*, Madrid: Foro Nuclear.

far the main final energy source, its relative importance has continuously decreased since 1973 (*figure* (2.20)). On the contrary, electricity and natural gas have seen their relative shares increase steadily with a remarkable expansion for natural gas since the mid-80's. The growing electrification of end-user applications has also boosted electricity consumption. This seems to be a strong trend, up to the point where coal has been almost completely replaced by electricity and natural gas.

Which sectors are responsible for this increase in natural gas and electricity consumption? As transport sectors use mainly petrol as an energy source, it is thus the industry and other sectors such as the commercial sector which have increased their consumption of natural gas (*figure* (2.21)). So, while transport is still projected to grow in the future, its higher use of oil consumption could be compensated by a decrease in oil energy use for the other final demand sectors.

The share of renewable energies sources (such as hydroelectric, solar or wind) in gross final energy demand is still very far from Spain's target of at least 20% of gross final energy demand[15]. Admittedly, Spain and most European countries have been

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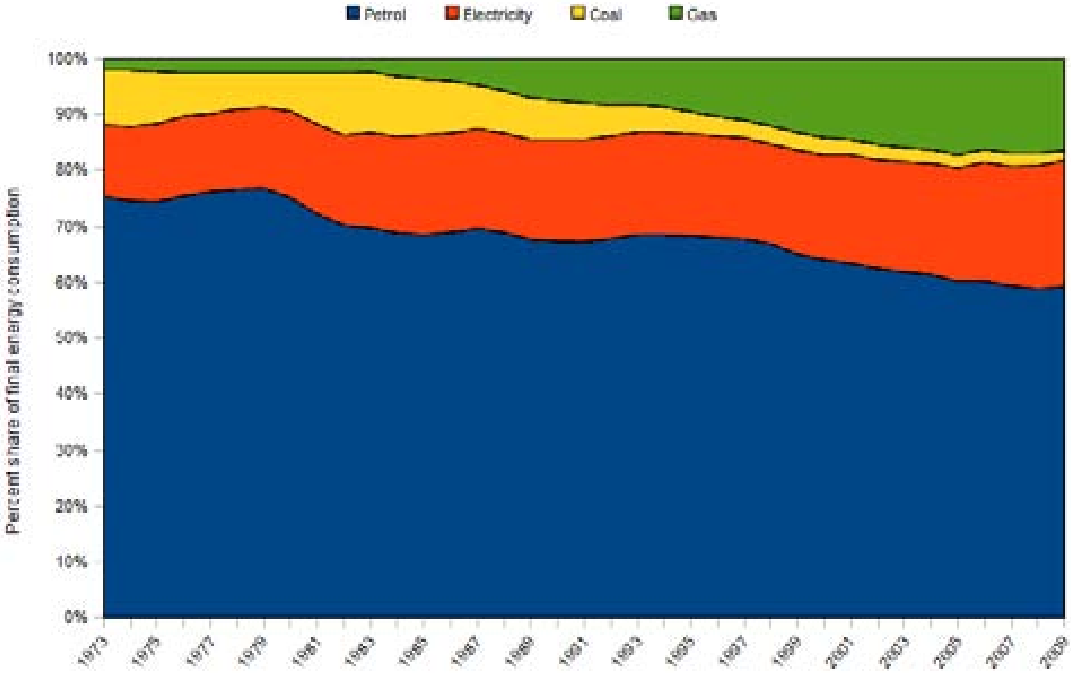
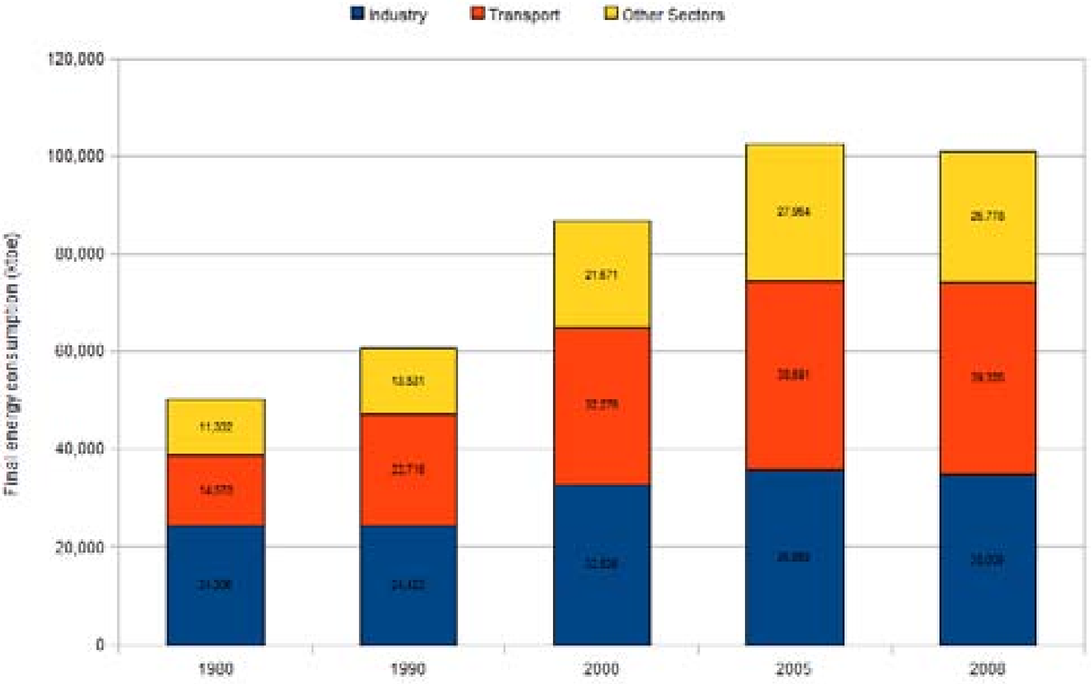
[15] The Directive on the promotion of energy from renewable sources sets an average level of primary renewable energy sources accounting for 20% of the total EU energy mix by 2020. But a distribution of the burden between the member states, part uniformly and part proportionately to GDP, is allowed. Spain's particular objective is of 20%, coinciding with the common target for the EU of 20%.

Figure 2.20: Percent share of final energy consumption (ktoe). Spain, 1973-2009.



Source: Foro Nuclear (2010), *Energía 2010*, Madrid: Foro Nuclear.

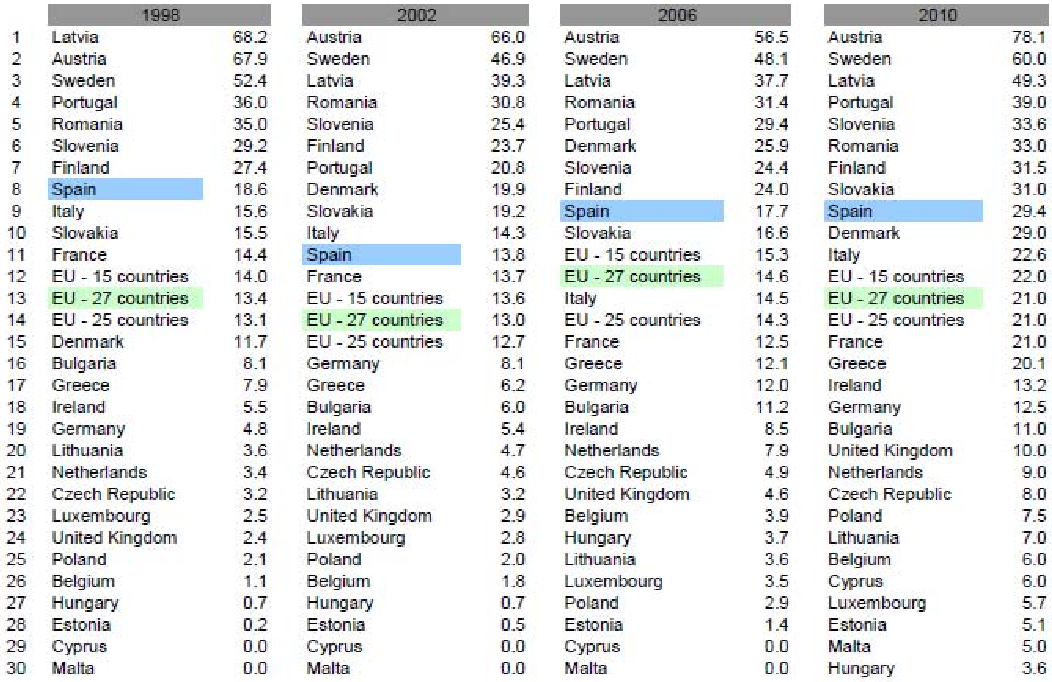
Figure 2.21: Final energy consumption by sectors (ktoe). Spain, 1973-2009.



Source: Foro Nuclear (2010), *Energía 2010*, Madrid: Foro Nuclear.

increasing their share of renewable sources for the production of electricity during the last decade (*table* (2.8)). Currently, Spain presents a consequent share of 30% from renewable energies to electrical power generation, on the way to the 2020 target of 40% set by the EU for the contribution of renewable energy to gross electricity consumption. However, this is far from sufficient to offset the still massive impact of aggregate fossil fuels in final energy demand. With a share of final energy demand constantly below 5%, except for a peak at 6.6% in 2009, renewable energies still have a long way to go before approaching the EU 2020 target of 20% (*figure* (2.22)).

Table 2.8: Electricity generated from renewable sources. EU 27 countries, 1998-2010.



	1998		2002		2006		2010	
1	Latvia	68.2	Austria	66.0	Austria	56.5	Austria	78.1
2	Austria	67.9	Sweden	46.9	Sweden	48.1	Sweden	60.0
3	Sweden	52.4	Latvia	39.3	Latvia	37.7	Latvia	49.3
4	Portugal	36.0	Romania	30.8	Romania	31.4	Portugal	39.0
5	Romania	35.0	Slovenia	25.4	Portugal	29.4	Slovenia	33.6
6	Slovenia	29.2	Finland	23.7	Denmark	25.9	Romania	33.0
7	Finland	27.4	Portugal	20.8	Slovenia	24.4	Finland	31.5
8	Spain	18.6	Denmark	19.9	Finland	24.0	Slovakia	31.0
9	Italy	15.6	Slovakia	19.2	Spain	17.7	Spain	29.4
10	Slovakia	15.5	Italy	14.3	Slovakia	16.6	Denmark	29.0
11	France	14.4	Spain	13.8	EU - 15 countries	15.3	Italy	22.6
12	EU - 15 countries	14.0	France	13.7	EU - 27 countries	14.6	EU - 15 countries	22.0
13	EU - 27 countries	13.4	EU - 15 countries	13.6	Italy	14.5	EU - 27 countries	21.0
14	EU - 25 countries	13.1	EU - 27 countries	13.0	EU - 25 countries	14.3	EU - 25 countries	21.0
15	Denmark	11.7	EU - 25 countries	12.7	France	12.5	France	21.0
16	Bulgaria	8.1	Germany	8.1	Greece	12.1	Greece	20.1
17	Greece	7.9	Greece	6.2	Germany	12.0	Ireland	13.2
18	Ireland	5.5	Bulgaria	6.0	Bulgaria	11.2	Germany	12.5
19	Germany	4.8	Ireland	5.4	Ireland	8.5	Bulgaria	11.0
20	Lithuania	3.6	Netherlands	4.7	Netherlands	7.9	United Kingdom	10.0
21	Netherlands	3.4	Czech Republic	4.6	Czech Republic	4.9	Netherlands	9.0
22	Czech Republic	3.2	Lithuania	3.2	United Kingdom	4.6	Czech Republic	8.0
23	Luxembourg	2.5	United Kingdom	2.9	Belgium	3.9	Poland	7.5
24	United Kingdom	2.4	Luxembourg	2.8	Hungary	3.7	Lithuania	7.0
25	Poland	2.1	Poland	2.0	Lithuania	3.6	Belgium	6.0
26	Belgium	1.1	Belgium	1.8	Luxembourg	3.5	Cyprus	6.0
27	Hungary	0.7	Hungary	0.7	Poland	2.9	Luxembourg	5.7
28	Estonia	0.2	Estonia	0.5	Estonia	1.4	Estonia	5.1
29	Cyprus	0.0	Cyprus	0.0	Cyprus	0.0	Malta	5.0
30	Malta	0.0	Malta	0.0	Malta	0.0	Hungary	3.6

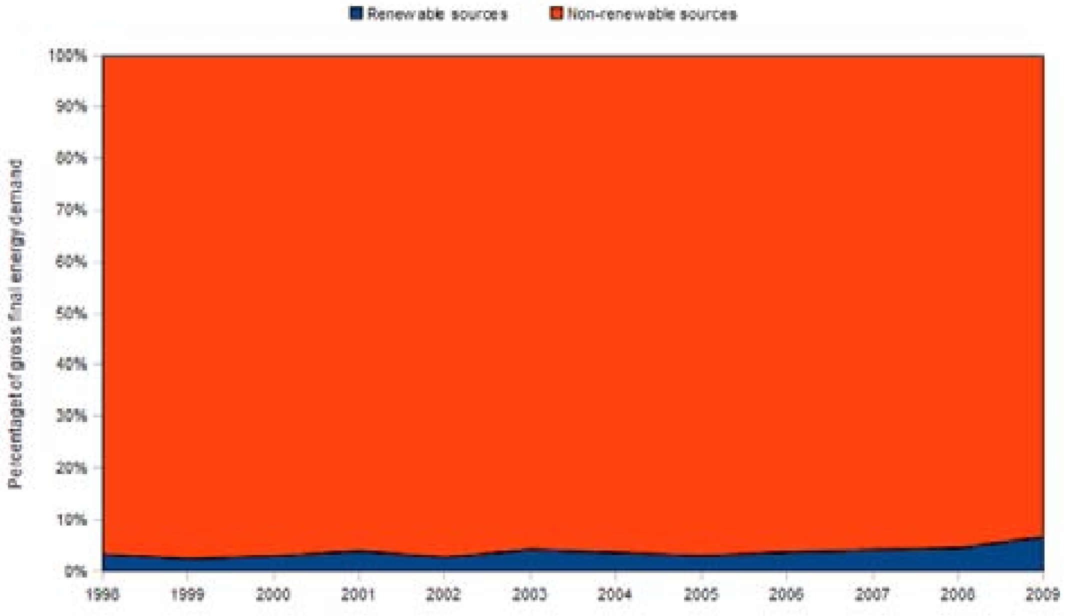
Source: Eurostat (2011), *Energy Statistics*, Luxembourg: Eurostat.

2.2.2 CO_2 emissions in Spain

Spain and the Kyoto Protocol targets

Spain's ratification of the Kyoto Protocol in 2002 implied a commitment to stabilize GHG emissions for the period 2008-2012 to a maximum 15% increase compared to 1990 levels. The reason why Spain was allowed to emit 15% more GHG emissions in 2008-12 compared to 1990 levels, was that it was not considered fully industrialised. *Table* (2.9) shows the GHG emissions index for the 27 EU countries over the period 1990-2008, with benchmark year 1990. Apart from Cyprus and Malta, Spain is the country with the largest increase in GHG emissions over that period. In 2008, GHG emissions would be, on average, 42% above 1990 levels. To bridge this gap above Kyoto limits, Spain has mostly offset its difference by purchasing emissions rights from less industrialized countries, using the flexible mechanisms provided under the

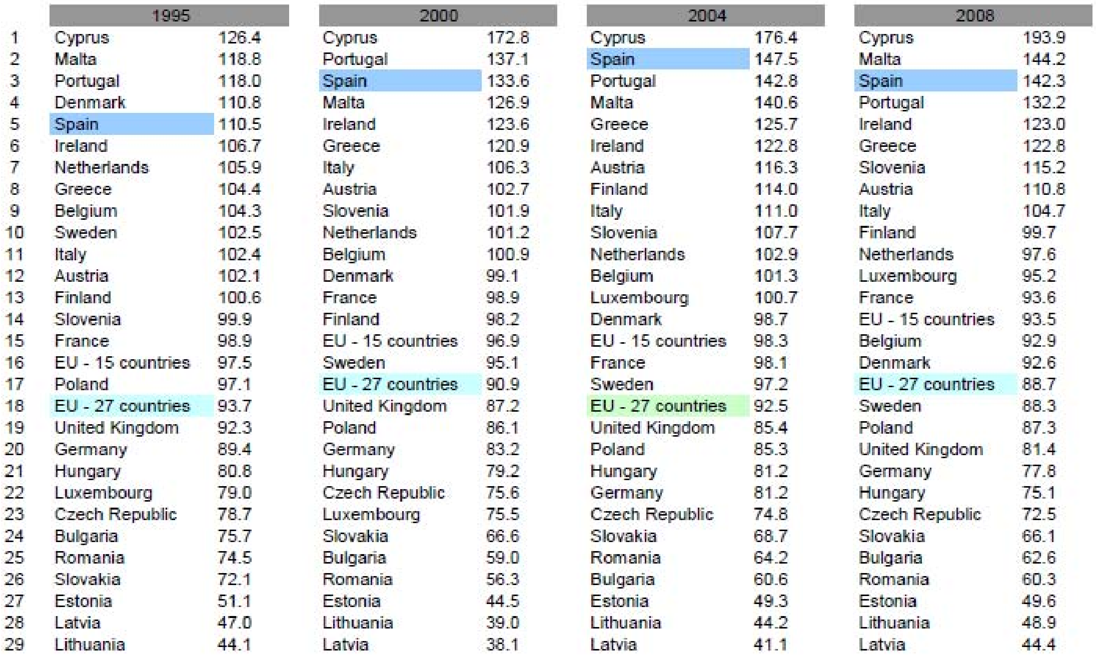
Figure 2.22: Final energy demand from renewable sources. Spain, 1998-2010.



Source: Eurostat (2011), *Energy Statistics*, Luxembourg: Eurostat; and Foro Nuclear (2010), *Energía 2010*, Madrid: Foro Nuclear.

Kyoto Protocol (particularly the Clean Development Mechanism). It has also invested in carbon-capturing sinks such as forests.

Table 2.9: Greenhouse gases emissions index. European countries. 1990 = 100. EU 27 countries, 1995-2008.

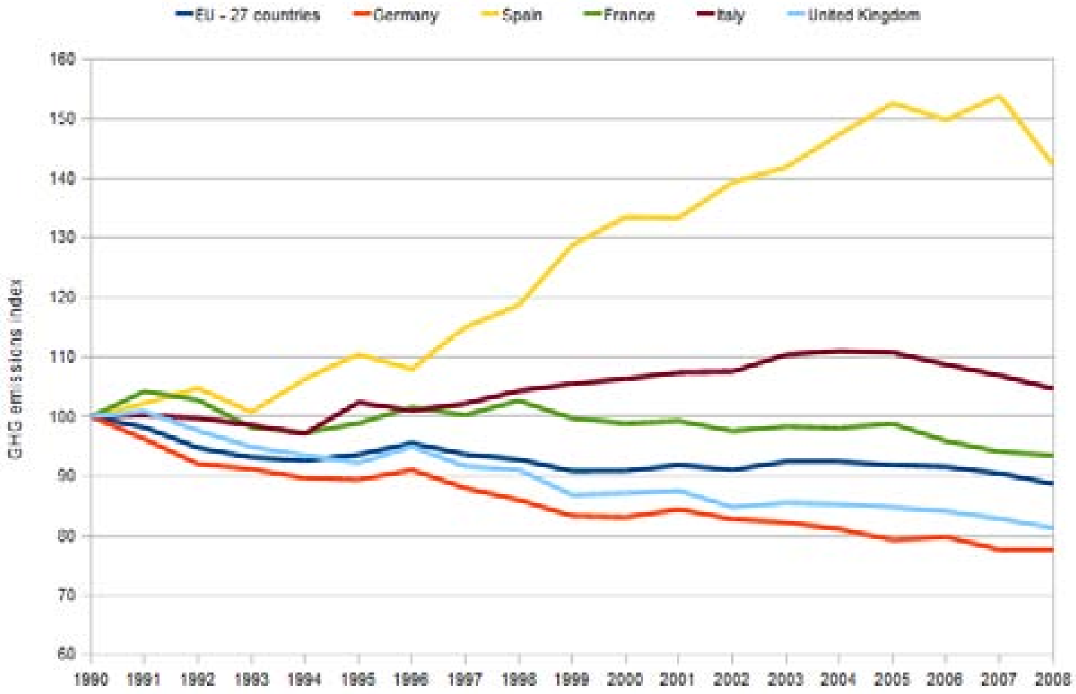


	1995		2000		2004		2008	
1	Cyprus	126.4	Cyprus	172.8	Cyprus	176.4	Cyprus	193.9
2	Malta	118.8	Portugal	137.1	Spain	147.5	Malta	144.2
3	Portugal	118.0	Spain	133.6	Portugal	142.8	Spain	142.3
4	Denmark	110.8	Malta	126.9	Malta	140.6	Portugal	132.2
5	Spain	110.5	Ireland	123.6	Greece	125.7	Ireland	123.0
6	Ireland	106.7	Greece	120.9	Ireland	122.8	Greece	122.8
7	Netherlands	105.9	Italy	106.3	Austria	116.3	Slovenia	115.2
8	Greece	104.4	Austria	102.7	Finland	114.0	Austria	110.8
9	Belgium	104.3	Slovenia	101.9	Italy	111.0	Italy	104.7
10	Sweden	102.5	Netherlands	101.2	Slovenia	107.7	Finland	99.7
11	Italy	102.4	Belgium	100.9	Netherlands	102.9	Netherlands	97.6
12	Austria	102.1	Denmark	99.1	Belgium	101.3	Luxembourg	95.2
13	Finland	100.6	France	98.9	Luxembourg	100.7	France	93.6
14	Slovenia	99.9	Finland	98.2	Denmark	98.7	EU - 15 countries	93.5
15	France	98.9	EU - 15 countries	96.9	EU - 15 countries	98.3	Belgium	92.9
16	EU - 15 countries	97.5	Sweden	95.1	France	98.1	Denmark	92.6
17	Poland	97.1	EU - 27 countries	90.9	Sweden	97.2	EU - 27 countries	88.7
18	EU - 27 countries	93.7	United Kingdom	87.2	EU - 27 countries	92.5	Sweden	88.3
19	United Kingdom	92.3	Poland	86.1	United Kingdom	85.4	Poland	87.3
20	Germany	89.4	Germany	83.2	Poland	85.3	United Kingdom	81.4
21	Hungary	80.8	Hungary	79.2	Hungary	81.2	Germany	77.8
22	Luxembourg	79.0	Czech Republic	75.6	Germany	81.2	Hungary	75.1
23	Czech Republic	78.7	Luxembourg	75.5	Czech Republic	74.8	Czech Republic	72.5
24	Bulgaria	75.7	Slovakia	66.6	Slovakia	68.7	Slovakia	66.1
25	Romania	74.5	Bulgaria	59.0	Romania	64.2	Bulgaria	62.6
26	Slovakia	72.1	Romania	56.3	Bulgaria	60.6	Romania	60.3
27	Estonia	51.1	Estonia	44.5	Estonia	49.3	Estonia	49.6
28	Latvia	47.0	Lithuania	39.0	Lithuania	44.2	Lithuania	48.9
29	Lithuania	44.1	Latvia	38.1	Latvia	41.1	Latvia	44.4

Source: Eurostat (2011), *Environment Statistics*, Luxembourg: Eurostat.

This sharp increase is particularly striking when compared to the GHG emissions index of the other four major EU economies. Even if GHG fell by 8% over the year 2008, the last year for which figures are available, the question remains wether this drop is mostly related to the economic crisis and a reduction in fuel consumption by transport and heavy industries like cement manufacturing, or is the consequence of a structural energy mix change, with renewable energy sources and gas gradually replacing coal and petrol in the generation mix.

Figure 2.23: Greenhouse gases emissions index. 1990 = 100. Major EU countries, 1990-2008.



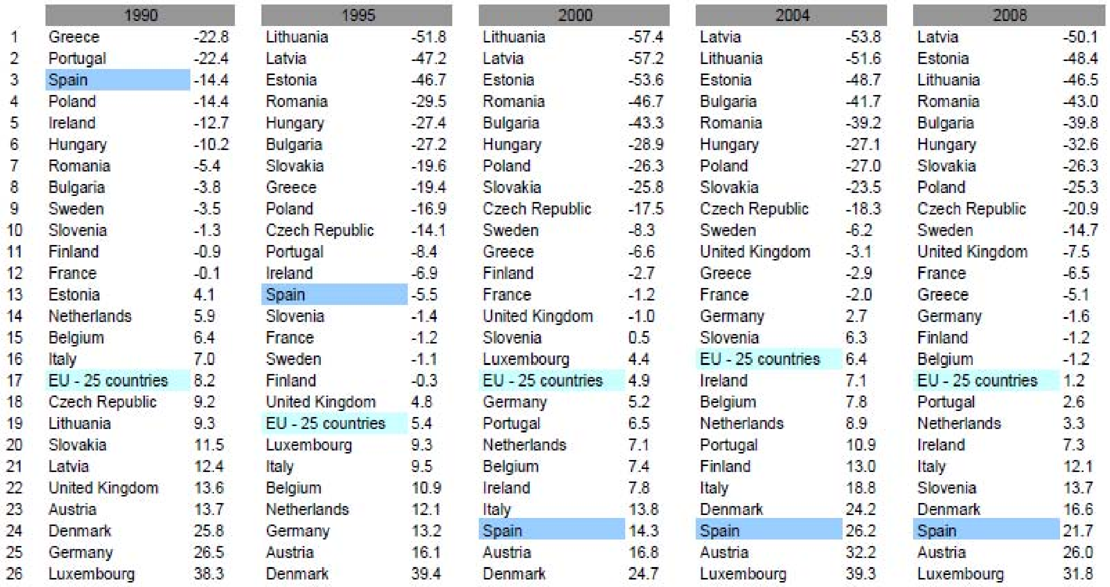
Source: Eurostat (2011), *Environment Statistics*, Luxembourg: Eurostat.

Spain is not the only country with difficulty to comply its Kyoto GHG emissions target, as evidence by *table* (2.10), but it is one of the three most problematic cases among EU countries, with Austria and Luxembourg. Due to an excess of 23% with respect to its limit commitment under the Kyoto Protocol, it presents the worst situation among the five major EU countries with respect to their Kyoto GHG emissions targets (*figure* (2.24)).

Socioeconomic indicators: CO_2 emissions per capita and per GDP unit

Several factors have played a key role in Spain's GHG emission increase and the distance taken away from Kyoto objectives: a fast and sustained economic growth during the the 1990-200 period, population growth and a lack of further effort in matters of

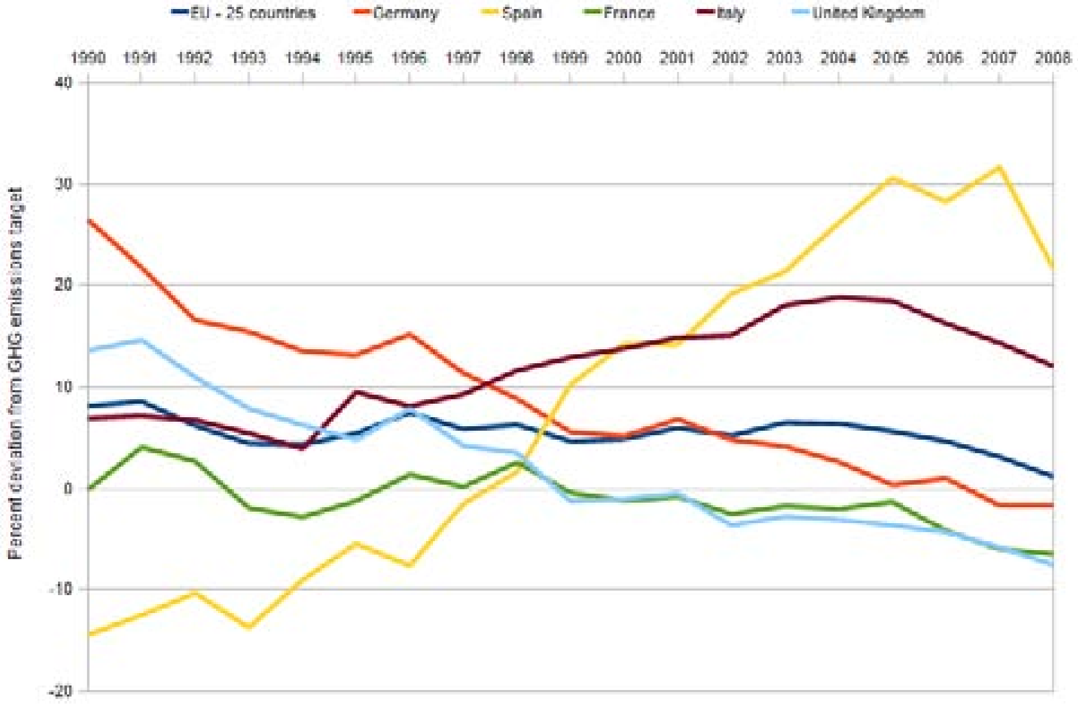
Table 2.10: Greenhouse gases emissions target. Percent deviation from the Kyoto Protocol obligations. EU 25 countries, 1990-2008.



	1990		1995		2000		2004		2008	
1	Greece	-22.8	Lithuania	-51.8	Lithuania	-57.4	Latvia	-53.8	Latvia	-50.1
2	Portugal	-22.4	Latvia	-47.2	Latvia	-57.2	Lithuania	-51.6	Estonia	-48.4
3	Spain	-14.4	Estonia	-46.7	Estonia	-53.6	Estonia	-48.7	Lithuania	-46.5
4	Poland	-14.4	Romania	-29.5	Romania	-46.7	Bulgaria	-41.7	Romania	-43.0
5	Ireland	-12.7	Hungary	-27.4	Bulgaria	-43.3	Romania	-39.2	Bulgaria	-39.8
6	Hungary	-10.2	Bulgaria	-27.2	Hungary	-28.9	Hungary	-27.1	Hungary	-32.6
7	Romania	-5.4	Slovakia	-19.6	Poland	-26.3	Poland	-27.0	Slovakia	-26.3
8	Bulgaria	-3.8	Greece	-19.4	Slovakia	-25.8	Slovakia	-23.5	Poland	-25.3
9	Sweden	-3.5	Poland	-16.9	Czech Republic	-17.5	Czech Republic	-18.3	Czech Republic	-20.9
10	Slovenia	-1.3	Czech Republic	-14.1	Sweden	-8.3	Sweden	-6.2	Sweden	-14.7
11	Finland	-0.9	Portugal	-8.4	Greece	-6.6	United Kingdom	-3.1	United Kingdom	-7.5
12	France	-0.1	Ireland	-6.9	Finland	-2.7	Greece	-2.9	France	-6.5
13	Estonia	4.1	Spain	-5.5	France	-1.2	France	-2.0	Greece	-5.1
14	Netherlands	5.9	Slovenia	-1.4	United Kingdom	-1.0	Germany	2.7	Germany	-1.6
15	Belgium	6.4	France	-1.2	Slovenia	0.5	Slovenia	6.3	Finland	-1.2
16	Italy	7.0	Sweden	-1.1	Luxembourg	4.4	EU - 25 countries	6.4	Belgium	-1.2
17	EU - 25 countries	8.2	Finland	-0.3	EU - 25 countries	4.9	Ireland	7.1	EU - 25 countries	1.2
18	Czech Republic	9.2	United Kingdom	4.8	Germany	5.2	Belgium	7.8	Portugal	2.6
19	Lithuania	9.3	EU - 25 countries	5.4	Portugal	6.5	Netherlands	8.9	Netherlands	3.3
20	Slovakia	11.5	Luxembourg	9.3	Netherlands	7.1	Portugal	10.9	Ireland	7.3
21	Latvia	12.4	Italy	9.5	Belgium	7.4	Finland	13.0	Italy	12.1
22	United Kingdom	13.6	Belgium	10.9	Ireland	7.8	Italy	18.8	Slovenia	13.7
23	Austria	13.7	Netherlands	12.1	Italy	13.8	Denmark	24.2	Denmark	16.6
24	Denmark	25.8	Germany	13.2	Spain	14.3	Spain	26.2	Spain	21.7
25	Germany	26.5	Austria	16.1	Austria	16.8	Austria	32.2	Austria	26.0
26	Luxembourg	38.3	Denmark	39.4	Denmark	24.7	Luxembourg	39.3	Luxembourg	31.8

Source: Eurostat (2011), *Environment Statistics*, Luxembourg: Eurostat.

Figure 2.24: Greenhouse gases emissions target. Percent deviation from the Kyoto Protocol obligations. Major EU countries, 1990-2008.

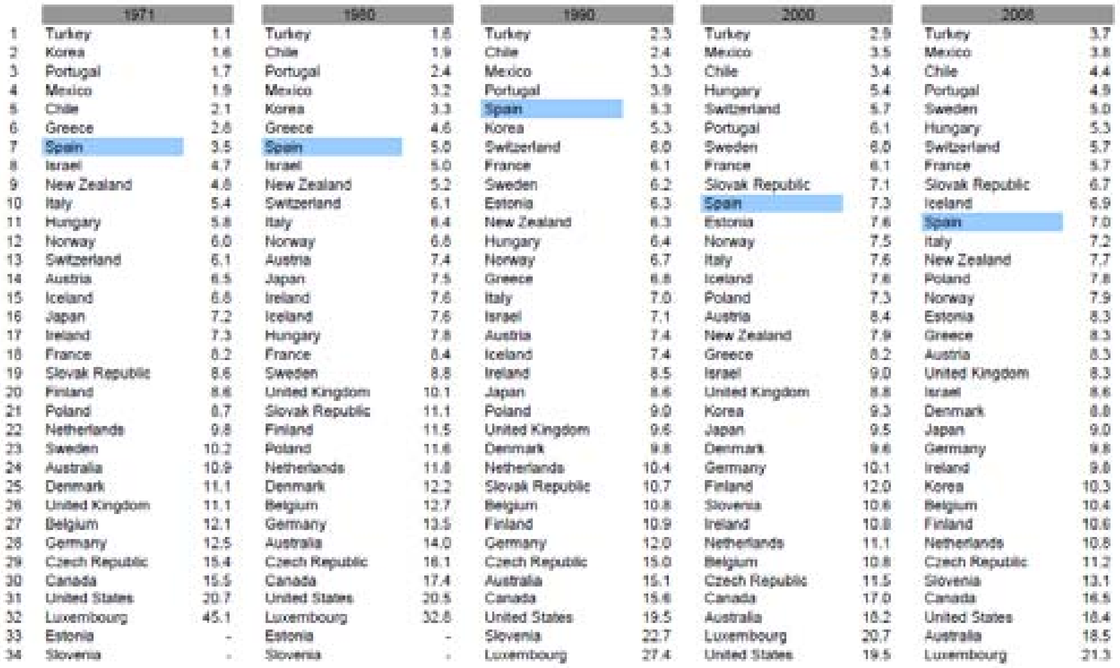


Source: Eurostat (2011), *Environment Statistics*, Luxembourg: Eurostat.

energy saving and efficiency. As a result of these, more specific drivers on Spain's

GHG emissions can be proposed: higher energy consumption, electricity generation and transport demand. With respect to population growth, *table* (2.11) indicates that GHG emissions per capita were moderate regarding the other OECD countries, about the average of Member States participating in the burden sharing emissions targets established under the Kyoto Protocol. As economic and population growths continue through 2020, the evolution of emissions highlights the difficulties that are being faced by Spain in the attempt to promote growth and economic convergence with the European Union while limiting the increase in GHG emissions.

Table 2.11: CO_2 emissions from fuel combustion per inhabitant (tonnes CO_2 / capita). OECD countries, 1971-2008.

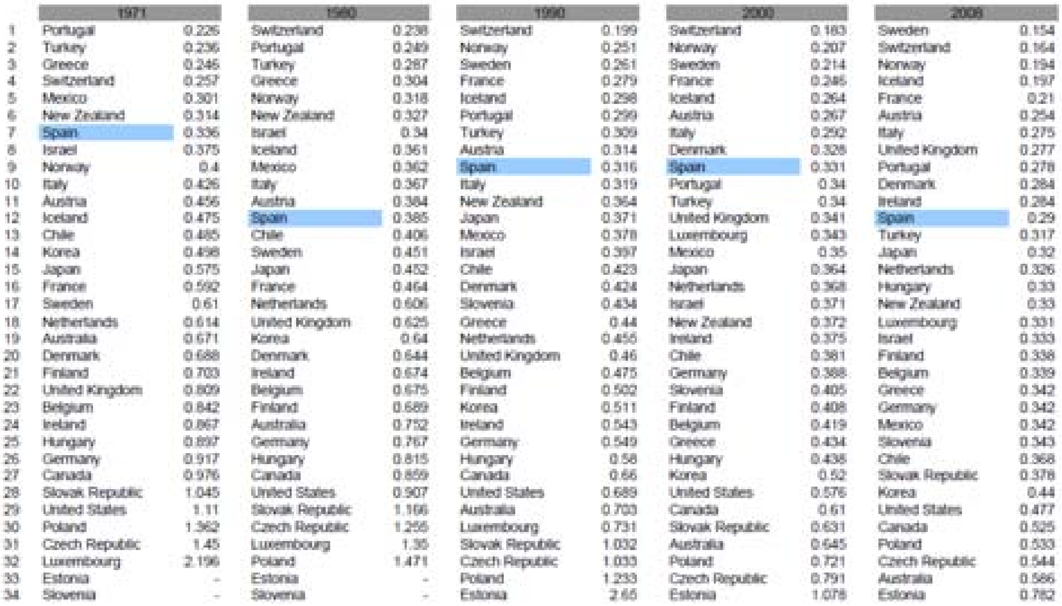


	1971		1980		1990		2000		2008	
1	Turkey	1.1	Turkey	1.6	Turkey	2.3	Turkey	2.9	Turkey	3.7
2	Korea	1.6	Chile	1.9	Chile	2.4	Mexico	3.5	Mexico	3.8
3	Portugal	1.7	Portugal	2.4	Mexico	3.3	Chile	3.4	Chile	4.4
4	Mexico	1.9	Mexico	3.2	Portugal	3.9	Hungary	5.4	Portugal	4.5
5	Chile	2.1	Korea	3.3	Spain	5.3	Switzerland	5.7	Sweden	5.0
6	Greece	2.6	Greece	4.6	Korea	5.3	Portugal	6.1	Hungary	5.3
7	Spain	3.5	Spain	5.0	Switzerland	6.0	Sweden	6.0	Switzerland	5.7
8	Israel	4.7	Israel	5.0	France	6.1	France	6.1	France	5.7
9	New Zealand	4.8	New Zealand	5.2	Sweden	6.2	Slovak Republic	7.1	Slovak Republic	6.7
10	Italy	5.4	Switzerland	6.1	Estonia	6.3	Spain	7.3	Iceland	6.9
11	Hungary	5.8	Italy	6.4	New Zealand	6.3	Estonia	7.6	Spain	7.0
12	Norway	6.0	Norway	6.6	Hungary	6.4	Norway	7.5	Italy	7.2
13	Switzerland	6.1	Austria	7.4	Norway	6.7	Italy	7.6	New Zealand	7.7
14	Austria	6.5	Japan	7.5	Greece	6.8	Iceland	7.8	Poland	7.8
15	Iceland	6.8	Ireland	7.6	Italy	7.0	Poland	7.3	Norway	7.9
16	Japan	7.2	Iceland	7.6	Israel	7.1	Austria	8.4	Estonia	8.3
17	Ireland	7.3	Hungary	7.8	Austria	7.4	New Zealand	7.9	Greece	8.3
18	France	8.2	France	8.4	Iceland	7.4	Greece	8.2	Austria	8.3
19	Slovak Republic	8.6	Sweden	8.8	Ireland	8.5	Israel	9.0	United Kingdom	8.3
20	Finland	8.6	United Kingdom	10.1	Japan	8.6	United Kingdom	8.8	Israel	8.6
21	Poland	8.7	Slovak Republic	11.1	Poland	9.0	Korea	9.3	Denmark	8.8
22	Netherlands	9.8	Finland	11.5	United Kingdom	9.6	Japan	9.5	Japan	9.0
23	Sweden	10.2	Poland	11.6	Denmark	9.8	Denmark	9.6	Germany	9.8
24	Australia	10.9	Netherlands	11.8	Netherlands	10.4	Germany	10.1	Ireland	9.8
25	Denmark	11.1	Denmark	12.2	Slovak Republic	10.7	Finland	12.0	Korea	10.3
26	United Kingdom	11.1	Belgium	12.7	Belgium	10.8	Slovenia	10.6	Belgium	10.4
27	Belgium	12.1	Germany	13.5	Finland	10.9	Ireland	10.8	Finland	10.6
28	Germany	12.5	Australia	14.0	Germany	12.0	Netherlands	11.1	Netherlands	10.8
29	Czech Republic	15.4	Czech Republic	16.1	Czech Republic	15.0	Belgium	10.8	Czech Republic	11.2
30	Canada	15.5	Canada	17.4	Australia	15.1	Czech Republic	11.5	Slovenia	13.1
31	United States	20.7	United States	20.5	Canada	15.6	Canada	17.0	Canada	16.5
32	Luxembourg	45.1	Luxembourg	32.8	United States	19.5	Australia	18.2	United States	18.4
33	Estonia	-	Estonia	-	Slovenia	22.7	Luxembourg	20.7	Australia	18.5
34	Slovenia	-	Slovenia	-	Luxembourg	27.4	United States	19.5	Luxembourg	21.3

Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

To check the importance of economic growth in the GHG emissions drift, *table* (2.12) compares the CO_2 emissions per unit of real GDP for the 34 OECD countries. Such an indicator strongly reflects energy supply constraints and choices of the economic sectors in an economy, although climate and other variables also affect energy use. It may also indicate the sectors that predominate in different countries' economies. Relatively high values of emissions per GDP indicate a potential for decoupling CO_2 emissions from economic growth. For example, trough fuel switching away from carbon-intensive sources or trough energy efficiency at all stages of the energy supply chain (from fuel extraction to energy end-use). Compared with other OECD countries, CO_2 emissions per unit of GDP in Spain appear not particularly high and have been rather stable over the period 1971-2008, with a sensible decrease in the years post-2005. No significant improvement has been done during that period, as compared with the declining trend of this indicator for the other four major EU countries (*figure* (2.25)). Overall, when compared with other ratio indicators for Spain, CO_2 emissions per unit of GDP still appears as the most problematic trend, probably due to Spain's growth model, based in sectors of great energy intensity.

Table 2.12: CO_2 emissions / GDP using purchasing power parities (kg CO_2 / US dollar (2000 prices)). OECD countries, 1971-2008.



	1971		1980		1990		2000		2008	
1	Portugal	0.226	Switzerland	0.238	Switzerland	0.199	Switzerland	0.183	Sweden	0.154
2	Turkey	0.236	Portugal	0.249	Norway	0.251	Norway	0.207	Switzerland	0.164
3	Greece	0.246	Turkey	0.287	Sweden	0.261	Sweden	0.214	Norway	0.194
4	Switzerland	0.257	Greece	0.304	France	0.279	France	0.246	Iceland	0.197
5	Mexico	0.301	Norway	0.318	Iceland	0.298	Iceland	0.264	France	0.21
6	New Zealand	0.314	New Zealand	0.327	Portugal	0.299	Austria	0.267	Austria	0.254
7	Spain	0.336	Israel	0.34	Turkey	0.309	Italy	0.292	Italy	0.275
8	Israel	0.375	Iceland	0.361	Austria	0.314	Denmark	0.328	United Kingdom	0.277
9	Norway	0.4	Mexico	0.362	Spain	0.316	Spain	0.331	Portugal	0.278
10	Italy	0.426	Italy	0.367	Italy	0.319	Portugal	0.34	Denmark	0.284
11	Austria	0.456	Austria	0.384	New Zealand	0.364	Turkey	0.34	Ireland	0.284
12	Iceland	0.475	Spain	0.385	Japan	0.371	United Kingdom	0.341	Spain	0.29
13	Chile	0.485	Chile	0.406	Mexico	0.378	Luxembourg	0.343	Turkey	0.317
14	Korea	0.498	Sweden	0.451	Israel	0.397	Mexico	0.35	Japan	0.32
15	Japan	0.575	Japan	0.452	Chile	0.423	Japan	0.364	Netherlands	0.326
16	France	0.592	France	0.464	Denmark	0.424	Netherlands	0.368	Hungary	0.33
17	Sweden	0.61	Netherlands	0.606	Slovenia	0.434	Israel	0.371	New Zealand	0.33
18	Netherlands	0.614	United Kingdom	0.625	Greece	0.44	New Zealand	0.372	Luxembourg	0.331
19	Australia	0.671	Korea	0.64	Netherlands	0.456	Ireland	0.375	Israel	0.333
20	Denmark	0.688	Denmark	0.644	United Kingdom	0.46	Chile	0.381	Finland	0.338
21	Finland	0.703	Ireland	0.674	Belgium	0.475	Germany	0.388	Belgium	0.339
22	United Kingdom	0.809	Belgium	0.675	Finland	0.502	Slovenia	0.405	Greece	0.342
23	Belgium	0.842	Finland	0.689	Korea	0.511	Finland	0.408	Germany	0.342
24	Ireland	0.867	Australia	0.752	Ireland	0.543	Belgium	0.419	Mexico	0.342
25	Hungary	0.897	Germany	0.767	Germany	0.549	Greece	0.434	Slovenia	0.343
26	Germany	0.917	Hungary	0.815	Hungary	0.58	Hungary	0.438	Chile	0.368
27	Canada	0.976	Canada	0.859	Canada	0.66	Korea	0.52	Slovak Republic	0.378
28	Slovak Republic	1.045	United States	0.907	United States	0.689	United States	0.576	Korea	0.44
29	United States	1.11	Slovak Republic	1.166	Australia	0.703	Canada	0.61	United States	0.477
30	Poland	1.362	Czech Republic	1.255	Luxembourg	0.731	Slovak Republic	0.631	Canada	0.525
31	Czech Republic	1.45	Luxembourg	1.35	Slovak Republic	1.032	Australia	0.645	Poland	0.533
32	Luxembourg	2.196	Poland	1.471	Czech Republic	1.033	Poland	0.721	Czech Republic	0.544
33	Estonia	-	Estonia	-	Poland	1.233	Czech Republic	0.791	Australia	0.586
34	Slovenia	-	Slovenia	-	Estonia	2.65	Estonia	1.078	Estonia	0.782

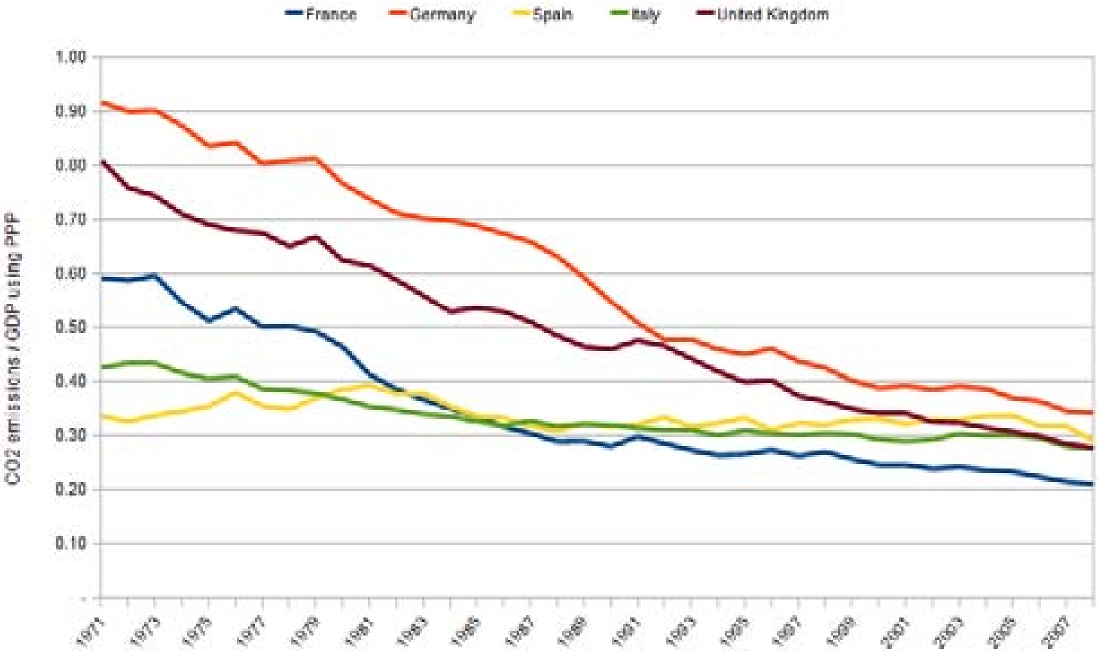
Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

Sectoral indicators: CO_2 emissions by fuel and CO_2 emissions by sectors

To inspect the impact of the energy mix on carbon emissions from fuel combustion, *figure* (2.27) shows the CO_2 emissions levels resulting from the use of the three different fossil fuels. This indicator weights the fossil fuel consumption levels by their global warming potential, and the results are expressed in CO_2 equivalents. Obviously, the CO_2 emissions levels for each fuel follow the trends of their use described in *figure* (2.14). However, their impact in terms of CO_2 emissions being different (*figure* (2.28)), the relative decrease of coal and oil consumption in favour of gas translates into a relative decrease in carbon intensity (carbon emissions per unit of primary energy supply) within the energy mix (*figure* (2.29)). This explains the importance for the inclusion of less polluting energy sources in the energy mix.

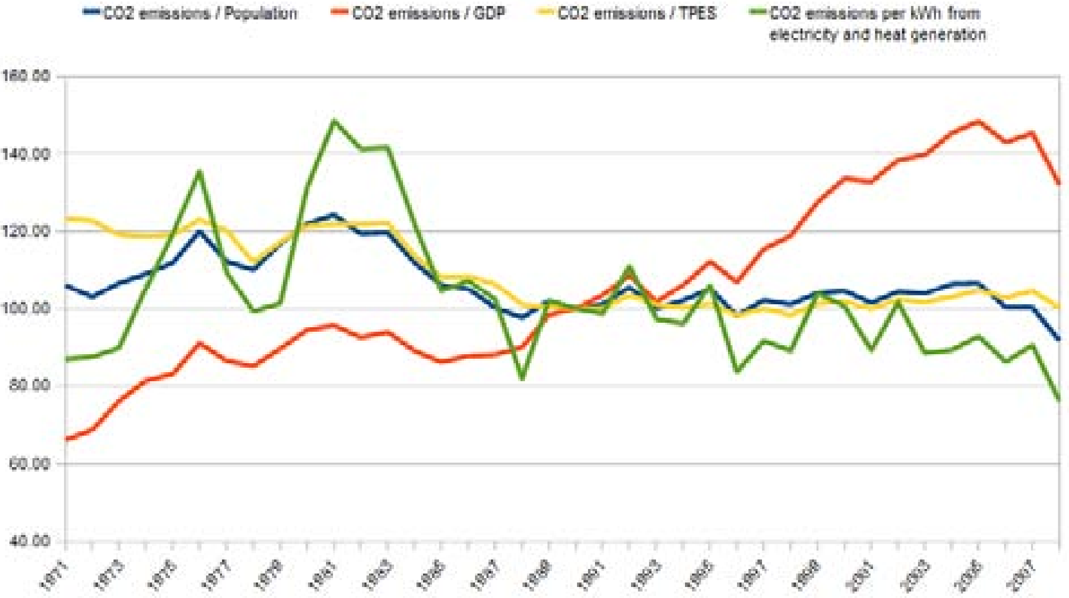
Given that energy use is still projected to increase in Spain, it must be ensured that CO_2 emissions will grow at a slower pace than energy use, as it has happened during the period 1971-2008 (*figure* (2.30)). Two directions can be taken. First, to

Figure 2.25: CO_2 emissions / GDP using purchasing power parities (kg CO_2 / US dollar (2000 prices)). Major EU countries, 1971-2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

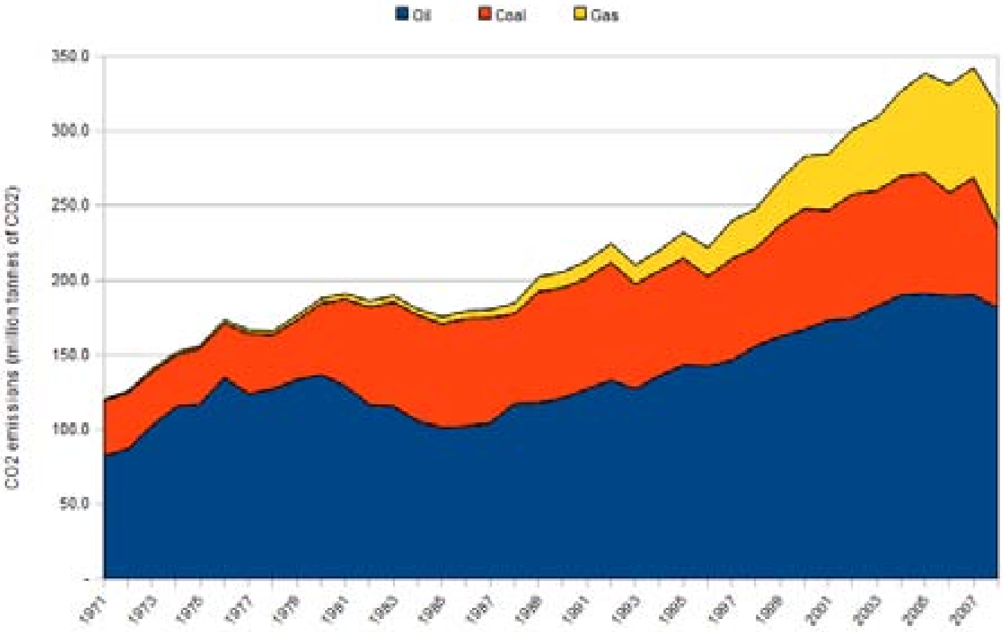
Figure 2.26: CO_2 emissions ratios (base year 1990 = 100). Spain, 1971-2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

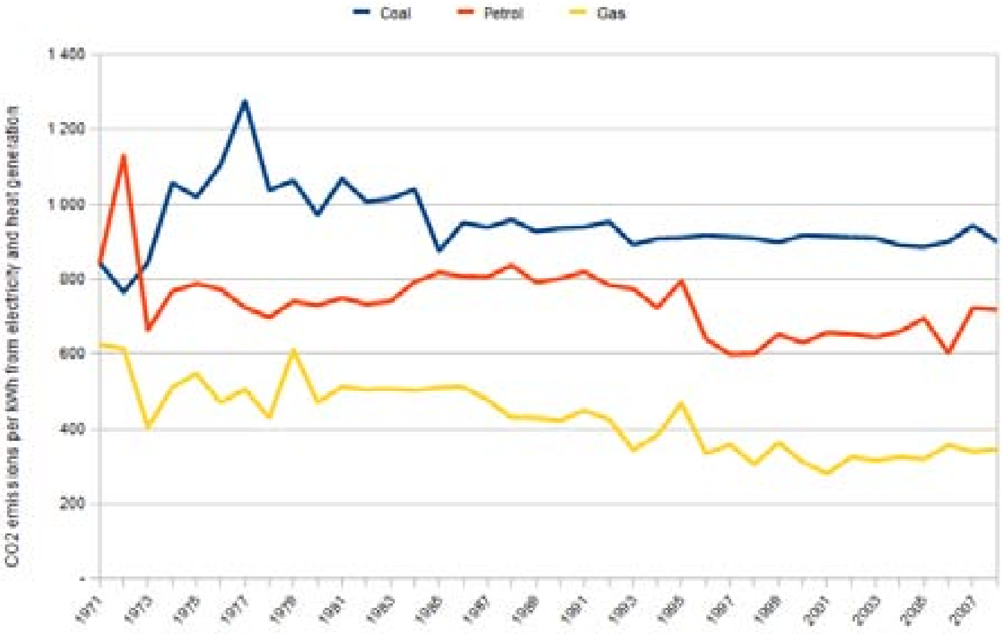
foster energy efficiency efforts and structural change in the Spanish economy. And, second, to continue substitution away from coal and oil towards an increased reliance on less polluting sources and renewable energy sources.

Figure 2.27: CO_2 emissions from fuel combustion by fuel. Spain, 1971-2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

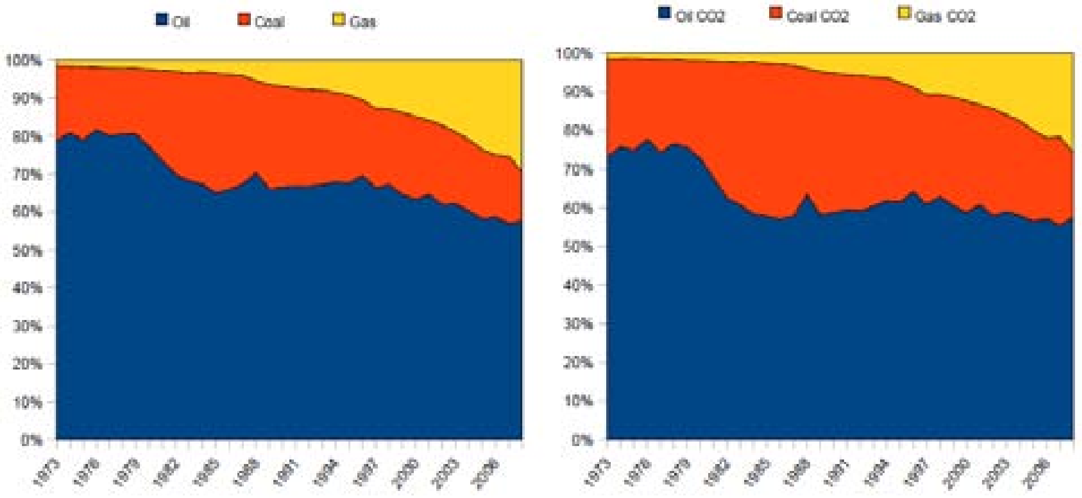
Figure 2.28: CO_2 emissions per kWh from electricity and heat generation. Spain, 1971-2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

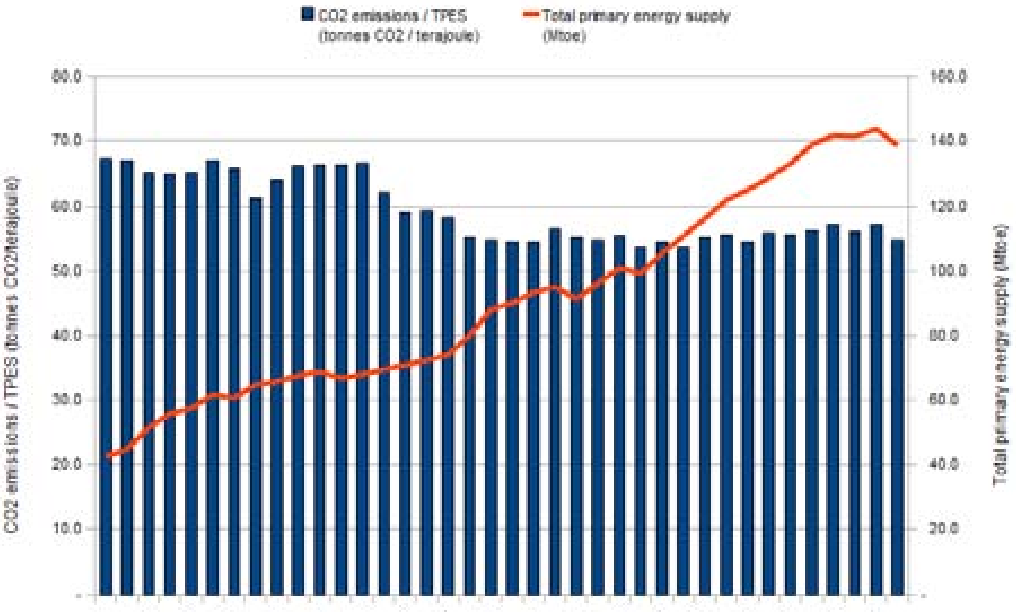
All sectors do not contribute in the same proportion to the excess in GHG emissions. To improve energy efficiency and switch to less polluting energies, one must define the key source sectors to act on. Such a sector is defined as an emission source

Figure 2.29: Percent share of primary energy consumption vs. Percent share of CO_2 emissions from fuel combustion by fuel. Spain, 1973-2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

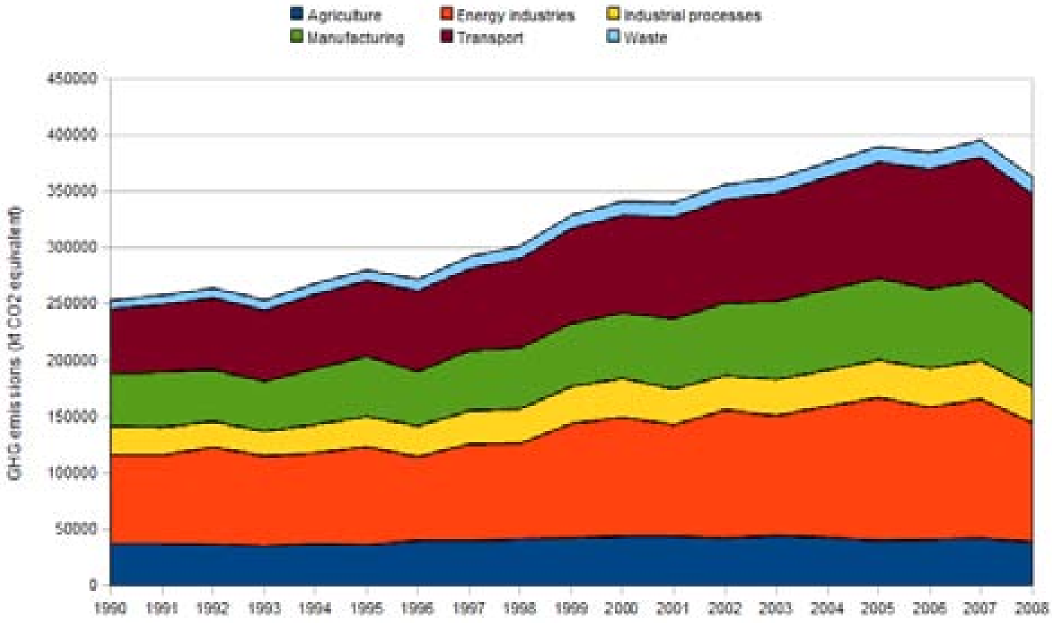
Figure 2.30: TPES vs. CO_2 emissions from fuel combustion / TPES. Spain, 1971-2008.



Source: IEA (2010), *CO2 Emissions from Fuel Combustion. 2010 Edition*, Paris: IEA.

category that has a significant influence on a economy's GHG inventory in terms of the absolute level of emissions and trend in emissions. *Figure* (2.31) shows the macro-sectors that predominate in terms of GHG emissions in Spain. The distribution projection shows clearly the importance of emissions imputable to the energy and transport sectors. According to the Eurostat data, in 2008, emissions from energy process and transport represented about 30% of total national emissions each.

Figure 2.31: GHG emissions by sector (kilotonne CO_2 equivalent). Spain, 1990-2008.



Source: Eurostat (2011), *Environment Statistics*, Luxembourg: Eurostat.

Emissions coming from sectors concerned with diffuse pollution, particularly the transport and the residential sector, share a consequent part of the emissions increase[16]. It can be deduced from *figure* (2.32), which gives a higher sectoral disaggregation for CO_2 emissions. The sectors showing the highest growth in emissions in the period 1990-2008 are transport, households and other services, counting with at least a 75% increase. As a comparison, the rest of the sectors grew, on average, only 35%. For example, agriculture, metallurgy or electricity production only increased by 10%, 31% and 40% respectively. Transport accounts over 30% of the total national energy consumption and is one of the most challenging sector to impact upon. Characterised by a modal imbalance, with predominance of road transport (90% in passenger transport and 83% in freight transport in 2008) transport has also faced a strong demand growth in recent years. Together with population growth, this has led to a 94.4% increase in intercity passenger transport and a 86.5% increase in transport freight between 1990 and 2008. If some improvement can be expected as the price of the oil barrel increases, on average, diffuse emissions are quite inelastic to price changes because people still have heating in their houses and travel from one place to the other.

The fulfillment of Spain's commitments under the Kyoto Protocol should require therefore a decisive action on diffuse emissions, related directly to the behaviours of

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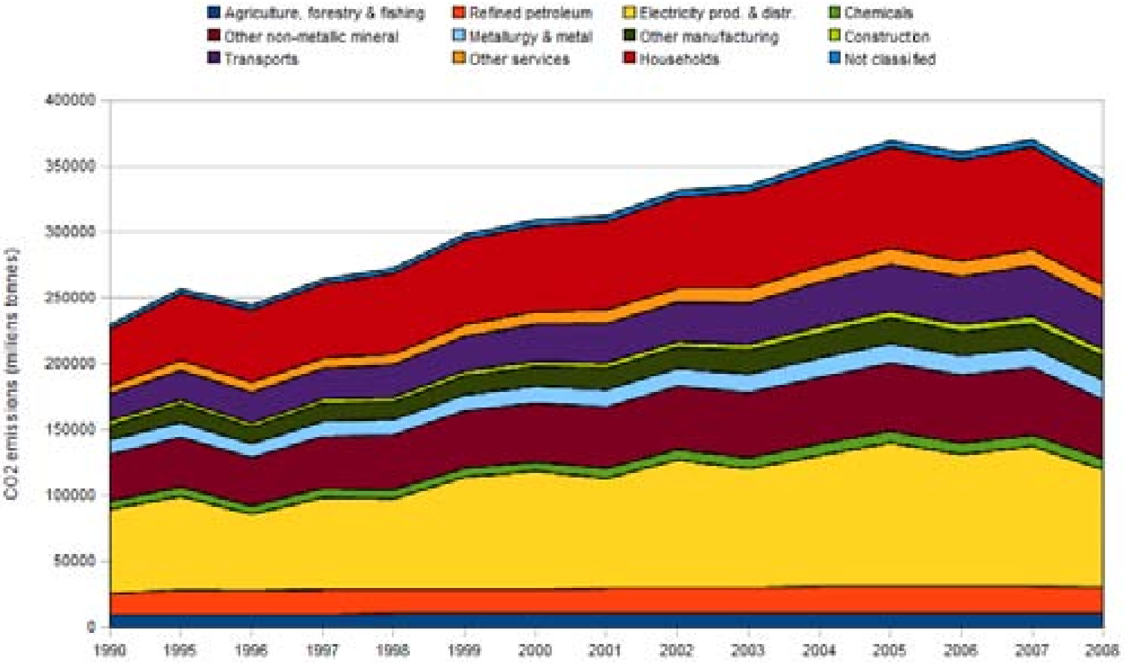
[16] Sectors with diffuse pollution are those which do not fall under the GHG emissions trading scheme, namely transport, waste, residential, commercial and institutional sectors, farming and fluorinated gases.

the citizens, and coming from sectors not included under the GHG emission trading regime adopted in 2005. Therefore, efforts to limit these diffuse emissions cannot be carried out by industrial corporations, as it is the case with GHG emission trading regime (and the price of CO_2 tons in the carbon market), and may require additional instruments, such as carbon taxes on fossil fuels consumption.

Figure 2.32: CO_2 emissions by sector. Spain, 1990-2008.



Source: INE (2010), *Atmospheric emissions satellite accounts. 1990 and 1995-20083 series*, Madrid: INE.

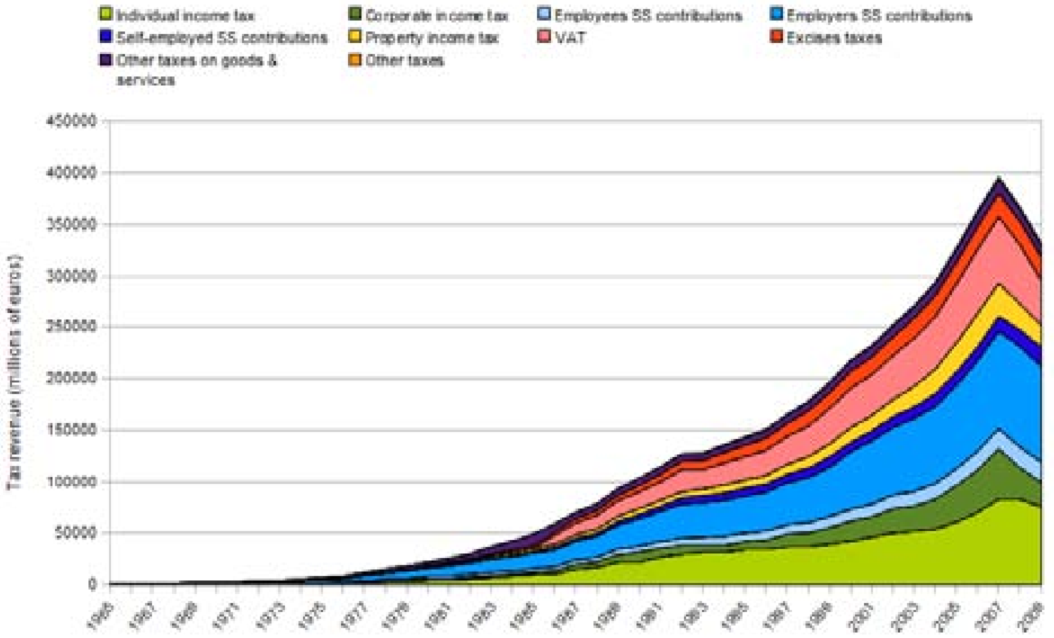
2.3 National tax system and emissions control in Spain

2.3.1 Trends in tax revenues

Spain has a quasi-federal tax system, with three levels of government (central, regional and municipal) where the central government and the social security entities collect around 70% of the tax revenues. Regional governments control also a significant share of total tax collection: 33 % of personal income tax; 35 % of VAT; 40% of excise duties on hydrocarbons, tobacco, beer and alcohol; 100% of excise duties on electricity and car registration. Furthermore, regional governments can adjust statutory personal income tax rates, provided the tax structure retains progression and the number of tax brackets is unchanged [Eurostat, 2010b].

As observed in *figure* (2.33), since its accession to the EU in 1986, Spain's buoyant economic activity has boosted tax revenues until 2007. The economic crisis over the years 2007-2009 decreased then dramatically tax collection for all tax types, but primarily corporate income tax and VAT tax. In terms of tax collection as percentage of GDP, the impact of the crisis has been more pronounced in Spain than in the other major EU countries, as indicated by the evolution of the total tax-to-GDP ratio (*figure* (2.34)). After an almost constant increase since 1965, the ratio severely dropped from 37.3% in 2007 to 30.7% in 2009. *Figure* (2.35) details a disaggregation of the different taxes (direct, indirect and Social Security contributions), weighted in percentage of GDP over the shorter period 1995-2008.

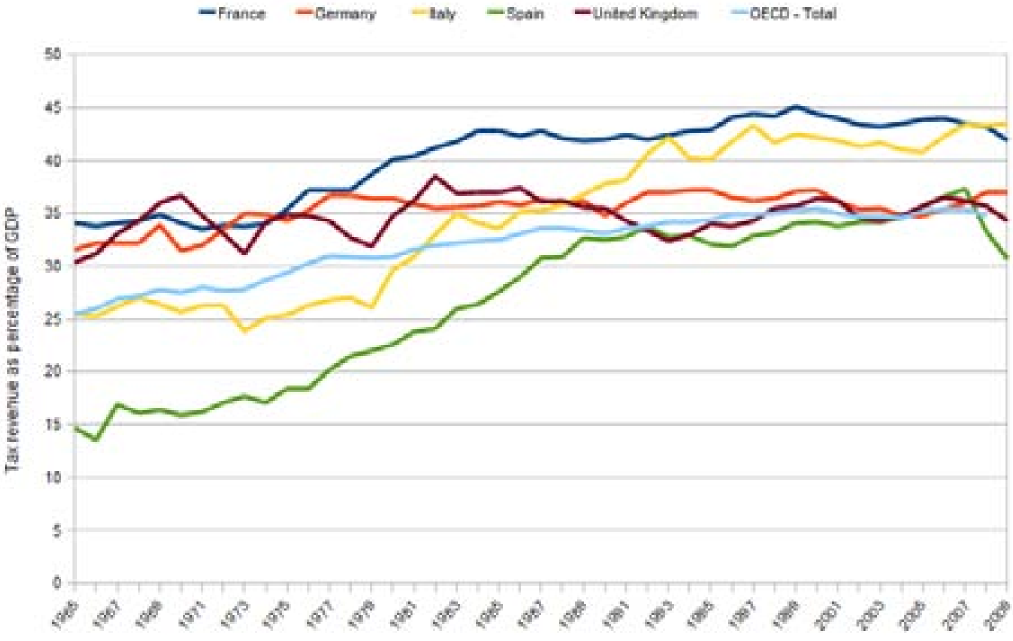
Figure 2.33: Tax revenues (millions of euros). Spain, 1965-2009.



Source: OECD (2010), *Revenue Statistics. Details of Tax Revenue - Spain*, Paris: OECD.

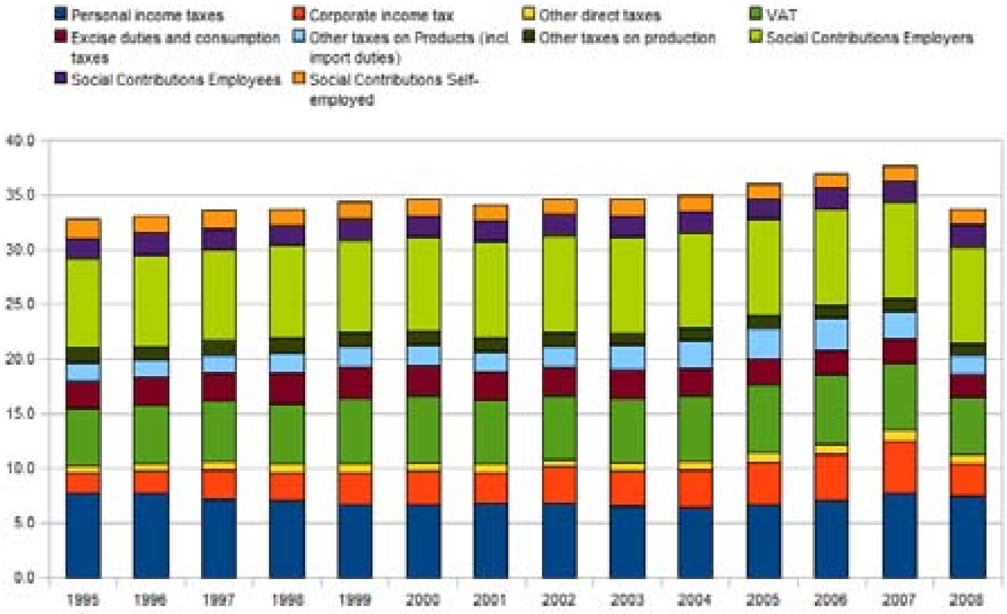
The distribution of tax revenues across tax types (*figure* (2.36)) shows that currently Spain collects revenues almost equally from social contributions, direct taxes and indirect taxes, with a recent growing importance of social contributions and a reduced share of indirect taxes. In terms of total tax revenues, personal income taxes remained stable on average over the period 1980-2009, at around 20% of total tax collection. Corporate income tax receipts increased steadily during the 90's until 2007 when they experienced a relative drawback. The most noticeable change is related to the introduction of the VAT tax in 1986 which, as a consequence, reduced correspondingly the share of other taxes on goods and services. Social security contributions shares have remained relatively stable since the introduction of the VAT tax, with the lion's share of the burden resting on employers. With respect to the other main EU

Figure 2.34: Tax revenues (% of GDP). Major EU countries, 1965-2009.



Source: OECD (2010), *Revenue Statistics*, Paris: OECD.

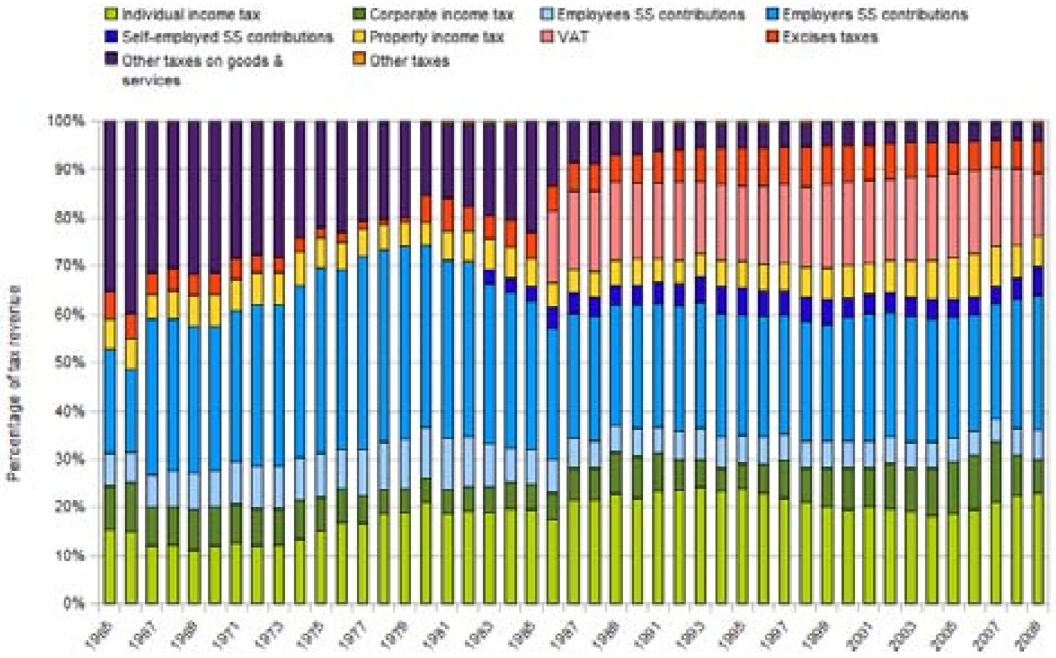
Figure 2.35: Tax revenues (% of GDP). Spain, 1995-2008.



Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

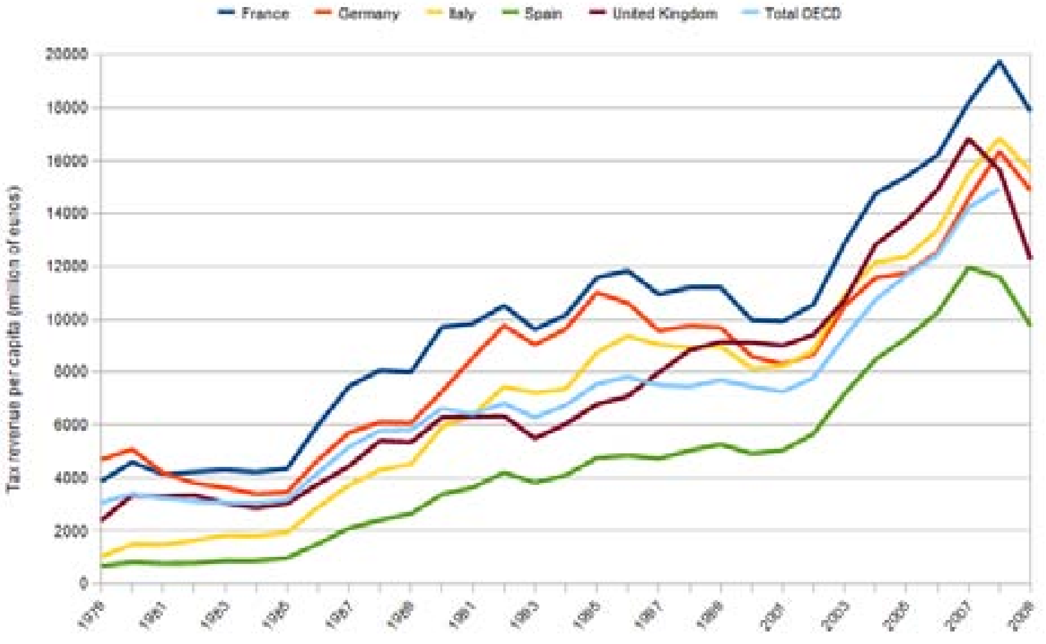
countries, Spain presents a lower tax revenue per capita with a ratio being in the low range for the euro area and the OECD countries (*figure* (2.37)).

Figure 2.36: Percentage of tax revenues by tax types. Spain, 1965-2009.



Source: OECD (2010), *Revenue Statistics. Details of Tax Revenue - Spain*, Paris: OECD.

Figure 2.37: Tax revenue per capita. Major EU countries, 1979-2009.



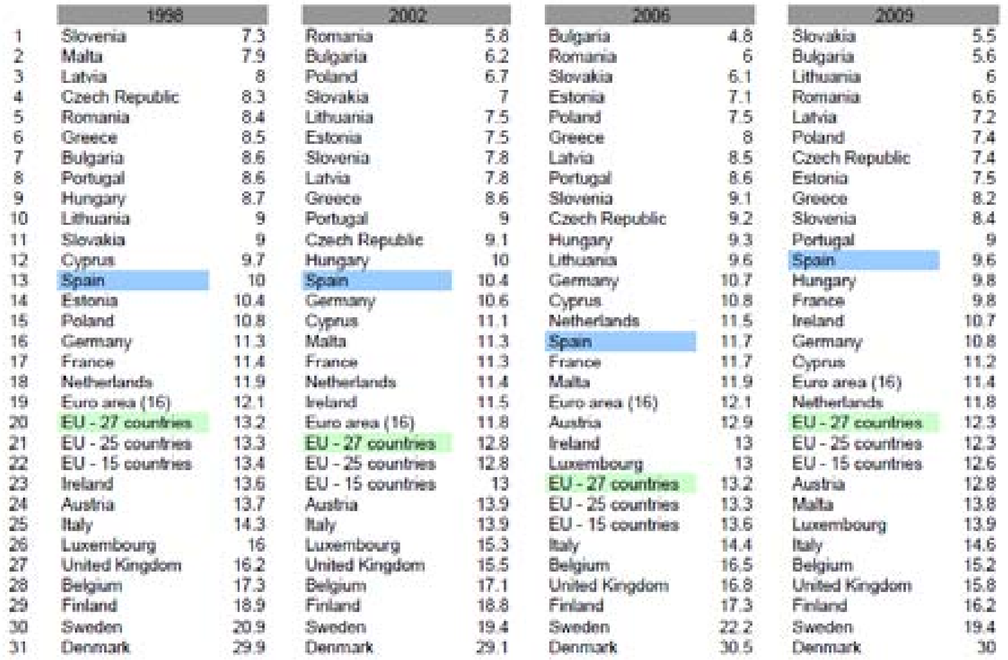
Source: OECD (2010), *Revenue Statistics*, Paris: OECD.

2.3.2 Comparative features of the tax system

Direct taxes

In Spain, direct taxes cover current taxes on income (personal income tax and corporate income tax) and wealth. The personal income tax, the so called "Impuesto sobre la Renta de las Personas Físicas" (IRPF), is levied on the income obtained by individuals, derived from all sources such as dependent work, self-employment or business, rent of properties, dividends, interests, capital gains, etc. It sets however different tax rates between "ordinary income" and "savings income". Dividends, interests and capital gains are "savings income", which are levied at a progressive system of 19% and 21% since 2010. The rest of income is "ordinary income" and, since 2007, it is levied at a progressive scale composed of four brackets (24%, 28%, 37% and 43%) [Eurostat, 2010].

Table 2.13: Taxes on income and wealth (% of GDP). EU 27 countries, 1998-2008.

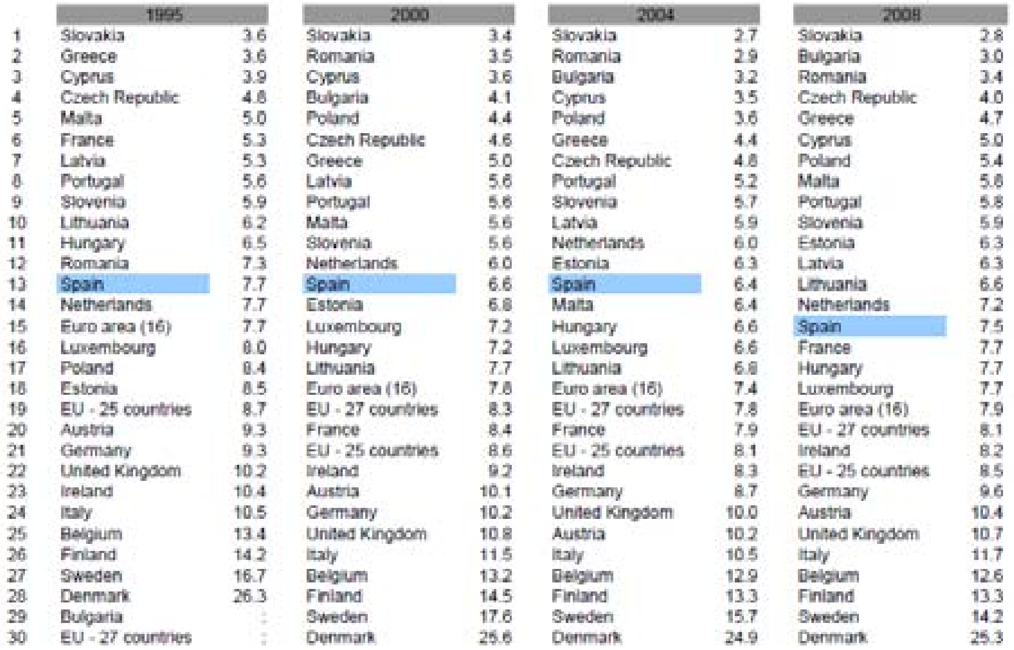


	1998		2002		2006		2009	
1	Slovenia	7.3	Romania	5.8	Bulgaria	4.8	Slovakia	5.5
2	Malta	7.9	Bulgaria	6.2	Romania	6	Bulgaria	5.6
3	Latvia	8	Poland	6.7	Slovakia	6.1	Lithuania	6
4	Czech Republic	8.3	Slovakia	7	Estonia	7.1	Romania	6.6
5	Romania	8.4	Lithuania	7.5	Poland	7.5	Latvia	7.2
6	Greece	8.5	Estonia	7.5	Greece	8	Poland	7.4
7	Bulgaria	8.6	Slovenia	7.8	Latvia	8.5	Czech Republic	7.4
8	Portugal	8.6	Latvia	7.8	Portugal	8.6	Estonia	7.5
9	Hungary	8.7	Greece	8.6	Slovenia	9.1	Greece	8.2
10	Lithuania	9	Portugal	9	Czech Republic	9.2	Slovenia	8.4
11	Slovakia	9	Czech Republic	9.1	Hungary	9.3	Portugal	9
12	Cyprus	9.7	Hungary	10	Lithuania	9.6	Spain	9.6
13	Spain	10	Spain	10.4	Germany	10.7	Hungary	9.8
14	Estonia	10.4	Germany	10.6	Cyprus	10.8	France	9.8
15	Poland	10.8	Cyprus	11.1	Netherlands	11.5	Ireland	10.7
16	Germany	11.3	Malta	11.3	Spain	11.7	Germany	10.8
17	France	11.4	France	11.3	France	11.7	Cyprus	11.2
18	Netherlands	11.9	Netherlands	11.4	Malta	11.9	Euro area (16)	11.4
19	Euro area (16)	12.1	Ireland	11.5	Euro area (16)	12.1	Netherlands	11.8
20	EU - 27 countries	13.2	Euro area (16)	11.8	Austria	12.9	EU - 27 countries	12.3
21	EU - 25 countries	13.3	EU - 27 countries	12.8	Ireland	13	EU - 25 countries	12.3
22	EU - 15 countries	13.4	EU - 25 countries	12.8	Luxembourg	13	EU - 15 countries	12.6
23	Ireland	13.6	EU - 15 countries	13	EU - 27 countries	13.2	Austria	12.8
24	Austria	13.7	Austria	13.9	EU - 25 countries	13.3	Malta	13.8
25	Italy	14.3	Italy	13.9	EU - 15 countries	13.6	Luxembourg	13.9
26	Luxembourg	16	Luxembourg	15.3	Italy	14.4	Italy	14.6
27	United Kingdom	16.2	United Kingdom	15.5	Belgium	16.5	Belgium	15.2
28	Belgium	17.3	Belgium	17.1	United Kingdom	16.8	United Kingdom	15.8
29	Finland	18.9	Finland	18.8	Finland	17.3	Finland	16.2
30	Sweden	20.9	Sweden	19.4	Sweden	22.2	Sweden	19.4
31	Denmark	29.9	Denmark	29.1	Denmark	30.5	Denmark	30

Source: Eurostat (2011), *Government Statistics*, Luxembourg: Eurostat.

The corporate tax is levied on the worldwide income of resident companies established in Spain. Its tax rate has been reduced from 35% to 32.5% in 2007 and to 30% in 2008. Special tax rates exist for the small companies with profit up to 120,202 EUR (25%) and foundations or public associations with special tax arrangements by law (10%). Finally the wealth tax, the so called "Impuesto sobre el Patrimonio", taxes wealth transfers, such as properties and other assets belonging to an individual and located in Spain. The tax is progressive and levied by the 17 autonomous regions, which have the possibility to set their own tax rates, within certain limits. A 100% tax rebate has been introduced in 2008, abolishing it in practice. *Table* (2.13) shows the income and wealth taxes-to-GDP ratios of the EU-27 countries over the years 1998-2008. Spain has been constantly below EU average, with an income and wealth tax collection as percentage of GDP around 10%, on average.

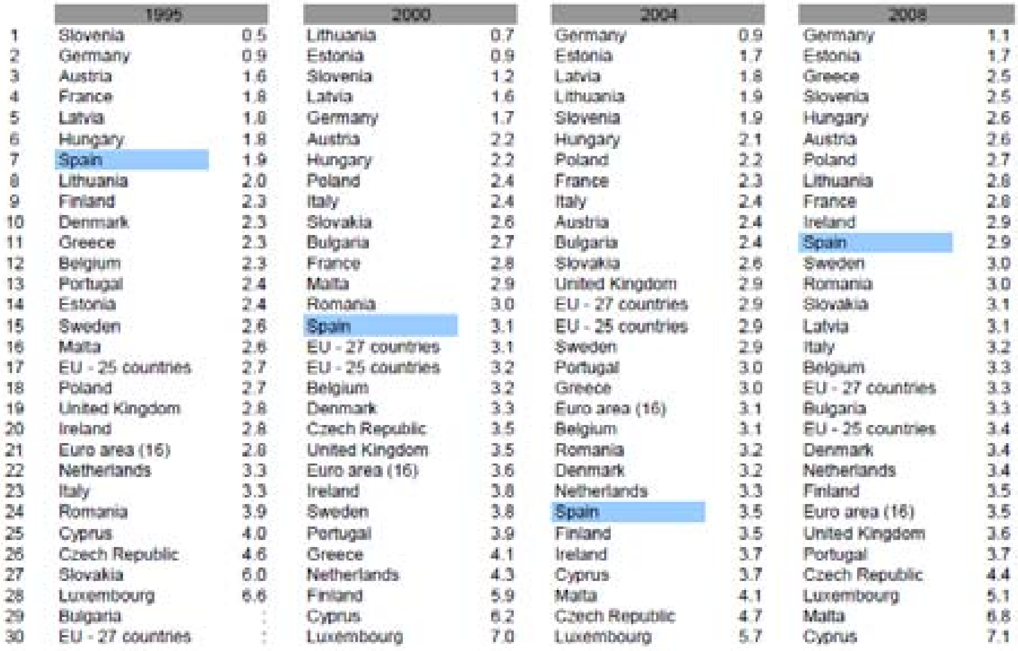
Table 2.14: Personal income tax revenues (% of GDP). EU 27 countries, 1995-2008.



	1995		2000		2004		2008	
1	Slovakia	3.6	Slovakia	3.4	Slovakia	2.7	Slovakia	2.8
2	Greece	3.6	Romania	3.5	Romania	2.9	Bulgaria	3.0
3	Cyprus	3.9	Cyprus	3.6	Bulgaria	3.2	Romania	3.4
4	Czech Republic	4.8	Bulgaria	4.1	Cyprus	3.5	Czech Republic	4.0
5	Malta	5.0	Poland	4.4	Poland	3.6	Greece	4.7
6	France	5.3	Czech Republic	4.6	Greece	4.4	Cyprus	5.0
7	Latvia	5.3	Greece	5.0	Czech Republic	4.8	Poland	5.4
8	Portugal	5.6	Latvia	5.6	Portugal	5.2	Malta	5.8
9	Slovenia	5.9	Portugal	5.6	Slovenia	5.7	Portugal	5.8
10	Lithuania	6.2	Malta	5.6	Latvia	5.9	Slovenia	5.9
11	Hungary	6.5	Slovenia	5.6	Netherlands	6.0	Estonia	6.3
12	Romania	7.3	Netherlands	6.0	Estonia	6.3	Latvia	6.3
13	Spain	7.7	Spain	6.6	Spain	6.4	Lithuania	6.6
14	Netherlands	7.7	Estonia	6.8	Malta	6.4	Netherlands	7.2
15	Euro area (16)	7.7	Luxembourg	7.2	Hungary	6.6	Spain	7.5
16	Luxembourg	8.0	Hungary	7.2	Luxembourg	6.6	France	7.7
17	Poland	8.4	Lithuania	7.7	Lithuania	6.8	Hungary	7.7
18	Estonia	8.5	Euro area (16)	7.8	Euro area (16)	7.4	Luxembourg	7.7
19	EU - 25 countries	8.7	EU - 27 countries	8.3	EU - 27 countries	7.8	Euro area (16)	7.9
20	Austria	9.3	France	8.4	France	7.9	EU - 27 countries	8.1
21	Germany	9.3	EU - 25 countries	8.6	EU - 25 countries	8.1	Ireland	8.2
22	United Kingdom	10.2	Ireland	9.2	Ireland	8.3	EU - 25 countries	8.5
23	Ireland	10.4	Austria	10.1	Germany	8.7	Germany	9.6
24	Italy	10.5	Germany	10.2	United Kingdom	10.0	Austria	10.4
25	Belgium	13.4	United Kingdom	10.8	Austria	10.2	United Kingdom	10.7
26	Finland	14.2	Italy	11.5	Italy	10.5	Italy	11.7
27	Sweden	16.7	Belgium	13.2	Belgium	12.9	Belgium	12.6
28	Denmark	26.3	Finland	14.5	Finland	13.3	Finland	13.3
29	Bulgaria	:	Sweden	17.6	Sweden	15.7	Sweden	14.2
30	EU - 27 countries	:	Denmark	25.6	Denmark	24.9	Denmark	25.3

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

Table 2.15: Corporate income tax revenues (% of GDP). EU 27 countries, 1995-2008.



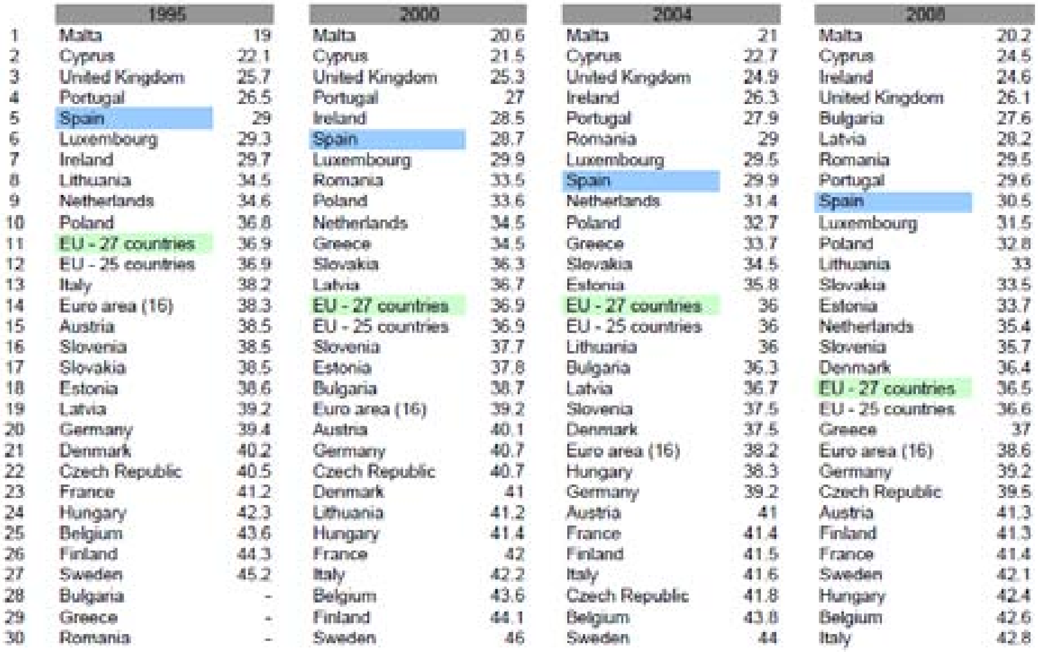
	1995		2000		2004		2008	
1	Slovenia	0.5	Lithuania	0.7	Germany	0.9	Germany	1.1
2	Germany	0.9	Estonia	0.9	Estonia	1.7	Estonia	1.7
3	Austria	1.6	Slovenia	1.2	Latvia	1.8	Greece	2.5
4	France	1.8	Latvia	1.6	Lithuania	1.9	Slovenia	2.5
5	Latvia	1.8	Germany	1.7	Slovenia	1.9	Hungary	2.6
6	Hungary	1.8	Austria	2.2	Hungary	2.1	Austria	2.6
7	Spain	1.9	Hungary	2.2	Poland	2.2	Poland	2.7
8	Lithuania	2.0	Poland	2.4	France	2.3	Lithuania	2.8
9	Finland	2.3	Italy	2.4	Italy	2.4	France	2.8
10	Denmark	2.3	Slovakia	2.6	Austria	2.4	Ireland	2.9
11	Greece	2.3	Bulgaria	2.7	Bulgaria	2.4	Spain	2.9
12	Belgium	2.3	France	2.8	Slovakia	2.6	Sweden	3.0
13	Portugal	2.4	Malta	2.9	United Kingdom	2.9	Romania	3.0
14	Estonia	2.4	Romania	3.0	EU - 27 countries	2.9	Slovakia	3.1
15	Sweden	2.6	Spain	3.1	EU - 25 countries	2.9	Latvia	3.1
16	Malta	2.6	EU - 27 countries	3.1	Sweden	2.9	Italy	3.2
17	EU - 25 countries	2.7	EU - 25 countries	3.2	Portugal	3.0	Belgium	3.3
18	Poland	2.7	Belgium	3.2	Greece	3.0	EU - 27 countries	3.3
19	United Kingdom	2.8	Denmark	3.3	Euro area (16)	3.1	Bulgaria	3.3
20	Ireland	2.8	Czech Republic	3.5	Belgium	3.1	EU - 25 countries	3.4
21	Euro area (16)	2.8	United Kingdom	3.5	Romania	3.2	Denmark	3.4
22	Netherlands	3.3	Euro area (16)	3.6	Denmark	3.2	Netherlands	3.4
23	Italy	3.3	Ireland	3.8	Netherlands	3.3	Finland	3.5
24	Romania	3.9	Sweden	3.8	Spain	3.5	Euro area (16)	3.5
25	Cyprus	4.0	Portugal	3.9	Finland	3.5	United Kingdom	3.6
26	Czech Republic	4.6	Greece	4.1	Ireland	3.7	Portugal	3.7
27	Slovakia	6.0	Netherlands	4.3	Cyprus	3.7	Czech Republic	4.4
28	Luxembourg	6.6	Finland	5.9	Malta	4.1	Luxembourg	5.1
29	Bulgaria	:	Cyprus	6.2	Czech Republic	4.7	Malta	6.8
30	EU - 27 countries	:	Luxembourg	7.0	Luxembourg	5.7	Cyprus	7.1

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

Due to the importance of labour taxes for this study, *table* (2.16) gives the implicit tax rate on labour for the EU-27 countries, defined here as the sum of all direct and indirect taxes and employees and employers social contributions levied on employed labour income divided by the total compensation of employees working in the economic territory. It is thus a proxy for an average effective tax burden on labour income in the economy. As for the composition of labour taxation, in most EU countries, social security contributions account for a greater share of labour taxes than the personal income tax. On average, about two thirds of the overall implicit tax rate on labour come from non-wage labour costs paid by both employees and employers.

Throughout the years 1995–2008, Spain has displayed an average implicit tax rate on labour well below the EU-27, with a stable difference of more than six percentage points. A small positive trend seems present, with a level going from 29% in 1995 to 30.5% in 2008, probably due to a noticeable increase in taxable wages and salaries. Despite a wide consensus on the desirability of lower taxes on labour, the trends in the implicit tax rate on labour for the EU countries confirm the widespread difficulty in achieving this objective.

Table 2.16: Implicit tax rate on labour. EU 27 countries, 1995-2008.



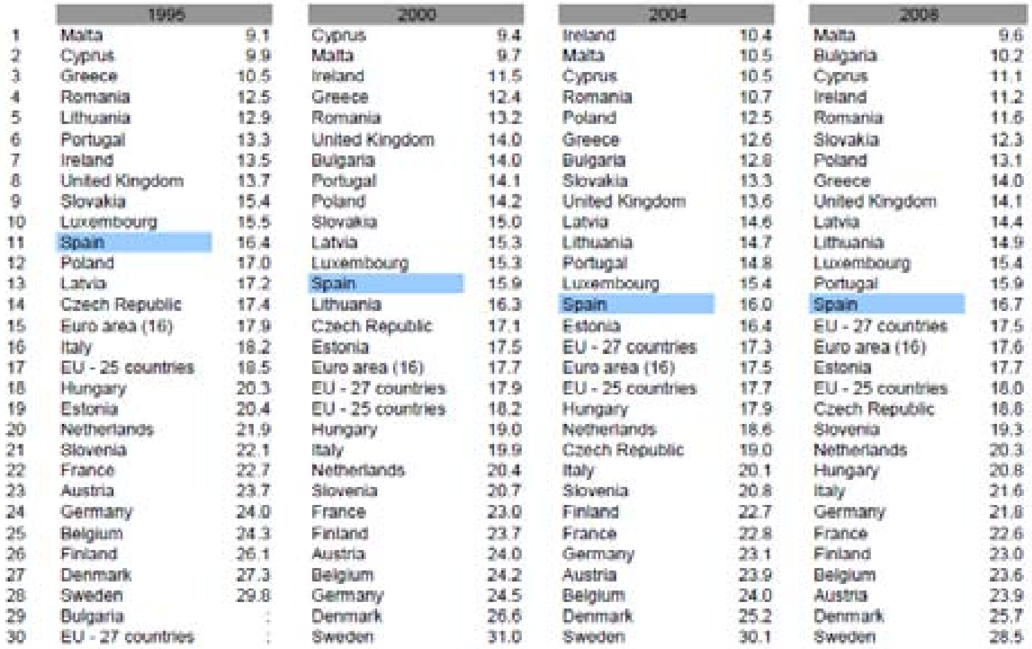
	1995		2000		2004		2008	
1	Malta	19	Malta	20.6	Malta	21	Malta	20.2
2	Cyprus	22.1	Cyprus	21.5	Cyprus	22.7	Cyprus	24.5
3	United Kingdom	25.7	United Kingdom	25.3	United Kingdom	24.9	Ireland	24.6
4	Portugal	26.5	Portugal	27	Ireland	26.3	United Kingdom	26.1
5	Spain	29	Ireland	28.5	Portugal	27.9	Bulgaria	27.6
6	Luxembourg	29.3	Spain	28.7	Romania	29	Latvia	28.2
7	Ireland	29.7	Luxembourg	29.9	Luxembourg	29.5	Romania	29.5
8	Lithuania	34.5	Romania	33.5	Spain	29.9	Portugal	29.6
9	Netherlands	34.6	Poland	33.6	Netherlands	31.4	Spain	30.5
10	Poland	36.8	Netherlands	34.5	Poland	32.7	Luxembourg	31.5
11	EU - 27 countries	36.9	Greece	34.5	Greece	33.7	Poland	32.8
12	EU - 25 countries	36.9	Slovakia	36.3	Slovakia	34.5	Lithuania	33
13	Italy	38.2	Latvia	36.7	Estonia	35.8	Slovakia	33.5
14	Euro area (16)	38.3	EU - 27 countries	36.9	EU - 27 countries	36	Estonia	33.7
15	Austria	38.5	EU - 25 countries	36.9	EU - 25 countries	36	Netherlands	35.4
16	Slovenia	38.5	Slovenia	37.7	Lithuania	36	Slovenia	35.7
17	Slovakia	38.5	Estonia	37.8	Bulgaria	36.3	Denmark	36.4
18	Estonia	38.6	Bulgaria	38.7	Latvia	36.7	EU - 27 countries	36.5
19	Latvia	39.2	Euro area (16)	39.2	Slovenia	37.5	EU - 25 countries	36.6
20	Germany	39.4	Austria	40.1	Denmark	37.5	Greece	37
21	Denmark	40.2	Germany	40.7	Euro area (16)	38.2	Euro area (16)	38.6
22	Czech Republic	40.5	Czech Republic	40.7	Hungary	38.3	Germany	39.2
23	France	41.2	Denmark	41	Germany	39.2	Czech Republic	39.5
24	Hungary	42.3	Lithuania	41.2	Austria	41	Austria	41.3
25	Belgium	43.6	Hungary	41.4	France	41.4	Finland	41.3
26	Finland	44.3	France	42	Finland	41.5	France	41.4
27	Sweden	45.2	Italy	42.2	Italy	41.6	Sweden	42.1
28	Bulgaria	-	Belgium	43.6	Czech Republic	41.8	Hungary	42.4
29	Greece	-	Finland	44.1	Belgium	43.8	Belgium	42.6
30	Romania	-	Sweden	46	Sweden	44	Italy	42.8

Source: Eurostat (2011), *Government Statistics*, Luxembourg: Eurostat.

Indirect taxes

Table (2.18) shows the trend of the effective taxation on consumption, or implicit tax rate on consumption (ITRC), over the period 1995-2008. The aggregate level of the ITRC is composed of different taxes on consumption, classified usually into four main sub-components: VAT, energy taxes, excise duties on tobacco and alcohol and

Table 2.17: Taxes on labour (% of GDP). EU 27 countries, 1995-2008.



	1995		2000		2004		2008	
1	Malta	9.1	Cyprus	9.4	Ireland	10.4	Malta	9.6
2	Cyprus	9.9	Malta	9.7	Malta	10.5	Bulgaria	10.2
3	Greece	10.5	Ireland	11.5	Cyprus	10.5	Cyprus	11.1
4	Romania	12.5	Greece	12.4	Romania	10.7	Ireland	11.2
5	Lithuania	12.9	Romania	13.2	Poland	12.5	Romania	11.6
6	Portugal	13.3	United Kingdom	14.0	Greece	12.6	Slovakia	12.3
7	Ireland	13.5	Bulgaria	14.0	Bulgaria	12.8	Poland	13.1
8	United Kingdom	13.7	Portugal	14.1	Slovakia	13.3	Greece	14.0
9	Slovakia	15.4	Poland	14.2	United Kingdom	13.6	United Kingdom	14.1
10	Luxembourg	15.5	Slovakia	15.0	Latvia	14.6	Latvia	14.4
11	Spain	16.4	Latvia	15.3	Lithuania	14.7	Lithuania	14.9
12	Poland	17.0	Luxembourg	15.3	Portugal	14.8	Luxembourg	15.4
13	Latvia	17.2	Spain	15.9	Luxembourg	15.4	Portugal	15.9
14	Czech Republic	17.4	Lithuania	16.3	Spain	16.0	Spain	16.7
15	Euro area (16)	17.9	Czech Republic	17.1	Estonia	16.4	EU - 27 countries	17.5
16	Italy	18.2	Estonia	17.5	EU - 27 countries	17.3	Euro area (16)	17.6
17	EU - 25 countries	18.5	Euro area (16)	17.7	Euro area (16)	17.5	Estonia	17.7
18	Hungary	20.3	EU - 27 countries	17.9	EU - 25 countries	17.7	EU - 25 countries	18.0
19	Estonia	20.4	EU - 25 countries	18.2	Hungary	17.9	Czech Republic	18.8
20	Netherlands	21.9	Hungary	19.0	Netherlands	18.6	Slovenia	19.3
21	Slovenia	22.1	Italy	19.9	Czech Republic	19.0	Netherlands	20.3
22	France	22.7	Netherlands	20.4	Italy	20.1	Hungary	20.8
23	Austria	23.7	Slovenia	20.7	Slovenia	20.8	Italy	21.6
24	Germany	24.0	France	23.0	Finland	22.7	Germany	21.8
25	Belgium	24.3	Finland	23.7	France	22.8	France	22.6
26	Finland	26.1	Austria	24.0	Germany	23.1	Finland	23.0
27	Denmark	27.3	Belgium	24.2	Austria	23.9	Belgium	23.6
28	Sweden	29.8	Germany	24.5	Belgium	24.0	Austria	23.9
29	Bulgaria	:	Denmark	26.6	Denmark	25.2	Denmark	25.7
30	EU - 27 countries	:	Sweden	31.0	Sweden	30.1	Sweden	28.5

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

residual taxes. The ratio has experienced significant variation over time; a first rising phase, until 1999, was followed by a small drop in 2000 and 2001. Then, from 2001 to 2006, the ratio has been increasing steadily every year to reach 16.3% in 2006. From 2006 to 2008, the ITRC decreased in Spain to 14.1%, being in 2008 the lowest ITRC throughout the whole EU-27 region. Some high consumption taxing countries, such as Denmark and Sweden, presented at that time a ratio twice higher than Spain. Even if the VAT is the most important consumption tax and the largest component of the ITRC, the sharp and broad drop of the ITRC in the EU-27 countries cannot be attributed to declines in VAT rates in 2008 (only Portugal reduced it that year). It seems rather the consequence of the economic crisis on consumption behaviour.

Spain also presents the lowest ratio of consumption taxes in percentage of GDP among the 27 Member States (*table* (2.19)). This can be partly due to a relatively low standard VAT rate: as from 1st July 2010, the standard VAT rate in Spain is 18%, up from 16%[17]. Also, some specific categories of goods, representing a consequent share of the tax base, benefit from reduced rates of 8% (up from 7% from July 2010) and 4%[18]. The ratio of consumption taxes in proportion to GDP dropped sharply in 2008

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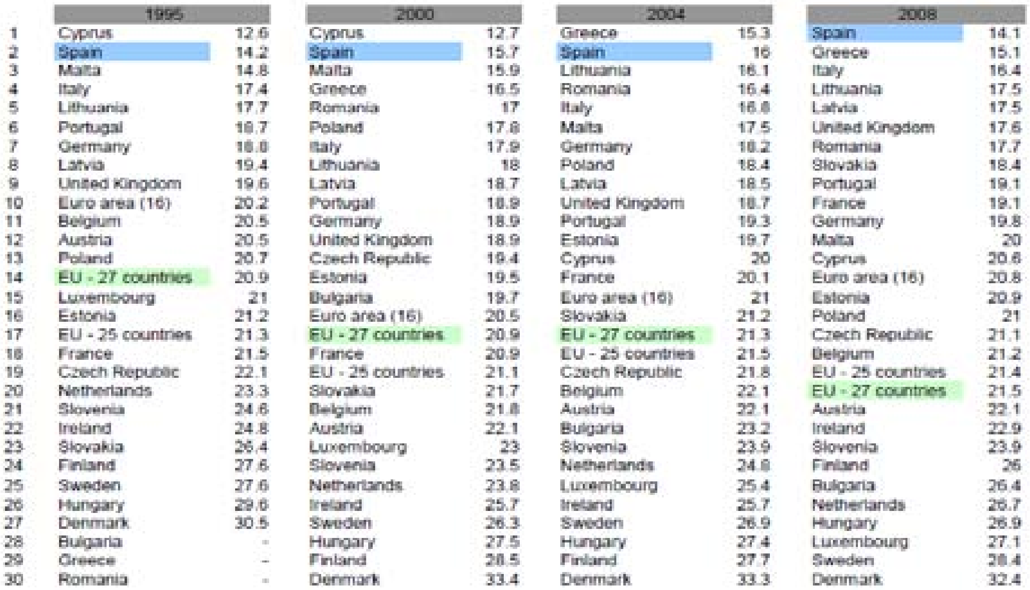
[17] In the Canary Islands, an indirect tax similar to the VAT is levied with a standard rate of 5 %. Another special duty on imports and certain goods is also applied.

[18] These goods include food, health products, housing, sports activities, entertainment services, hotels and restaurants, and agricultural services.

Table 2.18: Implicit tax rate on consumption. EU 27 countries, 1995-2008.

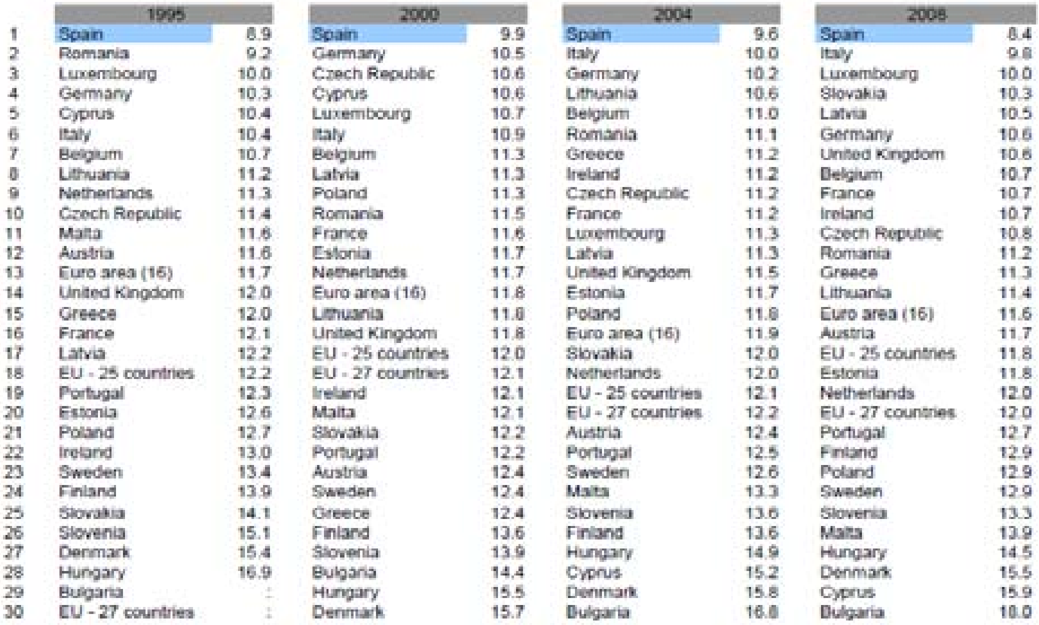


	1995		2000		2004		2008	
1	Cyprus	12.6	Cyprus	12.7	Greece	15.3	Spain	14.1
2	Spain	14.2	Spain	15.7	Spain	16	Greece	15.1
3	Malta	14.8	Malta	15.9	Lithuania	16.1	Italy	16.4
4	Italy	17.4	Greece	16.5	Romania	16.4	Lithuania	17.5
5	Lithuania	17.7	Romania	17	Italy	16.8	Latvia	17.5
6	Portugal	18.7	Poland	17.8	Malta	17.5	United Kingdom	17.6
7	Germany	18.8	Italy	17.9	Germany	18.2	Romania	17.7
8	Latvia	19.4	Lithuania	18	Poland	18.4	Slovakia	18.4
9	United Kingdom	19.6	Latvia	18.7	Latvia	18.5	Portugal	19.1
10	Euro area (16)	20.2	Portugal	18.9	United Kingdom	18.7	France	19.1
11	Belgium	20.5	Germany	18.9	Portugal	19.3	Germany	19.8
12	Austria	20.5	United Kingdom	18.9	Estonia	19.7	Malta	20
13	Poland	20.7	Czech Republic	19.4	Cyprus	20	Cyprus	20.6
14	EU - 27 countries	20.9	Estonia	19.5	France	20.1	Euro area (16)	20.8
15	Luxembourg	21	Bulgaria	19.7	Euro area (16)	21	Estonia	20.9
16	Estonia	21.2	Euro area (16)	20.5	Slovakia	21.2	Poland	21
17	EU - 25 countries	21.3	EU - 27 countries	20.9	EU - 27 countries	21.3	Czech Republic	21.1
18	France	21.5	France	20.9	EU - 25 countries	21.5	Belgium	21.2
19	Czech Republic	22.1	EU - 25 countries	21.1	Czech Republic	21.8	EU - 25 countries	21.4
20	Netherlands	23.3	Slovakia	21.7	Belgium	22.1	EU - 27 countries	21.5
21	Slovenia	24.6	Belgium	21.8	Austria	22.1	Austria	22.1
22	Ireland	24.8	Austria	22.1	Bulgaria	23.2	Ireland	22.9
23	Slovakia	26.4	Luxembourg	23	Slovenia	23.9	Slovenia	23.9
24	Finland	27.6	Slovenia	23.5	Netherlands	24.8	Finland	26
25	Sweden	27.6	Netherlands	23.8	Luxembourg	25.4	Bulgaria	26.4
26	Hungary	29.6	Ireland	25.7	Ireland	25.7	Netherlands	26.7
27	Denmark	30.5	Sweden	26.3	Sweden	26.9	Hungary	26.9
28	Bulgaria	-	Hungary	27.5	Hungary	27.4	Luxembourg	27.1
29	Greece	-	Finland	28.5	Finland	27.7	Sweden	28.4
30	Romania	-	Denmark	33.4	Denmark	33.3	Denmark	32.4

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

(from 9.4% in 2007 to 8.4%), following the broad trend of the ITRC.

Table 2.19: Taxes on consumption revenues (% of GDP). EU 27 countries, 1995-2008.

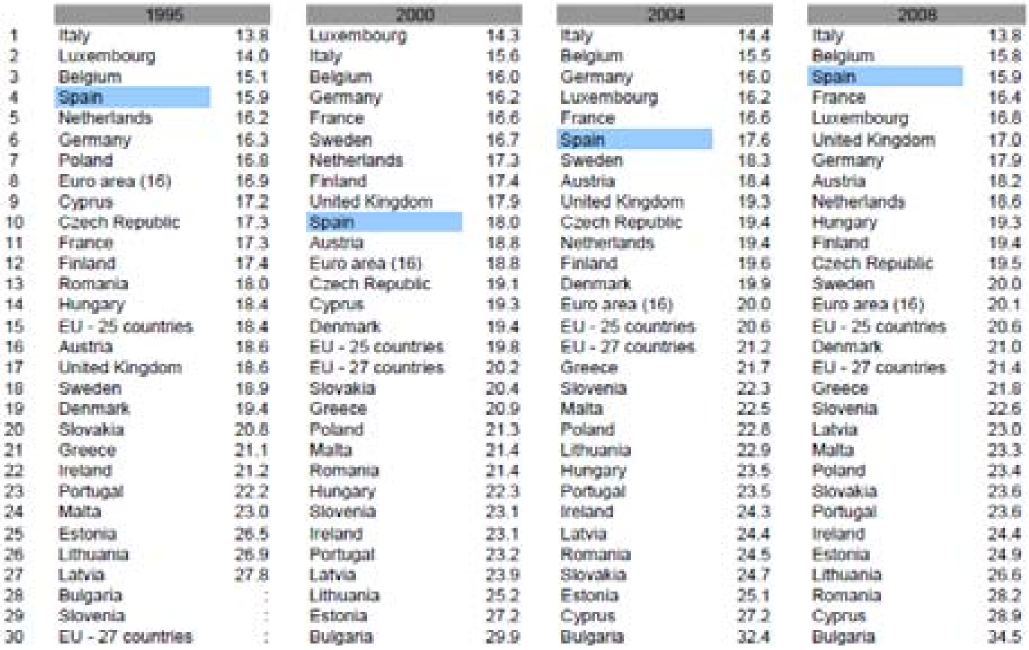


	1995		2000		2004		2008	
1	Spain	8.9	Spain	9.9	Spain	9.6	Spain	8.4
2	Romania	9.2	Germany	10.5	Italy	10.0	Italy	9.8
3	Luxembourg	10.0	Czech Republic	10.6	Germany	10.2	Luxembourg	10.0
4	Germany	10.3	Cyprus	10.6	Lithuania	10.6	Slovakia	10.3
5	Cyprus	10.4	Luxembourg	10.7	Belgium	11.0	Latvia	10.5
6	Italy	10.4	Italy	10.9	Romania	11.1	Germany	10.6
7	Belgium	10.7	Belgium	11.3	Greece	11.2	United Kingdom	10.6
8	Lithuania	11.2	Latvia	11.3	Ireland	11.2	Belgium	10.7
9	Netherlands	11.3	Poland	11.3	Czech Republic	11.2	France	10.7
10	Czech Republic	11.4	Romania	11.5	France	11.2	Ireland	10.7
11	Malta	11.6	France	11.6	Luxembourg	11.3	Czech Republic	10.8
12	Austria	11.6	Estonia	11.7	Latvia	11.3	Romania	11.2
13	Euro area (16)	11.7	Netherlands	11.7	United Kingdom	11.5	Greece	11.3
14	United Kingdom	12.0	Euro area (16)	11.8	Estonia	11.7	Lithuania	11.4
15	Greece	12.0	Lithuania	11.8	Poland	11.8	Euro area (16)	11.6
16	France	12.1	United Kingdom	11.8	Euro area (16)	11.9	Austria	11.7
17	Latvia	12.2	EU - 25 countries	12.0	Slovakia	12.0	EU - 25 countries	11.8
18	EU - 25 countries	12.2	EU - 27 countries	12.1	Netherlands	12.0	Estonia	11.8
19	Portugal	12.3	Ireland	12.1	EU - 25 countries	12.1	Netherlands	12.0
20	Estonia	12.6	Malta	12.1	EU - 27 countries	12.2	EU - 27 countries	12.0
21	Poland	12.7	Slovakia	12.2	Austria	12.4	Portugal	12.7
22	Ireland	13.0	Portugal	12.2	Portugal	12.5	Finland	12.9
23	Sweden	13.4	Austria	12.4	Sweden	12.6	Poland	12.9
24	Finland	13.9	Sweden	12.4	Malta	13.3	Sweden	12.9
25	Slovakia	14.1	Greece	12.4	Slovenia	13.6	Slovenia	13.3
26	Slovenia	15.1	Finland	13.6	Finland	13.6	Malta	13.9
27	Denmark	15.4	Slovenia	13.9	Hungary	14.9	Hungary	14.5
28	Hungary	16.9	Bulgaria	14.4	Cyprus	15.2	Denmark	15.5
29	Bulgaria	:	Hungary	15.5	Denmark	15.8	Cyprus	15.9
30	EU - 27 countries	:	Denmark	15.7	Bulgaria	16.8	Bulgaria	18.0

Source: Eurostat (2011), *Government Statistics*, Luxembourg: Eurostat.

The VAT revenues in percentage of GDP also show a recent decrease in Spain (*table* (2.20)). This new trend, from 2006 to 2008, parallels the economic crisis, which could have shifted some consumption patterns towards primary goods, typically subject to lower VAT rates, or involuntary inventory build-ups by firms. Overall, these data suggest that consumption taxes in Spain are among the lowest within the EU-27 region. Data for other indirect taxes, such as taxes on production and imports[19], show a similar conclusion: Spain presents one of the lowest ratio of taxes in percentage of GDP among the 27 Member States (*table* (2.21)).

Table 2.20: VAT revenues (% of GDP). EU 27 countries, 1995-2008.



	1995		2000		2004		2008	
1	Italy	13.8	Luxembourg	14.3	Italy	14.4	Italy	13.8
2	Luxembourg	14.0	Italy	15.6	Belgium	15.5	Belgium	15.8
3	Belgium	15.1	Belgium	16.0	Germany	16.0	Spain	15.9
4	Spain	15.9	Germany	16.2	Luxembourg	16.2	France	16.4
5	Netherlands	16.2	France	16.6	France	16.6	Luxembourg	16.8
6	Germany	16.3	Sweden	16.7	Spain	17.6	United Kingdom	17.0
7	Poland	16.8	Netherlands	17.3	Sweden	18.3	Germany	17.9
8	Euro area (16)	16.9	Finland	17.4	Austria	18.4	Austria	18.2
9	Cyprus	17.2	United Kingdom	17.9	United Kingdom	19.3	Netherlands	18.6
10	Czech Republic	17.3	Spain	18.0	Czech Republic	19.4	Hungary	19.3
11	France	17.3	Austria	18.8	Netherlands	19.4	Finland	19.4
12	Finland	17.4	Euro area (16)	18.8	Finland	19.6	Czech Republic	19.5
13	Romania	18.0	Czech Republic	19.1	Denmark	19.9	Sweden	20.0
14	Hungary	18.4	Cyprus	19.3	Euro area (16)	20.0	Euro area (16)	20.1
15	EU - 25 countries	18.4	Denmark	19.4	EU - 25 countries	20.6	EU - 25 countries	20.6
16	Austria	18.6	EU - 25 countries	19.8	EU - 27 countries	21.2	Denmark	21.0
17	United Kingdom	18.6	EU - 27 countries	20.2	Greece	21.7	EU - 27 countries	21.4
18	Sweden	18.9	Slovakia	20.4	Slovenia	22.3	Greece	21.8
19	Denmark	19.4	Greece	20.9	Malta	22.5	Slovenia	22.6
20	Slovakia	20.8	Poland	21.3	Poland	22.8	Latvia	23.0
21	Greece	21.1	Malta	21.4	Lithuania	22.9	Malta	23.3
22	Ireland	21.2	Romania	21.4	Hungary	23.5	Poland	23.4
23	Portugal	22.2	Hungary	22.3	Portugal	23.5	Slovakia	23.6
24	Malta	23.0	Slovenia	23.1	Ireland	24.3	Portugal	23.6
25	Estonia	26.5	Ireland	23.1	Latvia	24.4	Ireland	24.4
26	Lithuania	26.9	Portugal	23.2	Romania	24.5	Estonia	24.9
27	Latvia	27.8	Latvia	23.9	Slovakia	24.7	Lithuania	26.6
28	Bulgaria	:	Lithuania	25.2	Estonia	25.1	Romania	28.2
29	Slovenia	:	Estonia	27.2	Cyprus	27.2	Cyprus	28.9
30	EU - 27 countries	:	Bulgaria	29.9	Bulgaria	32.4	Bulgaria	34.5

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

Social contributions

Social contributions are divided into actual social contributions and imputed Social contributions. Actual social contributions include employers' actual Social contributions, employees' Social contributions and Social contributions by self-employed and non-employed persons. Imputed Social contributions designate the counterpart to social benefits paid directly by employers. In Spain, each professional category has minimum and maximum contribution bases. The total rate for the general regime (including general risk, unemployment insurance and professional education training) is 6.35% for the employees and 29.9% for employers [Eurostat, 2010].

Table (2.22) shows the importance of Social contributions, in percentage of GDP,

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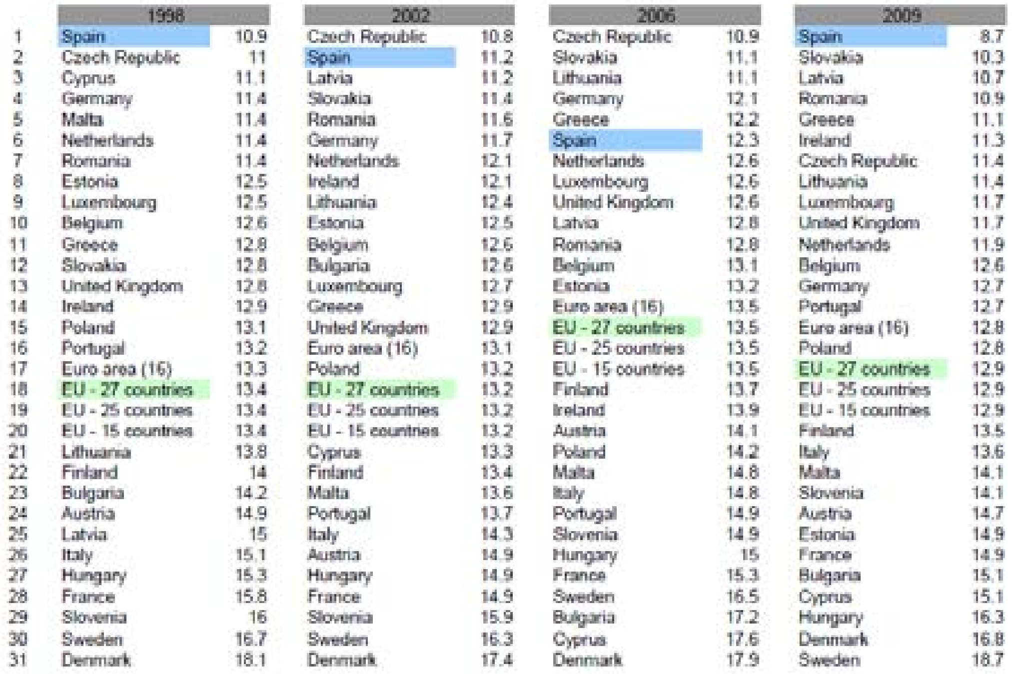
[19] In ESA95 formulation, taxes on production and imports include taxes on products and other taxes on production.

Table 2.21: Taxes on production and imports (% of GDP). EU 27 countries, 1998-2008.



	1998		2002		2006		2009	
1	Spain	10.9	Czech Republic	10.8	Czech Republic	10.9	Spain	8.7
2	Czech Republic	11	Spain	11.2	Slovakia	11.1	Slovakia	10.3
3	Cyprus	11.1	Latvia	11.2	Lithuania	11.1	Latvia	10.7
4	Germany	11.4	Slovakia	11.4	Germany	12.1	Romania	10.9
5	Malta	11.4	Romania	11.6	Greece	12.2	Greece	11.1
6	Netherlands	11.4	Germany	11.7	Spain	12.3	Ireland	11.3
7	Romania	11.4	Netherlands	12.1	Netherlands	12.6	Czech Republic	11.4
8	Estonia	12.5	Ireland	12.1	Luxembourg	12.6	Lithuania	11.4
9	Luxembourg	12.5	Lithuania	12.4	United Kingdom	12.6	Luxembourg	11.7
10	Belgium	12.6	Estonia	12.5	Latvia	12.8	United Kingdom	11.7
11	Greece	12.8	Belgium	12.6	Romania	12.8	Netherlands	11.9
12	Slovakia	12.8	Bulgaria	12.6	Belgium	13.1	Belgium	12.6
13	United Kingdom	12.8	Luxembourg	12.7	Estonia	13.2	Germany	12.7
14	Ireland	12.9	Greece	12.9	Euro area (16)	13.5	Portugal	12.7
15	Poland	13.1	United Kingdom	12.9	EU - 27 countries	13.5	Euro area (16)	12.8
16	Portugal	13.2	Euro area (16)	13.1	EU - 25 countries	13.5	Poland	12.8
17	Euro area (16)	13.3	Poland	13.2	EU - 15 countries	13.5	EU - 27 countries	12.9
18	EU - 27 countries	13.4	EU - 27 countries	13.2	Finland	13.7	EU - 25 countries	12.9
19	EU - 25 countries	13.4	EU - 25 countries	13.2	Ireland	13.9	EU - 15 countries	12.9
20	EU - 15 countries	13.4	EU - 15 countries	13.2	Austria	14.1	Finland	13.5
21	Lithuania	13.8	Cyprus	13.3	Poland	14.2	Italy	13.6
22	Finland	14	Finland	13.4	Malta	14.8	Malta	14.1
23	Bulgaria	14.2	Malta	13.6	Italy	14.8	Slovenia	14.1
24	Austria	14.9	Portugal	13.7	Portugal	14.9	Austria	14.7
25	Latvia	15	Italy	14.3	Slovenia	14.9	Estonia	14.9
26	Italy	15.1	Austria	14.9	Hungary	15	France	14.9
27	Hungary	15.3	Hungary	14.9	France	15.3	Bulgaria	15.1
28	France	15.8	France	14.9	Sweden	16.5	Cyprus	15.1
29	Slovenia	16	Slovenia	15.9	Bulgaria	17.2	Hungary	16.3
30	Sweden	16.7	Sweden	16.3	Cyprus	17.6	Denmark	16.8
31	Denmark	18.1	Denmark	17.4	Denmark	17.9	Sweden	18.7

Source: Eurostat (2011), *Government Statistics*, Luxembourg: Eurostat.

for the EU-27 countries. Spain's ratio has been quite stable, but on a upward trend, placing it above the Euro area average and higher that the EU-27 average by a 1.3 percentage point in 2008. The importance of Social contributions in the fiscal system is confirmed by *table* (2.23), which indicates that Spain is ranked among the EU countries with the highest Social contributions share in percentage of total taxation.

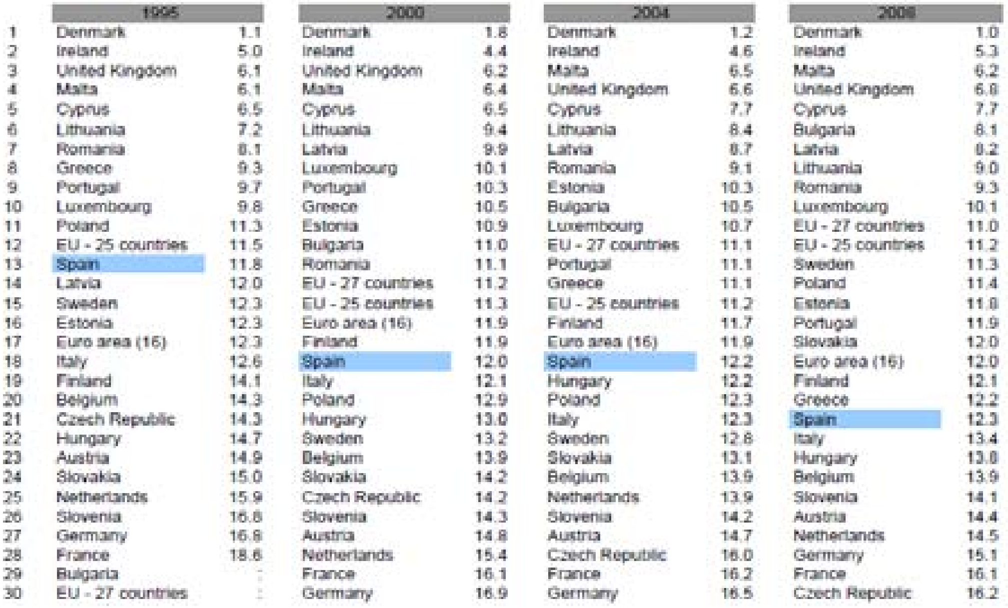
Since employers' Social contributions generate the most important part of the Social Security contributions (see *figure* (2.36)), it should be unsurprising to observe that employers Social contributions confirm this ranking. *Table* (2.24) shows indeed that employers' Social contributions in percentage of GDP include Spain among the seven highest ratios in the EU-27 area. On the contrary, employees' Social contributions in percentage of GDP show an inverse ranking: the ratios show that Spain supports one the the lowest burden (in percentage of GDP) among the 27 Member States (*table* (2.25)).

2.3.3 National GHG policy and environmental taxation

The national GHG reduction plan

To implement and control its GHG emission targets for the period 2008-2012, Spain created the National Climate Council and the Spanish Office for Climate Change, along with the Coordination Commission for Climate Change Policy, as a body for

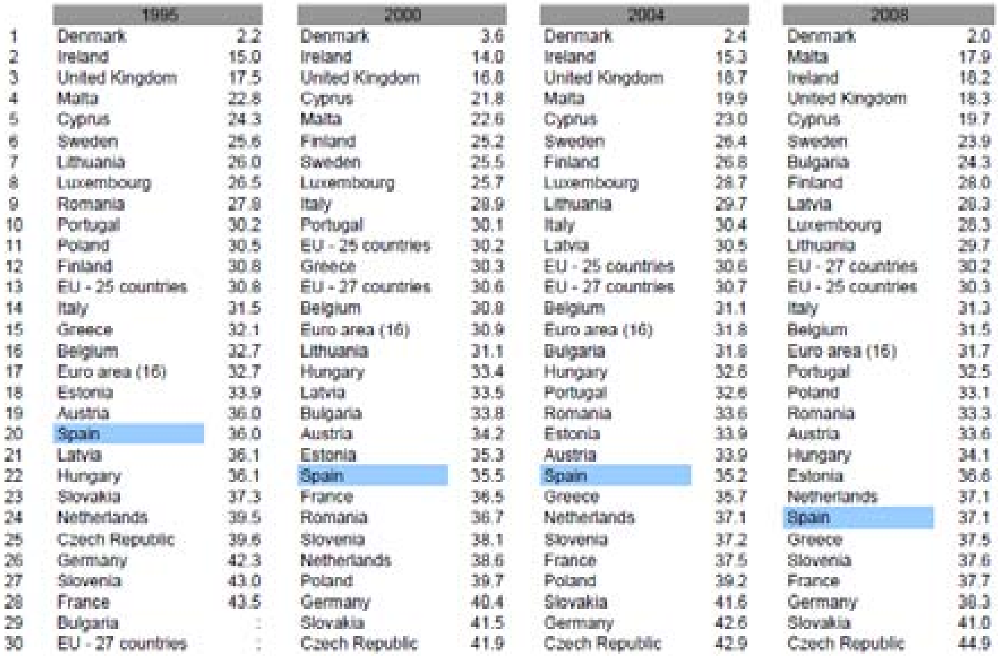
Table 2.22: Social contributions (% of GDP). EU 27 countries, 1995-2008.



	1995		2000		2004		2008	
1	Denmark	1.1	Denmark	1.8	Denmark	1.2	Denmark	1.0
2	Ireland	5.0	Ireland	4.4	Ireland	4.6	Ireland	5.3
3	United Kingdom	6.1	United Kingdom	6.2	Malta	6.5	Malta	6.2
4	Malta	6.1	Malta	6.4	United Kingdom	6.6	United Kingdom	6.8
5	Cyprus	6.5	Cyprus	6.5	Cyprus	7.7	Cyprus	7.7
6	Lithuania	7.2	Lithuania	9.4	Lithuania	8.4	Bulgaria	8.1
7	Romania	8.1	Latvia	9.9	Latvia	8.7	Latvia	8.2
8	Greece	9.3	Luxembourg	10.1	Romania	9.1	Lithuania	9.0
9	Portugal	9.7	Portugal	10.3	Estonia	10.3	Romania	9.3
10	Luxembourg	9.8	Greece	10.5	Bulgaria	10.5	Luxembourg	10.1
11	Poland	11.3	Estonia	10.9	Luxembourg	10.7	EU - 27 countries	11.0
12	EU - 25 countries	11.5	Bulgaria	11.0	EU - 27 countries	11.1	EU - 25 countries	11.2
13	Spain	11.8	Romania	11.1	Portugal	11.1	Sweden	11.3
14	Latvia	12.0	EU - 27 countries	11.2	Greece	11.1	Poland	11.4
15	Sweden	12.3	EU - 25 countries	11.3	EU - 25 countries	11.2	Estonia	11.8
16	Estonia	12.3	Euro area (16)	11.9	Finland	11.7	Portugal	11.9
17	Euro area (16)	12.3	Finland	11.9	Euro area (16)	11.9	Slovakia	12.0
18	Italy	12.6	Spain	12.0	Spain	12.2	Euro area (16)	12.0
19	Finland	14.1	Italy	12.1	Hungary	12.2	Finland	12.1
20	Belgium	14.3	Poland	12.9	Poland	12.3	Greece	12.2
21	Czech Republic	14.3	Hungary	13.0	Italy	12.3	Spain	12.3
22	Hungary	14.7	Sweden	13.2	Sweden	12.8	Italy	13.4
23	Austria	14.9	Belgium	13.9	Slovakia	13.1	Hungary	13.8
24	Slovakia	15.0	Slovakia	14.2	Belgium	13.9	Belgium	13.9
25	Netherlands	15.9	Czech Republic	14.2	Netherlands	13.9	Slovenia	14.1
26	Slovenia	16.8	Slovenia	14.3	Slovenia	14.2	Austria	14.4
27	Germany	16.8	Austria	14.8	Austria	14.7	Netherlands	14.5
28	France	18.6	Netherlands	15.4	Czech Republic	16.0	Germany	15.1
29	Bulgaria	:	France	16.1	France	16.2	France	16.1
30	EU - 27 countries	:	Germany	16.9	Germany	16.5	Czech Republic	16.2

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

Table 2.23: Social contributions (% of Total Taxation). EU 27 countries, 1995-2008.

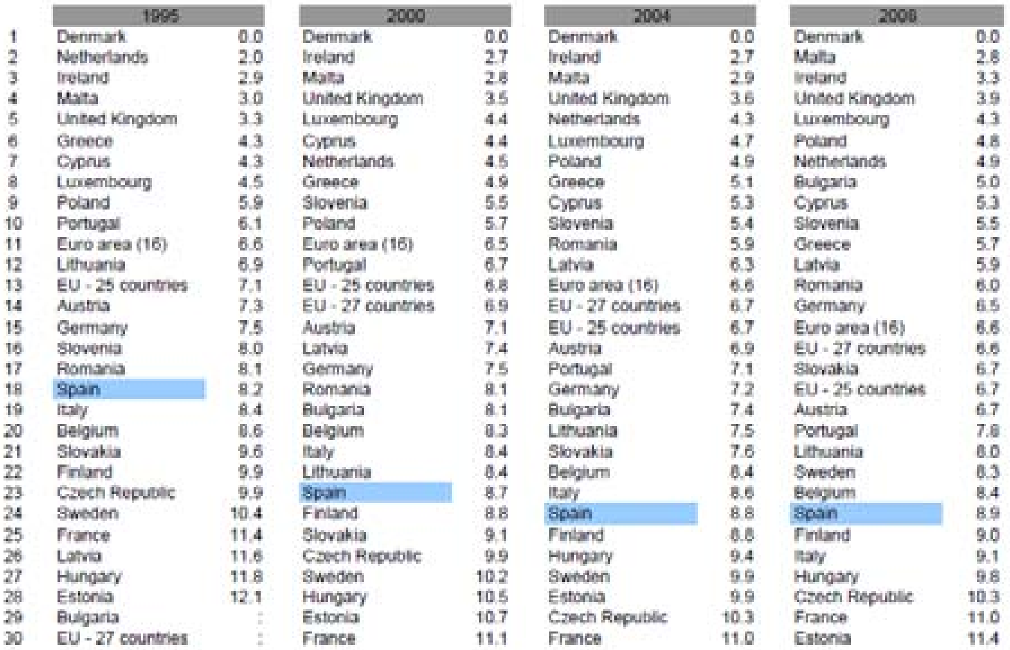


	1995		2000		2004		2008	
1	Denmark	2.2	Denmark	3.6	Denmark	2.4	Denmark	2.0
2	Ireland	15.0	Ireland	14.0	Ireland	15.3	Malta	17.9
3	United Kingdom	17.5	United Kingdom	16.8	United Kingdom	18.7	Ireland	18.2
4	Malta	22.8	Cyprus	21.8	Malta	19.9	United Kingdom	18.3
5	Cyprus	24.3	Malta	22.6	Cyprus	23.0	Cyprus	19.7
6	Sweden	25.6	Finland	25.2	Sweden	26.4	Sweden	23.9
7	Lithuania	26.0	Sweden	25.5	Finland	26.8	Bulgaria	24.3
8	Luxembourg	26.5	Luxembourg	25.7	Luxembourg	28.7	Finland	28.0
9	Romania	27.8	Italy	28.9	Lithuania	29.7	Latvia	28.3
10	Portugal	30.2	Portugal	30.1	Italy	30.4	Luxembourg	28.3
11	Poland	30.5	EU - 25 countries	30.2	Latvia	30.5	Lithuania	29.7
12	Finland	30.8	Greece	30.3	EU - 25 countries	30.6	EU - 27 countries	30.2
13	EU - 25 countries	30.8	EU - 27 countries	30.6	EU - 27 countries	30.7	EU - 25 countries	30.3
14	Italy	31.5	Belgium	30.8	Belgium	31.1	Italy	31.3
15	Greece	32.1	Euro area (16)	30.9	Euro area (16)	31.8	Belgium	31.5
16	Belgium	32.7	Lithuania	31.1	Bulgaria	31.8	Euro area (16)	31.7
17	Euro area (16)	32.7	Hungary	33.4	Hungary	32.6	Portugal	32.5
18	Estonia	33.9	Latvia	33.5	Portugal	32.6	Poland	33.1
19	Austria	36.0	Bulgaria	33.8	Romania	33.6	Romania	33.3
20	Spain	36.0	Austria	34.2	Estonia	33.9	Austria	33.6
21	Latvia	36.1	Estonia	35.3	Austria	33.9	Hungary	34.1
22	Hungary	36.1	Spain	35.5	Spain	35.2	Estonia	36.6
23	Slovakia	37.3	France	36.5	Greece	35.7	Netherlands	37.1
24	Netherlands	39.5	Romania	36.7	Netherlands	37.1	Spain	37.1
25	Czech Republic	39.6	Slovenia	38.1	Slovenia	37.2	Greece	37.5
26	Germany	42.3	Netherlands	38.6	France	37.5	Slovenia	37.6
27	Slovenia	43.0	Poland	39.7	Poland	39.2	France	37.7
28	France	43.5	Germany	40.4	Slovakia	41.6	Germany	38.3
29	Bulgaria	:	Slovakia	41.5	Germany	42.6	Slovakia	41.0
30	EU - 27 countries	:	Czech Republic	41.9	Czech Republic	42.9	Czech Republic	44.9

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

coordination and collaboration between the Government and the autonomous communities. The first Spanish climate change strategy was the Spanish Strategy for Compliance with the Kyoto Protocol, approved by the National Climate Council in

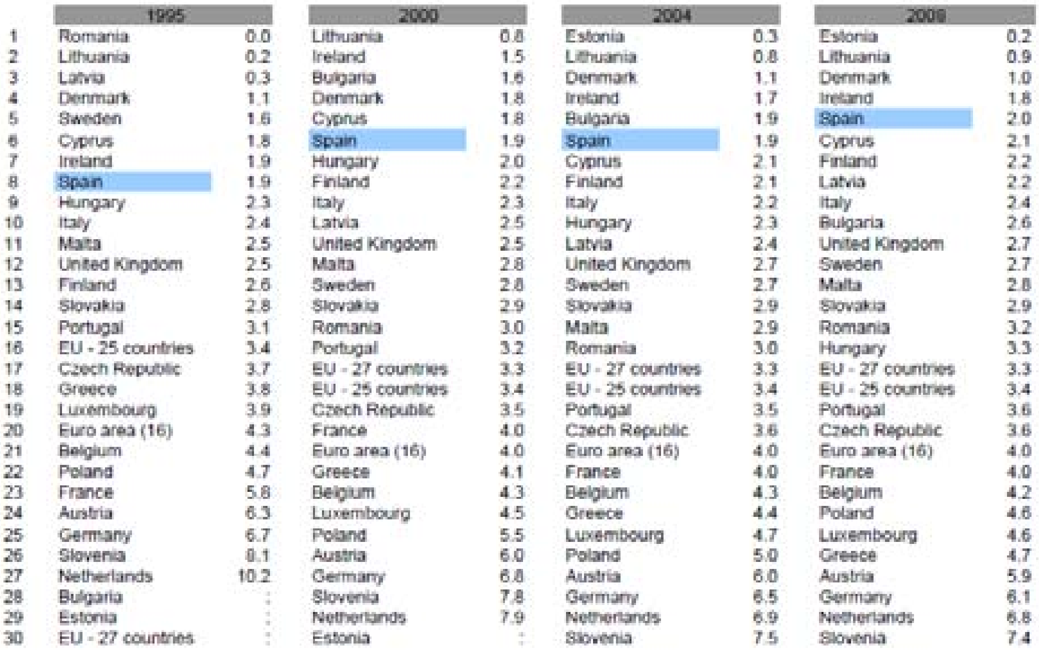
Table 2.24: Employers Social contributions (% of GDP). EU 27 countries, 1995-2008.



	1995		2000		2004		2008	
1	Denmark	0.0	Denmark	0.0	Denmark	0.0	Denmark	0.0
2	Netherlands	2.0	Ireland	2.7	Ireland	2.7	Malta	2.8
3	Ireland	2.9	Malta	2.8	Malta	2.9	Ireland	3.3
4	Malta	3.0	United Kingdom	3.5	United Kingdom	3.6	United Kingdom	3.9
5	United Kingdom	3.3	Luxembourg	4.4	Netherlands	4.3	Luxembourg	4.3
6	Greece	4.3	Cyprus	4.4	Luxembourg	4.7	Poland	4.8
7	Cyprus	4.3	Netherlands	4.5	Poland	4.9	Netherlands	4.9
8	Luxembourg	4.5	Greece	4.9	Greece	5.1	Bulgaria	5.0
9	Poland	5.9	Slovenia	5.5	Cyprus	5.3	Cyprus	5.3
10	Portugal	6.1	Poland	5.7	Slovenia	5.4	Slovenia	5.5
11	Euro area (16)	6.6	Euro area (16)	6.5	Romania	5.9	Greece	5.7
12	Lithuania	6.9	Portugal	6.7	Latvia	6.3	Latvia	5.9
13	EU - 25 countries	7.1	EU - 25 countries	6.8	Euro area (16)	6.6	Romania	6.0
14	Austria	7.3	EU - 27 countries	6.9	EU - 27 countries	6.7	Germany	6.5
15	Germany	7.5	Austria	7.1	EU - 25 countries	6.7	Euro area (16)	6.6
16	Slovenia	8.0	Latvia	7.4	Austria	6.9	EU - 27 countries	6.6
17	Romania	8.1	Germany	7.5	Portugal	7.1	Slovakia	6.7
18	Spain	8.2	Romania	8.1	Germany	7.2	EU - 25 countries	6.7
19	Italy	8.4	Bulgaria	8.1	Bulgaria	7.4	Austria	6.7
20	Belgium	8.6	Belgium	8.3	Lithuania	7.5	Portugal	7.8
21	Slovakia	9.6	Italy	8.4	Slovakia	7.6	Lithuania	8.0
22	Finland	9.9	Lithuania	8.4	Belgium	8.4	Sweden	8.3
23	Czech Republic	9.9	Spain	8.7	Italy	8.6	Belgium	8.4
24	Sweden	10.4	Finland	8.8	Spain	8.8	Spain	8.9
25	France	11.4	Slovakia	9.1	Finland	8.8	Finland	9.0
26	Latvia	11.6	Czech Republic	9.9	Hungary	9.4	Italy	9.1
27	Hungary	11.8	Sweden	10.2	Sweden	9.9	Hungary	9.8
28	Estonia	12.1	Hungary	10.5	Estonia	9.9	Czech Republic	10.3
29	Bulgaria	:	Estonia	10.7	Czech Republic	10.3	France	11.0
30	EU - 27 countries	:	France	11.1	France	11.0	Estonia	11.4

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

Table 2.25: Employees Social contributions (% of GDP). EU 27 countries, 1995-2008.

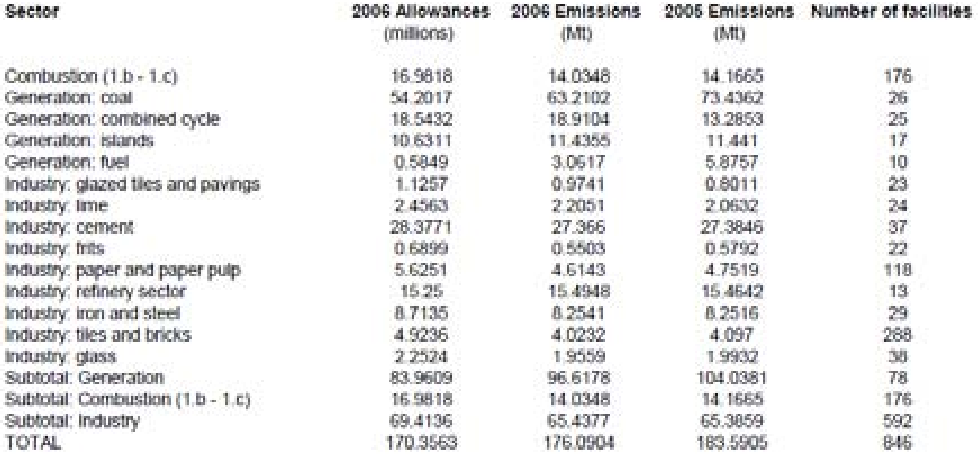


	1995		2000		2004		2008	
1	Romania	0.0	Lithuania	0.8	Estonia	0.3	Estonia	0.2
2	Lithuania	0.2	Ireland	1.5	Lithuania	0.8	Lithuania	0.9
3	Latvia	0.3	Bulgaria	1.6	Denmark	1.1	Denmark	1.0
4	Denmark	1.1	Denmark	1.8	Ireland	1.7	Ireland	1.8
5	Sweden	1.6	Cyprus	1.8	Bulgaria	1.9	Spain	2.0
6	Cyprus	1.8	Spain	1.9	Spain	1.9	Cyprus	2.1
7	Ireland	1.9	Hungary	2.0	Cyprus	2.1	Finland	2.2
8	Spain	1.9	Finland	2.2	Finland	2.1	Latvia	2.2
9	Hungary	2.3	Italy	2.3	Italy	2.2	Italy	2.4
10	Italy	2.4	Latvia	2.5	Hungary	2.3	Bulgaria	2.6
11	Malta	2.5	United Kingdom	2.5	Latvia	2.4	United Kingdom	2.7
12	United Kingdom	2.5	Malta	2.8	United Kingdom	2.7	Sweden	2.7
13	Finland	2.6	Sweden	2.8	Sweden	2.7	Malta	2.8
14	Slovakia	2.8	Slovakia	2.9	Slovakia	2.9	Slovakia	2.9
15	Portugal	3.1	Romania	3.0	Malta	2.9	Romania	3.2
16	EU - 25 countries	3.4	Portugal	3.2	Romania	3.0	Hungary	3.3
17	Czech Republic	3.7	EU - 27 countries	3.3	EU - 27 countries	3.3	EU - 27 countries	3.3
18	Greece	3.8	EU - 25 countries	3.4	EU - 25 countries	3.4	EU - 25 countries	3.4
19	Luxembourg	3.9	Czech Republic	3.5	Portugal	3.5	Portugal	3.6
20	Euro area (16)	4.3	France	4.0	Czech Republic	3.6	Czech Republic	3.6
21	Belgium	4.4	Euro area (16)	4.0	Euro area (16)	4.0	Euro area (16)	4.0
22	Poland	4.7	Greece	4.1	France	4.0	France	4.0
23	France	5.8	Belgium	4.3	Belgium	4.3	Belgium	4.2
24	Austria	6.3	Luxembourg	4.5	Greece	4.4	Poland	4.6
25	Germany	6.7	Poland	5.5	Luxembourg	4.7	Luxembourg	4.6
26	Slovenia	8.1	Austria	6.0	Poland	5.0	Greece	4.7
27	Netherlands	10.2	Germany	6.8	Austria	6.0	Austria	5.9
28	Bulgaria	:	Slovenia	7.8	Germany	6.5	Germany	6.1
29	Estonia	:	Netherlands	7.9	Netherlands	6.9	Netherlands	6.8
30	EU - 27 countries	:	Estonia	:	Slovenia	7.5	Slovenia	7.4

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

2004, for the period 2005-2007. In line with its compromise to fulfill the Kyoto Protocol, Spain has launched in 2005 the emission allowances market scheme, covering more than 1,000 installations in Spain, which account for more than 45% of the total GHG (see *table* (2.26) for 2006 data). One of the central elements of the emissions GHG emission trading regime is the National Allocation Plan (NAP). The NAP 2005-2007 established the first emissions limitation commitment under the Kyoto Protocol (+15%), the compliance path for that period, and determined the allowances to be distributed, in terms of activities, among the owners of the facilities.

Table 2.26: GHG allowances under the National Allocation Plan 2005-2007. Spain, 2006.



Sector	2006 Allowances (millions)	2006 Emissions (Mt)	2005 Emissions (Mt)	Number of facilities
Combustion (1.b - 1.c)	16.9818	14.0348	14.1665	176
Generation: coal	54.2017	63.2102	73.4362	26
Generation: combined cycle	18.5432	18.9104	13.2853	25
Generation: islands	10.6311	11.4355	11.441	17
Generation: fuel	0.5849	3.0617	5.8757	10
Industry: glazed tiles and pavings	1.1257	0.9741	0.8011	23
Industry: lime	2.4563	2.2051	2.0632	24
Industry: cement	28.3771	27.366	27.3846	37
Industry: frits	0.6899	0.5503	0.5792	22
Industry: paper and paper pulp	5.6251	4.6143	4.7519	118
Industry: refinery sector	15.25	15.4948	15.4642	13
Industry: iron and steel	8.7135	8.2541	8.2516	29
Industry: tiles and bricks	4.9236	4.0232	4.097	288
Industry: glass	2.2524	1.9559	1.9932	38
Subtotal: Generation	83.9609	96.6178	104.0381	78
Subtotal: Combustion (1.b - 1.c)	16.9818	14.0348	14.1665	176
Subtotal: Industry	69.4136	65.4377	65.3859	592
TOTAL	170.3563	176.0904	183.5905	846

Source: Ministerio de Medio Ambiente, 2007.

Currently, Spain follows the Spanish Climate Change and Clean Energy Strategy (EECCEL), approved by the National Climate Council in 2007, and with an horizon 2007-2012-2020. It is part of the Spanish Sustainable Development Strategy [Ministerio de la Presidencia, 2007], and sets the framework that gives stability and coherence to national, regional and local policies on climate change in the medium and long term. Its objectives are quite broad: compliance of Spanish international commitments under the Kyoto Protocol, security of energy supply and achieving energy consumption levels compatible with sustainable development.

The NAP 2008-2012, approved in 2006 and based on national emission projections, established a new target for the 2008-2012 commitment period. It sets an increase limit in GHG emissions in the period of 2008-2012 to less than +37% of the 1990 base year emissions, which represents also a 20% reduction with respect to the emissions verified in 2005. Compliance with this objective of +37% maximum is to be implemented trough the NAP 2005-2007 target (+15%), by acquisition of carbon credits trough the flexible mechanisms under the Kyoto Protocol (20%) and the remaining 2% by means of carbon sequestration through forests and other vegetation types.

In order to achieve the required emissions reductions for the 2008-2012 commitment period in the shortest possible time, the EECCEL has been complemented with a Plan of Urgent Measures, with an essential part being a new Saving and Energy Efficiency Action Plan 2008-2012, which aims at reducing energy consumption by improving processes efficiency. At the same time, the Renewable Energy Plan 2005-2010, approved in 2005, was intended to boost to a 12% by 2010 the contribution of renewable sources of the total primary energy consumption, ensure electricity production by renewable sources by a 30% of the gross electricity consumption, and 5.83% biofuel consumption over the gasoline and gasoil estimate for transport.

Environmental taxes in Spain

No doubt the development of the emission allowances market scheme is an important step for Spain. But it hides also a rather distinct situation with respect to another instrument of environmental policy: environmental taxes. The use of fiscal instruments to influence environmental behaviour seems indeed very limited in Spain, at least at the national level, even tough environmental legislation has evolved to adopt European Union Directives. This is partly due to the fact that much of the environmental legislation in Spain is regional, such that important differences exist between the Autonomous Communities, particularly in fields such as land use planning, waste management and protected areas. For environmental taxation specifically, several Autonomous Communities apply specific taxes on air pollution, water consumption or waste disposal. As fiscal measures, tax deductions on the Spanish Corporate Income Tax for investments in environmental protection and for R&D and technological innovation expenses were also implemented as environmental practices [OECD, 2008].

Table (2.27) shows the evolution of environmental tax revenues in percentage of GDP for the EU countries over the years 1995-2008. With the lowest ratio among all the 27 Member States, Spain's environmental policy looks quite deficient in terms of taxing pollution. Data show another reality: environmental tax revenues (as a percentage of GDP) have been slowly declining since 1999, passing from 2.32% to 1.63% in 2008. Admittedly, this downward trend has also been present for the EU averages, but in a much lower scale.

We know also from previous *figure* (2.34) that the low ratio of environmental tax revenues in percentage of GDP for Spain cannot be attributed to a specific low ratio of overall tax revenues in percent of GDP. It is rather the consequence of a low percentage share of environmental tax revenues in terms of total tax revenues, as indicated by *table* (2.28).

As in the majority of Member States, environmental taxation in Spain is mostly

Table 2.27: Environmental tax revenues (% of GDP). EU 27 countries, 1995-2008.

	1995		2000		2004		2008	
1	Denmark	4.5	Denmark	5.3	Denmark	6.0	Denmark	5.7
2	Slovenia	4.2	Netherlands	3.9	Netherlands	3.9	Netherlands	3.9
3	Netherlands	3.6	Malta	3.7	Cyprus	3.5	Bulgaria	3.5
4	Italy	3.5	Romania	3.4	Malta	3.3	Malta	3.5
5	Portugal	3.5	Finland	3.1	Slovenia	3.2	Cyprus	3.1
6	Malta	3.2	Italy	3.1	Finland	3.1	Slovenia	3.0
7	Greece	3.1	United Kingdom	3.0	Bulgaria	3.1	Finland	2.7
8	Ireland	3.1	Hungary	3.0	Portugal	3.1	Sweden	2.7
9	Luxembourg	3.0	Slovenia	2.9	Luxembourg	2.9	Hungary	2.7
10	Euro area (16)	2.9	Ireland	2.9	Sweden	2.9	Portugal	2.6
11	Finland	2.9	EU - 27 countries	2.8	EU - 25 countries	2.8	EU - 27 countries	2.6
12	Hungary	2.9	Luxembourg	2.8	EU - 27 countries	2.8	EU - 25 countries	2.6
13	Czech Republic	2.9	Sweden	2.8	Euro area (16)	2.8	Poland	2.6
14	United Kingdom	2.9	EU - 25 countries	2.8	Hungary	2.7	Euro area (16)	2.5
15	Cyprus	2.9	Euro area (16)	2.8	Italy	2.7	Luxembourg	2.5
16	France	2.8	Portugal	2.7	Czech Republic	2.7	Czech Republic	2.5
17	Sweden	2.8	Cyprus	2.7	Latvia	2.7	Italy	2.4
18	EU - 25 countries	2.8	Czech Republic	2.6	Poland	2.7	Ireland	2.4
19	Slovakia	2.3	France	2.5	Austria	2.6	United Kingdom	2.4
20	Germany	2.3	Bulgaria	2.5	Ireland	2.5	Austria	2.4
21	Belgium	2.2	Austria	2.4	United Kingdom	2.5	Estonia	2.4
22	Spain	2.2	Lithuania	2.4	Germany	2.5	Germany	2.2
23	Austria	2.1	Latvia	2.4	Slovakia	2.4	France	2.1
24	Romania	1.9	Germany	2.4	Belgium	2.3	Slovakia	2.0
25	Lithuania	1.9	Greece	2.3	France	2.3	Greece	2.0
26	Poland	1.8	Belgium	2.3	Lithuania	2.3	Belgium	2.0
27	Latvia	1.2	Slovakia	2.2	Estonia	2.3	Latvia	1.9
28	Estonia	1.0	Spain	2.2	Greece	2.1	Romania	1.8
29	Bulgaria	:	Poland	2.1	Romania	2.0	Lithuania	1.7
30	EU - 27 countries	:	Estonia	1.7	Spain	1.9	Spain	1.6

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

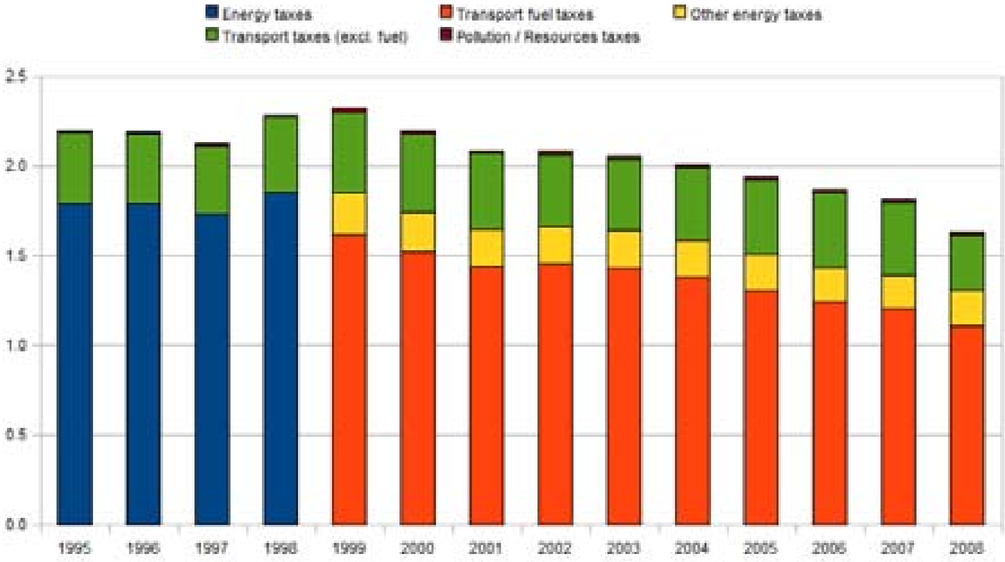
Table 2.28: Environmental tax revenues (% of total tax revenues). EU 27 countries, 1995-2008.

	1995		2000		2004		2008	
1	Malta	11.9	Malta	13.1	Cyprus	11.9	Denmark	11.9
2	Portugal	10.9	Romania	11.4	Denmark	11.4	Bulgaria	10.6
3	Slovenia	10.8	Denmark	10.7	Netherlands	10.3	Malta	10.2
4	Greece	10.7	Netherlands	9.8	Bulgaria	10.2	Netherlands	9.9
5	Cyprus	10.7	Ireland	9.1	Lithuania	9.6	Ireland	8.3
6	Denmark	9.3	Cyprus	8.9	Malta	9.3	Slovenia	8.1
7	Ireland	9.2	United Kingdom	8.1	Latvia	9.1	Cyprus	8.0
8	Netherlands	9.1	Latvia	8.1	Portugal	9.1	Poland	7.5
9	Italy	8.8	Lithuania	8.1	Romania	8.7	Estonia	7.3
10	United Kingdom	8.3	Portugal	8.0	Slovenia	8.7	Portugal	7.2
11	Euro area (16)	8.2	Slovenia	7.9	Ireland	8.3	EU - 27 countries	7.1
12	Czech Republic	8.0	Hungary	7.6	Poland	8.2	Luxembourg	7.0
13	Luxembourg	8.0	EU - 27 countries	7.6	Luxembourg	8.2	EU - 25 countries	7.0
14	EU - 25 countries	7.5	Czech Republic	7.6	EU - 27 countries	8.0	Euro area (16)	6.8
15	Hungary	7.2	Bulgaria	7.5	Slovakia	7.9	Slovakia	6.8
16	Lithuania	6.8	EU - 25 countries	7.5	EU - 25 countries	7.9	Czech Republic	6.8
17	Spain	6.7	Euro area (16)	7.5	Euro area (16)	7.8	Latvia	6.7
18	France	6.5	Italy	7.4	Finland	7.4	Hungary	6.7
19	Finland	6.4	Luxembourg	7.1	United Kingdom	7.4	United Kingdom	6.5
20	Romania	6.4	Greece	6.8	Hungary	7.3	Romania	6.3
21	Germany	5.8	Finland	6.6	Czech Republic	7.1	Finland	6.3
22	Slovakia	5.8	Slovakia	6.5	Greece	6.9	Greece	6.0
23	Sweden	5.8	Spain	6.5	Estonia	6.9	Sweden	5.8
24	Austria	5.2	Poland	6.4	Italy	6.8	Italy	5.7
25	Belgium	5.1	Germany	5.7	Germany	6.5	Germany	5.7
26	Poland	5.0	Austria	5.6	Austria	6.3	Austria	5.6
27	Latvia	3.7	France	5.6	Sweden	5.8	Lithuania	5.5
28	Estonia	2.7	Estonia	5.5	Spain	5.8	Spain	4.9
29	Bulgaria	:	Sweden	5.4	France	5.6	France	4.9
30	EU - 27 countries	:	Belgium	5.0	Belgium	5.3	Belgium	4.4

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

concentrated on energy. *Figure* (2.38) shows the breakdown of environmental tax revenues for Spain over the years 1995-2008. Energy taxes (which, from 1999 to 2008, are separated between 'transport fuel taxes' and 'other energy taxes') represent always around 80% of environmental tax revenues, even tough they were not originally conceived as environmental taxes. The data indicate also that Spain raises little revenue from energy taxes on sources other than transport fuels, such as electricity.

Figure 2.38: Environmental tax revenues (% of GDP). Spain, 1995-2008.

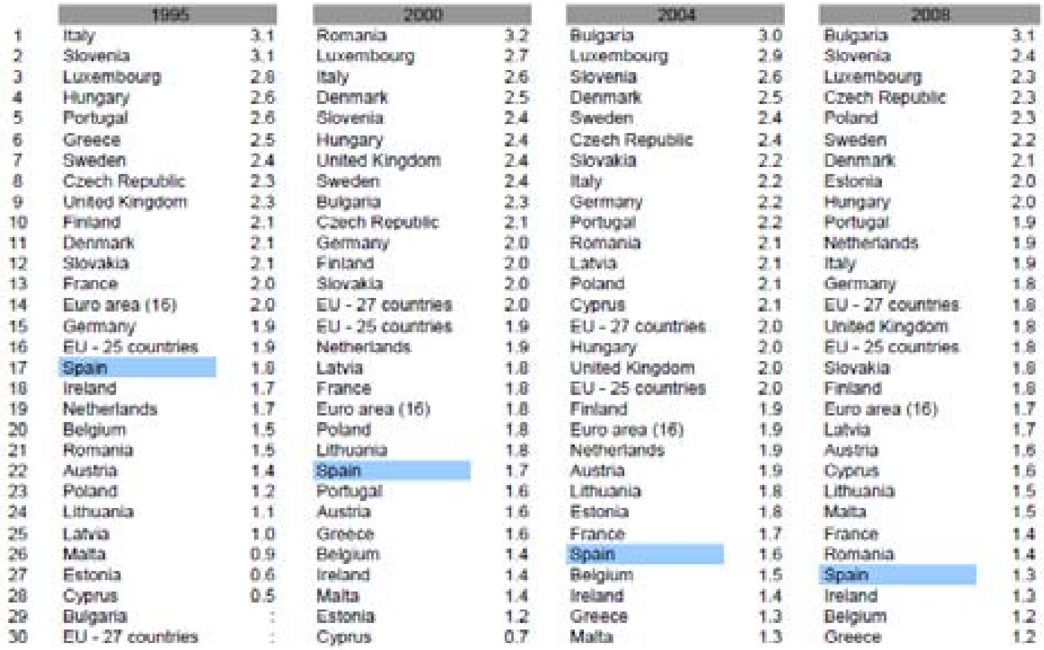


Source: OECD (2010), *Revenue Statistics*, Paris: OECD.

The deflated implicit tax rate on energy (ITRE) is given in *table* (2.4). This indicator measures the ratio between energy tax revenues (in Euros) and final energy consumption (in tons of oil equivalent), adjusted to inflation. It is expected that higher taxes levied on the use of energy should contribute to foster energy efficiency. Data indicate an historical persistence of large differences in the ITRE among Member States. For Spain, tax revenue per unit of energy has been falling relatively to EU-27 average, such that Spain has always presented an ITRE lower than the EU average over the observed period. This trend is confirmed among the five major EU countries in *figure* (2.39): every year Spain has presented the lowest ITRE, with an almost constant downward trend.

Environmental taxation is an ongoing debate, due to the contradictory forces in place which create sometimes uncomfortable political choices for governments. On the one hand, they must ensure high levels of environmental protection, a trend that could be even more important in the future, as attention increases on the threat from global warming. On the other hand, they must mitigate the growing social and political pressure to reduce energy taxation, when energy prices start to peak, as it was the case in the last few years.

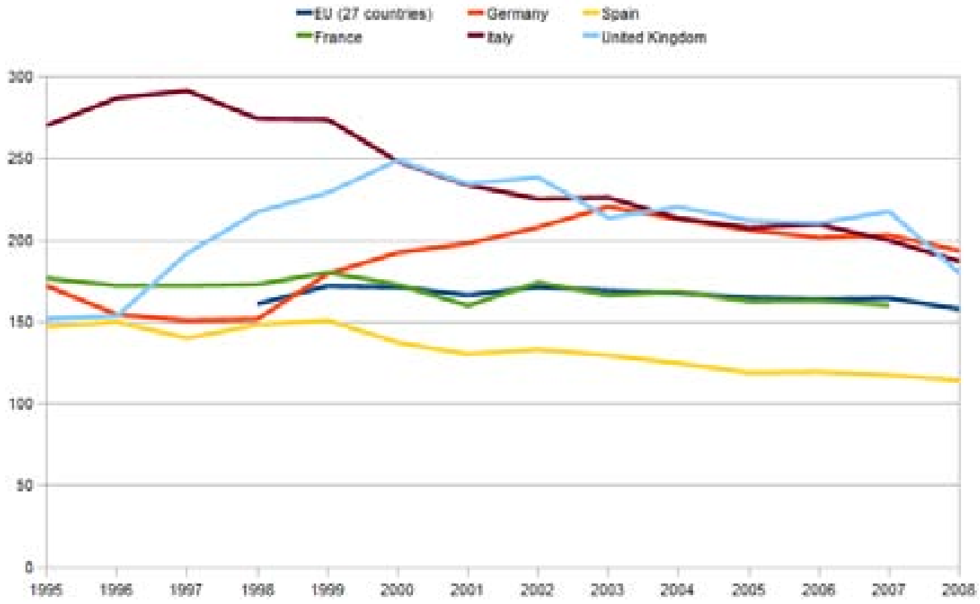
Table 2.29: Energy tax revenues (% of GDP). EU 27 countries, 1995-2008.



	1995		2000		2004		2008	
1	Italy	3.1	Romania	3.2	Bulgaria	3.0	Bulgaria	3.1
2	Slovenia	3.1	Luxembourg	2.7	Luxembourg	2.9	Slovenia	2.4
3	Luxembourg	2.8	Italy	2.6	Slovenia	2.6	Luxembourg	2.3
4	Hungary	2.6	Denmark	2.5	Denmark	2.5	Czech Republic	2.3
5	Portugal	2.6	Slovenia	2.4	Sweden	2.4	Poland	2.3
6	Greece	2.5	Hungary	2.4	Czech Republic	2.4	Sweden	2.2
7	Sweden	2.4	United Kingdom	2.4	Slovakia	2.2	Denmark	2.1
8	Czech Republic	2.3	Sweden	2.4	Italy	2.2	Estonia	2.0
9	United Kingdom	2.3	Bulgaria	2.3	Germany	2.2	Hungary	2.0
10	Finland	2.1	Czech Republic	2.1	Portugal	2.2	Portugal	1.9
11	Denmark	2.1	Germany	2.0	Romania	2.1	Netherlands	1.9
12	Slovakia	2.1	Finland	2.0	Latvia	2.1	Italy	1.9
13	France	2.0	Slovakia	2.0	Poland	2.1	Germany	1.8
14	Euro area (16)	2.0	EU - 27 countries	2.0	Cyprus	2.1	EU - 27 countries	1.8
15	Germany	1.9	EU - 25 countries	1.9	EU - 27 countries	2.0	United Kingdom	1.8
16	EU - 25 countries	1.9	Netherlands	1.9	Hungary	2.0	EU - 25 countries	1.8
17	Spain	1.8	Latvia	1.8	United Kingdom	2.0	Slovakia	1.8
18	Ireland	1.7	France	1.8	EU - 25 countries	2.0	Finland	1.8
19	Netherlands	1.7	Euro area (16)	1.8	Finland	1.9	Euro area (16)	1.7
20	Belgium	1.5	Poland	1.8	Euro area (16)	1.9	Latvia	1.7
21	Romania	1.5	Lithuania	1.8	Netherlands	1.9	Austria	1.6
22	Austria	1.4	Spain	1.7	Austria	1.9	Cyprus	1.6
23	Poland	1.2	Portugal	1.6	Lithuania	1.8	Lithuania	1.5
24	Lithuania	1.1	Austria	1.6	Estonia	1.8	Malta	1.5
25	Latvia	1.0	Greece	1.6	France	1.7	France	1.4
26	Malta	0.9	Belgium	1.4	Spain	1.6	Romania	1.4
27	Estonia	0.6	Ireland	1.4	Belgium	1.5	Spain	1.3
28	Cyprus	0.5	Malta	1.4	Ireland	1.4	Ireland	1.3
29	Bulgaria	:	Estonia	1.2	Greece	1.3	Belgium	1.2
30	EU - 27 countries	:	Cyprus	0.7	Malta	1.3	Greece	1.2

Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

Figure 2.39: Implicit tax rate on energy (deflated). Major EU countries, 1995-2008.



Source: Eurostat (2010), *Taxation trends in the European Union. Data for the EU Member States, Iceland and Norway. 2010 edition*, Luxembourg: Eurostat.

While application of an European wide environmental tax is not yet on the table, some countries have decided to implement carbon taxes on their own (Denmark, Holland, Norway, Sweden, Ireland, and Italy), while others have opted for increasing energy taxes (Austria and Germany). These different fiscal regimes and the wide differences in the implicit tax on carbon generate therefore some challenges when trying to implement international coordinated taxes.

2.4 Shifting the tax burden

2.4.1 The doubled dividend

In the context of an environmental tax reform, the double dividend (DD) hypothesis refers to the possibility of obtaining two type of gains: an environmental dividend and a non-environmental dividend. This could happen when an environmental tax is introduced to curb environmental damage and the revenues obtained from that tax are used to reduce other distortionary taxes [Bovenberg and de Moij, 1994a, 1994b; Bovenberg and Goulder, 1996; Bovenberg, 1999]. Goulder [1995] distinguishes three varieties of the DD: a weak, an intermediate and a strong DD. A *weak* DD is obtained when the revenues from the environmental tax serve to finance reductions in the marginal rate of an existing distortionary tax, leading to cost savings relative to the case where the tax revenues are returned to taxpayers in lump-sum fashion. So, the weak DD simply focus on what is done with the revenue from environmental taxes, arguing that it is better to use this revenue to reduce the rates of existing distortionary taxes than to provide lump-sum payments to citizens.

Stronger versions suggest that swapping some existing distortionary taxes with environmental taxes will reduce the distortionary cost of raising the current level of government revenue. The intermediate and strong double dividend notions differ then in the extensiveness of the class of distortionary taxes. An *intermediate* DD occurs when there exists *at least one* distortionary tax for which a zero or negative gross cost overall is obtained; whereas the *strong DD* refers to the case where a revenue-neutral substitution of an environmental tax for another distortionary tax would lead to a zero or negative gross cost, through the reduction of fiscal distortions. For example, the introduction of an environmental tax which revenues are recycled trough the reduction of a very strongly distorting tax might eventually provide a positive non-environmental welfare improvement that could over-compensate the fiscal distortion introduced by the environmental tax.

The strong DD concept must thus be approached in the context of the theory of optimal taxation, which pretends to minimize the distortionary costs of a tax system that generates a given level of government revenue. By targeting taxes that raise revenue in the most efficient way, this theory focuses thus on “revenue-optimal” taxes. This is why no tax change would be promoted if a fiscal system presents already a set of revenue-optimal taxes, since there is no possible change to those taxes that will raise the same revenue at a smaller distortionary cost. This implies that the strong double dividend should not hold in an economy where the taxes are revenue-optimal. But this last situation probably never holds, so this should not be a fundamental reason for environmental taxation not to allow adjustment of the tax structure closer to the revenue optimum. However, it can be expected that the strong DD does not apply to all sizes of environmental taxes. Higher tax rates increase indeed the distortionary costs of revenue raising. Assuming that high environmental taxes are imposed to reduce the distortionary cost of other taxes with low distortionary cost, the result may be an increase in the overall distortionary cost of the tax system.

In this study, we specify the environmental dividend as a reduction in carbon emissions. The variables used to measure a non-environmental dividend are restricted to economic growth and employment level. An environmental tax reform which can not only reduce carbon emissions but also improve economic growth and/or employment, by reducing the overall economic costs of the tax system, would appear as a politically appealing idea. Whatever the scale of the favourable impact on environment quality, the fiscal reform could give indeed a free lunch trough higher economic growth or lower unemployment, for a given level of public revenues. The part of the theoretical literature targeting explicitly employment creation has focused on the case of involuntary unemployment, and the DD that can be generated from this situation is often referred to as the “employment double dividend”.

2.4.2 The employment double dividend

The connection between the double dividend hypothesis and employment creation arises directly because one possible distortionary effect of taxation is the reduction of employment and high unemployment in many countries has driven particular focus on the large tax distortions in the labour market. Several taxes may be related to a reduction in employment: the ones that are obviously related to employment, such as income tax and social security taxes; but also the ones that affect the real value of workers’ wages, such as value added tax and excise duties.

The existence of an employment DD depends crucially, first, on how the tax revenues are recycled, and, second, on whether or not the labour market is in equilibrium. In the case of labour market disequilibrium, with supply greater than demand and consequent involuntary unemployment, an increase in employment will require an increase in labour demand. This could be achieved by reducing the cost of employing labour, for example by reducing employers’ social security taxes. In the case of labour market equilibrium, with demand equal to supply and no involuntary unemployment, employment creation will require an increase in labour supply. This increase could be obtained by boosting the returns to work; for example trough a reduction in direct taxes on labour income or by reducing sales taxes on goods for which workers have a negative price elasticity of demand.

Almost all models have confirmed the existence of a weak double dividend. The most important exception is when the lump-sum payments are more efficient than tax reductions at raising the incomes of poor households. But these results are not fundamental because the weak double dividend is simply about how to spend the environmental tax revenue. It doesn't suggest anything to enhance the case for environmental taxation. To ensure that environmental taxes can contribute to the efficiency of the economy in other ways than improving the environment, it is the strong double dividend that must hold.

With regard to the strong DD, there is a wider range of disagreement regarding the outcome. Several theoretical studies tend to confirm that no employment DD exists [Bovenberg and de Mooij, 1994a; Bovenberg and van der Ploeg 1994]. A common explanation is that the environmental tax tends to erode the basis of the labour tax, creating a higher distortion of the labour market, even if the revenues from environmental taxes are recycled trough cuts in labour taxes. Most of these studies present however the restriction of a perfect competitive labour market without involuntary unemployment.

Given the rigidities of the labour markets in industrialised countries, this competitive framework is probably not the most appropriate to study the employment DD hypothesis. Involuntary unemployment is a fundamental aspect of most labour markets and taking this feature into account would be expected to generate some changes in the DD conclusions. The idea is that, in the presence of full-employment, the burden of the environmental tax falls onto labour (i.e. all households), just as the labour tax. The (partial) replacement of a labour tax for an environmental tax is therefore similar to the substitution of an explicit tax for an implicit tax on labour. If now some involuntary unemployment is allowed into the model, the labour market is composed of employed and unemployed households. The difference with the full-employment specification is that now the members of the second group, the unemployed households, are affected by the environmental tax, but not by the labour tax. There is therefore more scope for shifting the tax burden from an overtaxed factor (labour) to undertaxed factors and goods, permitting a possible efficiency gain of the tax system.

For the specific case of the employment DD, we consider the situation of labour market disequilibrium, as this is generally assumed to be the situation in Spain and most of Europe. Involuntary unemployment reflects the situation where labour demand is lower than its supply. One of the potential reasons usually proposed is the existence of a wage higher than its market clearing value[20]. In terms of optimal tax theory, this wage distortion generating unemployment could be reduced by decreasing the tax burden on labour (e.g. existing taxes such as payroll taxes) and lowering labour costs, thus promoting an increase in labour demand and eventually leading to additional employment. To compensate the revenue loss, other taxes such as environmental taxes can then be introduced.

In nearly all theoretical analyses, taxes on labour as a production factor (e.g. employers' contributions to Social Security) or as a source of income (e.g. personal income tax) generate a negative impact on labour market participation and employment growth[21]. According to economic theory, a labour cost reduction (e.g. a reduction in labour taxes or social security contributions) would therefore contribute to employment growth. This increase in employment is believed to be proportionally smaller than the labour cost reduction that caused it, given the wage elasticity of labour demand being usually less than one. As a feedback effect, employment growth translates into a rise in the taxable base, such that the labour tax reduction partially finances itself. Hence, a large variety of simulation outcomes can emerge after a labour cost reduction, depending on the magnitude of the feedback effect.

In the case of employers' contributions to Social Security, the link between a reduction of labour taxation and employment growth is made trough two channels: a supply side effect and a demand effect. The supply side effect is due to the change in the relative cost of the labour factor. First, a reduced labour cost can achieve the same level of output at a lower cost. Second, a lower labour cost reshapes the optimal combination of the production factors, in favour of labour. This may also further reduce the total production cost. This supply side effect, and its corollary change in the actual level of output, employment and income, may lead to indirect changes in demand, through a rise in disposable income. This cheaper labour cost means also an improved competitive position, for unchanged production costs abroad, with its impacts on net export demand. Both demand effects, interior and exterior, increase total production, with a consecutive increase in the firm's demand for production factors.

There are some a priori reasons to suspect that tax shifting process from payroll taxes to environmental/energy taxes would increase total employment, while at the

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[20] Several wage-setting processes can be proposed to explain this situation. In this study, we follow a wage curve hypothesis as explained in chapter 5.

[21] This negative impact is obtained within the two major theoretical frameworks in labour economics: the neoclassical approach with perfectly competitive and clearing labour and product markets, and the (new) Keynesian theory assuming imperfect clearing processes.

same time reducing CO_2 emissions. The effects of the reduced payroll taxes could however be offset if the new environmental taxes reduce the workers' real wage by increasing the price of goods that workers buy. Due to the importance of energy goods in firms and households consumption, the increase in energy prices should result in a significant increase in the consumption price index. Thus, in order to guarantee their real wage, workers could ask for wage increases, offsetting the initial positive change in employment. In case there is a wage indexation mechanism in place, this increase in price results in higher wages, undermining firms profitability and labour productivity, which cost will be further carried into higher prices. Also, the Phillips curve effect predicts that the decrease in unemployment may culminate on an real wage increase.

This scenario shows that the price and wage dynamics of the tax shifting process from payroll taxes to environmental/energy taxes does not always reduce labour costs such that labour demand can be increased. Instead, it may well lead to inflation pressure, if no wage moderation policy is implemented. To reduce production costs and increase employment at the same time, the key is to ensure that labour costs reduction for the firms more than compensate the increase in energy prices. Since in Spain and most European countries, it is labour that is taxed more heavily than other factors, a shift away from the taxation of labour to the taxation of other factors can be expected to reduce production costs.

This reduction in production costs does not ensure an improvement in the efficiency of the tax system and the emergence of an employment double dividend. Additional taxes on energy use could indeed lead to it being over-taxed. Also, if the counterpart to a decrease in labour tax is an increase in energy taxation alone, this may improve the relative costs of labour and energy, but at the cost of possibly worsening the relative costs of capital and energy. However, this problem should be minor if energy is more substitutable with labour than with capital. In that case, the improvement in the relative costs of labour and energy would be more important than the worsening of the relative costs of energy and capital.

Now, even under the case of a labour market disequilibrium without involuntary unemployment, the tax shifting policy can still generate a double dividend, but this time not trough a demand-side mechanism (increasing labour demand) but through a supply-side mechanism (increasing labour supply). Assuming that the labour market is sufficiently flexible to ensure full employment, if the distortionary effect of employment taxes affect negatively the workers' labour force participation, one could eventually observe non-optimal level of labour supply. In that case, an increase in labour supply may be achieved if the rewards to working raises trough a reduction in labour taxation for example. Therefore if supply side incentives to work are increased, a tax shifting from labour taxes to environmental/energy taxes could possibly generate an employment double dividend.

In terms of public finances, part of the initial fiscal cost of the labour tax reductions should be recovered by the government (endogenously) through fiscal feedback effects. On the one hand, higher employment and/or higher wages, resulting from the policy measure, broaden the labour tax base, which leads to higher fiscal and para-fiscal receipts. Lower unemployment, on the other hand, leads to lower expenditure for unemployment benefits. However, these feedback effects will never fully compensate for the initial fiscal cost. Therefore, if the government wants to maintain the same fiscal solvency as before the policy, it has to find alternatives to finance the ESSC reductions. Overall, both the initial labour tax reductions and the compensation mechanisms will have an impact on wages and employment. Alternative financing mechanisms will indeed tend to reduce part of the employment effects stemming from the initial labour-promoting fiscal measures. The degree to which this occurs will depend very much on which specific fiscal measure is implemented.

2.4.3 Definition of the policy simulations

Initial policy variants

Among the numerous policy scenarios that can be evaluated within the model, we have first to choose between two opposite starting points. Either we can simulate the ex-ante introduction of a *new* carbon tax, calculated to generate a specific reduction of CO_2 emissions compared to the baseline, and combine it with different revenue recycling methods using the carbon tax revenues to lower rates for *current* taxes. Or we can simulate an ex-ante reduction in *current* tax rates (generating a reduction in corresponding tax revenues equivalent to a given percentage of GDP, for example), and impose a *new* carbon/energy tax to cover the ex-ante tax revenue losses and ensure in this way a public deficit neutral policy. Instead of determining an initial level of CO_2 emissions or energy efficiency to be reached, this second method aims to compare the economic efficiency of different tax policies with an equivalent *ex-ante* fiscal cost. The CO_2/energy tax rates are thus calibrated ex-post in order to compensate the revenue losses from the initial tax policies. Of course, overall economic efficiency is a complex concept, and the policy results cannot always be easily compared with each other, since we must weight together the impacts in both economic (lower economic burden) and environmental terms (higher energy efficiency or reductions in CO_2 emissions). By choosing the second option, we are however better positioned to compare the ex-post effects of size-equivalent tax policies changes related to *current* tax levels.

For the initial tax policy changes, we consider four different tax types from the

Spanish tax system in the benchmark year: the employers Social Security contributions (ESSC), the personal income tax (PIT), the corporate income tax (CIT) and the value-added tax (VAT). The four variants are defined in *table* (2.30).

For all these taxes, the fiscal policy that will be used as starting point will be the same: the simulation of an ex-ante reduction in tax rate, generating a decrease in corresponding tax revenues equivalent to a 1% reduction of GDP. The choice is quite arbitrary of course, and no attempt is made here to determine welfare-optimising level of emission reductions. However, the EU Directive proposition on a gradual increase of a CO_2/energy tax recognises explicitly the need for some ambitious targets and we consider an initial tax reform generating a change in public revenues equivalent to a 1% change in GDP quite an ambitious first target.

In the first variant, a decrease in ESSC, the tax policy is intended to directly favour employment trough labour cost reduction. As already explained, in Spain and Europe, total labour costs are relatively high, partly due to high Social Security contributions rates. Therefore, it may prove worthwhile to investigate the consequences of a reduction of these tax rates. In concrete terms, a unique ESSC reduction would be used for increasing labour demand, as labour cost diminishes and labour factor becomes more attractive as compared to other production factors.

In the second variant, a VAT decrease, the initial tax policy affects indirect taxation. A decrease in VAT rate directly impacts on the consumption price levels. This could not only lead to an increase in aggregate demand, but could also generate a price-wage spiral when there is an automatic wage indexing regime in place. As consumer prices decrease and output demand increases, labour demand by firms should increase too, with a positive impact on employment. Some second-round competitiveness effects could also begin, as the price-wage spiral starts to make output less expensive for export purposes as well, leading to a further final demand increase. Finally, the VAT decrease presents also the important advantage to be quite straightforward to implement, another worthwhile reason for analysis.

The third and fourth variants concentrate on reduction of income taxes for both the household and the corporate sector. Since any income tax reduces disposable incomes and tends to discourage consumption and saving, the focus of this variant will help to evaluate how an income tax reduction affects the consumption and saving behaviour of the agents, depending on the changes in relative prices.

Financing alternatives

The results of the variants, in terms of their impact on economic activity and environmental factors, will depend upon the initial level of taxation and, to a large extent, by the way in which the tax revenue losses are recovered or not. For each of the four taxation cases (named from A to D), we consider two different types of simulations, subdivided into four different "financing alternatives".

The first type of simulation assumes that the reduction in the tax rates are uncompensated by other policies which would restore public revenues or reduce public spending, in order to guarantee a constant ratio of public deficit to GDP. Indeed, without compensation mechanism, the government tax revenue is reduced. And for a given level of public spending (exogenous levels of public consumption and public investment), a lower public revenue implies a larger public deficit. This first "financing alternative" is used to assess the effects of the expansionary fiscal policies on prices and quantities and serves as a comparison benchmark with respect to the three other alternatives that propose some compensatory mechanisms.

The second type of simulations assume that a compensatory mechanism is imposed in order to maintain a constant ratio of public deficit to GDP. Thus, they keep the government budget balance in place by ensuring that the losses of fiscal revenue due to the initial tax reductions are immediately and fully compensated by additional tax revenues or lower public spending. Three different compensatory mechanisms are proposed:

1. The lower tax revenues and public savings are compensated by a lower public investment (financing alternative 2). In this case, the equilibrating rule is based on the restriction that the public investment is "savings driven", which means that public investment must adjust to any change in public savings, in order to ensure a constant ratio of public deficit to GDP.
2. The tax revenue losses are compensated by a new tax on CO_2 emissions, or carbon content of fuels (financing alternative 3).
3. The tax revenue losses are compensated by a twin tax on energy inputs with 50% of the tax to be based on the carbon content of the fuels and the other 50% on the energy content, as advocated by the 1992 EU directive proposal (financing alternative 4).

The assumption of fiscal neutrality is imposed for the last two alternatives, in order not to alterate the total burden of compulsory withholding taxes, thus following the recommendations of the European draft directive on CO_2/energy tax on fossil fuels. The objective of the equally weighted CO_2/energy tax[22] is to provide an incentive to reduce CO_2 emissions (carbon part of the tax) and to increase energy efficiency (energy

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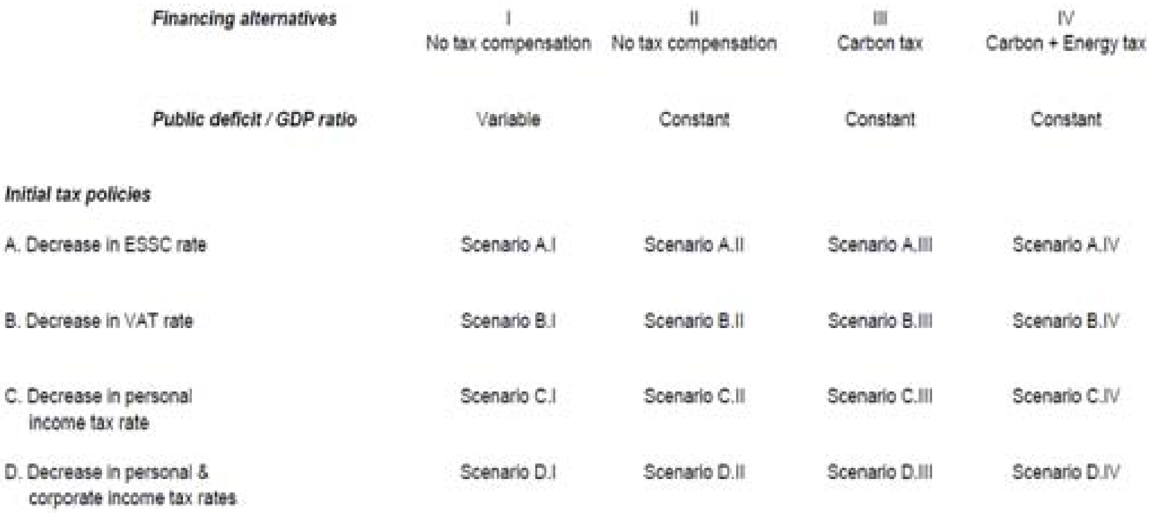
[22] If the objective is the reduction of CO_2 emissions, this twin tax is preferred to a tax based only on the energy content of the fuels, since it has been shown that this kind of tax has a small impact on CO_2 emissions reductions for households [Karadeloglou, 1992 and Bréchet, 1998].

part). As emphasized by the EU Directive proposal, another reason for the inclusion of an energy part in the CO_2/energy tax is to reduce the risk of high distortions on the European electricity market. The energy part of the tax serves indeed to mitigate the tax burden differential among Member States, resulting from the carbon part of the tax. Without the energy part, countries with a high share of coal plants and a low share of nuclear power in total electricity production capacity would be particularly at disadvantage.

Carbon emissions and energy efficiency are global challenges, affecting all agents in the economy. So, given the magnitude of the economic transformation required, private households could be engaged in the tax policy. The proposed energy tax and carbon tax are thus levied on intermediary fuel inputs for production sectors (such as electricity generation) and on final consumption for the representative consumer, with the tax restriction affecting all industrial sectors and the representative household uniformly. Setting a consumption tax on energy use for households simplifies levying of the tax but may generate welfare costs, as the tax renders electricity more expensive but may fail in reducing much demand, given the generally low price elasticity of energy demand. Also, a consumption tax ignores the option of switching towards more environmentally friendly fuels and towards more energy efficiency at the generation or supply stage. On the contrary, as an input tax in the production cycle, the CO_2/energy tax should provide a strong incentive for producers to change production patterns towards more environmentally friendly inputs or technologies.

Table 2.30: Alternative policy scenarios for the simulations



Financing alternatives	I No tax compensation	II No tax compensation	III Carbon tax	IV Carbon + Energy tax
Public deficit / GDP ratio	Variable	Constant	Constant	Constant
Initial tax policies				
A. Decrease in ESSC rate	Scenario A.I	Scenario A.II	Scenario A.III	Scenario A.IV
B. Decrease in VAT rate	Scenario B.I	Scenario B.II	Scenario B.III	Scenario B.IV
C. Decrease in personal income tax rate	Scenario C.I	Scenario C.II	Scenario C.III	Scenario C.IV
D. Decrease in personal & corporate income tax rates	Scenario D.I	Scenario D.II	Scenario D.III	Scenario D.IV

So, in total, we obtain four initial tax reforms, with each being analyzed together with four alternatives: the first two with no tax compensation financing, where the macroeconomic adjustment is either a larger public deficit to GDP ratio (alternative I) or a lower public investment (alternative II), and the other two with fiscal compensation policies, composing thus a grid of sixteen simulation outcomes. Throughout the remainder of this study, references to the different scenarios will be made as they are organised in table (2.30).

Chapter 3

Methodology and Literature

This chapter introduces the CGE methodology, to be used in this study, and overviews some of its applications for environmental fiscal reforms, with a particular emphasis on CGE models applied to Spain. The purpose of this section is not to undertake an exhaustive review of the literature, but rather, to select some specific models and examine their important features. In comparison with these models, we then explain the main characteristics of the static model for the Spanish economy, designed for the medium-run economic analysis of the policy simulations proposed in the previous section. We indicate the general features of the model and specify the major underlying assumptions.

3.1 Macro models for macroeconomic reforms

3.1.1 CGE vs Macroeconometric models

To represent the relations between the economy/energy/environment aggregates and the impacts of macroeconomic fiscal reforms, different methodologies can be proposed. Their use will depend on the statistics available, the structural factors to be represented, the spatial disaggregation levels, the time horizon, etc. While there is not perfect methodology, from a macroeconomic perspective, we can distinguish two major modelling methodologies used in the literature: macroeconometric models and general equilibrium models.

Macroeconometric models get their fundamentals from neo-keynesian tradition. Neo-keynesian models are guided by the demand side, even tough some supply side mechanisms can be present in the short run. They do not assume equilibrium for the different markets but are rather based on a keynesian regime of global demand restriction: unemployment derives from demand shortages and wage rigidities. For this reason, they are mostly focused on short- medium-run analysis, altough they can capture longer-term adjustments also. Parameters of these models are estimated by econometric methods using time series data, which legitimates their historical validation and allows for short-run forecasts. Also, macroeconometric models tend to have fewer theoretical restrictions and are thus 'more realistic' than CGE models, even tough still being quite complex. On the other hand, the use of econometrics limits the model capacity to explore the long-run, due to the implicit assumption of the permanence of structural behaviours. Econometrics models can thus hardly describe structural changes in the economy, otherwise than by making use of ad-hoc methods.

Computable general equilibrium (CGE) models are based on a walrasian representation of the economy and build upon general equilibrium theory that combines behavioral assumptions regarding rational economic agents with the analysis of equilibrium conditions. They describe the ressource allocation process in a market economy, as the result of interaction between demand and supply, generating equilibrium prices and an economy heading towards a general equilibrium. With respect to the keynesian framework, CGE models allow for the explicit modelisation of microeconomic optimisation mechanisms, which strengthen their theoretical foundations, compared with macroeconometric models.

The assumption of price flexibility implies that CGE models are de facto well adapted for the long-run analysis. Within CGE models, the time horizon is dependent on the theoretical specification forms (functional forms and closing rules), the flexibility assumptions related to price and quantity variables, and the value of parameters and elasticities. By construction, CGE models simulate the impacts of a structural shock on a time horizon from 10 to 15 years. Being calibrated to a single year, CGE models are also 'unhistorical', in the sense of being independent from past time series, unlike macroeconometric models. The focus on long-run analysis can be particularly well adapted for some problematics, such as the evaluation of environmental damage, while macroeconometric models show their strength on the analysis of macroeconomic stabilisation policies.

Overall, the main 'virtue' of the CGE approach is its rigorous and extensive microeconomic representation of price-dependent interactions between all markets in a given economy. When dealing with energy policies for example, it is important to simulate not only the direct adjustments on energy markets but also the indirect impacts on other markets. If spillover effects were minimal, one could rely on partial equilibrium analysis. But due to the important interactions between energy sectors and the remaining markets, energy policies tend to be best analised within a general equilibrium framework. This is even more relevant when tax interaction and tax recycling effects come into play. CGE models are in fact able to combine certain characteristics of disaggregated partial equilibrium models, such as the labour market, with those of highly aggregated macroeconomic models. Trough the description of an existing tax system, by taking into account the existing distortionary taxes, CGE models also allow to study the impacts of economic policies under a second-best scenario.

CGE models present however some drawbacks. First, by favouring the theoretical dimension to the statistical (econometric) one, CGE models may appear rather abstract, whereas macroeconometric models reproduce in details the medium-run economic dynamics. Second, this method relies on the choice of some parameter values, susceptible to be chosen in an a priori and arbitrary way and thus generate some bias in the model behaviour. While parameters of macroeconometric models are estimated using time series data, CGE models oblige to calibrate some parameters of the model to data reflective of real economies in a given base year equilibrium. The value of the other parameters must be defined explicitly and are usually based on previous econometric studies. Third, CGE models take into consideration current and capital accounts, but not financial accounts. This is also due to the use of social accounting matrices as the benchmark data set. Hence, they do not take into account the complete balance sheets of the agents and disregard for example the role of debt and credit in business cycles [Bezemer, 2009].

3.1.2 CGE models for emissions taxation

Partial equilibrium models, which simulate economic impacts in a unique market, are largely based on bottom-up specifications. They allow to concentrate on instantaneous adjustment in a specific market, such as a carbon tax or tradable carbon permits in the energy market. Some partial equilibrium models that focus on estimating the adjustments costs of reducing carbon emissions (such as implementing Kyoto policies) in energy markets are the PRIMES energy system model [Capros et al., 1999] for the EU and the MARKAL model [Hamilton et al., 1992 and Seebregts, 2001].

CGE and macroeconometric models, by contrast, are constructed on a top-down structure. However, to induce technological change, some models incorporate elements of a bottom-up approach within their top-down structure, such as technology change parameters or an energy technology backstop whose cost falls with time. Examples of such models are the GREEN model [Burniaux et al., 1992] and the MEGABARE model [Abare, 1996], which incorporates a "technology bundle" approach to modelling fuel substitution possibilities in producing electricity or iron and steel. Some models also introduce a link between the top-down macroeconomic model and a bottom-up energy market. This is the case for example in the GTAP-E model [Burniaux et al., 2002] or the CETM model [Rutherford et al., 1997], which presents a link between a partial equilibrium bottom-up process of the energy sector (ETA) and a general equilibrium model (MACRO). In that case, the relationship is enforced by passing the energy price and quantity variables between the two sub-models and iterate until the inputs quantities obtained from ETA match the solutions of the MACRO model. The MERGE-ETL (endogenous technological learning) model attempts also to incorporate an endogenous representation of technological change in the energy sector of the MERGE model [Manne et al., 1995].

Overall, general equilibrium models are more appropriate to capture the interactive effects between the different economic sectors, and the trade effects by taking into account an economy's relationship with other economies. Hence, CGE models have been used extensively in the analysis of various policy issues, such as tax policy evaluation, economic development and the income distribution, trade policy, economic integration and other regional trading arrangements[1]. A number of other global general equilibrium models have been developed to analyse energy, environmental and climate change policies. Among others, these include the G-Cubed model [McKibbin and Wilcoxen, 1992], a multicountry, multisector intertemporal general equilibrium model of the world economy; the ABARE Global Trade and Environment Model (Abare-GTEM) [Pant, 2002]; or the MIT-Emissions Projection and Policy Analysis (EPPA) model [Paltsev et al., 2005], a recursive-dynamic multi-regional general equilibrium model of the world economy designed to develop projections of economic growth and anthropogenic GHG and aerosols. While the partial equilibrium simulate costs in energy markets specifically, the general equilibrium models capture macroeconomic costs over the entire economy. This explains why estimates of the costs of implementing the Kyoto agreement, for example, tend to be much smaller in partial equilibrium models (such as PRIMES and MARKAL) than in general equilibrium models simulations.

3.2 Environmental CGE models applied to Spain

For Spain, five environmental AGE models have focused on the DD hypothesis. At the nationwide level, Manresa and Sancho [2005], Labandeira et.al. [2003], Gomez-Plana et.al. [2005] and González-Eguino [2011] have all use CGE models to simulate the effect of hypothetical tax reforms on CO_2 emissions. At the regional level, the only study is the one of André *et al.* [2005] for Andalusia. The purpose of this section is to briefly describe the principal objectives and structure of each of these models. The key characteristics of the models are summarized in *tables* (3.1) to (3.3).

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[1] See Shoven and Whalley [1992] and Pereira and Shoven [1992] for surveys on the use of AGE models in different policy fields.

Table 3.1: Key characteristics of relevant environmental CGE models for Spain

	Manresa and Sancho [2005]	**Gómez et al. [2005]**
Main simulation	Double dividend hypothesis	Double dividend hypothesis
Tax measures	(a) 10% ad-valorem tax on all energy goods (b) 15% tax on petrol and gasoline products (c) = (a) + (b)	25% reduction in the number of emission permits
Budget restriction		Revenue neutral tax reform
Recycling effect	(A) No recycling effect (B) Reduction in empoyer's S.S. contributions	(A) Lumpsum transfers to HH (B) Reduction in indirect taxes (VAT) (C) Reduction in payroll taxes for both skill levels (D) Reduction in payroll taxes for unskilled labour (E) Reduction in payroll taxes for skilled labour
Base year SAM	1990	1990
SAM used	Manresa and Sancho	Uriel et al. [1997] and Gomez-Plana [2001]
Time framework	Static	Static
Market features	Perfect competition Small open economy (price takers agents)	Imperfect competition Small open economy (price takers agents)
Production sectors	22 (10 energy production sectors)	16
Production technology	Constant returns to scale (CRS)	Increasing returns to scale and CRS
Production functions	Nested C-D/Leontieff prod. functions	Nested Leontieff/CES/C-D prod. funct'
Households	1 representative household	1 representative household
Demand functions	Nested C-D utility function	Nested C-D/CES/Leontief utility function
Labour market features	(1) Rigid model: no factor substitution and exogenous unemployment rate (2) Flexible model: factor substitution and endogenous unemployment rate	Equilibrium unemployment allowed Skilled / unskilled labour
Government Equilibrium	Exogenous spending and tax rates Endogenous savings (deficit)	Exogenous spending and tax rates Endogenous savings (deficit)
Foreign sectors	2 (European Union and Rest of the World) Exogenous activity level No exchange rates	1 Fixed trade balance - Endogenous deficit Flexible exchange rate
Macro closure rule	Savings endogenous/ Investment exogenous	Savings exogenous/Investment endogenous (Neoclasical type)
Pollutants considered	CO_2	CO_2
Environmental module	Fixed coefficients: energy used / emissions	Market for CO_2 emissions permits Fixed coefficients: fuel cons. / emissions
Policy conclusions	(a) + (1) U fixed, W decreases* (a) + (2) U decreases, W increases (b) + (1) U fixed, W decreases (b) + (2) U decreases, W decreases (c) + (1) U fixed, W decreases (c) + (2) U decreases, W decreases	(A) U decreases for skilled/unskilled, W decreases* (B) U decreases for skilled/unskilled, W increases (C) U increases for skilled/unskilled, W increases (D) U decreases unskilled & increases skilled, W increases (E) U increases unskilled & decreases skilled, W increases

* U: unemployment rate / W: social welfare

3.2.1 Manresa and Sancho [2005]

Manresa and Sancho [2005] were the first to use a CGE model to evaluate the possibility of a DD in Spain. The model includes a single representative consumer; 22 industries

Table 3.2: Key characteristics of relevant environmental CGE models for Spain (continued)

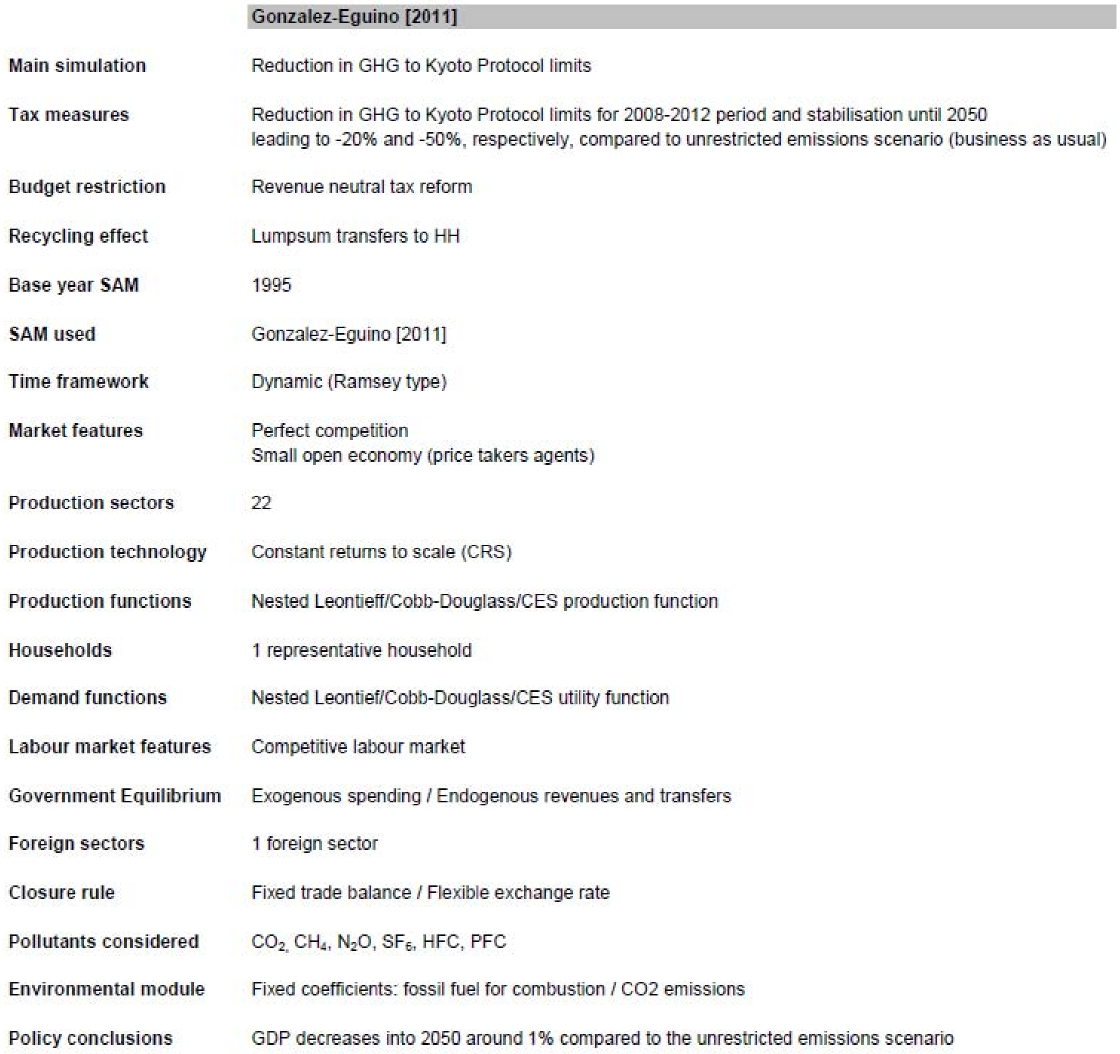
	Rodriguez et al. [2003]	**André et al. [2005]**
Main simulation	Double dividend hypothesis	Double dividend hypothesis
Tax measure	Ad-quantum tax on fossil fuel consumption: 45$ per ton of carbon emission	Ad-quantum tax on fossil fuel consumption: Range from 0.5 to 3 euros per tons of SO_2 and thousand tons of CO_2
Budget restriction	Revenue neutral tax reform	Revenue neutral tax reform
Recycling effect	(A) Lumpsum transfers to HH (B) Reduction in employer's S.S. contributions	(A) Reduction in employer's S.S. contributions (B) Reduction in Income tax
Base year SAM	1995	1990
SAM used	Rodriguez [2003]	Cardenete [1998]
Time framework	Static	Static
Market features	Perfect competition Small open economy (price takers agents)	Perfect competition Small open economy (price takers agents)
Production sectors	17	24
Production technology	Constant returns to scale	Constant returns to scale
Production functions	Nested Leontieff/CES/C-D prod. functions	Nested C-D/Leontieff prod. Functions
Households	1 representative household	1 representative household
Demand functions	Nested CES/Leontief/C-D utility function	Nested C-D utility function
Labour market features	Competitive labour market No unvoluntary unemployment	Feedback real wage - unemployment rate Labour rigidities
Government Equilibrium	Exogenous spending and tax rates Endogenous savings (deficit)	Exogenous spending and tax rates Endogenous savings (deficit)
Foreign sectors	2 (European Union and Rest of the World) Exogenous activity level - Endogenous deficit No exchange rates	1 (including Rest of Spain) Exogenous activity level - Endogenous deficit No exchange rates
Closure rule	Savings endogenous/ Investment exogenous	Savings endogenous (Johansen type)
Pollutants considered	CO_2	CO_2 and SO_2
Environmental module	Fixed coefficients: fossil fuel for combustion / CO_2 emissions	Fixed coefficients: fossil fuel consumption / CO_2 (SO_2) emissions
Policy conclusions	(A) W decreases, GDP decreases* (B) W increases, GDP decreases	CO_2 tax + (A): U decreases, W increases, GDP increases* SO_2 tax + (A): U decreases, W decreases, GDP decreases CO_2 tax + (B): U increases, W decreases, GDP decreases SO_2 tax + (B): U increases, W decreases, GDP decreases

* U: unemployment rate / W: social welfare

of which 10 correspond to energy production activities; a governmental account; a capital account and two accounts related to the foreign sector, one for the European Community and the other for the rest of the world. Taxes are distinguished between the direct income tax and a set of indirect taxes (value-added tax, production tax, labour tax, and tariffs).

The representative consumer gets income from selling endowments of labour and

Table 3.3: Key characteristics of relevant environmental CGE models for Spain (continued)



	Gonzalez-Eguino [2011]
Main simulation	Reduction in GHG to Kyoto Protocol limits
Tax measures	Reduction in GHG to Kyoto Protocol limits for 2008-2012 period and stabilisation until 2050 leading to -20% and -50%, respectively, compared to unrestricted emissions scenario (business as usual)
Budget restriction	Revenue neutral tax reform
Recycling effect	Lumpsum transfers to HH
Base year SAM	1995
SAM used	Gonzalez-Eguino [2011]
Time framework	Dynamic (Ramsey type)
Market features	Perfect competition Small open economy (price takers agents)
Production sectors	22
Production technology	Constant returns to scale (CRS)
Production functions	Nested Leontieff/Cobb-Douglass/CES production function
Households	1 representative household
Demand functions	Nested Leontief/Cobb-Douglass/CES utility function
Labour market features	Competitive labour market
Government Equilibrium	Exogenous spending / Endogenous revenues and transfers
Foreign sectors	1 foreign sector
Closure rule	Fixed trade balance / Flexible exchange rate
Pollutants considered	CO_2, CH_4, N_2O, SF_6, HFC, PFC
Environmental module	Fixed coefficients: fossil fuel for combustion / CO2 emissions
Policy conclusions	GDP decreases into 2050 around 1% compared to the unrestricted emissions scenario

capital plus net transfers from the government. The consumption decision process does not consider any particular nesting structure for the energy goods. The 22 goods consumed are matched to the 22 produced goods and are related trough a unique Cobb-Douglas function.

On the production side, the nesting structure is based mainly on Leontief type functions, except when some substitution is allowed between primary factor endowments. Domestic output is the combination of primary factors with intermediate goods. Energy factors are treated directly as intermediary goods and no specific substitution is considered among energy and non-energy inputs. Total supply is a fixed combination of domestic and imported outputs. This total supply is in turn demanded by the foreign sectors as exports.

The government produces a public consumption good, supports public investments and provides the private sectors with income transfers. All these government expenditures are financed through taxes and, if necessary, with a complementary bond-financed deficit. Taxes are of two general types: a direct income tax and a suite of indirect taxes (production tax, value-added tax, labour tax, and tariffs). The 'ecotax' on energy goods is an *ad-valorem* tax on energy sales value instead of an ad-quantum tax on CO_2 emission content. The public sector closure rule considers a fixed government spending and an endogenous public deficit.

All labour is endowed to the representative consumer and a distinction is made between used and non-used labour. The study considers two versions of the model to compare the impact that flexibility adjustments play in the existence of a DD. First, a rigid version, where labour supply is kept fixed and there is no factor substitution to changes in relatives prices (Leontief technology between labour and capital). In this version the used labour supply is totally inelastic and the non-used labour endowment is interpreted as a fixed level of unemployment. Second, the flexible version, with factor substitution (Cobb-Douglas technology) and involuntary unemployment in equilibrium. In this version, unemployment is determined endogenously as an excess labour supply while the consumer offers all his labour elastically at the going real wage. Therefore, if labour endowment at the going wage is higher than total labour demand by the productive industries, there is involuntary unemployment. More specifically, involuntary unemployment is derived from a wage curve specification, similar to that of Kehoe *et al.* [1989] and Polo and Sancho [1990]. Introducing a wage curve into the model implies substituting the flexible wage by a wage equation, with the wage rate linked to the rate of unemployment through an elasticity that measures labour market rigidities.

Carbon emissions are considered as a by-product of economic activities. Based on Eurostat estimates, fixed emission coefficients measure emissions volume (in metric tons) per energy unit used in production or final demand. These energy unit indices are obtained from a 1985 energy input-output table and energy price indices from Spain's National Statistics Institute. The calibration of the model is based on a national accounting matrix developed by the authors for Spain, which is an extension of the 1990 input-output table.

For each version of the model, the effects of an *ad-valorem* tax on all energy goods are simulated for two alternative scenarios: on one hand, the introduction of a new set of energy use taxes, on the top of the existing tax system, without tax revenue recycling; and, on the other hand, the adoption of new tax rates on energy products, but compensated by a budget neutral reduction in employers' Social Security contributions. Considering the two versions of the model, four alternative scenarios are therefore considered.

The results obtained indicate first that an employment DD can take place when the environmental tax is accompanied by a budget neutral reduction in payroll taxes. The second conclusion, confirmed by the sensitivity analysis, is that neutral tax policies are more efficient (in terms of utility or unemployment) the more "flexible" is the labour market (lower elasticity of real wage with respect to unemployment). Together less labour market rigidities and the reduction in employers' Social Security contributions yield a strong incentive to reduce unemployment.

3.2.2 André, Cardenete and Velázquez [2005]

André *et al.* [2005] use a CGE model to evaluate the environmental and economic impacts of a green tax reform in Andalusia. This model is very similar, but in a way extends, the one proposed by Cardenete and Sancho [2002], by including other polluting emissions and simulation scenarios. The model includes 24 productive sectors and a unique representative consumer. The model includes also a saving/investment account, a government account, a foreign sector and a set of direct and indirect taxes. The macro closure rule is savings driven.

Involuntary unemployment is also allowed into the model, by using exactly the same wage curve specification as Manresa and Sancho [2005]. Both CO_2 or SO_2 emissions are computed by using fixed coefficients that show the emission volume (in metric tons) per unit of energy good being used trough intermediate demand and final demand. A linear relationship between production and emissions is assumed so that the tax per ton of emissions that the government imposes is levied on the output produced by each energy-intensive sector. While this direct technological link is standard to compute CO_2 emissions, this is usually not the case for SO_2 emissions which intensities vary in function of the production process, requiring usually a bottom-up approach. In any case, with such an approach, the effect of the environmental tax happens through the energy use decision, by providing incentives to increase the production of cleaner sectors and reduce that of energy-intensive sectors.

The emissions data come from the 1990 environmental input-output tables for Andalusia, while the regional accounting matrix is an extension of the 1990 input-output tables of Andalusia. There are four simulation scenarios considered separately, all public deficit neutral. The introduction of a tax either on CO_2 or SO_2 emissions is combined with revenue recycling trough a reduction in income tax or in the employer's Social Security contributions. The tax simulation are performed on an *ad-quantum* basis for a range between 0.5 and 3 euros per unit of pollutant (tons of SO_2 and thousand tons for CO_2).

The results suggest that an employment DD is likely to arise when both the CO_2 or the SO_2 tax are compensated by reducing the payroll tax. A strong DD is also obtained only for low values of the CO_2 tax, when the reduction of the payroll tax overpowers the distorting effects of the CO_2 tax. On the contrary, no DD exists when the environmental tax revenue is recycled by reducing the income tax, the main direct tax in the Spanish tax system. The income tax recycling is more efficient at reducing emissions, but generates higher macroeconomic costs: all economic variables monotonically worsen. At the emissions level, the results show that SO_2 emissions seem to be relatively more sensitive to an environmental tax on CO_2 and SO_2 emissions. On average, emissions reduce in between 0.1 and 0.8 % of their benchmark level.

3.2.3 Labandeira, Labeaga and Rodríguez [2003]

Another study of the DD hypothesis in Spain is the one of Labandeira *et al.* [2003], based on Rodríguez [2003]. The static model includes five institutional sectors: a representative household, public sector, foreign sector, companies and non-profit institutions serving households. The 17 productive sectors present a constant return to scale nested technology and some substitution between energy sources is modelled trough CES functions. The macro closure rule is savings driven.

The labour market is considered perfectly competitive and therefore does not allow involuntary unemployment. The changes in the labour supply refer to changes in the size of the working population. If the labour supply diminishes, it is because leisure consumption increases, which reduces the working population and prevent any involuntary unemployment in the model. The national accounting matrix for the year 1995 is based on the one of Fernández and Manrique [2004] and combined with a submatrix of CO_2 emissions for each sector and institution consuming energy products.

The environmental submodel simulates the CO_2 emissions generated from the different agents in Spain for the year 1995. The emission technology is specified by fixed coefficients that give for each sector the CO_2 emission volume per unit of fossil fuel (carbon, refined petroleum, gas) being used in production and consumption. As in the other studies, by assuming a linear relationship between fossil fuels consumption and CO_2 emissions levels, the tax is not levied on actual but presumed emissions by the different economic agents.

The fiscal reform considers two different scenarios. The tax on CO_2 emissions is combined either with a simultaneous reduction in payroll taxes by employers or a lump-sum transfers to households. The environmental tax proposed in Rodríguez [2003] is an *ad-quantum* tax of 45$ per ton of carbon emission, while the one in Labandeira et al. [2003] has a rate of 12.3 euros per tonne of CO_2 emitted, that can be interpreted as the marginal damage cost of carbon emissions.

The results show that when the tax revenues are recycled trough a reduction in employer's Social Security contributions, a positive strong double dividend (environmental and fiscal) may be attained, but with a very little increase in non-environmental benefits (employment and social welfare). However, the recycling alternative, a lump-sum transfer to households, indicates that only environmental improvement is possible, given the reduction of social welfare after the tax levy on fossil fuel consumption.

Given that there is just one representative consumer in their model, they combine the use of a static general equilibrium model with a microeconomic household energy demand model, in the line of Bach et al. [2002] and Bourguignon et al. [2003]. The CGE informs on the efficiency effects of the fiscal reform, in terms of social welfare, prices and the activity levels of the different sectors and institutions. The household energy demand model allows then to disaggregate the effects of the policies simulated on households heterogeneity and thus analyse more precisely its distributional aspects.

Based on the Continuous Family Expenditure Survey for the period 1985-1995, the energy demand model uses the quadratic extension [Banks et al., 1997] to the almost ideal demand model by Deaton and Muellbauer [1980]. It estimates, in a simultaneous equation framework, the participation of each energy good in total expenditure made by every household as a function of prices, total expenditure, total expenditure squared and demographic conditioning [Labandeira et al., 2003].

To link the two models and analyse the distributional effects of changes in energy prices, the relative prices calculated by the CGE model are adjusted to the absolute prices used by the microeconomic model. The CGE model computes first the changes in relatives prices for each energy good with respect to the consumer price index; and integrates the new relative prices into the microeconomic model by multiplying the initial relative prices by the exchange ratio of relative prices obtained in the CGE model[2]. The results indicate slightly progressive effects although almost insignificant.

In another study, Labandeira et al. [2006] investigate the efficiency, competitiveness and welfare costs for Spain of fulfilling the Spanish National Plan for greenhouse gases launched in 2005, in order to join the European carbon market to be effective in 2008. To this end, they use a very similar CGE model to the previous one but including a competitive market for CO_2 pollution permits. The market of CO_2 pollution permits in Spain is considered isolated from the European permits market. They

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[2] Labandeira and Labeaga [1999] link also an input-output model and a microeconometric demand model to assess the effects of carbon taxes.

simulate a reduction of CO_2 emissions by a 16% under different market sizes and allocation frameworks for the Spanish pollution permits. The number of permits issued by the government becomes therefore endogenous, subject to this constraint of a 16% reduction of Spanish emissions.

Three scenarios are considered for the allocation mechanism of permits and the size of the market for permits. First, the real market, including grandfathering allocation of permits only between the few sectors included in the Spanish National Plan against greenhouse gases. Second, the wide market, including grandfathering allocation of permits among all producers in the Spanish economy, households remaining excluded from the market. And, third, the auctioned market, that simulates auctioned permits by the government among all producers in the Spanish economy, with tax revenues given back to the households through lump sum transfers.

The results obtained give several conclusions. First, the costs of reducing CO_2 emissions by a 16% have a small negative on national production and almost no costs in terms of employment and social welfare. Second, the efficiency costs and the welfare losses in the real market scenario are higher than in the wide market scenario, indicating that there are some efficiency costs from the narrow nature of the Spanish National Plan against greenhouse gases. Therefore, to improve efficiency, other sectors with lower abatement costs could be included to take part in the European carbon market. Third, welfare losses are much higher with auctioned permits than with grandfathering allocation of permits, affecting the competitiveness of the industrial sectors.

However, this study does not consider the scenario of a green tax reform for the auctioned permits alternative. The revenues of the auctioned permits are returned through lump sum transfers to the households instead of being recycled to reduce the distortions generated by the tax system. Taking this option into account could change the conclusions and show that auctioned permits combined with an appropriate revenue recycling scheme perform better that grandfathering allocation of permits, trough positive impacts on employment and social welfare. That is, provides a positive strong double dividend.

3.2.4 Gómez, Kverndokk and Faehn [2005]

Gómez *et al.* [2005] propose probably the most specific study to asses the DD hypothesis in Spain. They present a CGE model with some particular extensions with respect to the other studies in order to incorporate important features of the Spanish economy: imperfect competition, increasing returns to scale and equilibrium unemployment. First, the model incorporates increasing returns to scale and introduces imperfect competition into the model. For that, they assume the existence of some fixed costs on both labour and capital that imply a markup on marginal costs, which in turn gives positive profits to the firms that are supposed to compete a la Cournot.

Second, the model allows for equilibrium unemployment, but not in the same way as in Manresa and Sancho [2005] and André *et al.* [2005]. The labour market is modelled on the basis of a formal theory of equilibrium unemployment originally developed by Pissarides [1990], where unemployment appears as a result of the matching process in the labour market. A matching rule gives the number of jobs as a function of the number of workers searching for a job and the number of firms looking for workers. Workers (i.e., the unemployed) and firms (i.e., the vacancies) are assumed to spend some resources before matching and production takes place. Therefore, real wages net of taxes include a premium on reservation wages that represents search costs. The authors use the ad-hoc specification proposed in Balistreri [2002]. By distinguishing between skilled and unskilled workers they also try to account for the differences between the unskilled and skilled labour markets in Spain.

The model distinguishes 16 production sectors, which may present a technology with increasing returns to scales, and a comprehensive description of the Spanish tax structure is given. Also, the degree of competition is allowed to vary among industries, according to the degree of firm concentration. The impact of imperfect competition and increasing returns to scale on the carbon policies results are then quantified. The model considers a single private household and also computes CO_2 emissions both from firms and the household. The base SAM used for calibration is the MCS for 1990 developed by Uriel *et al.* [1997], with some extensions from Gómez [2001].

The environmental module consists of a market for CO_2 emissions permits. The CO_2 emissions from firms originate from the use of fossil energy as input factors. Emission levels are calculated by transforming fuels consumption in a common unity (EJ), which are then multiplied by emissions coefficients (mt. of CO_2). An emission permits market is created, where benchmark price for permits is zero. The policy changes are addressed by simulating reductions in the number of emission permits from the benchmark level. Then, when permits become scarce, firms begin to bid for them and the price increases. This mechanism, similar to an open auction of permits with a uniform price, may be interpreted as equivalent to a tax on CO_2 emissions. The results presented by the authors concern a simulation of 25% reduction in the number of emission permits.

All policy variants are simulated under a revenue neutral restriction for the government. The impacts on welfare and employment of various ways of tax revenue recycling into the Spanish economy are considered: reducing the payroll tax on all labour, exclusively reducing it on, respectively, unskilled and skilled labour, as well as reducing indirect taxes such as the VAT rates. The authors find indications that a carbon permit market in Spain, combined with revenue recycling through payroll tax reductions, reduces unemployment. In terms of economic efficiency, the reduction of payroll taxes for skilled workers is considered as a first-best option, because they tend to work in the most labour-intensive industries, which also have low carbon emissions. Revenue recycling also reduces abatement costs in terms of welfare significantly, though none of the recycling schemes simulated succeed to offset the welfare loss completely. All the recycling alternatives produce nearly the same, weak but positive, welfare effects, which implies no trade-off between welfare and unemployment concerns in the choice among these alternatives. However, no welfare gain obtained in terms of a better environment are calculated. The results also indicate that the modelling of imperfect competition and increasing returns to scale generate different outcomes than the ones from a constant returns to scale model with perfect competition.

3.2.5 González-Eguino [2011]

The study of González-Eguino [2011] also focuses on the impacts of reducing GHG emissions in Spain, even tough it doesn't take into consideration the double dividend hypothesis, trough a specific recycling of GHG tax revenues. Using a dynamic Ramsey-type CGE model, it tries to simulate the potential costs of establishing a market for emissions permits, in order to comply with the long-run emissions control objectives, as advocated by the Kyoto Protocol (scenario Kyoto 2050).

The model is based on a SAM for Spain for the year 1995. It disaggregates 22 productive sectors producing each an homogenous good with a technology represented trough subsequent CES functions. Fossil fuels compose a first Cobb-Douglas aggregate function, which is then related to electricity in a higher CES function. This aggregate energy nest is itself a substitute to the labour/capital Cobb Douglas aggregate. The GHG emissions are considered as a specific production factor, associated with a emission permit displaying its own price. It includes also a representative household, whose preferences are defined trough a series of CES functions, a government sector and a unique aggregate for the foreign sector. Consumers generate GHG emissions and are also subject to emission permits. The government closure rule implies a constant public deficit/surplus situation, such that, with constant public spending, the additional tax revenues are transferred lump-sum to the private household.. The foreign sector representation is rectricted to the trade balances with the domestic economy, under the hypothesis of Spain being a small open economy. The model closure rule implies a constant trade deficit with a variable exchange rate.

The model does not only consider carbon emissions but integrates the different GHG targeted by the Kyoto Protocol, with a disctinction being made between the GHG emissions resulting from fossil fuel combustion and emissions resulting from industrial processes. Economic growth is engineered trough an accumulation process of the production factors, labour (exogenous variation) and capital (endogenous variation).

Results indicate that reducing GHG emissions generates some economic costs, compared to the unrestricted emissions scenario. Compared to the unrestricted emissions scenario, stabilizing GHG emissions to the Kyoto Protocol limits would generate some GDP reduction around 1% into 2050, due to lower private consumption and lower investment. However, the economic costs may be tempered trough a gradual shift towards an economy less carbon intensive, with improvements in energy efficiency, changes in the energy mix and production-consumption patterns. Without measured indications of its potential effects, the author advocates that another key variable that could impact on the reduction of economic costs is the technology innovation.

3.3 Model features and strategic assumptions

The size of the model has been kept as small as possible, below a level where the cost of proposing additional equations to the model outweighs the gain of more detailed and refined insights. The risk of larger models is that the complexity of the model starts to jeopardize the original internal logic, such that the results become less transparent and harder to understand. In spite of its limited size, compared to some macroeconometric models, we believe the proposed model is large enough to allow a broad set of simulations and contribute to increase insight in the outcomes of a projection exercise.

The structure of the model is based on several widely used neo-classical assumptions in the theoretical literature on CGE modelling. This is the case for the perfect rationality and optimizing behaviours for agents. Some more technical assumptions are also considered, not imposed by the neoclassical paradigm, and that need to be mentioned as they restrict de facto the likelihood outcomes of the model.

The economic structure covers different 'activities': production, consumption, investment and governmental activity. Another way to break down the economy is to use the concept of 'agents'. The model distinguishes five different institutional units with a set of current and capital accounts and myopic expectations: the representative private household, the non-profit institutions serving households, the corporate enterprises (regrouping non-financial and financial corporate enterprises), the public administrations and the rest of the world (given that the model is open to international trade). In this model, the duality between cost and production functions on the production side, and between expenditure and utility function on the consumption side is exploited.

3.3.1 Agents

The model breaks down the production process into 28 economic sectors, which are groups of homogeneous units of production. Each of the 28 economic sectors considered is modelled through a representative firm. Each firm is limited to produce a single homogeneous good, which is differentiated from any other good in the economy. Firms get their income from products sales to other agents and transfers from other institutions. This income is then used to pay for intermediate commodities and primary factor services, make transfers to other agents and pay taxes. Firms are price-takers and employ a combination of energy and non-energy intermediate goods, and two primary factors, labour and capital, considered perfectly mobile across industries. Each production sector is modeled by a hierarchical production function that represents the different substitution and complementarity relations across the various inputs in each sector. Producer goods are directly demanded by other industries, the representative household, the government, the investment sector, and the foreign sector.

Private households are assumed to share homothetic and identical preferences and are therefore represented by a single, representative household. This simplification may seem appropriate when interest is focused primarily on industries and not on income distribution. The consumer is endowed with labour and an initial stock of capital, both provided to the production process. The number and types of commodities are the same for the producers and for the consumer. For practicability reasons, consumer demand is not based on consumer commodities but directly on the 28 produced commodities. Therefore, there is no need to map household demand in terms of consumer commodities into demand for produced commodities. A detailed budget constraint is formulated, which integrate the concepts of income tax and transfer systems. Disposable income is used for maximizing utility by purchasing goods, after taxes and savings are deducted. The household is assumed to take prices as given and have a set of preferences, resulting in demand functions for each commodity.

The third agent, the government, distributes transfers and provides a public good (including public investment) which is produced with commodities purchased at market prices. These purchases are financed by tax revenues and transfers. The current transactions of the general government can be divided into resources and expenditures. The model incorporates the main features of the Spanish tax system: income taxes including social security contributions, corporate taxes, value-added taxes, sales taxes, import tariffs and taxes carbon emissions and the energy content of fuels. In the model, the government is only characterised by its budget constraint. Given the hypothesis of fiscal neutrality, the ratio public deficit to GDP is considered constant.

The fourth agent represents the non-profit institutions serving households (NPISH), institutions with a particular juridical status, such as benevolence societies, unions, political parties, consumer associations, churches, etc. Like the public sector, they offer non-market goods and services to the households. Their behaviour is summarised by their budget constraint and no optimisation problem is considered for this representative agent while their savings are accounted for the investment-savings closure rule.

The foreign sector is divided into two blocks: a first group of countries including the former 15 European countries belonging to the European Community in 2000 (EU-15) and a second block of countries including the rest of the world, and labelled as the "rest of the world" entity. Trade with the foreign sector is incorporated via imperfect substitutability between imported and domestic varieties and imperfect transformability between exports and domestic sales. The modelling of the foreign sector activities is restricted to the specification of the balance of payments, because we do not represent explicitly the optimisation problem of the non-residents, given that there is no way to determine their budget constraint. The foreign sector closure rule assumes a fixed foreign savings and a variable exchange rate.

The savings-investment account completes the model, by representing the reconciliation of all sectoral financial balances. The macroeconomic closure is savings-driven and supposes that the investment expenditures adjust to the sum of domestic saving and net capital inflows.

3.3.2 Static Walrasian equilibrium with unemployment

The model is a static equilibrium one, so simulations results should be interpreted as showing the medium-run/long-run impact of a policy change after the economy has completed the adjustment to the new equilibrium[3]. Basically, a general equilibrium model is presented as a combination of prices and quantities such that, given these prices and quantities, the following conditions are satisfied: the representative household maximises his utility subject to his disposal income; the producers minimise their costs subject to technology constraints; the unit profits are zero in all production

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[3] The term 'static' means that there is only one time period in the model and hence no dynamics. Therefore, the results describe only the final adjustment to the new policy and not the transition path of the economy from the initial equilibrium to the final one.

sectors; the commodity and factor markets clear; investors maximise profits subject to arbitrage conditions in capital markets; the government account constraint in the presence of taxes is fulfilled and the balance of payments condition is satisfied.

In equilibrium, prices are flexibly adjusted until all the commodity markets and the factors markets clear. The labour market representation allows however for unemployment to persist even in the long run. The specification of the labour market is based on a wage curve framework, which reflects empirical evidence for Spain on the inverse relationship between the level of real wages and the rate of unemployment. If this approach can somehow be considered 'ad-hoc', by not presenting explicitly how the wage is determined, it allows to consider the existence of unemployment in the long run[4].

Given the assumption of constant returns to scale, the equilibrium exists and can be computed: the calibration procedure described in chapter 6 calibrates parameter values for production and demand functions on the basis of a Social Accounting Matrix built for Spain in the year 2000. Then, given the equilibrium conditions and the calibrated parameters, it is possible to find an equilibrium in which all prices are 1.0 and all quantities replicate the benchmark data set exactly. Once the benchmark equilibrium is replicated, a so-called "counterfactual" scenario is imposed on the model, such as an ad-valorem tax on CO_2 emissions. By comparing the results of the benchmark equilibrium with the ones of the counterfactual equilibrium it is possible to evaluate the impacts of an alternative policy measure.

3.3.3 Returns to scale

In the base case scenario, the representative firm of each sector faces perfectly competitive market conditions in both input and output markets. All sectors are assumed to operate at constant returns to scale and share a common production structure, based on a neo-classical type of production function. Also, to keep the computation simple, the model assumes no externalities and no adjustment costs. The assumptions of constant returns to scale and perfect competition may of course appear very restrictive. However, they are common in CGE modelling because they simplify considerably the computational procedure by determining output prices directly from factor prices, thus reducing the number of variables involved in the search of equilibrium.

Given that all sectors are assumed to operate under constant returns to scale (i.e., production function homogeneous of degree one) and producers face perfect competition (zero-profit) conditions in all markets, the determination of output prices can be

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[4] See also the approach to consider alternatives wage settings by Alho [2006].

determined independently of the level of activity. Zero-profit conditions imply that they should depend only on the marginal costs of production. The fact that profit-maximizing producers are willing to increase supply only as long as the market price of the product exceeds the marginal production cost implies that the level of output in equilibrium is determined by the demand at a price equal to marginal cost. The constant returns to scale assumption indicates also that this marginal cost pricing rule is formally identical to an average cost pricing rule, which is mathematically simpler to calculate.

Homogeneity of degree zero in prices is assumed for all supply and demand functions in the model. This proposition reflects the well-known fact that if all prices increase in the same proportion, but relative prices are unaltered, the relationships in the economy remain unchanged. As a consequence, only relatives prices are relevant for the specification of the quantities of goods supplied and demanded. This requires the determination of a numéraire price in the model, by arbitrarily setting one price equal to one, and then solving the system for all other prices. All price and income changes should therefore be interpreted as changes vis-à-vis the numéraire price index.

3.3.4 Functional forms and substitution possibilities

For Shoven and Whalley [1984], the functional forms selected for the demand and production functions in applied models must respect two kinds of constraints. First, the functional forms must satisfy the basic model assumptions and be consistent with the restrictions of the general equilibrium theoretical framework, such as continuous and homogeneous (of degree zero) demand functions or the satisfaction of Walras' law for demand functions. Second, the functional forms must be analytically tractable so that the evaluation of the demand and supply responses stays reasonably easy to evaluate for any price vector candidate as an equilibrium solution for the economy. This analytical handiness is also crucial for the calibration procedure and the determination of elasticities. Typically all the production functions are specified in terms of linear homogeneous functions, thereby ensuring that the optimal input ratios can be defined in terms of the relative input prices.

These constraints explain why most of the applied general equilibrium models use the widely extended and most tractable functional forms such as Leontief's fixed coefficients, Cobb-Douglas, Constant Elasticity of Substitution (CES), Linear Expenditure System (LES) or Translog functions. The choice of a specific functional form will then depend on the objectives of the model and the manner to best incorporate key parameter values (e.g., elasticities of substitutions and price elasticities) while keeping a minimum tractability. In this model, as it is common in the literature, the production structure is described trough the use of nested CES and Leontief production functions, exhibiting constant returns to scale. As advocated by Mansur and Whalley [1984] and Perroni and Rutherford [1995a, 1995b], the widespread choice of CES functions reflects a tradeoff between complexity and tractability (the ease with which equations can be coded) and allows corresponding Leontief and Cobb-Douglas functions to be separately considered as special cases[5]. On the other hand the choice of Leontief specification has been retained for pragmatic reasons.

3.3.5 Production and consumption nesting

Production processes and consumer preferences are both characterised by a multi-stage nesting structure that indicates how decisions are made in stages. The choice of the nesting structure must allow to focus on the most sensible substitution elasticities, like the ones between the capital and the energy aggregate; while permitting to use the available elasticities in the econometric literature. Production and consumption nesting are basically the same for the configuration of energy demand.

The decomposition of the energy demand is a key issue and is therefore modelled using three levels of nesting; like in the GREEN model [Burniaux *et al.*, 1992]. The model focuses in particular on energy intermediate inputs because energy use in production and consumption is typically the polluting source. And the specific nesting structure adopted here permits to monitor more closely energy-related emissions, by allowing limited but smooth substitution elasticities between the production factors and the different energy sources. The energy bundle is first disaggregated into an electric fuel component and a non-electric bundle. The non-electric bundle is then split into a coal fuel composite and an aggregate of refined oil and natural gas which is further disaggregated in the lowest nest. Crude oil is included in the intermediate goods.

On the production side, certain substitutability between domestic and imported goods is assumed, with an Armington specification, to allow the producers to choose the optimal mix of energy sources and intermediate inputs from domestic and foreign suppliers. Once the optimal combination of inputs is decided, sectoral output prices are determined, which represent the costs of inputs for other sectors. Due to inter-industrial linkages, each sector determines therefore its output prices and the optimal

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[5] CES functions are globally regular and can be characterised by their zero, first and second order properties. This means that the location (price and quantity), slope (marginal rate of substitution) and curvature (convexity) completely define the CES function. While its properties are well understood and yield convenient analytical expressions, the nested CES specification may appear restrictive for several reasons. See Engen et al. [1997].

combination of inputs simultaneously, so that changes in the price of one product affect the other product prices.

The domestic output obtained may be sold in the domestic or foreign market, on the assumption that producers maximise sales revenue for any given aggregate output level, subject to imperfect transformability between domestic sales and exports. Under the small country assumption, the world prices are considered exogenous. Traditional trade theory suggests in this case that export demand would be considered as totally elastic to changes in the relative prices: countries can export any amount of a given commodity at a given price and nothing at a higher price. This model considers a departure from the traditional trade theory "small country assumption", by allowing a symmetric assumption of product differentiation between domestic and foreign goods.

This assumption allows to consider exports and domestically sold goods as non-perfect substitutes, in order not to overstate both the links between export and domestic prices and the responsiveness of exports and demand shifts on world markets. In that case, exports prices for any commodity may differ from world prices and from domestic prices. These outputs are supposed imperfectly substitutable due, for example, to export subsidies, differences in timing or distance between the locations of activities. The assumptions of imperfect substitutability (between imports and the domestic output sold domestically) and imperfect transformability (between exports and domestic sales of domestic output) serve mainly to give the domestic price system a degree of independence from international prices and reconcile models with the observed two-ways trade flows.

Chapter 4

Database

4.1 Methodological introduction

A Social Accounting Matrix (SAM) can be defined as a double entry square matrix that reflects the circular flow of income of an economy in a given accounting period [United Nations, 1968]. Each row of a SAM shows the incomes paid by all accounts in the system to the row account, while the corresponding column shows the expenditures of that account to all other accounts in the system. The row and column totals for each account must be equal, such that total income equals total expenditure. This equality can be attributed some economic meaning, as it implicitly refers to the institutions budget constraints or the productions sectors zero profit conditions. The fact that row and column totals are the same for each account guarantees in turn the consistency of the entire accounting system.

As a system of balanced accounts, a SAM includes thus data on production and income generation on one hand, and on the revenues and expenditures of various institutional agents on the other. More precisely, it provides an overall presentation of the domestic production resulting from the use of production factors, the (re)distribution of income of these production factors to the institutional agents, the expenditures for consumption and investments of the agents, and the savings of the agents. By taking into account the behaviours of economic agents, a SAM offers a schematic organisation of the economic and social flows in an economy. It helps thus to represent the circular flow of income. The income generated in the production process is allocated to institutional sectors (such as households, corporations, government, foreign sector, etc.). These institutions use then their income to finance current expenditures, accumulate capital or pay taxes.

By its structure, a SAM can be viewed as a natural integration and extension of input-output tables into the national accounts framework. The input-output tables provide indeed only part of the information necessary for broad macroeconomic analysis. The extension to these tables consist thus in providing information on the (re)distributive aspects of the economic process and the type of expenditures of various institutions in the economy. It can then serve as an analytical basis for macroeconomic models, on their quest to approximate the functioning of the economy and analyse the potential effects from the implementation of macroeconomic policies. This aggregation of data input is what is used in CGE models.

This chapter provides the details on some relevant specificities of a new SAM elaborated for Spain, corresponding to the year 2000 (SPAM00). In fact, other SAMs have been created to represent the Spanish economy for the year 2000. However, none of them seems perfectly relevant for our proposed object of study. With respect to an energy fiscal reform, three major caveats can be attributed to the current SAMs for the year 2000. First, the use of basic prices and not acquisition prices; second, a reduced disaggregation of taxes; and third, the absence of disaggregated CO_2 emissions by fuel type sources.

The new SAM for Spain, the SPAM00, corresponds to the year 2000 and is based on the available data provided by the Spanish National Statistical Office (INE) on the Spanish National Accounts (base 2000). The main support from the input-output framework is the total symmetric input-output table, at basic prices 2000 (millions of euros) [INE, 2004], even tough the proposed SAM values flows in acquisition prices, following the European system of national and regional accounts (ESA-95) guidelines. The SPAM00 also incorporates disaggregated taxation accounts, based on national accounts unpublished data, generously provided by the INE. The additional information includes sectoral data for the taxes and subsidies on products. This database contains originally 73 economic sectors, that have been aggregated into 28 sectors for use in our CGE model, with the most extensive disaggregation for energy sectors. Additional data regarding emissions have also been added, as we explain below. The joint information of economic data and emissions data is one of the important features of this SAM for Spain. But before describing the basic components of the SPAM00 and its environmental module, we first present some previous applications for Spain.

4.2 Previous SAMs for Spain

Most SAMs are elaborated to be used for general equilibrium models. As such, their construction tends to depend on the nature of the subject under study. Kehoe et al. [1988, 1989] developed the first SAM for the Spanish economy for the year 1980, which was then updated by Polo and Sancho [1993]. Since then, several others SAMs for Spain have been elaborated at a national and regional scales. A new SAM for

Spain for the year 1990 was proposed by Uriel et al. [1997], which was then extended by Fernández and Polo [2001]. These first SAMs were followed by the ones for the year 1995, elaborated by Rodríguez [2003], Cardenete and Sancho [2005] and Uriel et al. [2005].

For the year 2000, different SAMs have also been constructed. The one of Rodriguez Morilla et al. [2004] proposes to integrate two matrices: one for social accounting data with another one for environmental data for emissions of greenhouses gases. The social accounting matrix for the year 2000 is obtained by updating a previous SAM of the Spanish economy for the year 1998. The update is done trough the use of National Accounts data for the year 2000 and a cross-entropy method, which, they assume, improves the traditional RAS method. It is composed of 30 productive sectors, two primary factors (labour and capital), two types of taxes (net taxes on production and net taxes on products), four institutional sectors (a representative household, the corporate sector, the NPISH and the government), the capital account and a unique foreign sector. The matrix of GHG emissions is based on INE data from the satellite atmospheric emissions accounts for the year 2000, valued in physical units.

Some characteristics of their SAM are different from the one we propose. First, their SAM presents a very aggregated presentation of the auxiliary account (taxes, subsidies, contributions and transfers). It only considers net taxes on production and net taxes on products, which may generate some operational limits when dealing with tax reforms related to environmental policy. Second, their decision to use basic prices may be questioned, as we discuss later. Third, the sectoral distribution of GHG emissions is not disaggregated by fuel type use, as it could be convenient for emissions resulting from combustion processes. Finally, the foreign sector is aggregated into one single entity.

Lucena and Serrano [2006] proposed a second SAM for Spain and the year 2000, more disaggregated than the one of Rodriguez Morilla et al. [2004], altough they don't take into account environmental data. Their SAM includes fourteen productive sectors, two primary factors (labour and capital), eight types of taxes (social contributions of employers and employees, other net taxes on production, import taxes, VAT, other net taxes on products and income tax), two types of transfers (social and other transfers), three domestic institutional sectors (a representative household, the corporate sector and government), the capital account and two foreign sectors (the European Union and the rest of the world).

Two of their declared objectives in constructing the SAM are to reconcile ESA95 conventions with a higher level of disaggregation of net taxation data within the SAM, and with a convenient valuation system for expressing the monetary value of input-output transactions. The disaggregation of net taxation data allows them to consider separately the components of net taxes on products: import taxes, VAT on products, other net taxes on products. They do not separate however taxes from subsidies and present both the other net taxes on production and the other net taxes on products in an aggregate way.

On the other hand, when the final goal of the SAM elaboration is to compute general equilibrium models and a symmetric input-output table is not available, they suggest to value input-output transactions at producers' prices as the most suitable strategy to model taxes appropriately. In other words, they advocate to transform monetary flows valued at basic prices into flows at market (producers') prices, because the use of these market prices allow to recover net taxation data and so distinguish consumption taxation from production taxation. To do so, they include transport and commercial margins as intermediate consumption in the corresponding branches.

The SAM of Rubio and Perdiz [2009] for the year 2000 is used to study in a detailed manner the income distributional impacts of alternative industrial policies. Their SAM includes 18 productive sectors and 24 produced commodities. Primary factors are highly disaggregated between eight categories of labour, four accounts of gross operating surplus and six accounts of gross mixed income. Institutions integrate households (five different income groups divided each time between five different professional status - employees, self-employees, property income, retired and recipients of other current transfers), the corporate sector, the government and the foreign sector. Net taxes and the capital account are also included. Net taxes (such as net taxes on products) however are not disaggregated.

Cardenete and Flores [2009] presents a fourth SAM for the year 2000 to study the multiplier effects of energy use on CO_2 emissions in Spain, trough an input-output modelling. Their SAM includes 27 production sectors, with an extensive disaggregation of the energy sector. Production factors cover labour and capital. Institutions are limited to a representative household, the government, and a foreign sector, with no clear mention of where the NPISH expenditures and revenues have been allocated. As usual, a capital account is also included. With respect to taxes, they consider employers and employees social contributions, VAT, import tariff, other net indirect taxes and income tax. Hence, other net taxes on products and other net indirect taxes are not disaggregated.

For valuation of transactions, the authors justify their use of basic prices as the only way to ensure a correct transformation of monetary units to physical units of emissions.

They advocate that the risk of not using basic prices is to distort the attribution of CO_2 emissions to the economic branches generating them. In their estimations of CO_2 emissions, they consider only total CO_2 emissions by sectors and do not offer a disaggregation of carbon emissions by fuel type use. This is of course a valid choice, but it does not allow to take into account possible substitution possibilities between fossil fuels, due to their contamination differentials.

Finally, Alvarez [2010] constructs a SAM valued at purchasers' prices for the simulation of external shocks on the Spanish economy together with transitory (expenditure programs) and permanent (tax rates increases) policies to counteract the 2008-2009 recession. It consists of 30 domestic an total production sectors, two primary factors (labor and capital), 30 consumption goods, six private and six public capital goods, three domestic institutions (a representative household, the corporate sector, the government), two foreign sectors. Alvarez [2010] presents also the highest disaggregation of taxes, subsidies and transfers accounts.

4.3 The SPAM00 basic components

Due to the object of study, our SAM has some similarities with the ones of Rubio and Perdiz [2009] and Cardenete and Flores [2009]. But, as we shall see, we present some important differences. Without the emissions sub-account, the SPAM00 is a 51x51 matrix that includes six main blocks: 28 production sectors, four institutions, five value-added accounts at market prices, ten auxiliary accounts, one gross capital formation, and two foreign sectors. As an additional module, it also presents the computed CO_2 emissions, disaggregated by fossil fuels use and attributed to the productive sectors and the representative household. The statistical sources for the elaboration of the SPAM00 are databases compiled by the INE and consisting of the *2000 symmetric table* at basic prices, the *2000 supply table* at basic prices and the *2000 use tables* at basic and purchasers' prices. Furthermore, some additional unpublished tax data were graciously provided by the INE. A schematic presentation of the SPAM00 appears in *table* (4.1) and the complete version appears at the end of this chapter. Table (4.2) shows the calculation of the gross domestic product at market prices, following the expenditure approach, the income approach[1] and the production approach.

For further analysis, some improvements could be proposed. A disaggregation of the household account into several income or professional categories would allow redistributive analysis. Based on expenditure surveys, the consumption goods could be

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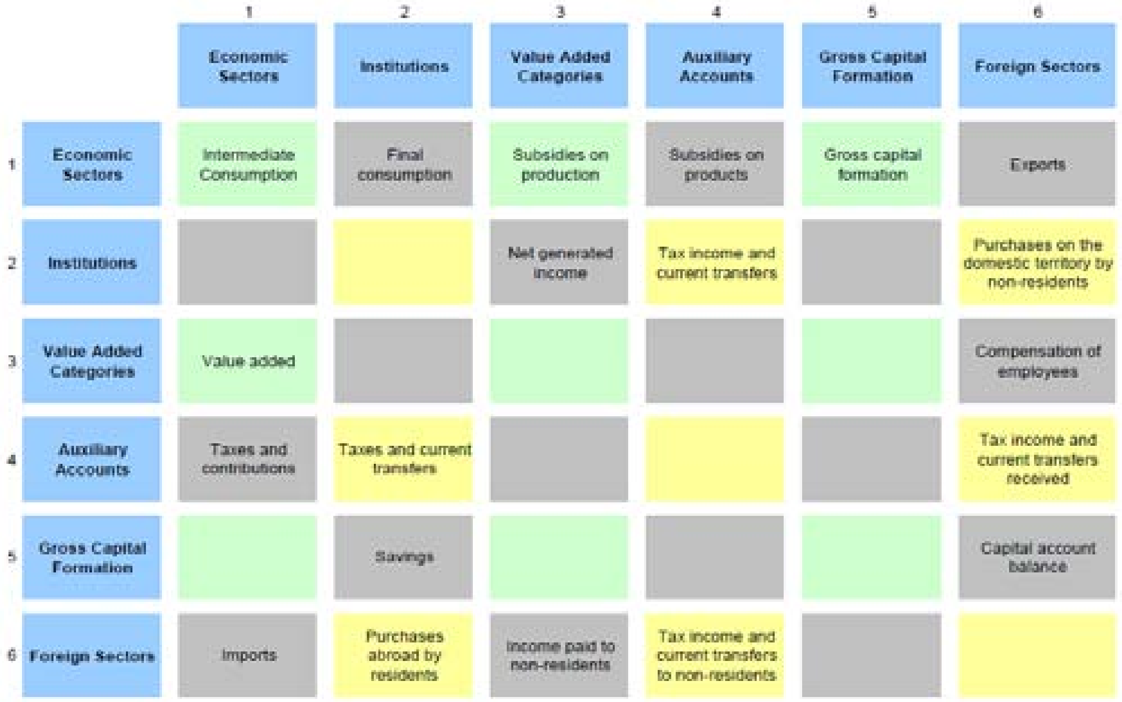
[1] The income approach measures GDP by calculating incomes that firms pay for the factors of production they hire. To get from factor cost to market prices we must add indirect taxes minus subsidies

Table 4.1: Schematic presentation of the SPAM00.



		1 Economic Sectors	2 Institutions	3 Value Added Categories	4 Auxiliary Accounts	5 Gross Capital Formation	6 Foreign Sectors
1	**Economic Sectors**	Intermediate Consumption	Final consumption	Subsidies on production	Subsidies on products	Gross capital formation	Exports
2	**Institutions**			Net generated income	Tax income and current transfers		Purchases on the domestic territory by non-residents
3	**Value Added Categories**	Value added					Compensation of employees
4	**Auxiliary Accounts**	Taxes and contributions	Taxes and current transfers				Tax income and current transfers received
5	**Gross Capital Formation**		Savings				Capital account balance
6	**Foreign Sectors**	Imports	Purchases abroad by residents	Income paid to non-residents	Tax income and current transfers to non-residents		

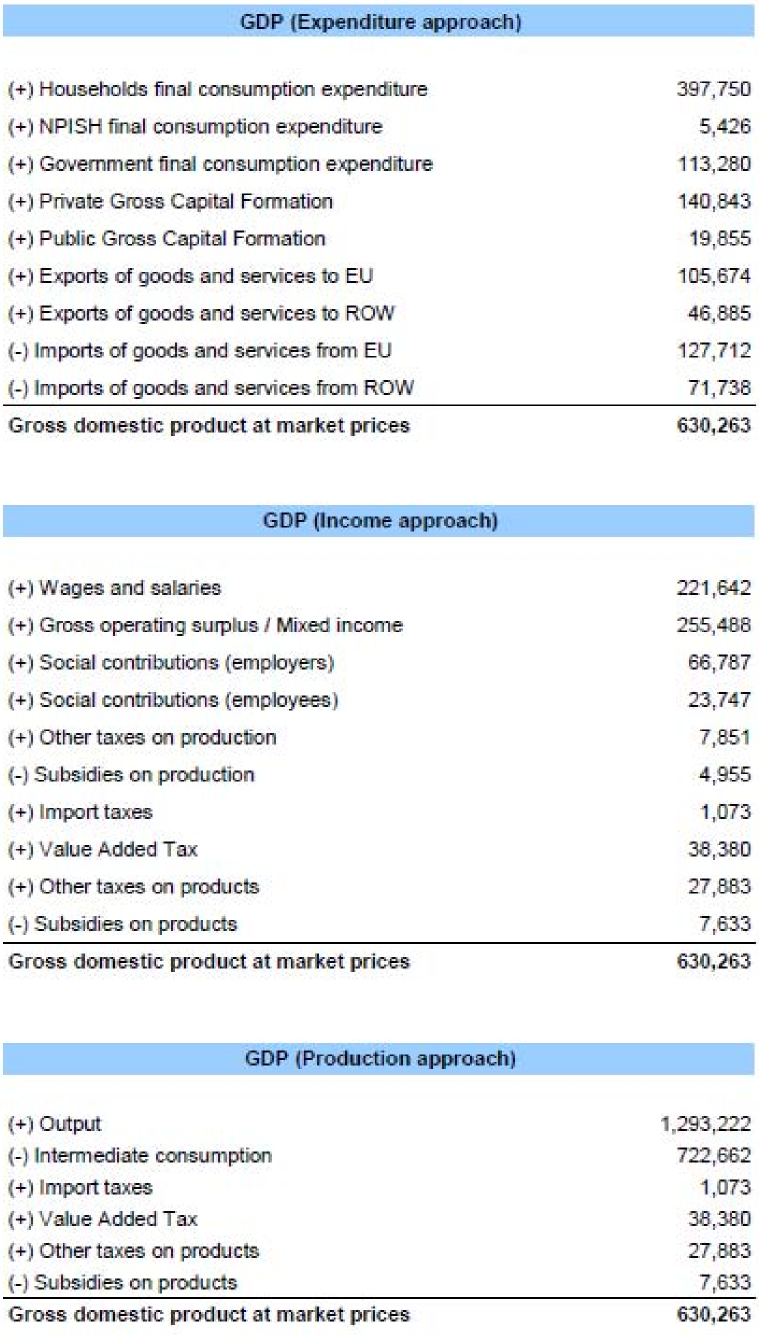
classified differently than the produced goods. Also, to underline the role of renewables energies in the energy mix, some sectoral data for specific renewable energies could be integrated, when statistics become available. This would enrich the substitution possibilities between energy sources within the model.

Economic sectors

The 28 economic sectors in the SPAM00 have been aggregated from the 73 domestic production sectors displayed in the 2000 symmetric input-output table (SIOT) from the INE. *Table* (4.3) shows the correspondences between different classifications of economic activities: the SPAM00 accounts, the SIOT from the INE and the European classification of economic activities (NACE) and of products by activities (CPA).

This new classification is based on several considerations. While we aimed to reduce sectoral disaggregation in a balanced way, in order to avoid unnecessary information for our study focus, we acknowledged also that the analysis of CO_2 emissions abatement must offer a sectoral disaggregation that captures several key dimensions. First, the classification tends to emphasize the differences in carbon intensities between sectors, by distinguishing energy intensive industries (energy producing sectors, metallurgy, manufacture of industrial chemicals, ceramic, glass, transport, etc.) from the rest of sectors. This highlights the main links between high polluting and low polluting sectors.

Table 4.2: GDP accounting. Spain, 2000.



GDP (Expenditure approach)	
(+) Households final consumption expenditure	397,750
(+) NPISH final consumption expenditure	5,426
(+) Government final consumption expenditure	113,280
(+) Private Gross Capital Formation	140,843
(+) Public Gross Capital Formation	19,855
(+) Exports of goods and services to EU	105,674
(+) Exports of goods and services to ROW	46,885
(-) Imports of goods and services from EU	127,712
(-) Imports of goods and services from ROW	71,738
Gross domestic product at market prices	**630,263**

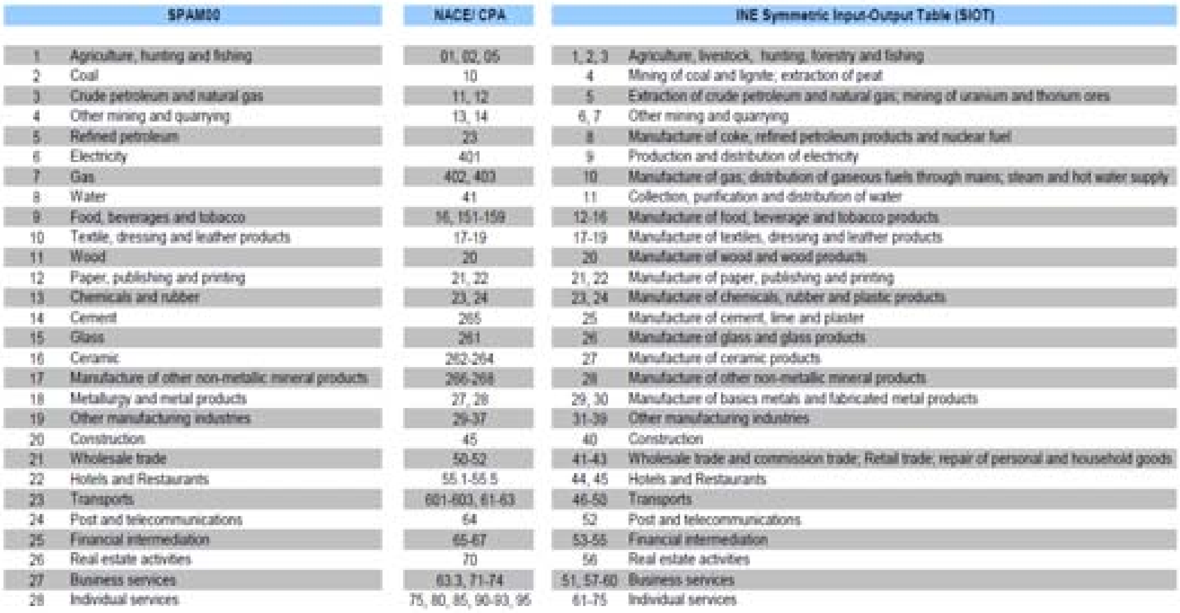
GDP (Income approach)	
(+) Wages and salaries	221,642
(+) Gross operating surplus / Mixed income	255,488
(+) Social contributions (employers)	66,787
(+) Social contributions (employees)	23,747
(+) Other taxes on production	7,851
(-) Subsidies on production	4,955
(+) Import taxes	1,073
(+) Value Added Tax	38,380
(+) Other taxes on products	27,883
(-) Subsidies on products	7,633
Gross domestic product at market prices	**630,263**

GDP (Production approach)	
(+) Output	1,293,222
(-) Intermediate consumption	722,662
(+) Import taxes	1,073
(+) Value Added Tax	38,380
(+) Other taxes on products	27,883
(-) Subsidies on products	7,633
Gross domestic product at market prices	**630,263**

Data: INE

Second, the model must allow to analyse the substitution possibilities across energy goods (high polluting goods) by differentiating to the largest extent possible the energy activities. In this respect, the model identifies four sectors concerned with the supply and distribution of conventional energy (final energy goods): three fossil fuels (coal, refined oil products, natural gas) and one source of non-fossil energy (electricity). Due to data availability reasons, no separation is made between heavy-oil and light fuel-oil and between gasoline and diesel. Finally, the disaggregation level may also focus on

Table 4.3: Correspondences SPAM00, NACE/CPA and SIOT classifications. Year 2000.



SPAM00		NACE/ CPA	INE Symmetric Input-Output Table (SIOT)	
1	Agriculture, hunting and fishing	01, 02, 05	1, 2, 3	Agriculture, livestock, hunting, forestry and fishing
2	Coal	10	4	Mining of coal and lignite; extraction of peat
3	Crude petroleum and natural gas	11, 12	5	Extraction of crude petroleum and natural gas; mining of uranium and thorium ores
4	Other mining and quarrying	13, 14	6, 7	Other mining and quarrying
5	Refined petroleum	23	8	Manufacture of coke, refined petroleum products and nuclear fuel
6	Electricity	401	9	Production and distribution of electricity
7	Gas	402, 403	10	Manufacture of gas; distribution of gaseous fuels through mains; steam and hot water supply
8	Water	41	11	Collection, purification and distribution of water
9	Food, beverages and tobacco	16, 151-159	12-16	Manufacture of food, beverage and tobacco products
10	Textile, dressing and leather products	17-19	17-19	Manufacture of textiles, dressing and leather products
11	Wood	20	20	Manufacture of wood and wood products
12	Paper, publishing and printing	21, 22	21, 22	Manufacture of paper, publishing and printing
13	Chemicals and rubber	23, 24	23, 24	Manufacture of chemicals, rubber and plastic products
14	Cement	265	25	Manufacture of cement, lime and plaster
15	Glass	261	26	Manufacture of glass and glass products
16	Ceramic	262-264	27	Manufacture of ceramic products
17	Manufacture of other non-metallic mineral products	266-268	28	Manufacture of other non-metallic mineral products
18	Metallurgy and metal products	27, 28	29, 30	Manufacture of basics metals and fabricated metal products
19	Other manufacturing industries	29-37	31-39	Other manufacturing industries
20	Construction	45	40	Construction
21	Wholesale trade	50-52	41-43	Wholesale trade and commission trade; Retail trade; repair of personal and household goods
22	Hotels and Restaurants	55.1-55.5	44, 45	Hotels and Restaurants
23	Transports	601-603, 61-63	46-50	Transports
24	Post and telecommunications	64	52	Post and telecommunications
25	Financial intermediation	65-67	53-55	Financial intermediation
26	Real estate activities	70	56	Real estate activities
27	Business services	63.3, 71-74	51, 57-60	Business services
28	Individual services	75, 80, 85, 90-93, 95	61-75	Individual services

Data: INE

the openness level of the sector to the international concurrence, in order to take into account the competitiveness problem.

The different sectors are assumed to produce different homogeneous goods and services for domestic and foreign consumption. Economic branches get their revenues (presented in the row) from selling their production as intermediate commodities to domestic production sectors (intermediate demand), as consumption commodities to domestic consumers (final demand), as capital goods to domestic capital accounts (gross capital formation) and as exports to the foreign sectors. The domestic and foreign supply of goods and services is given in the columns.

The SPAM00 is valued at purchasers' prices, such that the intermediary consumption, the value-added and the final demand submatrices include indirect taxes on products and commercial and transportation margins. However in the original 2000 symmetric table, intermediate consumption flows are valued at basic prices. Therefore, some methodological adjustments have been required to transform the matrix at purchasers' prices. First we generate a new matrix of intermediate consumption at purchasers' prices, by using the cross entropy method [Robinson et al., 2000] for allocating taxes on products to intermediate consumption. Then, commercial and transportation margins from the supply table were allocated to trade and transport sectors. Since total margins are now valued as production costs, this allows us to disaggregate consumption and production taxes efficiently.

Institutions

There are six agents represented by the data: four domestic institutions and two foreign institutions. The domestic institutions are the representative household (HH) the corporate sector (Companies), the non profit institutions serving households (NPISH) and the government (Gov). The foreign institutions are the European Union (EU) and the rest of the world (ROW). Domestic institutions draw their revenues from current transfers, property income, primary factors income (wages and operating surplus) and transfers from the external sectors.

In the case of the household, NPISH and the government, part of the revenues are used to pay for consumption expenditures. The household and the corporate sector use also their revenues to pay the income tax. And, for all agents, another share serves to pay for current transfers (welfare benefits and other current transfers) and property expenses. The remaining part of income is saved, as indicated in the capital account. Note that the household's consumption expenditure includes domestic purchases and direct purchases abroad (intra or extra EU).

Generation of income

The third block is related to the generation of income process. The rows show incomes generated by national production factors, in domestic industries or abroad. The columns of this block show how these incomes are allocated to the institutional sectors in the domestic economy and to the rest of the world. With respect to the labour factor, the 2000 Symmetric table only provides sectoral data for the compensation of employees, which includes wages and salaries gross of employers' Social Security contributions. A sectoral disaggregation for wages and salaries and for employers' Social Security contributions was given in the 2000 Use table. Therefore we calculated the relative proportions of both variables by sector and applied these coefficients to the total compensation of employees in the Symmetric table. The small discrepancies were corrected by using a RAS method to ensure adequate values for each row and column.

The sectoral disaggregation for the operating surplus/gross mixed income was obtained directly from the 2000 Symmetric table. With respect to the 'other net taxes on production' account, the Symmetric table offers aggregate values for taxes minus subventions on production. Therefore, we used unpublished data provided by the INE with a separate sectoral disaggregation for the two variables, other taxes on production and other subventions on production.

Auxiliary accounts

The auxiliary accounts block includes data on direct and indirect taxes, subsidies and auxiliary transfers. Thanks to the support from the INE, we provide a disaggregation of net taxes on products and other net taxes on production into their basic components. Direct taxes include the income tax (private and corporate) and the employees' Social Security contributions. Indirect taxes include tariffs, value-added tax and net tax on products. Finally, transfers include welfare benefits, adjustments for the change in net equity of households on pension funds reserves, other current transfers and property income. The taxes are levied on the representative household, the corporate sector and the foreign sector. Tax revenues accrue to the government and the foreign sector. Production sectors benefit however from subsidies on products as a source of revenue paid by the government and the foreign sector (as revenue transfers from the EU). Transfers revenues are collected from all institutions and redistributed among all of them also.

Data for the income tax paid by households and the corporate sector were taken from the INE National Accounts. For employees' Social Security contributions, only aggregated data are given in the INE National Accounts. However, since we got the sectoral disaggregation of employers' contributions and assuming that the share of total employers' and employees' contributions rates are equivalent over the same sectoral contribution base, we use the relative share of total employers' contributions by sector and apply these ratios to the total employees' contributions to disaggregate it by sectors also[2].

For import taxes and taxes on products (excluding VAT and import taxes), data from the Symmetric table are reported net of subsidies. So, we made use of some additional data provided by the INE and the Supply table to disaggregate taxes from subsidies. Data for the transfers variables (welfare benefits, capital gains/losses in pension funds, other current transfers and property income) were obtained directly from the INE National Accounts.

Capital account

The capital account explains how savings from domestic and foreign institutional sectors are allocated to finance domestic investment (private and public). The balancing item is net lending to (net borrowing from) the foreign sector. In other words, domestic savings and the balance of capital are channeled into domestic capital formation.

Statistics for the savings of domestic and foreign agents were obtained from the

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[2] See also [Alvarez, 2010].

INE National Accounts. Sectoral data for gross capital formation (GCF) are provided by the Symmetric table, but we change price valuation from basic prices to purchasers' prices. To distinguish between private and public investment, we used an unpublished matrix of gross fixed capital formation, provided by the INE, which differentiates private and public investment by sectors. Note that since the value-added tax on construction goods and services is rather a VAT on investment we reassign the VAT referred to construction as a a VAT on investment goods, even tough investment goods have a wider base than construction goods.

Foreign sectors

The foreign sector block is composed of two vectors: the EU and the ROW. It takes into account the current and capital transactions between non-residents and Spanish residents. Current account transactions refer not only to the balance of trade in goods and services (imports in the rows and exports in the columns), but also to factor incomes (such as wages, interest and dividends) and transfer payments. The second component of the balance of payments, the capital account, records the changes in national ownership of investment assets. In essence, the foreign sector obtains its revenues from selling its goods and services (imports) and from factor incomes (labour income here) and transfers paid by residents. On the contrary, foreign institutions pay for exports to their regions, for resident factors incomes in their territory and for transfers to residents. The balance between the foreign sector revenues and its payments to domestic institutions consists of the net financing capacity (or necessity) of the domestic economy, which is the result of the accounting identity that domestic current surplus (deficit) is by definition equal to net national savings (financing needs). This capital transaction account demonstrates that Spain faces a net financing necessity for the year 2000[3].

Data for exports to the EU and the ROW are found in the Symmetric table. However, import data come as aggregated for both regions. Therefore, we use the Supply table to calculate the ratio of EU imports to ROW imports for each sector and apply these coefficients to the sectoral aggregated imports in the Symmetric table. Tax, transfers and primary factor incomes come from the INE National Accounts.

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[3] The value of the financing necessity is of 25326 million euros. The distribution between governmental and non-governmental is for balancing reasons, as the foreign countries finance the domestic economy as a whole and not in separated accounts.

4.4 The emissions module

Carbon emissions

The objective of an environmental module is to extend the matrix explained above by one account describing the quantity (in physical units) of CO_2 emissions, as by-products of the production activities concerned[4]. There are two main sources of carbon dioxide emissions, those from fossil fuel combustion and those from noncombustion processes. Noncombustion industrial processes comprise fugitive emissions from oil and natural gas systems (as leakage or evaporation), emissions from aluminum production and emissions from the manufacture of cement. These emissions usually only represent around 2% of the total CO_2 emissions in most industrialised economies like Spain. Therefore they are not computed in this study. Even if fuel combustion is widely dispersed throughout most activities in national economies, it is possible to obtain a relatively accurate estimate of national CO_2 emissions by accounting for the carbon content in fuels supplied to the economy[5]. During the combustion process, the carbon and hydrogen of the fossil fuels are converted mainly into carbon dioxide and water, releasing the chemical energy in the fuel as heat. This heat is generally either used directly or used (with some conversion losses) to produce mechanical energy, often to generate electricity or for transportation [IPCC, 2006, 1.5].

The INE satellite atmospheric emissions accounts for the year 2000 provide sectoral data for CO_2 emissions, valued in physical units. In total, carbon emissions are disaggregated for 53 sectors and the households[6]. However, the disaggregation of the sectors doesn't match with our own disaggregation in the SPAM00. Second, the sectoral disaggregation doesn't indicate in which proportion the CO_2 emissions come from the use of domestic fossil fuels or imported fossil fuels. Third, carbon emissions are not distinguished by fuel type use. But in a study of CO_2 emissions mitigation, we believe a disaggregation of CO_2 emissions by fuel type use offers an important addition to the analysis of emissions abatement policies within a CGE model, due to their contamination differentials. In the SPAM00, the three fossil fuels that are used to compute carbon emissions are coal, oil and natural gas. Because crude oil is largely transformed into refined oil and petroleum products (apart from the gas sector, there is almost no consumption of crude oil outside the refining sector), the carbon dioxide

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[4] This elaboration is more restrictive than the standard national accounting matrix including environmental accounts (NAMEA) elaboration, an integrated system of economic and environmental accounts which fulfills all requirements of matrix accounting. Furthermore, a detailed NAMEA integrates several types of pollution.

[5] CO_2 emissions are fuel specific, since the carbon content of each fuel differs.

[6] Studies such as the ones of Alcántara and Roca [1995] or Alcántara and Padilla [2008] are examples of CO_2 emissions estimation procedures for Spain and the impact of the productive structures on these emissions trough input-output analysis.

emissions generated by oil are attributed to the consumption of refined oil. The consumption of electricity does not generate CO_2 emissions directly; it is the generation of electricity that is associated with carbon emissions.

In the absence of statistics on physical units of fossil fuels use by economic sectors, we need a method of estimating CO_2 emissions related to intermediary and final consumption, differentiating between each of the three fossil fuels use in Spain. We favour a top-down approach[7] based on the use of CO_2 emission factor for each fuel: as it is well known, CO_2 emissions of a fossil fuel energy carrier is proportional to the carbon content of that fuel[8].

To do so, we rely on different data sources. First, we take advantage of the CO_2 emissions coefficients in terms of monetary units, obtained by Fuentes Saguar [2008] for the year 2000. For each fossil fuel, she disaggregates CO_2 emission coefficients (kt CO_2/million €) for intermediary consumption and final consumption, as indicated below. Due to some imbalances with the data reported by the U.S. Energy Information Administration (EIA) on aggregate CO_2 emissions by fuel use for the year 2000 in Spain, we update these coefficients to the EIA data.

Table 4.4: CO_2 emissions coefficients from fossil fuels (kt CO_2/million €)

	Oil	*Coal*	*Gas*
Intermediary demand	5.43	29.67	10.01
Final demand	3.13	17.89	4.5

By using these coefficients, we estimate total carbon emissions from petroleum, coal and gas consumption, in kilotons. For each fuel, it represents the consumption of the whole economy, including intermediate consumption, imports and final consumption. We first specify the (28x1) vectors of intermediate consumption, imports from the EU and imports from the ROW for each of the three fossil fuels[9]. Data for intermediary consumption vector are taken from the Symmetric matrix whereas data for imports vectors are derived from the imports use tables (cif). To this three vectors we must add the consumption of resident households of each particular fuel.

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[7] This top-down method is usually referred as the "Reference Approach" [IPCC, 2006], in contrast with the Sectoral Approach which is based on detailed information on how the individual fuels are used in each sector.

[8] The CO_2 emissions derive from stationary combustion (e.g. combustion in energy industries like power plants and refineries) and mobile combustion (road and other traffic). But since CO_2 emissions are independent of combustion technology, the default CO_2 emission factors for fossil fuels are applicable to all combustion processes, both stationary and mobile. Combustion conditions being unimportant, CO_2 emissions can be estimated fairly accurately based on the quantities of fuels combusted and the averaged carbon content of the fuels.

[9] We thus estimate the value that each of the 28 economic branches imports, from the EU or the ROW, in terms of coal, gas or refined petroleum.

Under these assumptions, we estimate CO_2 emissions, in kt, for each economic sector i as the sum of intermediary consumption of fuel f , imports from the EU of fuel f and imports of the ROW of fuel f:

$$CO_{2,i,f} = (ic_{i,f} + impEU_{i,f} + impROW_{i,f}) \cdot idco2coef_f \tag{4.1}$$

In the same way, the representative household's CO_2 emissions from fuel f use are given by the following relation:

$$CO_{2,H,f} = hc_f \cdot fdco2coef_f \tag{4.2}$$

where

$CO_{2,i,f}$: carbon emission level from fuel f use in sector i , in kt CO_2;
$CO_{2,H,f}$: household's carbon emission level from fuel f use, in kt CO_2;
$ic_{i,f}$: intermediate consumption of fuel f in sector i, in million €;
$impEU_{i,f}$: imports from EU of fuel f in sector i, in million €;
$impROW_{i,f}$: imports from ROW of fuel f in sector i, in million €;
$idco2coef_f$: CO_2 emission coefficient (kt CO_2/million €) for inter. cons. of fuel f;
hc_f : household's consumption of fuel f;
$fdco2coef_f$: CO_2 emission coefficient (kt CO_2/million €) for final cons. of fuel f;

Accounting for total CO_2 emissions in the economy, CO_2TOT, requires summing and matchingCO_2 emissions over all fossil fuels domestic consumption

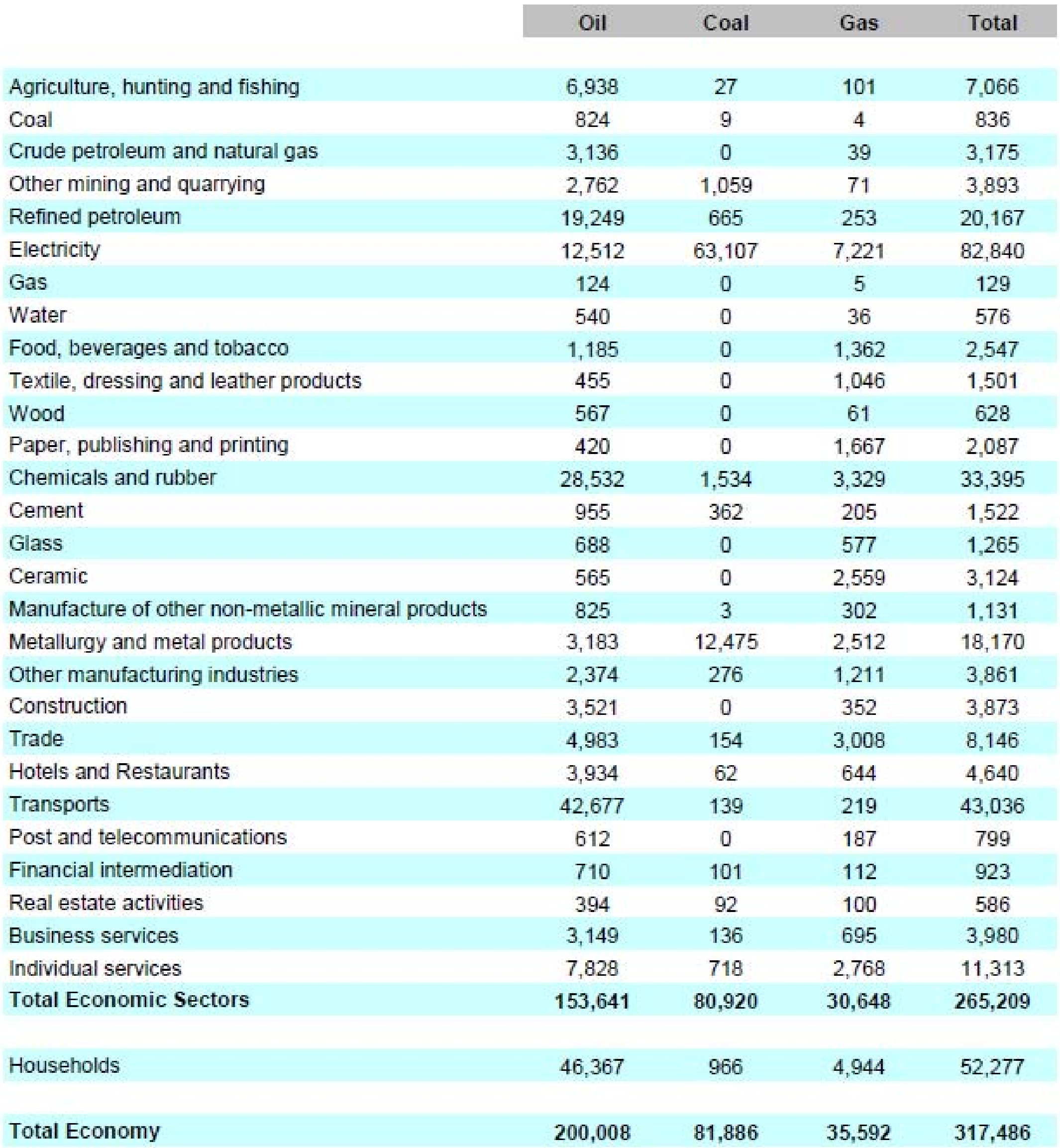
$$CO_2TOT = \sum_f \left(\sum_i CO_{2,i,f} + CO_{2,H,f} \right) \tag{4.3}$$

Carbon emissions sources

Carbon emissions data for Spain in 2000 are given in *table* (4.5). The disaggregation we obtain from the EIA data indicate a total of 318 Mio tonnes of CO_2 in the year 2000. This aggregate number from the IEA is higher than the 304 Mio tonnes of CO_2 emissions provided by the INE for 2000. However, consistency between both databases remains valid, since the difference is relatively minor and consists principally in differences in the CO_2 emissions from the households.

Figure (4.1) illustrates these data graphically. As mentioned previously, the 28 sectors classification was intended to show the impact of high polluting (energy intensive industries) and low polluting sectors. Unsurprisingly, production activities and transport account for the larger part of CO_2 emissions in Spain. Electricity production comes by far as the most polluting sector, due to its important use of coal sources in

Table 4.5: CO_2 emissions from fossil fuels combustion by sector (thousands metric tons). Spain, 2000.



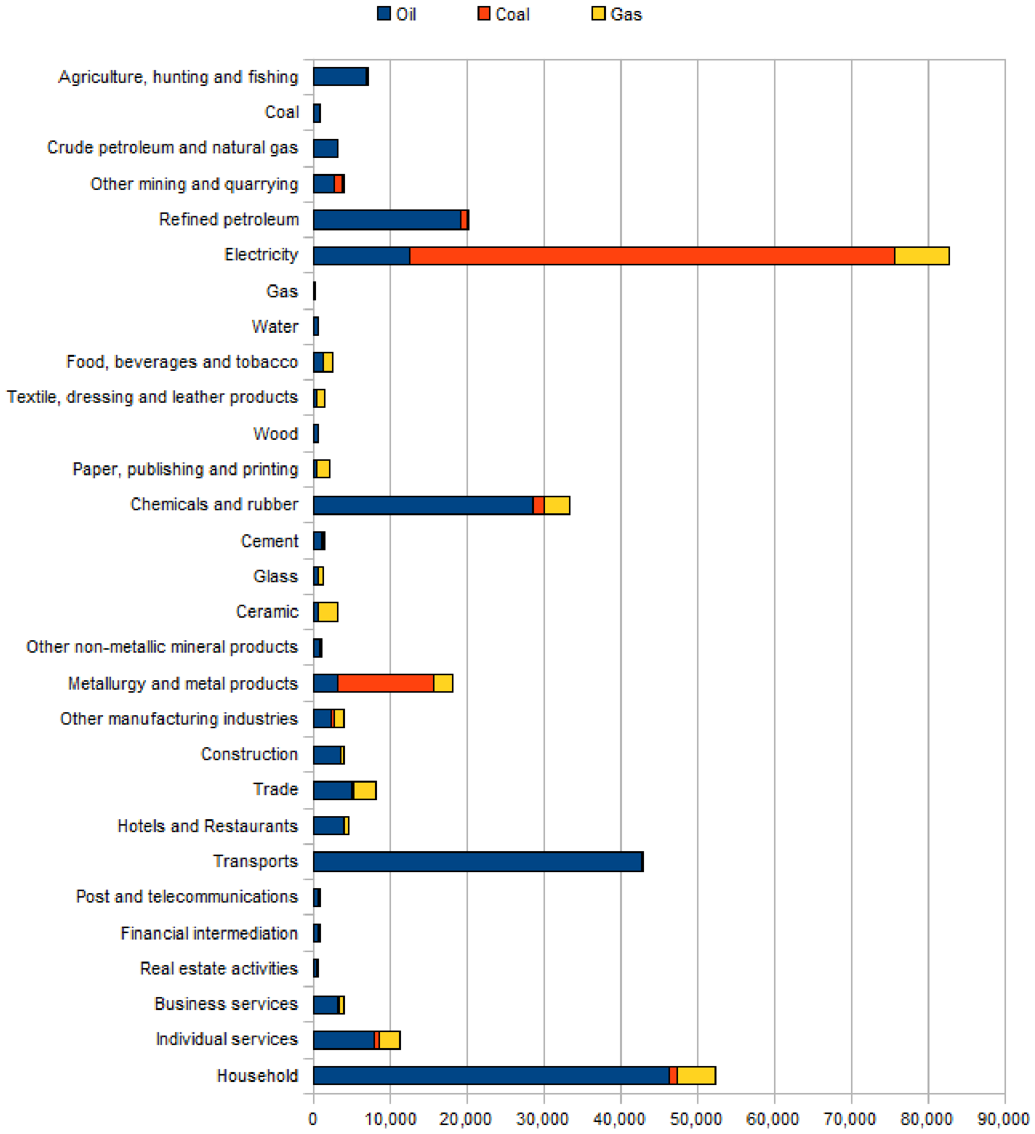
	Oil	Coal	Gas	Total
Agriculture, hunting and fishing	6,938	27	101	7,066
Coal	824	9	4	836
Crude petroleum and natural gas	3,136	0	39	3,175
Other mining and quarrying	2,762	1,059	71	3,893
Refined petroleum	19,249	665	253	20,167
Electricity	12,512	63,107	7,221	82,840
Gas	124	0	5	129
Water	540	0	36	576
Food, beverages and tobacco	1,185	0	1,362	2,547
Textile, dressing and leather products	455	0	1,046	1,501
Wood	567	0	61	628
Paper, publishing and printing	420	0	1,667	2,087
Chemicals and rubber	28,532	1,534	3,329	33,395
Cement	955	362	205	1,522
Glass	688	0	577	1,265
Ceramic	565	0	2,559	3,124
Manufacture of other non-metallic mineral products	825	3	302	1,131
Metallurgy and metal products	3,183	12,475	2,512	18,170
Other manufacturing industries	2,374	276	1,211	3,861
Construction	3,521	0	352	3,873
Trade	4,983	154	3,008	8,146
Hotels and Restaurants	3,934	62	644	4,640
Transports	42,677	139	219	43,036
Post and telecommunications	612	0	187	799
Financial intermediation	710	101	112	923
Real estate activities	394	92	100	586
Business services	3,149	136	695	3,980
Individual services	7,828	718	2,768	11,313
Total Economic Sectors	**153,641**	**80,920**	**30,648**	**265,209**
Households	46,367	966	4,944	52,277
Total Economy	**200,008**	**81,886**	**35,592**	**317,486**

Data: U.S. Energy Information Administration

power plants. Refineries present also an important impact. Mobile combustion (road and other transport) comes as a high second. In terms of the main manufacturing industries, the chemical and petrochemical industry account for the largest share of CO_2 emissions, followed by metallurgy (iron and steel industry), other manufacturing industries, other mining and ceramic.

As it can be seen in figure (4.1), household consumption accounts for an important share of CO_2 emissions, due to the use of fuel oils in housing and petrol and diesel in transportation. This represents a major reason why CO_2 emissions taxation should not focus only on productive sectors, but also include the household sector in order to

Figure 4.1: CO_2 emissions from fossil fuels combustion by sector (thousands metric tons). Spain, 2000.



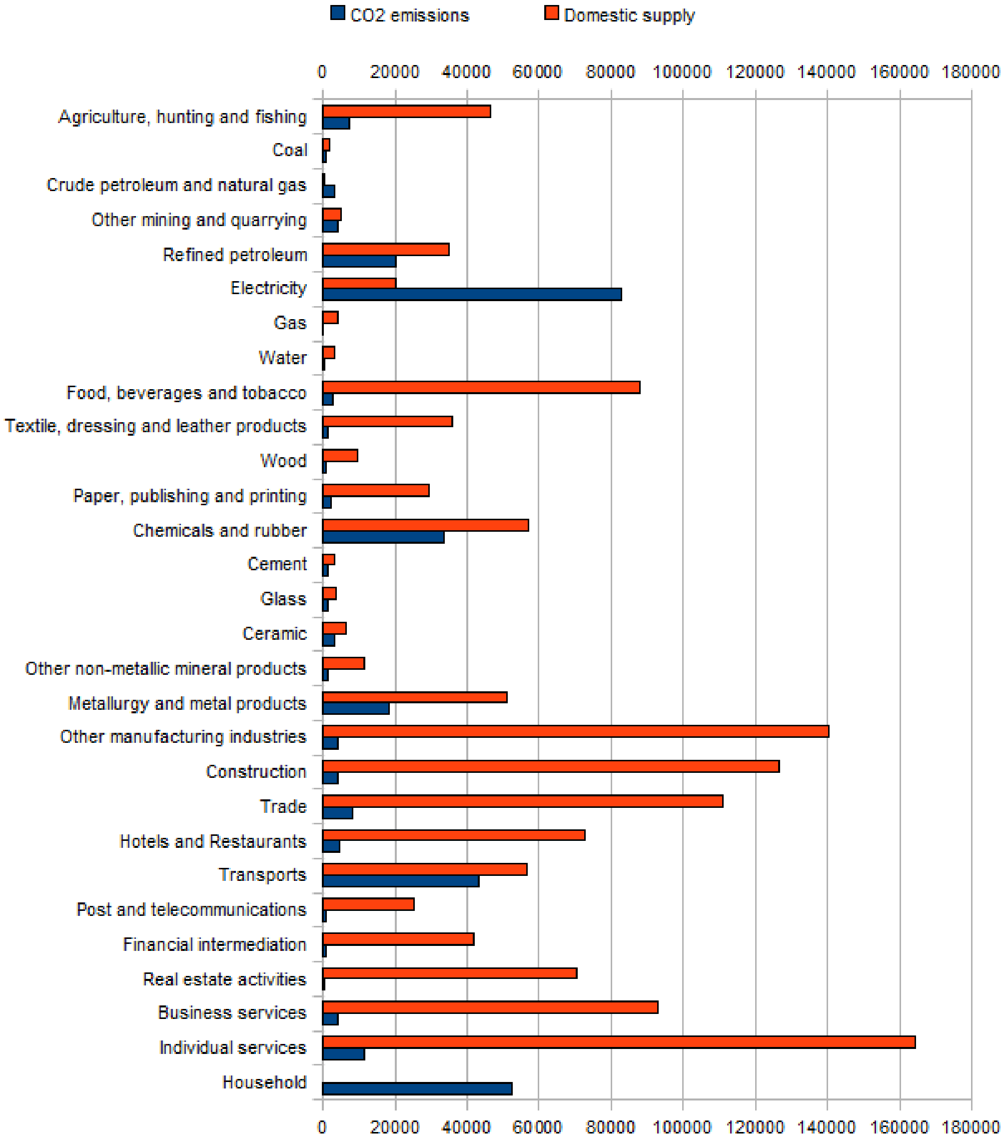
Data: U.S. Energy Information Administration

mitigate its impact on fossil fuels use in housing and mobility.

An interesting observation comes from comparing the contributions to CO_2 emissions of the 28 economic sectors with their relative share of total supply. In this way, a comparative scale is given for the economic importance of these sectors. As illustrated in *figure* (4.2), the most important economic sectors in Spain are not the most polluting ones. For example, the importance of the service sectors in total supply is very high, while their shares of CO_2 emissions are relatively minor. This is also the case for the construction sector, several manufacturing sectors (e.g. food, beverage and tobacco industry), and agriculture, hunting and fishing.

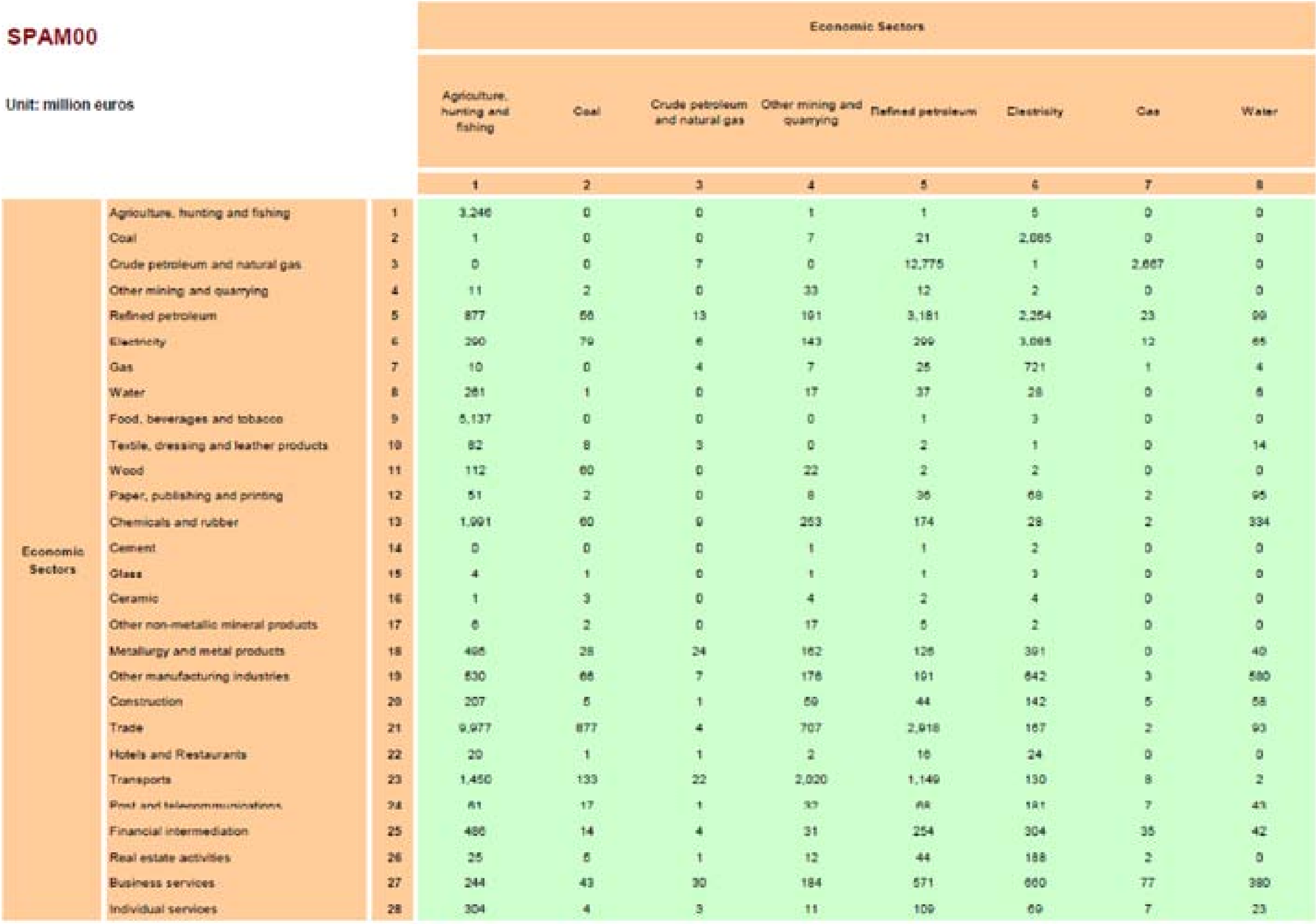
The least "emissions efficient" production sectors of Spain, in terms of output size, are the energy sectors, transport, other mining, ceramic, cement and glass industries. This overview helps to distinguish in which sectors lie opportunities to improve energy efficiency and reduce in a decisive manner CO_2 emissions. These questions are at the hearth of this analysis.

Figure 4.2: CO_2 emissions from fossil fuels combustion (thousands metric tons) and domestic output by sector (million euros). Spain, 2000.



Data: U.S. Energy Information Administration and INE

Table 4.6: SPAM00 (million euros). Spain. 2000.



SPAM00

Unit: million euros

			Economic Sectors							
			Agriculture, hunting and fishing	Coal	Crude petroleum and natural gas	Other mining and quarrying	Refined petroleum	Electricity	Gas	Water
			1	2	3	4	5	6	7	8
Economic Sectors	Agriculture, hunting and fishing	1	3,246	0	0	1	1	5	0	0
	Coal	2	1	0	0	7	21	2,085	0	0
	Crude petroleum and natural gas	3	0	0	7	0	12,775	1	2,667	0
	Other mining and quarrying	4	11	2	0	33	12	2	0	0
	Refined petroleum	5	877	66	13	191	3,181	2,254	23	99
	Electricity	6	390	79	6	143	299	3,085	12	65
	Gas	7	10	0	4	7	25	721	1	4
	Water	8	261	1	0	17	37	28	0	6
	Food, beverages and tobacco	9	5,137	0	0	0	1	3	0	0
	Textile, dressing and leather products	10	82	8	3	0	2	1	0	14
	Wood	11	112	60	0	22	2	2	0	0
	Paper, publishing and printing	12	51	2	0	8	36	68	2	95
	Chemicals and rubber	13	1,991	60	9	253	174	28	2	334
	Cement	14	0	0	0	1	1	2	0	0
	Glass	15	4	1	0	1	1	3	0	0
	Ceramic	16	1	3	0	4	2	4	0	0
	Other non-metallic mineral products	17	6	2	0	17	5	2	0	0
	Metallurgy and metal products	18	495	26	24	162	126	391	0	40
	Other manufacturing industries	19	630	66	7	176	191	642	3	580
	Construction	20	207	5	1	59	44	142	5	58
	Trade	21	9,977	877	4	707	2,918	167	2	93
	Hotels and Restaurants	22	20	1	1	2	16	24	0	0
	Transports	23	1,450	133	22	2,020	1,149	130	8	2
	Post and telecommunications	24	61	17	1	37	68	181	7	43
	Financial intermediation	25	486	14	4	31	254	304	35	42
	Real estate activities	26	25	5	1	12	44	188	2	0
	Business services	27	244	43	30	184	571	660	77	380
	Individual services	28	304	4	3	11	109	69	7	23

Source: own elaboration. Data: INE.

Table 4.7: SPAM00 (million euros). Spain, 2000. (continued)

Economic Sectors											
Food, beverages and tobacco	Textile, dressing and leather products	Wood	Paper, publishing and printing	Chemicals and rubber	Cement	Glass	Ceramic	Other non-metallic mineral products	Metallurgy and metal products	Other manufacturing industries	Construction
9	10	11	12	13	14	15	16	17	18	19	20
21,608	624	677	462	146	1	1	0	1	2	44	444
0	0	0	0	24	5	0	0	0	264	9	0
0	0	0	0	16	0	0	0	0	0	0	0
29	3	0	29	559	143	119	218	731	2,278	51	1,781
139	41	88	55	3,591	91	52	62	121	392	252	648
498	234	165	463	701	140	85	111	260	933	1,094	336
136	106	6	167	332	21	58	256	30	261	121	35
133	34	9	19	64	2	4	8	10	47	72	42
14,992	488	0	42	195	0	0	0	0	0	10	1
120	9,606	31	16	396	2	5	14	31	86	1,227	83
447	65	3,051	283	72	8	23	97	41	212	2,258	2,342
1,218	128	204	7,974	662	22	35	64	106	134	1,393	261
1,564	1,984	513	1,391	15,672	30	265	423	371	2,600	7,869	3,078
0	1	0	0	2	99	5	1	1,492	5	6	1,601
1,051	1	17	0	182	0	143	0	1	101	886	621
3	0	0	0	22	9	5	29	2	47	34	3,662
0	1	0	0	2	48	74	83	130	87	78	10,068
1,130	191	258	818	598	23	51	168	682	14,540	18,958	8,808
462	365	269	485	1,142	123	232	261	619	4,905	37,517	7,262
200	46	14	62	65	18	7	118	35	122	249	27,674
17,930	12,070	667	5,546	12,769	297	720	794	1,778	3,293	25,727	1,382
47	23	11	18	207	5	11	0	1	77	128	257
2,663	807	690	989	1,866	555	199	630	1,165	2,259	2,870	1,301
385	231	39	100	448	31	16	76	74	154	468	617
657	311	81	257	492	32	39	55	94	524	1,065	1,337
777	154	47	77	320	8	17	30	42	235	439	1,144
3,302	1,279	257	1,680	3,139	216	205	563	644	2,012	6,066	4,722
323	110	34	367	287	16	18	11	42	202	402	61

Source: own elaboration. Data: INE

Table 4.8: SPAM00 (million euros). Spain, 2000. (continued)

Economic Sectors								Institutions			
Trade	Hotels and Restaurants	Transports	Post and telecommunications	Financial intermediation	Real estate activities	Business services	Individual services	HH	Companies	NPISH	Gov
21	22	23	24	25	26	27	28	29	30	31	32
213	1,730	14	13	3	5	40	777	14,648.0		0.0	0.0
8	2	5	0	3	3	5	24	54.0		0.0	0.0
0	0	12	10	0	0	4	0	0.0		0.0	0.0
27	3	13	12	0	2	12	40	69.3		0.0	0.0
873	710	6,141	108	117	72	404	1,396	14,831.0		0.0	0.0
2,066	339	829	525	256	307	506	1,827	5,304.0		0.0	0.0
300	84	22	19	11	10	69	276	1,098.0		0.0	0.0
241	130	80	27	7	29	77	388	1,663.0		0.0	0.0
110	14,362	75	40	2	0	34	1,207	55,945.1		0.0	0.0
397	771	87	140	2	2	393	765	26,114.2		0.0	0.0
138	285	195	6	1	1	71	204	489.8		0.0	0.0
611	306	300	198	573	428	6,479	2,461	6,976.2		0.0	0.0
1,138	1,576	963	118	32	177	1,439	4,292	9,835.4		0.0	7,024.0
1	21	2	26	1	0	26	3	25.0		0.0	0.0
124	48	6	35	1	0	33	115	326.0		0.0	0.0
13	212	13	132	1	1	35	36	311.0		0.0	0.0
8	20	37	53	0	1	9	35	61.0		0.0	0.0
394	198	333	8	23	83	596	443	1,192.5		0.0	0.0
6,819	1,199	2,284	2,097	177	46	3,201	6,435	42,783.3		0.0	219.0
1,474	743	446	254	556	8,179	1,052	2,995	3,390.5		0.0	0.0
2,011	767	1,305	36	53	105	353	843	8,588.4		0.0	0.0
355	61	354	72	318	40	2,534	1,274	71,988.9		0.0	0.0
5,281	98	13,334	102	306	52	2,096	1,015	8,200.9		0.0	842.5
1,585	835	490	3,944	1,002	988	3,990	2,296	8,709.0		0.0	0.0
2,496	973	888	272	7,443	4,145	1,147	1,301	16,986.8		0.0	0.0
5,910	2,231	563	397	967	607	2,522	2,326	42,922.5		0.0	47.8
10,581	1,670	3,930	3,132	3,203	3,730	8,929	9,366	9,300.6		28.8	1,241.9
1,067	638	218	253	206	247	3,866	7,086	45,938.6		6,307.2	98,984.8

Source: own elaboration. Data: INE

Table 4.9: SPAM00 (million euros). Spain, 2000. (continued)

Value Added Categories					Auxiliary Accounts						
Compensation of employees		Operating surplus/mixed income, gross	Other net taxes on production		Net taxes on products				Income tax	Social contributions (employees)	Welfare benefits
Wages and salaries	Social contributions (employers)		Taxes on production	Subsidies on production	Import taxes	VAT	Other taxes on products	Subsidies on products			
33	34	35	36	37	38	39	40	41	42	43	44
				1,110				2,875			
				25				512			
				6				0			
				11				1			
				3				1			
				13				12			
				9				1			
				57				77			
				253				1,550			
				111				186			
				38				3			
				73				6			
				114				8			
				7				0			
				18				3			
				24				2			
				25				1			
				266				7			
				366				69			
				202				121			
				639				23			
				193				18			
				380				1,621			
				51				38			
				86				4			
				157				0			
				454				89			
				256				419			

Source: own elaboration. Data: INE

Table 4.10: SFAM00 (million euros). Spain, 2000. (continued)

Auxiliary Accounts			Gross Capital formation		Foreign Sector	
Other current transfers	Property income	Adjustments for the change in net equity of households on pension funds reserves	Private	Public	Intra-EU	Extra-EU / ROW
45	46	47	48	49	50	51
			1,070.3	30.0	6,635.3	1,003.4
			-2.8	0.0	1.5	0.7
			161.4	0.0	3.5	0.0
			7.8	0.0	311.0	301.7
			246.7	0.0	3,161.1	2,167.1
			0.0	0.0	26.5	96.0
			-116.0	0.0	0.0	0.0
			-1.9	0.0	0.0	0.0
			419.2	0.0	7,322.2	3,069.3
			244.3	5.9	5,267.9	2,774.6
			97.7	2.7	672.1	267.4
			127.7	0.0	2,643.4	1,228.8
			349.6	2.7	11,119.2	4,963.0
			-20.8	0.0	94.5	71.9
			-32.3	0.0	589.3	176.2
			127.6	0.0	1,001.5	1,311.7
			53.2	1.8	685.4	234.4
			3,363.0	721.9	6,759.5	3,182.0
			45,423.6	2,654.5	42,753.1	15,538.8
			63,816.1	15,153.6	3.0	6.0
			0.0	0.0	591.0	681.0
			0.0	0.0	0.0	0.0
			0.0	0.0	7,067.0	4,221.0
			0.0	0.0	561.0	186.0
			0.0	0.0	2,104.0	714.0
			7,517.2	1,334.7	17.0	26.0
			17,116.3	0.0	5,937.0	4,373.0
			876.0	47.5	367.0	409.0

Source: own elaboration. Data: INE

Table 4.11: SPAMCC (million euros). Spain. 2000. (continued)

				Economic Sectors							
				1	2	3	4	5	6	7	8
Institutions	HH		29								
	Companies		30								
	NPISH		31								
	Gov		32								
Value Added Categories	Compensation of employees	Wages and salaries	33	3,227	368	23	363	306	1,080	105	570
		Social contributions (employers)	34	469	169	8	129	135	462	43	236
	Operating surplus / mixed income, gross		35	20,634	87	37	459	1,983	6,436	823	659
	Other net taxes on production	Taxes on production	36	139	5	1	13	20	274	27	20
		Subsidies on production	37								
Auxiliary Accounts	Net taxes on products	Import taxes	38	56	0	2	1	4	1	0	0
		VAT	39	629	12	0	7	2,114	1,042	116	121
		Other taxes on products	40	32	0	0	0	10,248	639	71	0
		Subsidies on products	41								
	Income tax		42								
	Social contributions (employees)		43	167	60	3	46	48	164	15	84
	Welfare benefits		44								
	Other current transfers		45								
	Property income		46								
	Adjustments for the change in net equity of households on pension funds reserves		47								
Gross Capital formation	Private		48								
	Public		49								
Foreign Sector	Intra-EU		50	2,832	41	550	260	2,663	116	0	0
	Extra-EU / ROW		51	3,361	638	14,900	1,440	2,671	2	0	0

Source: own elaboration. Data: INE

Table 4.12: SEAM00 (million euros). Spain. 2000. (continued)

Economic Sectors											
9	10	11	12	13	14	15	16	17	18	19	20
5,703	3,424	1,089	3,214	4,849	252	382	1,023	1,197	6,253	13,589	20,899
2,111	1,101	365	1,007	2,000	103	180	382	407	2,294	4,988	7,133
5,695	2,407	919	3,468	5,278	871	469	744	1,137	6,510	9,730	14,913
117	49	19	53	124	14	13	17	22	84	156	747
243	171	4	9	84	0	6	4	1	35	452	0
4,210	3,295	60	598	1,487	1	57	42	9	255	6,571	0
5,616	25	2	4	20	0	4	3	1	12	1,386	1,117
751	392	130	358	711	38	57	125	145	816	1,774	2,536
6,892	4,720	994	4,086	18,017	59	723	302	333	9,964	58,264	7
4,098	4,504	857	776	5,210	186	198	164	69	3,278	19,503	11

Source: own elaboration. Data: INE

Table 4.13: SEAMCC (million euros). Spain. 2000. (continued)

Economic Sectors								Institutions			
21	22	23	24	25	26	27	28	29	30	31	32
24,686	17,961	7,484	3,521	10,158	2,794	22,779	64,353				
6,931	3,028	2,606	1,038	3,501	758	6,057	19,197				
33,087	20,515	14,464	8,286	10,720	44,220	15,902	25,034				
957	267	262	162	230	3,234	328	500				
											3,975
0	0	0	0	0	0	0	0				
1,202	4,586	1,200	1,487	52	552	2,374	1,384				
0	0	0	15	849	0	6,140	1,898				
											3,150
								43,939	20,255		
2,464	1,077	927	369	1,245	270	2,154	6,826		0	0	0
								266	7,820	30	75,470
								35,714	21,344	1,206	98,039
								9,941	105,694	120	20,462
									1,445		
								46,745	74,131	398	
											19,018
546	260	3,718	524	2,178	19	8,546	908	2,964			3,632
410	348	2,114	294	476	17	4,873	1,142	2,597			

Source: own elaboration. Data: INE

Table 4.14: SFAMCC (million euros). Spain, 2000. (continued)

Value Added Categories					Auxiliary Accounts						
33	34	35	36	37	38	39	40	41	42	43	44
221,545	207	124,227								0	83,537
	6,566	121,083								2,699	
	17	283								0	
	59,938	9,915	7,851		1,073	38,380	27,883		64,002	21,208	
301	5								105	134	49
391	54								136	101	77

Source: own elaboration. Data: INE

Table 4.15: SPAMCC (million euros). Spain. 2000. (continued)

Auxiliary Accounts			Gross Capital formation		Foreign Sector	
45	46	47	48	49	50	51
38,209	38,008	1,446			26,734	6,004
16,498	83,863					
6,534	346					
94,839	7,017					
					335	260
					980	
			4,920			
					4,483	
					23	26
					234	161
					29	48
					3,496	2,720
					15,290	6,751
					6,676	17,813
						837
3,812	25,239					
2,826	3,785					

Source: own elaboration. Data: INE

Chapter 5

The Model

5.1 Producers

5.1.1 Production technology

The production process

Figure (5.1) provides an overview of the production technology. Production follows a 'top-down approach'[1] and is described by a six-stage nested function, allowing for a flexible treatment of substitution elasticities that reflect adjustment possibilities in the demand for production factors, originating from variations in their relative prices. The description of the production nesting should reflect the presumption about how the economic system operates. It starts from aggregate output and unfolds until at the end of each branch an intermediate good or factor of production is specified. This approach supposes that the unique output aggregate, with its own unique price, is the result of a cost minimisation process performed by the firms that combine the non-energy intermediate inputs with an aggregate of all the remaining production factors (labour, capital, energy), which are themselves disaggregated into lower nests, until the demands for homogeneous factors are specified. This specification follows a production structure similar to the GTAP-E model [Burniaux *et al.*, 2002].

Since the optimal production behaviour may be represented in a primal or dual formulation[2], the dual form is exploited for presenting the equations. In each stage,

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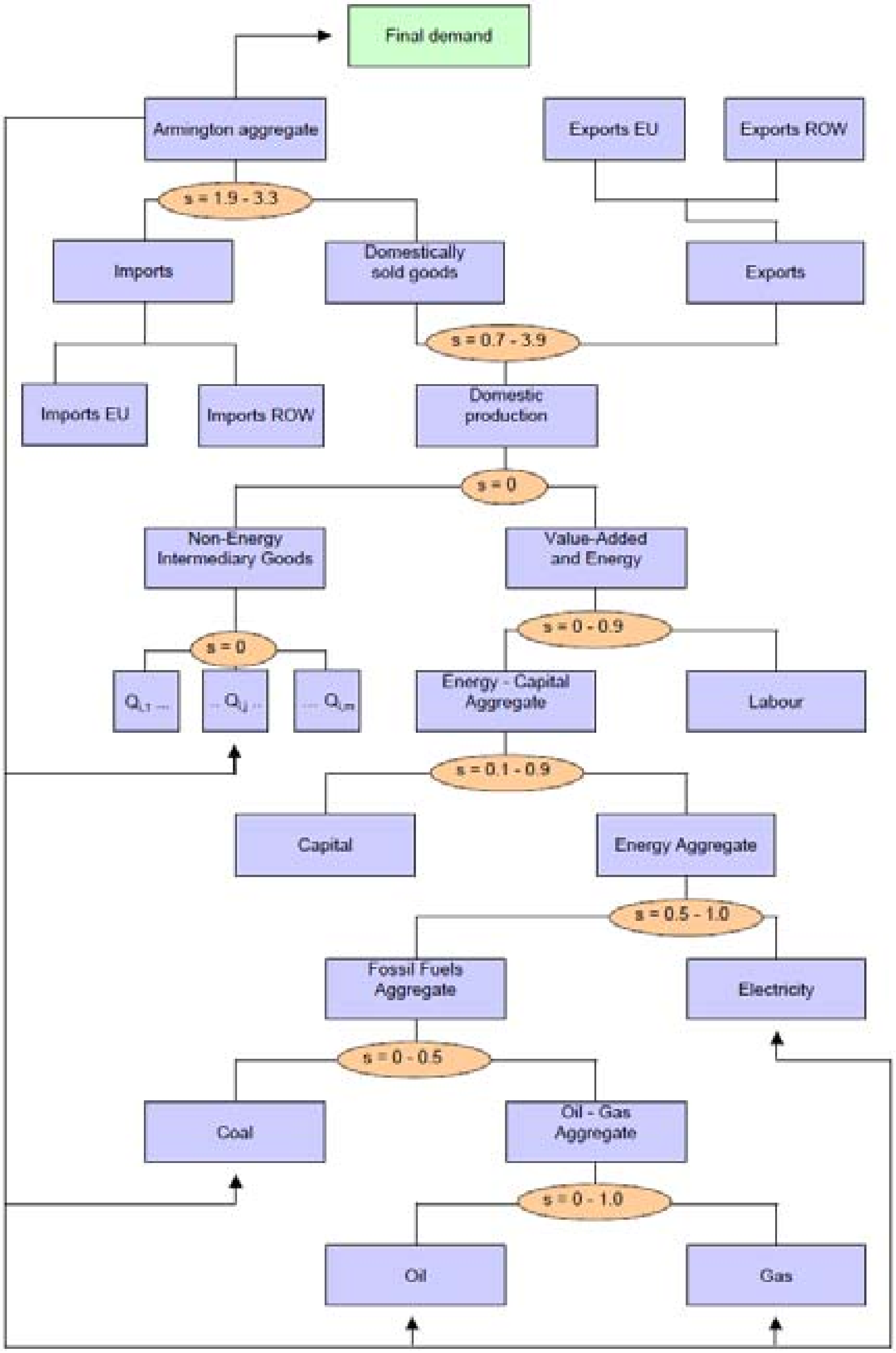
[1] The 'top-down approach' starts with a detailed description of the macroeconomy and then derives the demand for energy and factors inputs in terms of the demand for various sectors' outputs through highly aggregate production or cost functions.

[2] The primal formulation represents preferences and technology by utility and production functions, whereas the dual formulation represents them by expenditure and cost functions. In that case, the independent variable is the price and not the quantity as in the primal case. Like the production function, the cost function can be seen as a description of the technological constraints of the produc-

Figure 5.1: Production technology structure.



firms' objective functions are cost functions. The production function of every industry is assumed to be a strictly increasing, twice continuously differentiable, quasi-concave function, possessing a unique dual cost function. The cost function is twice continu-

---

tion sectors. Under certain assumptions and because we use homogeneous functions of degree one, equivalence between profit maximisation and cost minimisation can be easily verified. See Varian [1992], chapter 6 and Cornes [1992].

ously differentiable, concave and linear-homogeneous in price, and increasing with the quantity produced from zero to infinity.

The producer is assumed to minimise the cost of supplying a given quantity of aggregated output, subject to the production technology. The optimal quantities of primary factors and intermediate goods are then directly derived from first order conditions, on the basis of the cost minimization principle, as a function of their relative prices and output level. In the perfect competition scenario, each producer uses a set of factors up to the limit where the marginal revenue product of each factor is equal to its marginal cost (factor price or rent). Activity-specific commodity prices are derived to clear the market for each domestic output.

Modeling the energy and primary factors linkages

In this study, the modeling of the production technology tree raises two important questions about the structure of the substitution possibilities between the different inputs. First, between alternative fuels (inter-fuel substitution) and, second, between the energy aggregate as a whole and other primary factors, such as labor and capital (fuel-factor substitution). The structure of inter-fuel substitution in production we present allows for three levels of nested substitution. First, a substitution between electricity and a 'non-electric' composite fuel. Second, within the non-electric branch, a substitution between coal and an aggregate of the two other fossil fuels (oil and gas). And, third, a substitution between oil and gas, within the non-coal branch.

The fuel-factor substitution question, in particular the issue of the energy-capital complementarity or substitutability, is still an important debate in the literature of energy taxation studies, as it appears to be a crucial factor in the adjustment of aggregate output to energy price changes [Vinals, 1984; Burniaux *et al.*, 1992]. The scope for substitutability across carbon-intensive energy goods and primary production factors is thus emphasised. When output is produced according to a technology in which labour (L), capital (K) and energy (E) are substitutable, most models acknowledge the higher likely substitutability between K and E than between L and E.

The nesting of the productive factors L, K and E is similar to the one described, for instance, in the GREEN model [Burniaux *et al.*, 1992; van der Mensbrugghe, 1994], in the Belgian SPOT model [Bréchet, 1999], in the model of Wendner [2001] or in the GTAP–E model [Burniaux and Truong, 2002]. In this fuel-factor substitution, the general assumption is that energy and capital are weakly separable in production such that firms choose the cost-minimizing energy-mix given an energy-capital bundle.

This nesting choice is preferred to the one based on an K-L aggregate for several reasons[3]. First, because the substitution elasticity between L and E may be quite different from the substitution elasticity between K and E [Kemfert, 1998; Kemfert and Welsch, 2000]. Second, because it reflects the idea that energy production and utilization requires appropriate equipment, implying that energy and capital are quasi-complements[4]. Third, aggregating energy together with capital indicates that new technologies, embodied in new capital goods, can be the reason of energy substitution trends and energy saving patterns. In the short run, an increase in energy price would probably not generate an immediate substitution between energy and capital in any given technology, thus making K and E complements within a given technology structure. But in the longer run, the energy price rise may imply the introduction of a less energy-intensive but more capital intensive technology, so that K and E become substitutable for each other. Thus, given an energy price increase, although the capital factor cannot be used to replace energy immediately in any given technology, in the longer run the function of substitutability between K and E becomes more important as less energy-intensive but more capital intensive technology is put in place, to counter the energy price rise. The crux to the problem of specification is that a model must allow to represent the flexibility (in energy usage) in the long run but also allow for rigidity or inflexibility in the short to medium term due to capital constraint[5].

Production Prices

The price mechanism plays a key role in allocating resources in the economy. The description of prices proceeds usually in the opposite direction as the one presented for factor demands. The price disaggregation follows a bottom-up approach, starting from the bottom of the tree and moving up the price formation, as shown in *Figure* (5.2). At the bottom of the three, it is assumed that basic prices are determined as equilibrium prices on the factors and goods markets. The "basic" prices include the effective price of each energy component, the price of the labour and the capital factors and the prices of the non-energy intermediary goods. For considering the capital and labour prices identical in each sector, we assume that labour and capital are perfectly mobile within domestic sectors to enable wage rates to adjust between these sectors.

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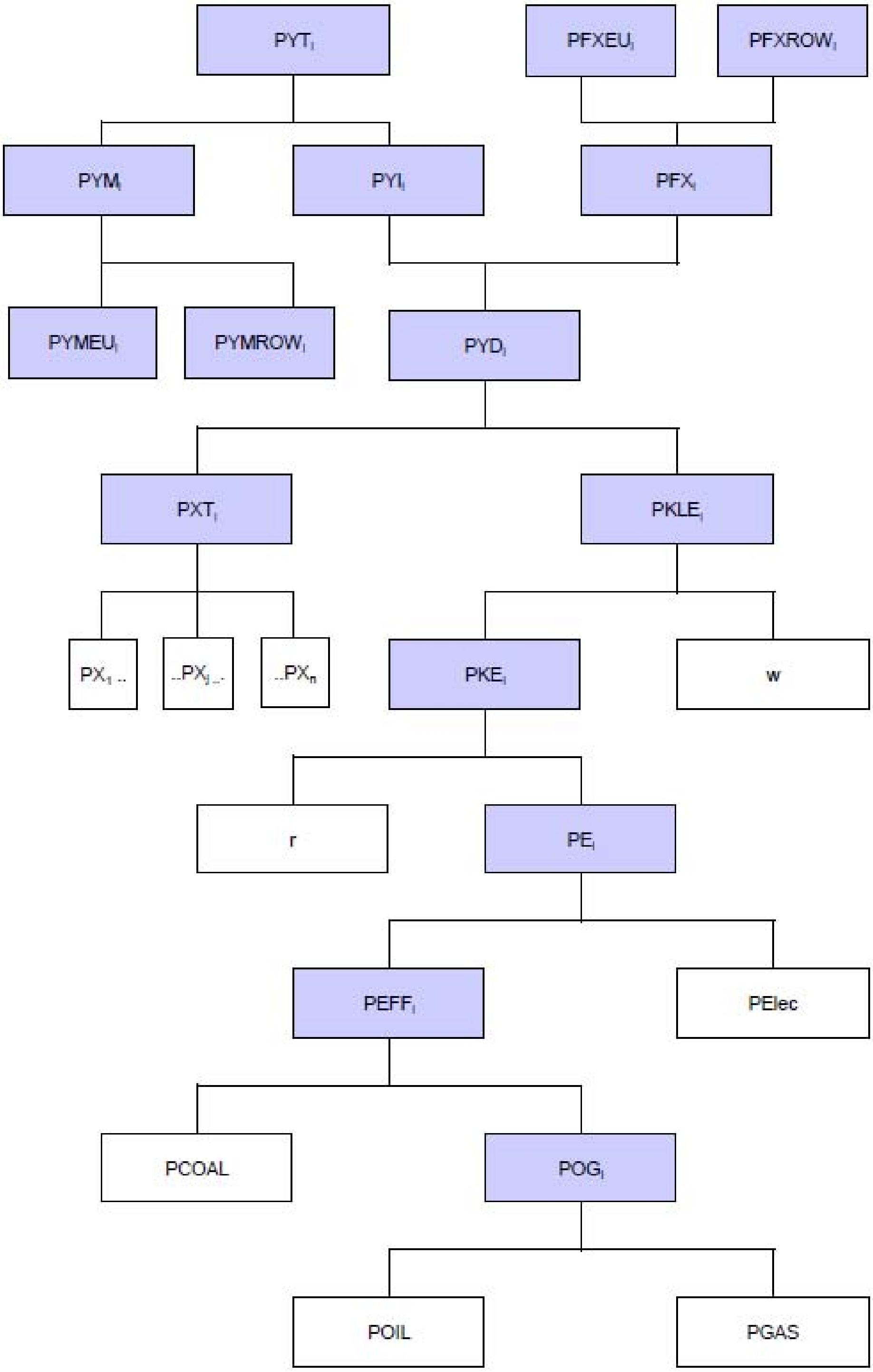
[3] This approach represents one of the many nesting possibilities. For instance, the GEM-E3 model [Capros *et al.*, 1998] considers quite a different structure by differentiating on the first nest capital from an aggregate of labour, energy and materials bundle. This aggregate is further disaggregated between electricity and the rest of the components, which are then split between fuels (coal, oil and gas), labour and materials.

[4] However, in her study for the German industry, Kemfert [1998] obtains substitution elasticities for all combinations lying in the range between zero and one, showing that these three factors are imperfect substitutes, not complements. She neither finds empirical evidence that labour is a similar substitute for both energy and capital.

[5] Due to the fact that energy-capital substitutability is a long-term adjustment process, empirical estimates of the substitution elasticity tend to vary significantly between empirical studies.

Figure 5.2: Production prices structure.



Once the basic prices are specified, the higher levels equilibrium producer prices can be derived from them as the unit costs duals of production functions (CES or Leontief equations). It reflects the idea that if the basic prices are uniform across sectors and are therefore economy-wide prices, the derived prices are not and vary among sectors, due to the difference in input mix between sectors. This implies that the marginal cost pricing rule generates different sector-specific prices. We suppose also that the small country assumption holds, Spain being unable to affect world prices. Its imports and exports prices are therefore considered exogenously fixed in foreign currency.

We now present the production structure, following a bottom-up approach. Formally this is done in two steps. Starting from the energy nest of the different sectors and the assumption that producers minimize their costs, we first derive demand functions for the productions factors (energy inputs, labour and capital). Once we have specified the inputs demand functions that minimize the marginal production cost in each sector, we determine the production volume that maximizes profit.

5.1.2 Production Structure

Sixth level : Oil - Gas aggregate

The lowest level disaggregates the oil/gas aggregate into demand for refined oil and demand for natural gas. In this final level of the energy nest, the producer minimises the cost of the oil-gas bundle subject to the CES production function that describes the industry-specific substitution possibilities between the refined oil composite, OIL_i, and the gas composite, GAS_i.

$$\underset{OIL_i,GAS_i}{min} POG_i \cdot OG_i = \left(1+\tau_{OIL}^{CO_2}+\tau_{OIL}^{ENE}\right) POIL \cdot OIL_i + \left(1+\tau_{GAS}^{CO_2}+\tau_{GAS}^{ENE}\right) PGAS \cdot GAS_i \tag{5.1}$$

$$s.t. \qquad OG_i = b_{OG,i}\left[\alpha_{OIL_i} OIL_i^{-\rho_i^{OIL}} + (1-\alpha_{OIL_i}) GAS_i^{-\rho_i^{OIL}}\right]^{-\frac{1}{\rho_i^{OIL}}} \tag{5.2}$$

where

$POIL$: unitary price of the oil fuel composite

$PGAS$: unitary price of the gas fuel composite

$\tau_f^{CO_2}$: ad-valorem tax on CO_2 emissions from fuel f consumption (with $f \in i$and $f \subset$(coal, gas, oil))

τ_{ene}^{ENE} : ad-valorem tax on energy from fuel f consumption (with $ene \in i$ and $ene \subset$(coal, gas, oil, electricity))

$b_{OG,i}$: scaling term for the oil-gas aggregation function ($b_{OG,i} > 0$)

α_{OIL_i} : CES share parameter (share of oil composite in the OG_i aggregate) ($0 \leq \alpha_{OIL_i} \leq 1$)

ρ_i^{OIL} : substitution parameter b/ the oil composite and the gas composite ($-1 \leq \rho_i^{OIL} \leq \infty$ and $\rho_i^{OIL} \neq 0$)

The scaling term $b_{OG,i}$ ensures that the OG_i aggregate volume will be equal to the composition of the amounts of OIL_i and GAS_i that have produced it. It can be interpreted as an efficiency parameter in the CES production function. Note also that the substitution parameter is a transformation of the elasticity of substitution between the oil composite and the gas composite, σ_i^{OIL}. Both parameters are related in the following way:

$$\sigma_i^{OIL} = \frac{1}{1+\rho_i^{OIL}} \Leftrightarrow \rho_i^{OIL} = \frac{1-\sigma_i^{OIL}}{\sigma_i^{OIL}} \ , \ 0 \leq \sigma_i^{OIL} \leq \infty \tag{5.3}$$

Using this relation, the CES function can be written as,

$$OG_i = b_{OG,i} \left[\alpha_{OIL_i} OIL_i^{1-\frac{1}{\sigma_i^{OIL}}} + (1-\alpha_{OIL_i}) GAS_i^{1-\frac{1}{\sigma_i^{OIL}}} \right]^{\frac{\sigma_i^{OIL}}{\sigma_i^{OIL}-1}} \tag{5.4}$$

The solution to the optimisation problem provides the reduced F.O.C. that specify the demanded volume of oil and gas composites[6]:

$$OIL_i^* = \frac{\alpha_{OIL_i}^{\sigma_i^{OIL}}}{b_{OG,i}} \left(\frac{POG_i}{\left(1+\tau_{OIL}^{CO_2}+\tau_{OIL}^{ENE}\right) POIL} \right)^{\sigma_i^{OIL}} \cdot OG_i \tag{5.5}$$

$$GAS_i^* = \frac{(1-\alpha_{OIL_i})^{\sigma_i^{OIL}}}{b_{OG,i}} \left(\frac{POG_i}{\left(1+\tau_{GAS}^{CO_2}+\tau_{GAS}^{ENE}\right) PGAS} \right)^{\sigma_i^{OIL}} \cdot OG_i \tag{5.6}$$

Finally, equation (5.7) gives the optimal mix of oil and gas fuels and is described as a function of the relative prices of both inputs and the share parameters. It shows that a decline in the price of one input relative to the other source would directly shift demand in its favour, without totally eliminating demand for the other higher-price input. The role of the elasticity of substitution appears clearly: the higher the elasticity σ_i^{OIL}, the larger the optimal change in the ratio between the quantities of both inputs in response to changes in their relatives prices.

$$\frac{OIL_i^*}{GAS_i^*} = \left(\frac{\alpha_{OIL_i}}{(1-\alpha_{OIL_i})} \frac{\left(1+\tau_{GAS}^{CO_2}+\tau_{GAS}^{ENE}\right) PGAS}{\left(1+\tau_{OIL}^{CO_2}+\tau_{OIL}^{ENE}\right) POIL} \right)^{\sigma_i^{OIL}} \tag{5.7}$$

At the price level, equation (5.8) specifies the derived price for the oil-gas bundle

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[6] The conditional factor demands corresponding to the CES technology can be derived from the cost function using Sheppard's Lemma

as a CES dual price of the oil price and the gas price, both defined as basic prices.

$$\begin{aligned} POG_i \;=\; & \frac{1}{b_{OG,i}} \Big[\alpha_{OIL_i}^{\sigma_i^{OIL}} \cdot \left(\left(1+\tau_{OIL}^{CO_2}+\tau_{OIL}^{ENE}\right) POIL \right)^{1-\sigma_i^{OIL}} && (5.8) \\ & +(1-\alpha_{OIL_i})^{\sigma_i^{OIL}} \cdot \left(\left(1+\tau_{GAS}^{CO_2}+\tau_{GAS}^{ENE}\right) PGAS \right)^{1-\sigma_i^{OIL}} \Big]^{\frac{1}{1-\sigma_i^{OIL}}} && (5.9) \end{aligned}$$

Multiplication of this price index with OG_i defines the expenditures on the composite good.

Fifth level : Fossil fuels aggregate

On the fifth level, the fossil fuels aggregate is decomposed into coal, $COAL_i$, and the aggregate OG_i. The incorporation of this nesting level in the production structure is aimed to account for the difference in substitutability between subsets of the energy inputs, such as the low substitutability between coal and gas compared to the one between oil and gas.

$$\min_{OG_i, COAL_i} PEFF_i \cdot EFF_i = POG_i \cdot OG_i + \left(1+\tau_{coal}^{CO_2}+\tau_{coal}^{ENE}\right) PCOAL \cdot COAL_i \tag{5.10}$$

$$s.t. \qquad EFF_i = b_{EFF,i} \left[\alpha_{OG_i} OG_i^{\,1-\frac{1}{\sigma_i^{OG}}} + (1-\alpha_{OG_i}) COAL_i^{\,1-\frac{1}{\sigma_i^{OG}}} \right]^{\frac{\sigma_i^{OG}}{\sigma_i^{OG}-1}} \tag{5.11}$$

where

POG_i : CES dual price of the oil/gas aggregate

$PCOAL$: unitary price of the coal fuel composite

$b_{EFF,i}$: scaling term for the aggregate fossil fuels function

α_{OG_i} : share of the oil/gas bundle in the EFF_i aggregate

σ_i^{OG} : CES parameter b/ the coal composite and the oil/gas aggregate

The equations (5.12) and (5.13) provide the reduced form F.O.C. for the oil/gas aggregate demand OG_i^* and the coal demand $COAL_i^*$,

$$OG_i^* = \frac{\alpha_{OG_i}^{\sigma_i^{OG}}}{b_{EFF,i}} \left(\frac{PEFF_i}{POG_i} \right)^{\sigma_i^{OG}} \cdot EFF_i \tag{5.12}$$

$$COAL_i^* = \frac{(1-\alpha_{OG_i})^{\sigma_i^{OG}}}{b_{EFF,i}} \left(\frac{PEFF_i}{\left(1+\tau_{coal}^{CO_2}+\tau_{coal}^{ENE}\right) PCOAL} \right)^{\sigma_i^{OG}} \cdot EFF_i \tag{5.13}$$

The maximisation process requires that the CES dual price that incorporates the coal fuel composite price and the oil-gas bundle price, be equal to the average unit cost of producing the non-electric fuels bundle, as defined in equation (5.14).

$$\begin{aligned} PEFF_i \;=\; & \frac{1}{b_{EFF,i}} \Big[\alpha_{OG_i}^{\sigma_i^{OG}} \cdot POG_i^{1-\sigma_i^{OG}} \\ & + (1-\alpha_{OG_i})^{\sigma_i^{OG}} \cdot \left(\left(1+\tau_{coal}^{CO_2}+\tau_{coal}^{ENE}\right) PCOAL \right)^{1-\sigma_i^{OG}} \Big]^{\frac{1}{1-\sigma_i^{OG}}} \end{aligned} \tag{5.14}$$

Fourth level : Energy aggregate

The first level of the energy nesting is specified by splitting the energy aggregate into demand for the electric fuel, $Elec_i$, and demand for the non-electric aggregate, EFF_i. This disaggregation is considered equivalent to distinguishing electric fuels from fossil-fuels. This distinction allows to focus on the crucial impact that electricity generation technologies may have in terms of CO_2 emissions. And it may unveil the historically trend of "electrification" in the Spanish economy.

$$\underset{Elec_i, EFF_i}{min} PE_i \cdot E_i = \left(1+\tau_{elec}^{ENE}\right) PElec \cdot Elec_i + PEFF_i \cdot EFF_i \tag{5.15}$$

$$s.t. \qquad E_i = b_{E,i} \left[\alpha_{Elec_i} Elec_i^{1-\frac{1}{\sigma_i^{Elec}}} + (1-\alpha_{Elec_i}) EFF_i^{1-\frac{1}{\sigma_i^{Elec}}} \right]^{\frac{\sigma_i^{Elec}}{\sigma_i^{Elec}-1}} \tag{5.16}$$

where

$PElec_i$: unitary price of the electricity good

$PEFF_i$: CES dual price of the fossil fuels energy bundle

$b_{E,i}$: scaling term for the aggregate energy function

α_{Elec_i} : share of the electricity component in the E_i aggregate

σ_i^{Elec} : substitution elasticity between the electric fuel and the fossil fuels bundle

The solution to this minimisation problem yields the following optimal demands of electricity and fossil fuels aggregate,

$$Elec_i^* = \frac{\alpha_{Elec_i}^{\sigma_i^{Elec}}}{b_{E,i}} \left(\frac{PE_i}{\left(1+\tau_{elec}^{ENE}\right) PElec} \right)^{\sigma_i^{Elec}} \cdot E_i \tag{5.17}$$

$$EFF_i^* = \frac{(1-\alpha_{Elec_i})^{\sigma_i^{Elec}}}{b_{E,i}} \left(\frac{PE_i}{PEFF_i} \right)^{\sigma_i^{Elec}} \cdot E_i \tag{5.18}$$

Equation (5.19) defines the unit price for the aggregate energy bundle, which is composed of the electric fuel price and the fossil fuels bundle price.

$$PE_i = \frac{1}{b_{E,i}} \left[\alpha_{Elec_i}^{\sigma_i^{Elec}} \cdot \left(\left(1+\tau_{elec}^{ENE}\right) PElec \right)^{1-\sigma_i^{Elec}} + (1-\alpha_{Elec_i})^{\sigma_i^{Elec}} \cdot PEFF_i^{1-\sigma_i^{Elec}} \right]^{\frac{1}{1-\sigma_i^{Elec}}} \tag{5.19}$$

Third level: K-E structure

At the next stage in production, the capital-energy bundle is further disaggregated into its basic components: a perfectly mobile capital factor, K_i, and the energy bundle E_i. These energy aggregate and capital combine with a constant elasticity of substitution σ_i^K. The producer minimises the cost of the capital-energy bundle subject to the CES function,

$$\underset{K_i,E_i}{min} PKE_i \cdot KE_i = r \cdot K_i + PE_i \cdot E_i \tag{5.20}$$

$$s.t. \qquad KE_i = b_{KE,i}\left[\alpha_{K_i} K_i^{1-\frac{1}{\sigma_i^K}} + (1-\alpha_{K_i}) E_i^{1-\frac{1}{\sigma_i^K}}\right]^{\frac{\sigma_i^K}{\sigma_i^K-1}} \tag{5.21}$$

where
r : economy-wide price of capital services
PE_i : CES dual price of the energy bundle
$b_{KE,i}$: scaling term for the KE_i function
α_{K_i} : share of the capital component in the KE_i aggregate
σ_i^K : CES parameter between the capital factor and the energy bundle

The equations (5.22)and (5.23) provide the reduced form F.O.C. for capital demand and energy demand,

$$K_i^{d*} = \frac{\alpha_{K_i}^{\sigma_i^K}}{b_{KE,i}}\left(\frac{PKE_i}{r}\right)^{\sigma_i^K} KE_i \tag{5.22}$$

$$E_i^{*} = \frac{(1-\alpha_{K_i})^{\sigma_i^K}}{b_{KE,i}}\left(\frac{PKE_i}{PE_i}\right)^{\sigma_i^K} KE_i \tag{5.23}$$

Equation (5.24) specifies the CES dual price for the capital-energy bundle. The price of capital services is the effective rate of return on a given unit of capital, and so would include the profit generated in using the capital (gross of depreciation of the capital), and the interest payments to the financiers of capital. Under the assumption of perfect competition in each industry, the restriction of zero profits must hold as a long run perspective. This condition allows competition to arbitrage real profits away. The price of capital services can therefore be interpreted as the long-term real interest rate in the economy, r, identical for all sectors.

$$PKE_i = \frac{1}{b_{KE,i}}\left[\alpha_{K_i}^{\sigma_i^K} \cdot r^{1-\sigma_i^K} + (1-\alpha_{K_i})^{\sigma_i^K} \cdot PE_i^{1-\sigma_i^K}\right]^{\frac{1}{1-\sigma_i^K}}. \tag{5.24}$$

Second level: KE - L structure

The second nesting level concerns, on the one hand, the aggregate intermediate demand, X_i, and, on the other hand, the KEL_i aggregate. The KEL aggregate is broken down into an homogeneous labour factor and a capital-energy aggregate. A CES production function describes the industry-specific substitution possibilities between labour (L_i) and the capital-energy bundle (KE_i). The cost minimisation problem is the following,

$$\underset{KE_i,\, L_i}{min}\, PKEL_i \cdot KEL_i = PKE_i \cdot KE_i + w\,(1 + \theta_{ESSC,i} + \theta_{HSSC,i}) \cdot L_i \tag{5.25}$$

$$s.t. \qquad KEL_i = b_{KEL,i} \left[\alpha_{KE_i} KE_i^{1-\frac{1}{\sigma_i^{KE}}} + (1 - \alpha_{KE_i}) L_i^{1-\frac{1}{\sigma_i^{KE}}} \right]^{\frac{\sigma_i^{KE}}{\sigma_i^{KE}-1}} \tag{5.26}$$

where

PKE_i : CES dual price of the capital-energy bundle

w : wage rate

$\theta_{ESSC,i}$: employers' Social Security contributions rate

$\theta_{HSSC,i}$ employee's Social Security contributions rate

$b_{KEL,i}$: shift parameter for the KEL_i function

α_{K_i} : share of the capital-energy bundle in the KEL_i aggregate

σ_i^K : substitution elasticity between labour and the capital-energy aggregate

The optimal demands for L_i^d and KE_i are the following,

$$KE_i^* = \frac{\alpha_{KE_i}^{\sigma_i^{KE}}}{b_{KEL,i}} \left(\frac{PKEL_i}{PKE_i} \right)^{\sigma_i^{KE}} KEL_i, \tag{5.27}$$

$$L_i^{d*} = \frac{(1 - \alpha_{KE_i})^{\sigma_i^{KE}}}{b_{KEL,i}} \left(\frac{PKEL_i}{w\,(1 + \theta_{ESSC,i} + \theta_{HSSC,i})} \right)^{\sigma_i^{KE}} KEL_i. \tag{5.28}$$

Equation (5.29) indicates the unitary price of the KEL bundle, equivalent to the marginal cost of producing one unit of the KEL bundle. The producer's price of the homogeneous labour factor is the gross average wage rate, more the employer's and employee's social security contributions to be paid.

$$PKEL_i = \frac{1}{b_{KEL,i}} \left[\alpha_{KE_i}^{\sigma_i^{KE}} PKE_i^{1-\sigma_i^{KE}} + (1 - \alpha_{KE_i})^{\sigma_i^{KE}} \left(w\,(1 + \theta_{ESSC,i} + \theta_{HSSC,i}) \right)^{1-\sigma_i^{KE}} \right]^{\frac{1}{1-\sigma_i^{KE}}} \tag{5.29}$$

Second level: X structure

The intermediate goods aggregate is also split into the n non-energetic intermediate products $X_{i,j}$, following a Leontief specification. There is no substitution of one intermediate good for another and output can increase only if the input of all factors increases proportionally. It is supposed that, given the desired quantity of the aggregate XT_i obtained in the superior level, the representative firm minimizes the unit cost of purchasing the aggregate XT_i, by allocating, in an optimal way, the factors that constitute it. The cost minimisation subject to the Leontief aggregation function[7] is written as

$$\min_{\sum_{j=1}^{n=24} X_{i,j}} PXT_i \cdot XT_i = \sum_{j=1}^{n=24} PX_j \cdot X_{i,j} \tag{5.30}$$

$$s.t. \qquad XT_i = min \left(\frac{X_{i,1}}{x_{i,1}}, ..., \frac{X_{i,n}}{x_{i,n}} \right) \tag{5.31}$$

where

PXT_i : price of the non-energy intermediate aggregate for sector i
$X_{i,j}$: quantity of the non-energy intermediate good j for sector i
PX_j : price of the non-energy intermediate good j
$x_{i,j}$: Leontief coefficient of the j intermediary input $X_{i,j}$ in the aggregate intermediary good

The demand for any intermediate good $X_{i,j}$ is obtained as a fixed proportion of the aggregate intermediary good,

$$X^*_{i,j} = x_{i,j} \cdot XT_i \tag{5.32}$$

The price specification of the aggregate XT_i is a weighted sum of all the prices of the intermediary inputs.

$$PXT_i = \sum_{j=1}^{n} x_{i,j} \cdot PX_j \tag{5.33}$$

First level : KEL - X structure

At the highest nest, every representative firm i minimizes the unit cost of producing the domestic output YD_i, by using, in an optimal way, the aggregate of n non-energy intermediary goods $X_{i,j}$ and an aggregate of capital, labour and energy inputs KEL_i.

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[7] This minimisation problem cannot be solved with the Lagrange method because the Leontief type production function in the constraint is not differentiable with respect to its inputs. To obtain the demand functions, we must use a CES function (as a generalized function of Leontief and Cobb-Douglas type functions), derive demand functions from it by the Lagrange method and evaluate them with elasticity of substitution at zero.

The composition of the non-energy intermediary good aggregate, XT_i, and the KEL_i aggregate is done according to a Leontief function, with fixed coefficients representing the inter-industrial linkages in the economy. This approach specifies that the intermediate inputs are not substitutable for the other factors[8]. The optimisation problem takes the following form:

$$\min_{X_i, KEL_i} PYD_i \cdot YD_i = PXT_i \cdot XT_i + PKEL_i \cdot KEL_i \tag{5.34}$$

$$s.t. \qquad YD_i = min\left(\frac{XT_i}{xt_i}, \frac{KEL_i}{kel_i}\right) \tag{5.35}$$

where

PYD_i	:	aggregate price of the domestically produced good of sector i
$PKEL_i$	:	CES dual price of value added plus energy for sector i
xt_i	:	Leontief coefficient of the aggregate intermediary input XT_i in sector i (quantity of aggregate intermediate input per activity unit of sector i)
kel_i	:	Leontief coefficient of the KEL_i aggregate in sector i

The demand for the intermediate goods aggregate, XT_i, and the demand for the KEL_i bundle are determined as fixed shares of the activity level,

$$XT_i^* = xt_i \cdot YD_i \tag{5.36}$$

$$KEL_i^* = kel_i \cdot YD_i \tag{5.37}$$

The producer price is equivalent to the unit cost of aggregate domestic production, non-inclusive of producer taxes/subsidies, and follows the Leontief specification function between the KEL bundle and the non-energy intermediate inputs aggregate. This producer price, PYD_i, is given by equation (5.38).

$$PYD_i = PXT_i \cdot xt_i + PKEL_i \cdot kel_i \tag{5.38}$$

Aggregate output allocation: Destination markets

Since goods in the model are traded in world markets, the total marketed domestic output of sector i, resulting from the production process, is oriented towards two alternative destinations: domestic sales and export markets. It is supposed that the domestic producers perceive the domestic market as different from the export market,

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[8] This restriction of non-substitution between intermediates inputs and primary factors is a very common specification in CGE models. However, some substitutability can take place, like during the energy price shocks of the 1970s, when firms started to save fuel via the purchase of new, more energy efficient capital equipment.

so that imperfect transformability between the domestic market and the export market may be assumed. The first reason to consider imperfect transformation is based on aggregation considerations. Given that a CGE model tends to group together industries with different export shares, a higher sectoral aggregation (i.e., wider product coverage) will involve a higher probability that the exported goods differ from the domestically-sold ones. As a consequence, the larger the sectoral aggregation, the lower the value of the transformation elasticities. Second, imperfect transformability may be due to some difficulty to penetrate export markets, which might force different quality standards for the export market than those applicable for the domestic market.

The Constant Elasticity of Transformation (CET) function is usually used to reflect the imperfect transformability between two destinations. The specification of the CET function is formally identical to a CES function, except for the sign of the substitution parameters, and is somewhat symmetric to the Armington assumption used on the import side.

Due to imperfect transformability and to differences in taxation that affect the domestic and foreign markets, the sales price of domestically produced goods supplied on the domestic market should differ from the sales price of exports. In a model of a small open economy, this last price is obtained by applying the real exchange rate ER to the exogenous foreign currency world prices, $\overline{PEX}_i$. The gross-of-tax export prices and the gross-of-tariff import prices tend to get closer to world prices as the elasticity of transformation between domestic sales and exports in production and the elasticity of substitution between domestically produced goods and imports in consumption approach infinity.

In this case, the optimisation problem is formulated somewhat differently since the interest of the domestic producer is not anymore to minimise costs, but to maximise sales. To decide how to optimally allocate the total supply between domestically sold and exported commodities, it is assumed that producers maximise the value of their supply mix subject to a CET function (the technological frontier), and in response to the market-clearing price ratio between domestic and export markets.

$$\underset{YI_i,EX_i}{max} PYD_i^{CET} \cdot YD_i = (1+\tau_i^Y) \cdot PYI_i \cdot YI_i + (1+\tau_i^Y) \cdot \overline{PEX}_i \cdot ER \cdot EX_i \tag{5.39}$$

$$s.t. \qquad YD_i = b_{DF,i} \left[\alpha_{YI_i} {YI_i}^{\rho_i^{YI}} + (1-\alpha_{YI_i}) {EX_i}^{\rho_i^{YI}} \right]^{\frac{1}{\rho_i^{YI}}} \tag{5.40}$$

where

PYD_i^{CET} : CET unit price of the total output supplied of good i
YI_i : output of sector i sold in the domestic market
EX_i : quantity of total output i sold in the foreign market
$\overline{PEX}_i$: exogenous price for good i set by the rest of the world
τ_i^Y : net tax rate on production of good i
$b_{DF,i}$: CET function shift parameter
α_{YI_i} : share of the total output YT_i for domestic sales
ρ_i^{YI} : transformation parameter between the domestic good and the exported good

The CET function has a similar functional form than the CES function, but is concave with respect to the origin. Hence, the transformation parameter ρ_i^{YI} is also related to the elasticity of transformation σ_i^{YI} but in the mathematical statement, the negative sign in front of the function exponent disappears[9].

$$\rho_i^{YI} = \frac{\sigma_i^{YI} + 1}{\sigma_i^{YI}} \Leftrightarrow \sigma_i^{YI} = \frac{1}{\rho_i^{YI} - 1}$$

The optimal mix between domestic sales and exports, given in the F.O.C. condition (5.41), indicates that an increase in the domestic-export price ratio generates a shift toward the destination that proposes the higher return, that is an increase in the domestic-export supply ratio. Given that the optimal amount of the locally produced good sold in the domestic market, YI_i^*, is a function of the Armington aggregate, YT_i; once the value of YI_i^* is known, the value of EX_i^* can be derived. Hence, the optimal amount of export product EX_i^* is implicitely also a function of the Armington aggregate, YT_i.

$$\frac{YI_i^*}{EX_i^*} = \left(\frac{(1 - \alpha_{YI_i})}{\alpha_{YI_i}} \frac{(1 + \tau_i^Y) \cdot PYI_i}{(1 + \tau_i^Y) \cdot \overline{PEX}_i \cdot ER} \right)^{\sigma_i^{YI}} \tag{5.41}$$

Finally, equation (5.42) defines the CET unit price of the total output supplied of good i. It corresponds to the price received by the suppliers, inclusive of producer taxes/subsidies. It is therefore the price that satisfies the zero profit condition such that, at this price, the return from selling one unit of output YD_i is equivalent to the unit cost of producing this output, defined as the sum of all inputs factors per output

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[9] The range of the function exponent remains ($-1 \leq \rho_i^{YI} \leq \infty$ and $\rho_i^{YI} \neq 0$).

unit multiplied by their respective prices, including the taxes.

$$\begin{aligned} PYD_i^{CET} &= \frac{1}{b_{DF,i}} \Big[\alpha_{YI_i}^{-\sigma_i^{YI}} \cdot \big((1+\tau_i^Y) \cdot PYI_i \big)^{1+\sigma_i^{YI}} \\ &\quad + (1-\alpha_{YI_i})^{-\sigma_i^{YI}} \cdot \big((1+\tau_i^Y) \cdot \overline{PEX}_i \cdot ER \big)^{1+\sigma_i^{YI}} \Big]^{\frac{1}{1+\sigma_i^{YI}}} \end{aligned} \tag{5.42}$$

Total domestic demand

All the demands for energy and non-energy intermediary goods are supplied by domestic and imported commodities. It is assumed that there are no binding foreign exchange constraints on the operation of the economy, so that energy and other intermediate inputs can be freely imported. To accommodate the phenomenon that a country imports a commodity with the same statistical classification as the one produced domestically, domestic and foreign goods are assumed to be imperfect substitutes, following Armington [1969]. The Armington specification allows an explicit representation of bilateral trade flows by assuming that aggregate marketed production of any "homogeneous" commodity i is generated by a combination of imported and domestic goods. It implies also that each country faces a downward-sloping demand curve for its exports. This approach of modelling imports is extensively used in CGE models since it appears more realistic than perfect substitutability between goods. It is examined in detail by de Melo and Robinson [1989] and by Devarajan, Lewis and Robinson [1990].

More specifically, the total domestic demand for each product i is captured by a CES composite, YT_i, of the locally produced good sold in the domestic market, YI_i, and the aggregate of imports, YM_i[10]. The latter is another function of the commodity imported from the EU countries and imports from the rest of the world. An expenditure minimization rule allows the determination of the optimal combination of the composites, with the ratio between demands from two competing origins (local and foreign) of the commodity depending on their price ratio. Given that the relevant prices for producers and consumers are the market prices at which transactions take place, it is necessary to take into account the distortionary taxes and subsidies that affect producer and consumer behaviour. The unit price of the domestically produced good i, PYI_i, is affected by the ad-valorem net tax rate on products sold domestically, τ_i^X. On the other side, the domestic price of imports is affected by an ad-quantum tariff rate for the non-EU contries only, $\tau_{i,ROW}^{YM}$, and the ad-valorem net tax rate on products sold domestically, τ_i^X. For the non-EU countries bundle, the import price

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[10] This Armington specification would be valid for all goods except for crude oil, which can be seen as an homogeneous good across regions. Therefore, the law of one price holds and domestic agents do not differentiate between crude oil produced domestically and crude oil produced abroad.

is composed of the exogenous price of imports from the rest of the world, in foreign currency, $\overline{PYM}_{i,row}$, multiplied by the real exchange rate, ER, in order to express the world market prices on internationally traded goods in domestic currency. For the EU region block, there is obviously no need to take into account the exchange rate and the import tariff, as the countries listed in that group belong to an economic union. Given these prices, the producer chooses the optimal mix between commodities from different sources that minimizes the aggregate production cost, subject to the Armington technological restriction,

$$\begin{aligned} \min_{YD_i,YM_i} PYT_i^{ARM} \cdot YT_i &= (1+\tau_i^X) \cdot PYI_i \cdot YI_i \qquad (5.43) \\ &\quad + \sum_{r=1}^{n=2} \left[\left(1+\tau_{i,ROW}^{YM}+\tau_i^X\right) \cdot \overline{PYM}_{i,r} \cdot ER \cdot YM_{i,r} \right] \\ s.t. \qquad YT_i &= b_{YT,i} \left[\alpha_{YD_i} YI_i^{1-\frac{1}{\sigma_i^{YD}}} + (1-\alpha_{YD_i}) \sum_{r=1}^{n=2} YM_{i,r}^{1-\frac{1}{\sigma_i^{YD}}} \right]^{\frac{\sigma_i^{YD}}{\sigma_i^{YD}-1}} \qquad (5.44) \end{aligned}$$

where

YT_i : total amount of good i supplied

PYT_i^{ARM} : Armington unit price of the total output supplied of good i

$YM_{i,r}$: quantity of imported good i from region r

$b_{YT,i}$: scaling term for the total supply aggregation function for sector i

α_{YD_i} : share of domestically produced good in the total supply for sector i

σ_i^{YD} : Armington elasticity of substitution b/ the domestic / imported good

The optimal demands of the domestic good i sold in the domestic market and the imported i good are the following,

$$YI_i^* = \frac{\alpha_{YD_i}^{\sigma_i^{YD}}}{b_{YT,i}} \left(\frac{PYT_i^{ARM}}{(1+\tau_i^X) \cdot PYI_i} \right)^{\sigma_i^{YD}} YT_i \qquad (5.45)$$

$$YM_{i,r}^* = \frac{(1-\alpha_{YD_i})^{\sigma_i^{YD}}}{b_{YT,i}} \left(\frac{PYT_i^{ARM}}{\left(1+\tau_{i,ROW}^{YM}+\tau_i^X\right) \cdot \overline{PYM}_i \cdot ER} \right)^{\sigma_i^{YD}} YT_i \qquad (5.46)$$

The optimal allocation depends on the ratio of domestic to import prices, given by the following first-order condition:

$$\frac{YI_i^*}{YM_i^*} = \left(\frac{\alpha_{YI_i}}{(1-\alpha_{YI_i})} \frac{\left(1+\tau_{i,ROW}^{YM}\right) \cdot \overline{PYM}_i \cdot ER}{PYI_i} \right)^{\sigma_i^{YD}} \qquad (5.47)$$

Equation (5.48) specifies the Armington unit price of the total output supplied, PYT_i^{ARM}, or absorption price (local currency) from the import price and the price of the locally produced good. This price includes the indirect taxation and is therefore the reference price of goods for intermediate consumption, government consumption and investment demand.

$$\begin{aligned} PYT_i^{ARM} \;=\; & \frac{1}{b_{YT,i}} \left[\alpha_{YD_i}^{\sigma_i^{YD}} \left((1+\tau_i^X) \cdot PYI \right)_i^{1-\sigma_i^{YD}} \right. \\ & \left. + (1-\alpha_{YD_i})^{\sigma_i^{YD}} \sum_{r=1}^{n=2} \left((1+\tau_{i,ROW}^{YM}+\tau_i^X) \cdot \overline{PYM}_i \cdot ER \right)^{1-\sigma_i^{YD}} \right]^{\frac{1}{1-\sigma_i^{YD}}} \end{aligned} \tag{5.48}$$

5.2 Household

5.2.1 Overview

The unique household class is represented by a single consumer who is endowed with labour and an initial stock of capital. Both capital and labour factors are supplied to other institutional sectors and are homogeneous and mobile across domestic industries, but internationally immobile. The main sources of household income revenue come from the returns of supplying primary factors of productions and from transfers from other domestic and foreign institutions. The representative household uses his disposable income, net of direct taxes, to consume goods and services, make transfers to other institutions and saves the rest. Government influences household decisions by means of transfers and taxes on consumption and on labour and capital income. The general-equilibrium approach to tax analysis allows to capture the important influences of these taxes on several household choices about labour supply, and the consumption of different commodities.

Like for the productive sectors, the consumer preferences are characterized by a multi-stage nesting structure that indicates how decisions are made in stages (see *Figure* (5.3)). The theory used for this static framework is standard and, following Ballard *et al.* [1985], considers an individual that maximizes a utility function, in stages. Consumers are assumed to be deciding on the optimal allocation of their given disposable income on saving and the consumption goods partitioned between 28 commodities that correspond to the preceding production sectors (see *Table* (4.3)). This maximisation provides all demands as functions of income and prices. Furthermore, the duality between expenditure and utility function is used. The dual decision problem for the household is to minimize expenditure in order to achieve a given utility.

In a first step, the consumer faces a consumption-savings decision[11]. He decides

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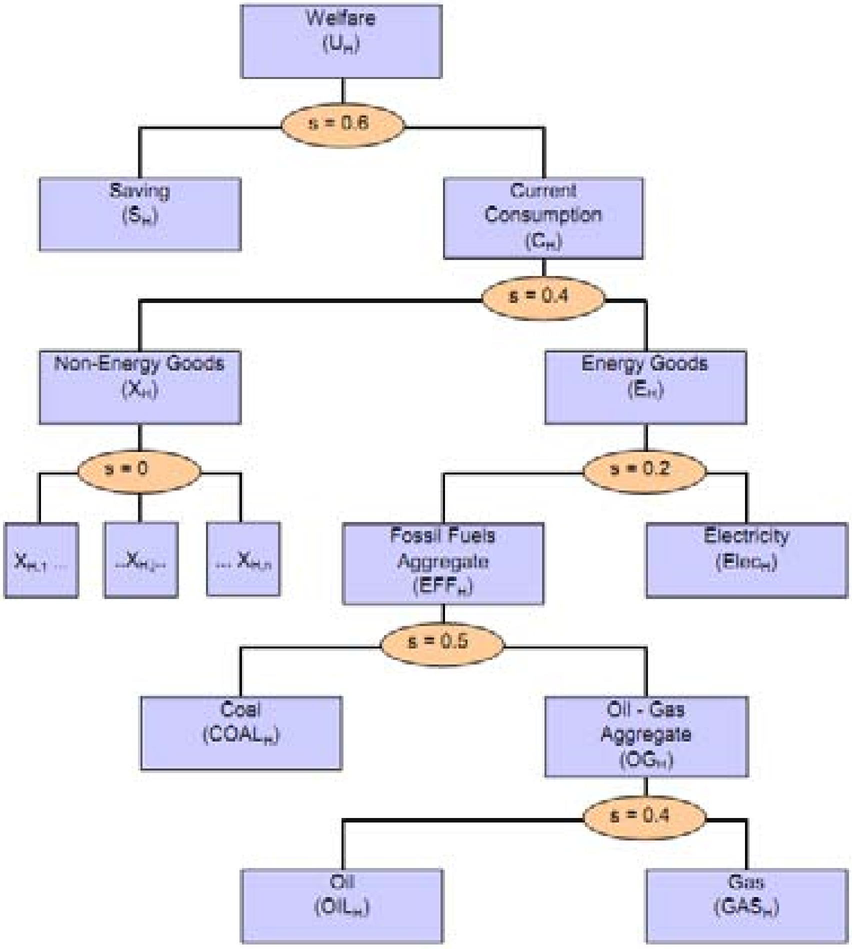
[11] As it will be explained, changes in future consumption are associated to changes in the level of

Figure 5.3: Consumption nesting structure.



therefore the proportion of his disposable income he wants to spend on present consumption and savings by maximising his intertemporal utility function subject to his budget constraint. That choice depends on assumptions about the form of the utility function and the intertemporal substitution elasticity that indicates the willingness to substitute full consumption between time periods. To allow saving to enter in the household utility function, it is treated as a "good" that is acquired for future consumption. Since no financial intermediation sector is included in the model, we suppose that household saving is directly rented to other institutional sectors to finance public and private investment. Saving takes therefore the form of purchase of investment commodities. These investment goods are supposed to be produced by a final demand sector that allocates the demand of investment commodities to industries producing durable and investment goods, according to the national accounting data for fixed private investment. In this static model, the representative household makes his saving decisions under the myopic expectation that all present prices will remain constant trough all future periods. After the consumption-savings decision has been

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savings.

made[12], the household decides the optimal mix between a non-energy consumption bundle and an energy aggregate. In this model, household utility is not influenced by environment quality.

The functional forms chosen for the different stages of the consumption function serve to highlight the intertemporal substitution possibilities, as well as the substitution possibilities between the energy sources. While the non-energy goods are aggregated within a Leontief function, the structure of energy demand follows the same nesting of inter-fuel substitution as in the case of producers' demand for energy. Before describing the whole consumption structure, we first specify the household disposable income.

Household income

As shown in expression (5.49), household gross income derives mainly from payments to production factors owned by him. Factors incomes include the rental value of labour and capital endowments sold. Labour income is equivalent to the product of the wage rate and labour employed. Labour employed is equivalent to the labour supply, L_H, minus labour supply times the unemployment rate, u. Capital income corresponds to the capital rents of the household's total capital endowment[13], K_H. The household receives also, from other domestic agents, property incomes, PIR_H, welfare benefits (including unemployment benefits), WBR_H, current transfers, CTR_H, and adjustments for change in net equity, ADJ_H; all valued, as transfers, at prices PTR. Finally, the household obtains revenues from employers social security contributions, valued at prices $PESSC$.

$$\begin{aligned} Y_H &= w \cdot L_H \cdot (1-u) + r \cdot K_H + PESSC \cdot ESSCR_H && (5.49) \\ &\quad + PTR\ (PIR_H + WBR_H + CTR_H + ADJ_H) && (5.50) \end{aligned}$$

Household net disposable income, YD_H, represents the income available for present and future consumer expenditures. It is equal to household income less direct income taxes, minus all transfers paid to other domestic and foreign agents. Direct income taxes, that will modify the consumption and savings patterns in the tax-distorted economy, are based on a proportional income tax, τ^{Y_H}, applied on the household gross income. Income taxes are paid to the domestic government and to foreign agents,

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[12] It is because they define the saving and labor-supply responses that these first two stages are the most important ones in the context of fundamental tax reform.

[13] In a dynamic model, the initial capital stock accumulates over time as savings provides for investment in each period.

according to their benchmark shares. Transfers paid to other domestic agents include property income paid, PIP_H, welfare benefits paid, WBP_H, current transfers paid, CTP_H, and direct purchases abroad by residents, CM_H, less the purchases on the domestic territory by non-residents, CNR. In order to preserve the homogeneity of the model, transfers need to be multiplied by a price index. As previously stated, the transfers are valued with the price deflator PTR.

$$YD_H = Y_H(1-\tau^{Y_H}) - PTR\,(PIP_H + WBP_H + CTP_H + CM_H - CNR) \tag{5.51}$$

Household net savings, S_H, valued at price PS_H, can then be calculated as the difference between household net disposable income and the household final consumption expenditure, C_H, valued at price PC_H.

$$PS_H \cdot S_H = YD_H - PC_H \cdot C_H \tag{5.52}$$

5.2.2 Household behaviour

The household solves several interrelated problems to maximize his utility. We present them in different levels, as shown in *figure* (5.3).

First level : C - S structure

To determine his consumption patterns, the representative household must first decide how much he wants to save for future consumption, S_H, and how much he wants to spend on present consumption, C_H, by maximizing his utility U_H subject to his with-tax budget constraint YD_H. This choice depends upon the elasticity of substitution between savings and present consumption and the changes in the net rate of return. The only motive for private saving is to smooth consumption over the present and future periods[14]. Given that there is no financial intermediation sector included in the model, saving is invested directly and the price of saving should therefore be computed as a weighted average of the prices of the investment goods[15], such that $PS_H = PS = PI$.

We assume that preferences over savings and present consumption, C_H, can be represented by a CES function and that there is no minimal consumption of savings. The

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[14] We assume no uncertainty, ruling out the precautionary motive for saving, which may serve as a substitute for insurance in an uncertain world. Also, no bequests are considered.

[15] Considering PI as the Leontief aggregate, we have: $PI = \sum_{i=1}^{17} inv_i \cdot PI_i$.

budget constraint states that the household disposable income should equal expenditure on present consumption and saving. In formal terms, the top level households' tradeoff is

$$\max_{S_H, CLE_H} U_H = \left[\alpha_{S_H}^{\frac{1}{\sigma^{S_H}}} S_H^{1-\frac{1}{\sigma^{S_H}}} + (1-\alpha_{S_H})^{\frac{1}{\sigma^{S_H}}} C_H^{1-\frac{1}{\sigma^{S_H}}} \right]^{\frac{\sigma^{S_H}}{\sigma^{S_H}-1}} \tag{5.53}$$

$$s.t. \qquad YD_H = PS \cdot S_H + PC_H \cdot C_H \tag{5.54}$$

where α_{S_H} is the value share for saving in available income ($0 < \alpha_{S_H} < 1$) and the curvature parameter, σ^{S_H}, determines the intertemporal elasticity of substitution between current consumption and savings.

The optimal demands for the household saving and the present consumption aggregate are given by

$$S_H^* = \frac{\alpha_{S_H} YD_H}{PS_H^{\sigma^{S_H}} \left(\alpha_{S_H} \cdot PS^{1-\sigma^{S_H}} + (1-\alpha_{S_H}) \cdot PC_H^{1-\sigma^{S_H}} \right)} \tag{5.55}$$

$$C_H^* = \frac{(1-\alpha_{C_H}) YD_H}{PC_H^{\sigma^{S_H}} \left(\alpha_{S_H} \cdot PS^{1-\sigma^{S_H}} + (1-\alpha_{S_H}) \cdot PC_H^{1-\sigma^{S_H}} \right)} \tag{5.56}$$

As it appears from equations (5.55) and (5.56), household saving and current consumption will vary depending on the change in the household disposable income (and thus the change in the income tax rate, τ^{Y_H}), their relative prices and the intertemporal elasticity of substitution, σ^{S_H}. On the one hand, the income effect of a higher diposable income increases both current consumption and household saving. On the other hand, if present and future consumption are substitutes, the resulting substitution effect indicates that an increase in the relative price of current consumption, with respect to the price of private investment, will tend to shift a higher part of the household disposable income towards saving. For a given level of disposable income, this substitution effect suggests that current consumption will decline while household savings will increase if the relative price of current consumption increases.

Finally, the unit expenditure function, that gives the minimum cost of achieving a fixed level of utility, for the top level of the household's decision problem is:

$$PU_H = \left[\alpha_{S_H} \cdot PS^{1-\sigma^{S_H}} + (1-\alpha_{S_H}) \cdot PC_H^{1-\sigma^{S_H}} \right]^{\frac{1}{1-\sigma^{S_H}}} \tag{5.57}$$

This cost-of-living index for a unit of utility is conveniently scaled to equal unity in the benchmark equilibrium.

Second level : C structure

In the second stage, after the saving allocation has been decided, the consumer must decide how to spend his remaining disposable income, $YD_H - PS \cdot S_H$, on the components of current consumption, C_H. By assuming a CES structure with a elasticity of substitution σ^{X_H}, the household maximises his utility by choosing the levels of an energy aggregate, E_H and a non-energy consumption goods aggregate, X_H, subject to his new budget constraint.

$$\max_{X_H, E_H} C_H = \left[\alpha_X^{\frac{1}{\sigma^{X_H}}} X_H^{1-\frac{1}{\sigma^{X_H}}} + (1-\alpha_X)^{\frac{1}{\sigma^{X_H}}} E_H^{1-\frac{1}{\sigma^{X_H}}} \right]^{\frac{\sigma^{X_H}}{\sigma^{X_H}-1}} \tag{5.58}$$

$$s.t. \qquad YD_H - PS \cdot S_H = PC_H \cdot C_H \tag{5.59}$$

where α_X is the utility weight on the non-energy consumption goods aggregate in the sub-utility function, representing the intensity of household preferences for non-energy consumption goods relative to energy consumption goods.

The resulting optimal consumption demands are specified in equations (5.60) and (5.61),

$$X_H^* = \frac{\alpha_X \left(YD_H - PS \cdot S_H \right)}{PX_X^{\sigma^{X_H}} \cdot PC_H} \tag{5.60}$$

$$E_H^* = \frac{\left(1-\alpha_X\right) \left(YD_H - PS \cdot S_H \right)}{PE^{\sigma^{X_H}} \cdot PC_H} \tag{5.61}$$

Equation (5.62) defines the price of aggregate consumption, net of indirect taxes,

$$PC_H = \left[\alpha_X PX_H^{1-\sigma^{X_H}} + \left(1-\alpha_X\right) PE_H^{1-\sigma^{X_H}} \right]^{\frac{1}{1-\sigma^{X_H}}} \tag{5.62}$$

Third level: X structure

On the following nest, the non-energy consumption goods aggregate is decomposed into its n components $X_{H,j}$, by using a Leontief specification. The cost minimisation procedure is

$$\min_{X_{H,1},\ldots,X_{H,n}} PX_H \cdot X_H = \sum_{j=1}^{n=24} \left(1 + \tau_j^{VAT}\right) \cdot PYT_j^{ARM} \cdot X_{H,j} \tag{5.63}$$

$$s.t. \qquad X_H = min \left(\frac{X_{H,1}}{x_{H,1}}, \ldots, \frac{X_{H,n}}{x_{H,n}} \right) \tag{5.64}$$

where $PX_{H,j}$ is the consumer price of the non-energy good j and $x_{H,j}$ is the Leontief coefficient of the j intermediary input $X_{H,j}$ into the non-energy goods aggregate.

The resulting demand for any good $X_{H,j}$ is obtained as a fixed proportion of the aggregate good, while the price specification of X_H is a weighted sum of all the prices of the intermediary inputs.

$$X_{H,j}^{*} = x_{H,j} \cdot X_H \tag{5.65}$$

$$PX_H = \sum_{j=1}^{n} x_{H,j} \cdot \left(1 + \tau_j^{VAT}\right) \cdot PYT_i^{ARM} \tag{5.66}$$

Third level : E structure

At the same level, the energy bundle is disaggregated by following a similar nesting to the one of the production structure. First, the consumer chooses the consumption levels of electricity and fossil fuels that minimise the expenditure cost, given the prices PYT_{elec}^{ARM} and $PEFF_H$:

$$\underset{Elec_H, EFF_H}{min} PE_H \cdot E_H = \left(1 + \tau_{elec}^{VAT} + \tau_{elec}^{ENE}\right) PYT_{elec}^{ARM} \cdot Elec_H + PEFF_H \cdot EFF_H \tag{5.67}$$

$$s.t. \qquad E_H = \left[\alpha_{Elec_H}^{\frac{1}{\sigma^{Elec_H}}} Elec_H^{1-\frac{1}{\sigma^{Elec_H}}} + (1 - \alpha_{Elec_H})^{\frac{1}{\sigma^{Elec_H}}} EFF_H^{1-\frac{1}{\sigma^{Elec_H}}}\right]^{\frac{\sigma^{Elec_H}}{\sigma^{Elec_H}-1}} \tag{5.68}$$

where α_{Elec_H} represents the share of the electricity component in the energy aggregate and σ^{Elec_H} the substitution elasticity between the electric fuel composite and the fossil fuels bundle.

Equations (5.69) and (5.70) determine the optimal demands of electric fuel, $Elec_H$, and fossil fuels aggregate, EFF_H.

$$Elec_H^{*} = \alpha_{Elec_H} \left(\frac{PE_H}{(1 + \tau_{elec}^{VAT} + \tau_{elec}^{ENE})\, PYT_{elec}^{ARM}}\right)^{\sigma^{Elec_H}} \cdot E_H \tag{5.69}$$

$$EFF_H^{*} = (1 - \alpha_{Elec_H}) \left(\frac{PE_H}{PEFF_H}\right)^{\sigma^{Elec_H}} \cdot E_H \tag{5.70}$$

Equation (5.71) specifies the unit price of the aggregate energy bundle in function of the price of the electric composite, $PElec$, and the fossil fuels bundle, $PEFF$.

$$PE_H = \left[\alpha_{Elec_H}\left(\left(1+\tau^{VAT}_{elec}+\tau^{ENE}_{elec}\right)PYT^{ARM}_{elec}\right)^{1-\sigma^{Elec_H}} + (1-\alpha_{Elec_H})PEFF_H^{1-\sigma^{Elec_H}}\right]^{\frac{1}{1-\sigma^{Elec_H}}} \tag{5.71}$$

Fourth level : EFF structure

On the fourth level, the fossil fuels aggregate is decomposed into coal, $COAL_H$, and an aggregate of oil and gas fuels, OG_H,

$$\min_{OG_H, COAL_H} PEFF_H \cdot EFF_H = POG_H \cdot OG_H + \left(1+\tau^{VAT}_{Coal}+\tau^{CO_2}_{Coal}+\tau^{ENE}_{Coal}\right)PYT^{ARM}_{coal} \cdot COAL_H \tag{5.72}$$

$$s.t. \qquad EFF_H = \left[\alpha_{OG_H}^{\frac{1}{\sigma^{OG_H}}} OG_H^{1-\frac{1}{\sigma^{OG_H}}} + (1-\alpha_{OG_H})^{\frac{1}{\sigma^{OG_H}}} COAL_H^{1-\frac{1}{\sigma^{OG_H}}}\right]^{\frac{\sigma^{OG_H}}{\sigma^{OG_H}-1}} \tag{5.73}$$

where α_{OG_H} represents the share of the oil/gas bundle in the EFF_H aggregate and σ^{OG_H} the substitution elasticity between the coal composite and the oil/gas bundle.

The expenditure minimisation problem yields the following optimal demands,

$$OG^*_H = \alpha_{OG_H}\left(\frac{PEFF_H}{POG_H}\right)^{\sigma^{OG_H}} \cdot EFF_H \tag{5.74}$$

$$COAL^*_H = (1-\alpha_{OG_H})\left(\frac{PEFF_H}{\left(1+\tau^{VAT}_{Coal}+\tau^{CO_2}_{Coal}+\tau^{ENE}_{Coal}\right)PYT^{ARM}_{coal}}\right)^{\sigma^{OG_H}} \cdot EFF_H \tag{5.75}$$

Equation (5.76) indicates the price for the non-electric fuels bundle.

$$\begin{aligned} PEFF_H \;=\; & \Big[\alpha_{OG_H} POG_H^{1-\sigma^{OG_H}} \qquad (5.76) \\ & + (1-\alpha_{OG_H})\left(\left(1+\tau^{VAT}_{Coal}+\tau^{CO_2}_{Coal}+\tau^{ENE}_{Coal}\right)PYT^{ARM}_{coal}\right)^{1-\sigma^{OG_H}}\Big]^{\frac{1}{1-\sigma^{OG_H}}} \end{aligned}$$

Fifth level : OG structure

Finally, the last energy nest disaggregates the oil/gas aggregate into the demanded volume for refined oil, OIL_H, and for natural gas, GAS_H,

$$\begin{aligned}
\underset{OIL_H,GAS_H}{min} POG_H \cdot OG_H &= \left(1+\tau_{Oil}^{VAT}+\tau_{Oil}^{CO_2}+\tau_{Oil}^{ENE}\right) PYT_{oil}^{ARM} \cdot OIL_H && (5.77)\\
&\quad + \left(1+\tau_{Gas}^{VAT}+\tau_{Gas}^{CO_2}+\tau_{Gas}^{ENE}\right) PYT_{gas}^{ARM} \cdot GAS_H\\
s.t. \qquad OG_H &= \left[\alpha_{OIL_H}^{\frac{1}{\sigma^{OIL_H}}} OIL_H^{1-\frac{1}{\sigma^{OIL_H}}}\right.^{\frac{\sigma^{OIL_H}}{\sigma^{OIL_H}-1}} && (5.78)\\
&\quad \left. +(1-\alpha_{OIL_H})^{\frac{1}{\sigma^{OIL_H}}} GAS_H^{1-\frac{1}{\sigma^{OIL_H}}}\right]^{\frac{\sigma^{OIL_H}}{\sigma^{OIL_H}-1}} && (5.79)
\end{aligned}$$

where α_{OIL_H} represents the share of the oil composite in the OG_H aggregate and σ^{OIL_H} the substitution elasticity between the oil composite and the gas composite.

Constrained minimisation of this expenditure function gives

$$OIL_H^{*} = \alpha_{OIL_H}\left(\frac{POG_H}{\left(1+\tau_{Oil}^{VAT}+\tau_{Oil}^{CO_2}+\tau_{Oil}^{ENE}\right) PYT_{oil}^{ARM}}\right)^{\sigma^{OIL_H}} \cdot OG_H \qquad (5.80)$$

$$GAS_H^{*} = (1-\alpha_{OIL_H})\left(\frac{POG_H}{\left(1+\tau_{Gas}^{VAT}+\tau_{Gas}^{CO_2}+\tau_{Gas}^{ENE}\right) PYT_{gas}^{ARM}}\right)^{\sigma^{OIL_H}} \cdot OG_H \qquad (5.81)$$

Again, the unit price of the oil-gas bundle is equivalent to

$$\begin{aligned}
POG_H &= \left[\alpha_{OIL_H}\left(\left(1+\tau_{Oil}^{VAT}+\tau_{Oil}^{CO_2}+\tau_{Oil}^{ENE}\right) PYT_{oil}^{ARM}\right)^{1-\sigma^{OIL_H}}\right. && (5.82)\\
&\quad \left. +(1-\alpha_{OIL_H})\left(\left(1+\tau_{Gas}^{VAT}+\tau_{Gas}^{CO_2}+\tau_{Gas}^{ENE}\right) PYT_{gas}^{ARM}\right)^{1-\sigma^{OIL_H}}\right]^{\frac{1}{1-\sigma^{OIL_H}}}
\end{aligned}$$

5.3 Corporations

Corporations may be described as entities with proper legal personality that serve as intermediaries between the production sector and the domestic and foreign agents. Corporations' income is the sum of capital income, current transfers received from other institutional sectors and revenues of social security contributions paid by employers, $ESSCR_F$, and employees, $HSSCR_F$. Capital income derive from the capital remuneration on the stock of capital they own, K_F, and includes retained profits and other remuneration on the stock of capital owned by the firms. Retained profits are equal to a fixed share of firms gross operating surplus, the rest being distributed to households, the public sector and the foreign sector. Current transfers, valued at prices

PTR, include property income received from other domestic agents, PIR_F and other current transfers, CTR_F.

$$Y_F = r \cdot K_F + PTR\ (PIR_F + CTR_F) + PESSC \cdot ESSCR_F + PHSSC \cdot HSSCR_F \tag{5.83}$$

The net disposable income of the corporate sector, YD_F, is then obtained by applying the ad-valorem corporate tax rate τ^{Y_F} on the total income of corporations.

$$YD_F = (1 - \tau^{Y_F}) \cdot Y_F \tag{5.84}$$

Corporate saving, S_F, valued at price PS, is finally obtained as the difference between the corporate sector's disposable income minus current transfers to other agents. The current transfers include property income paid, PIP_F, welfare benefits paid, WBP_F, other current transfers paid, CTP_F, and payments to households for the adjustments for change in net equity, ADJ_H.

$$PS \cdot S_F \ = \ YD_F - PTR\ (PIP_F + WBP_F + CTP_F + ADJ_H) \tag{5.85}$$

5.4 Non-profit institutions serving households

The non-profit institutions serving households (NPISH) represent institutions with a particular juridical status that offer non-market goods and services to the households, similar to the ones provided by the public sector. As for the corporations, their revenues come from the capital remuneration on the stock of capital they own, K_{NP}, from the revenues of social security contributions paid by employers, $ESSCR_{NP}$, and from the current transfers received from other institutional sectors. These transfers, valued at price PTR, include property income received from other domestic agents, PIR_{NP} and other current transfers, CTR_{NP}.

$$Y_{NP} = r \cdot K_{NP} + PTR\ (PIR_{NP} + CTR_{NP}) + PESSC \cdot ESSCR_{NP} \tag{5.86}$$

Note that as non-profit institutions, they are not charged any income tax. Their total revenues is therefore equivalent to their disposable income which is used to consume different goods and services and pay current transfers, trough an exogenously given pattern. The rest is dedicated to saving, S_{NP}, with price PS.

$$PS \cdot S_{NP} = Y_{NP} - PC_{NP} \cdot C_{NP} - PTR\ (PIP_{NP} + WBP_{NP} + CTP_{NP}) \qquad (5.87)$$

The aggregate consumption of the NPISH represents the sum of their demands for domestic goods and services, $C_{NP,i}$, with basic price $PC_{NP,i}$.

$$PC_{NP} \cdot C_{NP} = \sum_{i=1}^{m=28} \left(1 + \tau_i^{VAT}\right) \cdot PYT_i^{ARM} \cdot C_{NP,i} \qquad (5.88)$$

5.5 Government

5.5.1 Overview

The public sector plays a key role in the resource allocation process by means of its tax and transfer schemes. It affects constantly the behaviour of the agents, trough the impacts it has on price formation (via indirect taxes and subsidies) and on net disposable income (via direct taxes and transfers). Also, public investment policy can affect the production sectors, both directly and indirectly. The assumptions about government behaviour are rather conventional. There is no maximisation of any objective function but rather an exogenously given spending pattern. The different types of government revenues and expenditures are all modelled on a macroeconomic level. The government's behaviour consists mainly in collecting income revenues from taxes, capital stock remuneration and transfers received from the other institutional sectors. Total government revenue is then allocated among transfers to other institutions, non-transfer expenditures and public savings. Public savings are then used to finance public investment. Transfers include lump sum transfers to households and subsidies to firms while non-transfer expenditures are restricted to the purchases of goods and services[16] and the provision of public services (e.g. justice, law enforcement, education, health). Transfers are treated as lump-sum payments and ignore the distortionary effects of particular transfer policies. Taxes are computed as ad valorem tax rates and tax revenues collected by the government are endogenous, depending on the level of economic activity. The Social Security system, controlled by the government, levies payroll taxes on households and redistributes to them Social Security benefits.

In defining the government behaviour, a key element is the hypothesis regarding the specification of the public deficit (or surplus). The choice between different closure

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[16] Expenditures include usually purchase of industry outputs and payments for factor services. However, the SAM used does not present any data on labour and capital use (wages and payments to capital) in the public sector.

rules will basically depend on the policy scenario under study. A first option is to consider the government aggregate spending (including public investment) constant in real terms, with a public deficit being determined endogenously, as the difference between public revenues (endogenous to the level of economic activity) and public spending. The second option, used in this model, is to regard all the policies simulated as "public deficit neutral", which implies a constant ratio of public deficit (or surplus) to GDP. This fiscal neutrality is usually considered as an appropriate long term hypothesis. In this second case, government spending is not anymore constrained to be invariant at its benchmark level. The rule of fiscal neutrality only indicates that any change in public revenues, (e.g., carbon taxation, change in payroll taxes revenues) must be automatically offset by an equivalent change in public spending, trough changes in public consumption and/or public investment, or a contrary equivalent change in public revenues. Given that there is only one time period in this model, which represents all future time periods, and as the public deficit must be the same in all periods, the government cannot run an excessive deficit in one period and make it up by running a surplus in a later period.

In order for the government to maintain its constant ratio of public deficit to GDP, different options may be proposed for the government closure rule. On the one hand, we can consider that public revenues and public spending are endogenous to the taxation levels. As the difference between both terms, public savings is therefore also an endogenous variable. In this case, public savings is treated as a flexible residual while all the tax rates and transfers levels are exogenous. The equilibrating variable is thus the public investment, which must adjust to maintain a constant ratio of public deficit to GDP. In this case, public investment is "savings driven". On the other hand, when public investment is fixed, the equilibrating variable that adjusts to restore the predetermined deficit/surplus position is usually a tax rate (or the government transfers to other institutional sectors) that guarantees a level of public revenues consistent with a constant ratio of public deficit to GDP.

5.5.2 Public revenues

In the base year, several distortionary taxes are considered, with tax rates being fixed as parameters. The calculation of excises and indirect taxes is made at the level of each production/consumption category. Current taxes on income and wealth distinguish household and corporate income taxes. The following revenue sources are considered for the public sector.

1. Revenues from direct taxes:

- Income tax on household's revenues, RTY_H, are determined by applying an income tax rate τ^Y on the household's total income:

$$RTY_H = (1 - \lambda_{TYH}) \cdot \tau^{Y_H} \cdot Y_H \tag{5.89}$$

where λ_{TYH} represents the share of the household's income tax revenues allocated to the foreign sector. Since there is just one representative household, the model does not have to specify a progressive income tax[17] and considers only one income tax rate.

- Revenues from the corporate income tax, τ^{Y_F}[18]:

$$RTY_F = (1 - \lambda_{TYF}) \cdot \tau^{Y_F} \cdot Y_F \tag{5.90}$$

where λ_{TYF} represents the share of the corporate income tax revenues allocated to the foreign sector.

- Revenues from employer's Social Security contributions:

$$RESS = (1 - \lambda_{ESSC}) \sum_{i=1}^{m=28} \theta_{ESSC,i} \cdot w \cdot L_i \tag{5.91}$$

where λ_{ESSC} represents the share of the employer's Social Security contributions allocated to the foreign sector.

- Revenues from employee's Social Security contributions:

$$RHSS = (1 - \lambda_{ESSC}) \sum_{i=1}^{m=28} \theta_{HSSC,i} \cdot w \cdot L_i \tag{5.92}$$

where λ_{HSSC} represents the share of the employee's Social Security contributions allocated to the foreign sector.

2. Revenues from indirect taxes and excises:

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[17] Under a progressive income tax, it is common to consider two different tax rates: the marginal tax rate on income (the tax on the last currency unit earned) and the average tax rate on income (total taxes divided by total income). When average and marginal tax rates differ, we face two different after-tax returns. The average tax rate has its impact on the budget constraint while the marginal tax rate affects the consumption-leisure tradeoff and the present-future tradeoff [Auerback and Kotlikoff, 1987].

[18] Note that this tax corresponds to one of the two sorts of capital taxation: the one relative to taxes on the income from savings, such as the corporate income tax, taxation of interest and dividends, and the taxation of capital gains. The other component of capital taxation corresponds to taxes on the stock of capital like the wealth tax, the tax on bequests and the property taxes.

- Revenues from net taxes on production:

$$RTYD = \sum_{i=1}^{m=28} \tau_i^Y \cdot PYD_i \cdot YD_i \tag{5.93}$$

- Revenues from value-added taxes

$$RTYVAT = \sum_{i=1}^{m=28} \tau_i^{VAT} \cdot PYT_i^{ARM} \cdot (C_{H,i} + C_{NP,i} + C_{GOV,i}) \tag{5.94}$$

  where $C_{H,i}$, $C_{NP,i}$ and $C_{GOV,i}$ are the consumption of good i by the household, the NPISH and the government, respectively.

- Revenues from net taxes on domestically consumed products (locally produced or imported)[19]:

$$RTYT = \sum_{i=1}^{m=28} \tau_i^X (PYI_i \cdot YI_i + PYM_{i,r} \cdot ER \cdot YM_{i,r}) \tag{5.95}$$

- Revenues from import tariffs, where $\tau_{i,ROW}^{YM}$ indicates the tariff rate on imports from non-EU countries:

$$RTYM = \sum_{i=1}^{m=28} \tau_{i,ROW}^{YM} \cdot PYM_{i,ROW} \cdot ER \cdot YM_{i,ROW} \tag{5.96}$$

- Revenues from taxes on carbon emissions, where $\tau_f^{CO_2}$ represents the ad-valorem tax on the carbon content of the fossil fuel f used by the domestic production sector i and the household[20]:

$$RTPOLL = \sum_{f=1}^{n=3} \tau_f^{CO_2} \left(\sum_i CO_{2,i,f} + CO_{2,H,f} \right) \tag{5.97}$$

  where $CO_{2,i,f}$ represents the carbon emissions from domestic sector i due to the use of fossil fuel f and $CO_{2,H,f}$ indicates the carbon emissions generated from fossil fuel f consumption by the household.

- Revenues from taxes on the energy content of energy goods, where τ_g^{ENE} represents the ad-valorem tax on the energy content due to the consumption of energy

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[19] In the model, these taxes are considered industry based taxes rather than commodity based taxes.

[20] Initially, the carbon emission tax rate is an ad-quantum tax rate. The specification of the carbon emissions tax as an ad-valorem tax rate is explained below.

good g:

$$RTENE = \sum_{g=1}^{n=4} \tau_g^{ENE} \left(\sum_i ENE_{i,g} + ENE_{H,g} \right) \tag{5.98}$$

3. Current transfers received from other institutional sectors[21], including property income received, PIR_{GOV}, and other current transfers received, CTR_{GOV}.

4. Net revenues from the remuneration on the stock of capital it owns, K_{GOV}. Note that the common approach to define a unit of capital (that which earns a currency unit per year) is less appropriate for the government sector because governmental capital should not always generate a return. However, to apply the private rate of return to a government capital stock, we assume, as in Ballard *et al.* [1985, 107], that the interaction of the economy and the governmental process generates a rough equilibration of rates of return.

Given these revenue sources, the government income may be expressed, in a aggregate way, with the following expression:

$$\begin{aligned} Y_{GOV} &= RTY_H + RTY_F + RESS + RHSS + RTYD + RTYVAT + RTYT \\ &\quad + RTYM + RTPOLL + RTENE + PTR\ (PIR_{GOV} + CTR_{GOV}) + r\,K_{GOV} \end{aligned} \tag{5.99}$$

5.5.3 Public spending

Government public spending, $PUBSP_{GOV}$, is the sum of transfers to domestic and foreign agents and total public consumption, C_{GOV}. Current transfers to domestic and foreign agents include property income paid, PIP_{GOV}, welfare benefits paid, WBP_{GOV}, and other current transfers paid to institutional sectors, CTP_{GOV}. It also integrates some transfers to foreign factor owners, as a government tax collected for the EU and returned to the EU, $TEUP_{GOV}$. All transfers are considered exogenous.

Once the transfers to domestic and foreign agents have been made, public spending is reduced to the sum of public consumption, C_{GOV}.

$$PUBSP_{GOV} = PC_{GOV} \cdot C_{GOV} + PTR\ (PIP_{GOV} + WBP_{GOV} + CTR_{GOV} + TEUP_{GOV}) \tag{5.100}$$

Aggregate public consumption represents the sum of the demands of the public sector for goods and services, $C_{GOV,i}$, valued at prices PYT_i^{ARM}, and used to provide

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[21] Transfer payments are not assumed to be taxed in the model.

public services.

$$PC_{GOV} \cdot C_{GOV} = \sum_{i=1}^{m=28} \left(1 + \tau_i^{VAT}\right) \cdot PYT_i^{ARM} \cdot C_{GOV,i} \tag{5.101}$$

5.5.4 Public Sector Closure Rule

In this model, the reference case scenario assumes an endogenous public savings, S_{GOV}, valued at price PSg, treated as the difference between government income and public spending. In other words, once the transfers to domestic and foreign agents have been made, the government revenues are used for public consumption, while the rest is saved for public investment.

$$PSg \cdot S_{GOV} \quad = Y_{GOV} - PUBSP_{GOV} \tag{5.102}$$

The difference between government revenues and the sum of public spending and public investment, INV_{GOV}, will give the public deficit (or surplus) position, $PUBDEF_{GOV}$.

$$\begin{aligned} PS \cdot PUBDEF_{GOV} &= Y_{GOV} - PUBSP_{GOV} - PSg \cdot INV_{GOV} \\ &= PSg \cdot S_{GOV} - PSg \cdot INV_{GOV} \end{aligned} \tag{5.103}$$

The optimal public capital investment for each sector, $IDPB_i$, is obtained as a fixed share of total public investment, where $idpb_i$ is the Leontief fixed coefficient for public investment in the ith sector:

$$IDPB_i \quad = \quad idpb_i \; INV_{GOV} \tag{5.104}$$

In case public savings are not sufficient to finance public investment requirements, the public sector uses the savings it receives from the rest of the institutional sectors trough borrowing. The net financing capacity (or necessity) of the government is used to compute the total financing capacity of the nation. In the model, we fix the public deficit to GDP ratio in order to allow for consistent welfare estimates. This implies that if government savings falls or augments, public investment will have to vary in the same proportion. If the government deficit is not fixed, then it is impossible to distinguish between a change in consumer welfare which is due to efficiency improvements and one which arise solely because the government is running a larger deficit.

5.6 Foreign sector

The modelling of the foreign sector activities is restricted to the specification of the balance of payments, which indicates all the financial and real operations registered between the domestic economy and the foreign sector. The reason is that the single-country model we use does not allow to represent explicitly the optimisation problem of the non-residents, given that there is no way to determine their budget constraint.

The overall balance of payments, for each foreign regions block r, is given in equation (5.105). It represents the foreign closure rule of the model.

$$\begin{aligned} FINCAP \;=\; & \sum_{i=1}^{m=28} \overline{PYM}_i \cdot ER \cdot YM_i - \sum_{i=1}^{m=28} \overline{PEX}_i \cdot ER \cdot EX_i \\ & + w \cdot LD_H^F \cdot (1-u) - w \cdot LS_H^F \\ & + PTR\,(PIP_F + WBP_F + CTP_F - PIR_F - WBR_F - CTR_F) \\ & + PTR \cdot (CM_H - CNR) + PTR\,(TEUP_{GOV} - TEUR) \\ & + \lambda_{TYH} \cdot \tau^{Y_H} \cdot Y_H + \lambda_{TYF} \cdot \tau^{Y_F} \cdot Y_F \\ & + \lambda_{ESSC} \sum_{i=1}^{m=28} \theta_{ESSC,i} \cdot w \cdot L_i + \lambda_{ESSC} \sum_{i=1}^{m=28} \theta_{HSSC,i} \cdot w \cdot L_i \\ & - PHSSC \cdot HSSCR \end{aligned} \tag{5.105}$$

The balance of payments is split into the current balance (right-hand side of equation (5.105)) and the financial balance (left-hand side of the equation). The current account registers the trade flows, the factor rents and the current transfers between the domestic economy and the foreign sector. It also accounts for the domestic consumption of non-residents, CNR, and the consumption of national residents abroad, CM_H[22]. Since the behaviour of the non-residents is unknown, the trade flows (commercial balance) will depend exclusively on the domestic imports and exports demands, as part of the producer optimising behaviour. Imports like exports are valued at domestic prices. Multiplying export and import prices by the exchange rate transforms the balance equation to a condition in domestic currency, but does not change its real economic significance. Due to the small-country assumption (Spain would be too small to affect prices in international markets), Spain is assumed to be a price taker on all world commodity markets, such that import and export prices are considered fixed in foreign currency terms.

The factor rents register the remunerations obtained from the labour and capital

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[22] The domestic consumption of non-residents and the consumption of national residents abroad correspond mainly to tourism purchases in a foreign country. Both variables are considered exogenous, for the reason explained above.

endowments that both the foreign sector and the domestic sectors may offer abroad and demand from abroad. More specifically, wages are paid to the foreign sector for the foreign labour supplied in the domestic country, LD_H^F, while the domestic sector receives wage payments from domestic labour supplied abroad, LS_H^F. Current transfers concern transactions without counterparts between the residents of two different countries. Current transfers paid to the rest of the world consist of welfare benefits, WBP_F, property income paid, PIP_F, and other current transfers from domestic institutions to the foreign sector, CTP_F. In the same way, transfers received from the foreign sector consist of property income paid by the foreign sector, PIR_F, welfare benefits, WBR_F, as well as other current transfers paid by the foreign sector to domestic institutions, CTR_F. Some other transfers to foreign sectors consist of government tax collected for the EU and returned to the EU, $TEUP_{GOV}$, income tax and social security benefits associated with the labour of non-residents. In the same way, Spain receives subventions on production and products, as transfers from the institutions of the EU, $TEUR$, as well as income tax payments and social security benefits associated with the labour of residents abroad.

In total, the current balance may vary and the domestic country, as well as the foreign sector, can run current account surpluses or deficits. To satisfy the macroeconomic balances, the current account imbalances of the domestic economy (in the case of Spain, a current account deficit) are compensated by net inflows of foreign capital[23]. In other words, the equation of the balance of payments shows that the counterpart of the current account balance is the net capital inflows or outflows registered in the financial balance. This second main component of the balance of payments represents therefore the net financing capacity (or necessity) of the economy, $FINCAP$.

Two options are available with regard to the closure of the rest of the world account: fixing either the exchange rate variable or the balance on the current account. The first option holds foreign savings (or borrowing) fixed at some target value while allowing the real exchange rate to adjust. If the financial balance is fixed, the exchange rate must be variable to ensure that the capital account is equal and opposite to a non-constant current account level. The second option fixes the real exchange rate and allows foreign savings to vary to the changes in the trade balance account. The problem with a variable foreign savings is that it allows to finance domestic spending trough foreign borrowing without clear constraint. Such a costless transfer does not provide a clear legitimate basis for comparison between second-best instruments, since any tax reduction will look good. Hence we prefer the first option, by fixing the foreign savings and allowing the exchange rate to adjust.

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[23] Of course, on the contrary, a current account surplus would be compensated by net outflows of domestic capital.

5.7 Investment and savings

5.7.1 Overview

The savings-investment account completes the model, by representing the reconciliation of all sectoral financial balances. It closes the model by aggregating the savings from different institutions and allocating them to domestic investment. For the savings-investment balance, closures are either "investment-driven" or "savings-driven". The macroeconomic closure represents the mechanism by which aggregate investment is brought to equality with aggregate savings. But it also represents the way trough which the economic system adjusts to exogenous shocks.

The first closure is known as "Johansen closure" and assumes that real investment quantities are fixed and the value of savings adjusts to equal the cost of the investment aggregate. This can be done by adjusting the base-year savings rates of the institutional sectors. A second closure rule, referred as the "neoclassical closure", supposes that the investment expenditures adjust to the sum of domestic saving and net capital inflows. Finally, the "Keynesian closure" specifies that the savings ratio and the aggregate investments are exogenously determined. The balance between savings and investment is attained trough the variation of gross output, for a given saving rate.

The volume of investment decided by the firms is given by the comparison of the available stock of capital in the current period with the desired one. In a dynamic framework, investment serves to expand capacity for the following periods and replaces obsolete capital stock. The fact that the model under study is static generates a conceptual problem with the data available: while static models do not deal with issues of next periods, the data from the SAM always provide information about investment. In order to keep model consistency and compromise the gap between the model framework and actual data we assume that investment just contributes to the formation of final demand, by allocating total investment to the different sectors demanding new capital goods. However, the model does not specify any explicit investment decisions for firms nor for the household or the government[24]. But it describes how the household saving, government saving, corporate saving and non-profit corporate saving are endogenously determined. Considering that the macroeconomic closure rule is savings-driven, the overall consistency of the model is obtained by ensuring that the value of private and public investment expenditures is equal to the total savings of domestic and foreign sectors, private and public ("neoclassical closure").

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[24] The firms and the household do not act directly as investors that allocate the accumulated capital stock among various firms to maximise the rate of return from their investment activities. In other words, producer's investment is not the result of the firm's optimisation, but instead follows savings from consumer's optimisation.

5.7.2 Savings-Investment Closure

The macro closure rule being savings driven, aggregate private fixed investment is determined as a residual, as the sum of domestic private savings and net capital inflows, minus the public deficit (public investment that cannot be financed by public savings). Domestic private saving is the sum of household saving, S_H, corporate saving, S_F, and NPISH saving, S_{NPISH}. Net foreign capital inflows, NS_{ROW} , is equal to the foreign capital inflows minus the domestic capital outflows, both variables being converted into domestic currency. It represents also the net lending capacity or borrowing necessity of the domestic economy, $FINCAP$, that compensates the current account imbalances by net inflows or outflows of capital added to or subtracted from the domestic flow of saving.

$$PS \cdot TINV = PS\,(S_H + S_F + S_{NPISH} - PUBDEF_{GOV}) + PS \cdot NS_{ROW} \tag{5.106}$$

$$FINCAP = PS\,(S_H + S_F + S_{NPISH} - PUBDEF_{GOV}) - PS \cdot TINV \tag{5.107}$$

Once the aggregate level of investment is determined, it is then distributed optimally to the various sectors in order to equate rates of return on new investment.

5.7.3 Private investment

To describe the allocation of private fixed investment, one would ideally use a capital composition matrix to specify how a unit of investment good in a particular sector is composed from the capital inputs from various sectors. In the absence of information on the sectoral composition of investment by sector of origin, we simply specify a composite investment good using information on investment demand for the private sectors. This private fixed investment, $INVP$, is allocated to the domestic economic sectors demanding new capital goods, so as to equalize the marginal productivity of capital across sectors. By using a fixed-coefficients structure, the specification excludes also variations in the composition of investment that may occur due to changes in taxation. The sectoral price of goods used to build investment is equivalent to the Armington unit price inclusive of net indirect taxes, PYT_i^{ARM}. The cost-minimisation procedure is the following:

$$\underset{IDPV_i}{min}\; PS \cdot INVP = \sum_{i=1}^{m=28} PYT_i^{ARM} \cdot IDPV_i \tag{5.108}$$

$$s.t. \qquad INVP = min\left(\frac{IDPV_1}{idpv_1}, ..., \frac{IDPV_m}{idpv_m}\right) \tag{5.109}$$

The optimal private capital demand for each industry, $IDPV_i$ is also obtained as a fixed share of total private investment, where $idpv_i$ is the Leontief fixed coefficient for private investment in the ith sector:

$$IDPV_i \;=\; idpv_i \, INVP \tag{5.110}$$

5.8 Labour market

5.8.1 The role of wage formation for modelling unemployment

Testing empirically the double dividend hypothesis being one of the objective of this study, we must take into consideration the modeling of involuntary unemployment. In CGE models, the wage setting process is usually ad-hoc (for some exceptions, see e.g., Böhringer *et al.* [2001], Carraro *et al.* [1996)], and Goméz *et al.* [2005]). A vast extent of studies have focused on the wage-formation alternatives to analyse labour market policies but the focus is usually not put on environmental considerations. The introduction of equilibrium unemployment into CGE models has been acknowledged in different ways. First, by simply assuming exogenously fixed wages that distorts the perfect competition outcomes [Bovenberg and van der Ploeg, 1996]. But endogenous wage setting has also been considered to model involuntary unemployment in equilibrium: the search-matching model [Bovenberg and van der Ploeg, 1995]; the efficiency wage model [Schneider, 1997]; the monopoly union model [Nielsen *et al.,* 1995]; or the wage bargaining model [Carraro *et al.,* 1996; Koskela *et al.,* 1998]. Most of the studies tend to give some evidence in favour of an employment DD.

The impact of labour tax and excises on employment is leveraged trough different channels like the reaction of wages to the tax change and the extent to which the tax burden weighs on the labour cost for the employer. This tax burden on the labour cost for the employer can itself be explained differently depending on the theoretical framework privileged: either by the wage elasticities of labour demand and labour supply, in a classical model, or on partly institutionally determined factors, such as the relative bargaining power of employers and employees or the degree of coordination of the wage formation process, in a more Keynesian outlook. The conclusions remain however quite similar and have been confirmed by many international studies[25]: in general, labour taxes have a stronger negative impact on employment the more these taxes are shifted into higher labour costs for employers and the less they are borne by employees' net wages.

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[25] See e.g. OECD [1994], De Bruyne et al. [1998], Elmeskov et al. [1998], Knoester et al. [1987], Leibfritz [1997], Pearson et al. [2000], Pissarides [1998], Scarpetta [1996], Summers et al. [1993].

For example, in a tight labour market, characterised by a hard to expand and thus inelastic labour supply (classical standpoint) and a relatively strong bargaining position for employees in the absence of a sufficient coordination between government and social partners (Keynesian standpoint), a reduction in labour taxation, trough a reduction of employers' taxes or social security contributions, would tend to benefit the employees and culminate in higher gross wages, lowering probably employment creation. On the contrary, when taxes are borne entirely by employees, in the form of a lower net wage, and are not passed on into higher labour costs, they tend to have little or no direct negative impact on employment (at the expense of lower disposable income for employees). When labour costs remain constant, labour demand tends to stay stable too, the relative cost of labour compared to capital and the initial international competitive position being unchanged [Burggraeve et al., 1993].

Spain has suffered a very high unemployment rate during the last two decades[26], reaching a peak of about 24% at the beginning of 1994 [INE, 2006]. Thereafter, it has decreased very strongly towards a rate of around 8% in 2008, to jump again above 20% since 2010. Such a high unemployment rate indicates, among other reasons, that the competitive labour market approach does not seem to be the most realistic way to view the Spanish labour market. The perfect competition conditions of most CGE models under classical assumptions consider flexible prices and market clearing for all the goods and production factors, such as labour. Consequently, standard CGE models usually do not specify what happens when the labour market does not clear, as it often happens in reality.

5.8.2 Wage curve

To reflect imperfect competition mechanisms within the labour market and incorporate involuntary unemployment into the model, we use a wage curve specification as an organizing framework [Blanchflower and Oswald, 1990, 1994]. This wage curve corresponds to the empirical evidence for Spain on the inverse relationship between the level of real wages and the unemployment rate. Blanchflower and Oswald who formulated and empirically tested the wage curve [1995, 2005] found that stable wage curves are a better representation of the wage-unemployment relationship than the more conventional unemployment theories described by the Phillips curve and Harris-Todaro model. In contrast to the wage curve, the Phillips curve focuses on the relation between the wage growth rate and the unemployment rate whereas the Harris-Todaro model [Harris and Todaro, 1970] suggests a reverse relationship, where high wage

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[26] The Spanish unemployment features have been widely studied. See for example Blanchard and Jimeno [1995], Dolado and Jimeno [1997] or Marimon and Zilibotti [1998].

regions tend to be high unemployment regions also[27].

The wage curve is based on a statistical regularity describing a negative correlation between the level of real wages and the level of unemployment: local labour markets with higher (lower) unemployment rate tend to have lower (higher) real wages levels. Introducing a wage curve into the model implies substituting the flexible wage by a wage equation, with the wage rate linked to the level of unemployment (in the region or the industry) trough a downward-sloping convex curve. Blanchflower and Oswald [1995] identify a typical logarithmic in form wage curve by:

$$ln \, \frac{w}{CPI} = \beta \, ln \, u + \psi \tag{5.111}$$

where $\frac{w}{CPI}$ is the real wage, u is the unemployment rate in the worker's area, and ψ denotes the residual terms (*e.g.* age, gender, race, years of schooling or regional specific dummy variables). The parameter β represents the elasticity of real wage with respect to unemployment and is therefore negative. Blanchflower and Oswald [1995] advocate that this elasticity parameter β is approximately equal to-0.1 for any region or country, showing a low degree of flexibility in wages. Blanchflower and Oswald [2005] investigated the robustness of a uniform elasticity of -0.1 and reported that, since its introduction 1994, the wage curve hypothesis has been found to exist in 43 countries and with a almost uniform elasticity value of -0.1, even at different time periods. In a meta-analysis of 208 elasticities of the wage curve, Nijkamp and Poot [2005] found similar results, with an 'unbiased' wage curve elasticity of about -0.07.

Figure (5.4) illustrates a traditional labour market diagram with the real wage rate on the vertical axis and the quantity of labour on the horizontal axis. The relation between the individual labour supply and the hourly wage is usually non-monotic as a result of the combination of a substitution effect and two income effects. The substitution effect implies an increasing relation between the wage and labour supply, while the income effect works in the opposite direction if leisure is a normal good. In sum, a wage increase has an ambivalent effect on labour supply. First, there is an incentive to diminish the time allocated to leisure and increase labour supply, since this factor is better remunerated (the substitution effect and the "indirect" income effect). But equally the increase in the wage rate increases real income, which raises the consumption of all normal goods, including leisure, reducing labour supply (the "direct" income effect). This is why the supply of labour generally raises with the

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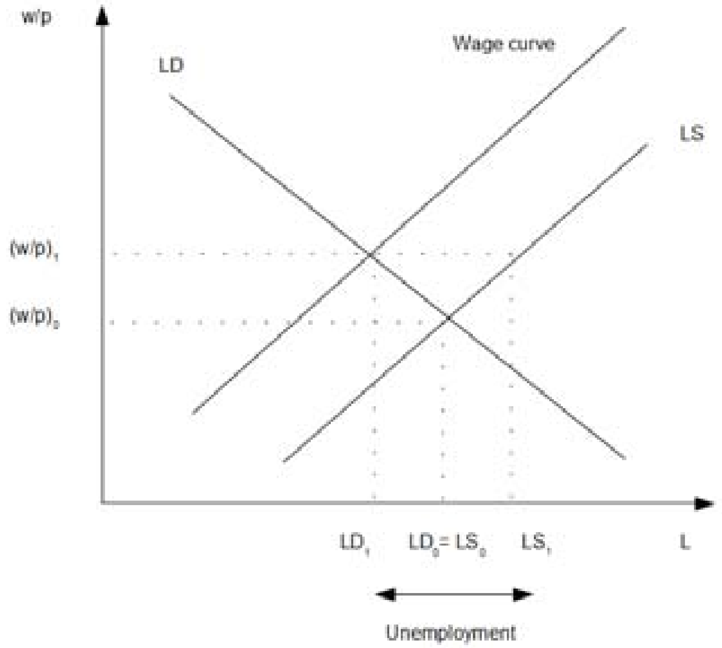
[27] In the Harris-Todaro model, unemployment is not a consequence of high wages above marginal productivity, as supposed by the neoclassical theory. Rather, it is the interregional wage differentials that motivate workers to move towards regions with higher wages, increasing labour supply in these regions and eventually regional unemployment. Under this theoretical framework, the wage curve would be seen as an assumption of imperfect labour mobility between regions.

wage at low wage levels (the substitution effect prevails) and diminishes for higher wage levels (the income effect prevails) [Cahuc, 2004].

The position of the wage curve is set to characterise the institutional framework of the regional labour market and the local wage rigidity, measured by the elasticity of individual real wages with respect to local unemployment. Together with labour demand, the wage curve identifies different combinations of wage and employment outcomes. Under a perfectly competitive labour market, full employment occurs by the market clearing real wage at the intersection of the labour demand function, *LD*, and the conventional labour supply function, *LS*. Under a wage curve modeling, given that "the wage curve replaces the labour supply curve" [Blanchflower *et al.*, 1995, 163] on the labour market and lies to the left of the later, the intersection of the labour demand curve and the wage curve sets a real wage higher than the the market clearing wage and determines at the same time the level of involuntary unemployment, as the difference between LS_1 and LD_1.

Figure 5.4: The wage curve and unemployment



The advantage of the wage curve specification is its handiness to incorporate unemployment with flexible prices into CGE models. Its major drawback is that it is not founded on any explicit micro-foundation to explain how wages are determined, the negative correlation of the wage curve being mainly driven empirically. However, Blanchflower and Oswald [1994, chapter 3] provide some theoretical support for their empirically downward sloping wage curve, being efficiency wages and wage bargaining the two most important[28].

Efficiency wages represents probably the main theoretical support of the empirical wage curve and is based on the idea that the firms tend to motivate an efficient behaviour by means of attractive wages [Solow, 1979]. This theory suggests that a low level of unemployment can be an incentive to increase wages: given the job opportunities, firms may have to set wages above market level to retain efficient workers. However, when the unemployment rate is low and labour demand is scarce, workers may be afraid of losing their job and work efficiently so that the firm does not need to pay an efficiency wage premium.

To some extent, labour contract models may also support the wage curve hypothesis. Wage bargaining theory suggests that the level of unemployment may affect the union's bargaining power. When unemployment is high, workers have problems to find other good job opportunities and their bargaining power is therefore reduced, lowering the wage obtained. In the efficient bargaining model [McDonald and Solow, 1981], parties bargain simultaneously about the wage rate and the hours of work. If a union's objective function aims to defend both employed and unemployed members (or even non-members), the unemployment level may impact the union's tradeoff between wages and employment. It can start bargaining employment opportunities in favour of the unemployed members (or non-members), at the cost of somewhat lower wages.

Integration of the wage curve approach for introducing endogenous unemployment into CGE modeling has been implemented by Böhringer *et al.* [2001], Markusen and Rutherford [2004] and in different research areas such as poverty and income distribution (Davies and Rattso [2000]), trade and labour market impacts (Carneiro and Abbache [2003]) or energy policy (Böhringer and Löschel [2006] and Küster *et al.* [2007]).

Evidence on the existence of a wage curve in Spain has been demonstrated by several authors. For example, Sanromá and Ramos [1999] and Villaverde [1999] suggest that the elasticity of real wages with respect to local unemployment is indeed negative and that regional wages are strongly persistent and respond slightly to unemployment differentials. They indicate that the persistent unemployment differentials between Spanish regions are the consequences not only from low migration, but also from high wage rigidity, resulting probably from the influence of nationwide sectoral wages on regional wages. Using industry and regional data, Jimeno and Bentolila [1998] also find a reduced wage elasticity to regional unemployment, with an estimated elasticity

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[28] Two other theoretical approaches are given (contracts models and persistent disequilibrium) but are usually considered secondary.

of $\beta = -0.07$. Differentiating unemployment rates by sector and gender (but not by regions), Canziani [1997] obtains a wage elasticity to unemployment with values between $\beta = -0.30$, when gender and age dummies are included, and $\beta = -0.13$ when they are not. García and Montuenga [2003] obtain also an estimated elasticity within this range, with a value of $\beta = -0.17$. Finally, Sanromá and Ramos [2003] and Montuenga *et al.* [2003], estimating a wage curve for the whole Spanish economy, obtain both a similar elasticity estimate of $\beta = -0.13$.

Taken together, these studies support the following considerations. First, a wage curve hypothesis seems appropriate for Spain. Second, the estimated elasticities of wages to unemployment all indicate a reduced wage flexibility (i.e., a low responsiveness of wages to unemployment) in the Spanish labour market when shocks hit the economy. Third, the value of the estimated elasticity is not different from the rest of OECD countries. The wage curve specification has been implemented for Spain in studies such as the one of Kehoe *et al.* [1989], Polo and Sancho [1990], Llop and Manresa [2004], Manresa and Sancho [2005] and André et al. [2005].

The wage equation used in this model follows the specification of Blanchflower and Oswald [1995]:

$$ln\,\frac{w}{CPI} = \beta\; ln\; u + \psi \tag{5.112}$$

where β is a parameter that captures the sensitivity of the real wage, w/cpi, to the unemployment rate, u[29]. In accordance with the estimates for the Spanish economy presented here, we set a value for $\beta = -0.13$.

By taking the antilog, we obtain the wage equation used in this model for implementing the wage curve and its associated involuntary unemployment level:

$$\frac{w}{CPI} = k\, u^{\beta} \tag{5.113}$$

where k is a calibration parameter which, in the benchmark equilibrium (all prices are unity), is equal to $1/u_0^{\beta}$. From this last equation, the unemployment rate can be easily derived.

This wage curve specification offers two special cases for given values of β. First, if $\beta = 0$, the real wage is constant and the unemployment rate varies to adjust to

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[29] This equation is a variant of the following wage curve, mentioned by Kehoe et al. [1989]:

$$\frac{w}{CPI} = k\,(1-u)^{1/\delta}$$

where k is a calibration parameter which, in the benchmark equilibrium (all prices are unity), is equal to $k = (1-u_0)^{-1/\delta}$. Here, u_0 is the unemployment rate in the benchmark equilibrium the fixed real wage. This case may refer to a fixed minimum wage scenario, which can be seen as a particular case of the wage curve specification. Second, if $\beta \to \infty$, labour supply is considered perfectly inelastic and the real wage varies to keep the unemployment rate constant.

Chapter 6

Equilibrium and Calibration

6.1 Equilibrium conditions

This section provides an algebraic summary of the equilibrium conditions for our small open economy model. The absence of non-convexities in household preferences and in production technology allows the existence of a competitive equilibrium for the economy represented in this model. By means of the equations derived in the preceding sections, it is now possible to formulate the equilibrium conditions of this general equilibrium model in which every agent is assumed to optimize his own objective function in light of optimal decisions taken by others, given prices, technologies and resources.

Basically, a general equilibrium model is presented as a combination of prices and quantities such that, given these prices and quantities, the following conditions are satisfied:

1. the representative household maximises his utility subject to his budget constraint[1];
2. the producers minimise their costs subject to technology constraints;
3. the unit profits are zero in all production sectors;
4. the commodity and factor markets clear;
5. investors maximise profits subject to arbitrage conditions in capital markets;
6. the government account constraint in the presence of taxes is fulfilled;
7. the balance of payments condition is satisfied.

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[1] The household may also minimise expenditures in order to achieve a certain utility level.

More specifically, Mathiesen [1985] and Rutherford [1995] showed that a general equilibrium model can be formulated and solved as a mixed complementarity problem (MCP), where a system of inequalities may represent a unique general equilibrium solution if three classes of equilibrium conditions and inequalities are satisfied:

1. The zero profit conditions requiring that in the case of perfect competition and constant-returns-to-scale case, no activity operating at a positive intensity earns an excess profit after making payments for intermediate inputs, factors and direct taxes[2].
2. The market clearance conditions requiring that market demand equals supply for any good and factor of production.
3. The income balance conditions requiring that for each economic agent the value of income must equal the value of factor endowments.

A MCP problem is solved by linking these three inequality conditions to three vectors of non-negative variables that represent the fundamental unknowns of the system: activity levels, market prices and income levels. In equilibrium, the activity level variable exhibits complementary slackness with respect to a zero profit condition, the price variable is associated to a market-clearance condition, and the income variable is related to an income-balance condition. Macroeconomic closures finally ensure the macroeconomic balances for the government, the savings-investment account and the foreign sector.

More specifically, the equilibrium in mixed complementarity format can be written as follows [Mathiesen, 1985; Paltsev, 2004]:

$$\begin{aligned} \text{Given} \quad &: \quad f : R^{b\times d\times g} \rightarrow R^{b\times d\times g} \\ \text{Find} \quad &: \quad z \in R^{b\times d\times g} \\ \text{s.t. } f(z) \quad &\geq \quad 0,\ z \geq 0,\ z' f(z) = 0 \end{aligned}$$

where z indicates the vector of decision variables associated with the solution of the economic equilibrium problem and $f(\cdot)$ represents the corresponding equilibrium condition. The vector $z' = [p, y, w]$ consists of three vectors of decision variables :

- p : a non-negative vector of b prices including the prices of all the m final goods, n intermediate goods and the two primary factors of production;

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[2] In the case of decreasing or increasing returns to scale, this condition may of course not hold. The condition will be expressed more generally as profit maximisation subject to technology constraints.

- y : a non-negative vector of d activity levels, including the activity levels of the m production sectors, the consumption sector, the investment sector and the government sector (such that $d = m + 3$);
- w : a vector of income levels of the representative household, the government and the non-profit institutions serving households.

The vector of variables z and the equilibrium conditions $f(\cdot)$ represent a complementary pair and are said to be complements to each other. The complementarity problem stipulates that in equilibrium each of the decision variables z must be non-negative and corresponds to a non-negative equilibrium condition, $f(\cdot)$. The optimal solution is found if each variable is characterised by complementary slackness, $z'f(z) = 0$. This complementary slackness condition indicates that for $z'f(z) = 0$ to be true, a solution is found either if $z = 0$, or $f(z) = 0$, or both. Hence, in the complementarity format, the equilibrium problem is defined as a system of weak inequalities and complementary slackness conditions. The "mixed" problem indicates that the solution is a mix of equalities $f(z) = 0$ and inequalities $f(z) \geq 0$.

The solution system of a MCP is similar to the first order necessary conditions of a standard non linear programming (NLP) optimization approach of a general equilibrium problem. But the advantage of the mixed complementarity approach are twofold. First, unlike in conventional NLP, this formulation doesn't require to specify a given expression to maximize or minimize. Second, it doesn't require to specify only equality constraints. This can be a serious advantage when the modeler wants to take into account some economic processes that can be rigorously represented only trough inequalities, such as some price and quantity constraints. We now specify in more detail the equilibrium conditions.

6.1.1 Zero profit conditions

The zero profit condition applies to all activities: production, private consumption, public consumption and investment. In terms of MCP, activity level, y, and profit are the complementary variables with this zero profit condition. The complementary slackness condition states that either a positive amount of y is produced ($y > 0$) and profit is zero, or profit is negative and no production activity takes place ($y = 0$). By assuming that all activity levels are positive (the condition $y \geq 0$ is satisfied with strict inequality), the zero profit condition must hold for all activities, as shown below.

- For producers, the zero-profit condition is justified by the assumption that all the firms are competitive and face constant returns to scale. In equilibrium, competition eliminates excess profits and the production price equals the unit cost function. The orthogonality symbol, $\perp$, links the variables to the complementary slackness conditions.

$$\pi_i^{YD} \;=\; PYD_i - \left(\sum_{j=1}^{n} x_{i,j} \cdot PX_{i,j} + kel_i \cdot PKEL_i\right) = 0 \tag{6.1}$$

$$\perp \;\; YD_i > 0 \tag{6.2}$$

$$\pi_i^{KEL} \;=\; PKEL_i - \frac{1}{b_{KEL,i}} \left[\alpha_{KE_i}^{\sigma_i^{KE}} PKE_i^{1-\sigma_i^{KE}} \right. \tag{6.3}$$

$$\left. +(1-\alpha_{KE_i})^{\sigma_i^{KE}} \left(\frac{w}{CPI}\left(1+\theta_{ESSC,i}+\theta_{HSSC,i}\right)\right)^{1-\sigma_i^{KE}}\right]^{\frac{1}{1-\sigma_i^{KE}}} = 0$$

$$\perp \;\; KEL_i > 0 \tag{6.4}$$

$$\pi_i^{KE} \;=\; PKE_i - \frac{1}{b_{KE,i}} \left[\alpha_{K_i}^{\sigma_i^{K}} \cdot r_i^{1-\sigma_i^{K}} + (1-\alpha_{K_i})^{\sigma_i^{K}} \cdot PE_i^{1-\sigma_i^{K}}\right]^{\frac{1}{1-\sigma_i^{K}}} = 0 \tag{6.5}$$

$$\perp \;\; KE_i > 0 \tag{6.6}$$

$$\pi_i^{E} \;=\; PE_i - \frac{1}{b_{E,i}} \left[\alpha_{Elec_i}^{\sigma_i^{Elec}} \cdot \left(\left(1+\tau_{elec}^{ENE}\right) PElec\right)^{1-\sigma_i^{Elec}} \right. \tag{6.7}$$

$$\left. +(1-\alpha_{Elec_i})^{\sigma_i^{Elec}} \cdot PEFF_i^{1-\sigma_i^{Elec}}\right]^{\frac{1}{1-\sigma_i^{Elec}}} = 0$$

$$\perp \;\; E_i > 0 \tag{6.8}$$

$$\pi_i^{EFF} \;=\; PEFF_i - \frac{1}{b_{EFF,i}} \left[\alpha_{OG_i}^{\sigma_i^{OG}} \cdot POG_i^{1-\sigma_i^{OG}} \right. \tag{6.9}$$

$$\left. +(1-\alpha_{OG_i})^{\sigma_i^{OG}} \cdot \left(\left(1+\tau_{coal}^{CO_2}+\tau_{coal}^{ENE}\right) PCOAL\right)^{1-\sigma_i^{OG}}\right]^{\frac{1}{1-\sigma_i^{OG}}} = 0$$

$$\perp \;\; EFF_i > 0 \tag{6.10}$$

$$\pi_i^{OG} \;=\; POG_i - \frac{1}{b_{OG,i}} \left[\alpha_{OIL_i}^{\sigma_i^{OIL}} \cdot \left(\left(1+\tau_{OIL}^{CO_2}+\tau_{OIL}^{ENE}\right) POIL\right)^{1-\sigma_i^{OIL}} \right. \tag{6.11}$$

$$\left. +(1-\alpha_{OIL_i})^{\sigma_i^{OIL}} \cdot \left(\left(1+\tau_{GAS}^{CO_2}+\tau_{GAS}^{ENE}\right) PGAS\right)^{1-\sigma_i^{OIL}}\right]^{\frac{1}{1-\sigma_i^{OIL}}} = 0$$

$$\perp \;\; OG_i > 0 \tag{6.12}$$

where π_i^{YD}, π_i^{KEL}, π_i^{KE}, π_i^{E}, π_i^{EFF}, π_i^{OG}, are the units profits at the six different nesting levels and YD_i, KEL_i, KE_i, E_i, EFF_i, OG_i are the corresponding associated complementary variables.

- To model foreign trade and import demand, we have assumed an Armington activity, that we consider strictly positive. The zero-profit condition states therefore that the Armington price of producing one unit of the Armington good must be equal to the unit cost of producing this good:

$$\begin{aligned}
\pi_i^{YT^{ARM}} &= PYT_i^{ARM} - \frac{1}{b_{YT,i}} \Big[\alpha_{YD_i}^{\sigma_i^{YD}} \left((1+\tau_i^X) \cdot PYI \right)_i^{1-\sigma_i^{YD}} \qquad (6.13) \\
&\quad + (1-\alpha_{YD_i})^{\sigma_i^{YD}} \sum_{r=1}^{n=2} \left(\left(1+\tau_{i,ROW}^{YM}+\tau_i^X\right) \cdot \overline{PYM}_i \cdot ER \right)^{1-\sigma_i^{YD}} \Big]^{\frac{1}{1-\sigma_i^{YD}}} = 0 \\
&\perp \; YT_i > 0 \qquad (6.14)
\end{aligned}$$

where YT_i is the associated complementary variable which indicates the activity level of producing an Armington good i.

- Regarding export demand, the zero-profit condition indicates that the CET unit price of the total output supplied of good i must be equivalent to the CET unit cost:

$$\begin{aligned}
\pi_i^{YD^{CET}} &= PYD_i^{CET} - \frac{1}{b_{DF,i}} \Big[\alpha_{YI_i}^{-\sigma_i^{YI}} \cdot \left((1+\tau_i^X) PYI_i \right)^{1+\sigma_i^{YI}} \qquad (6.15) \\
&\quad + (1-\alpha_{YI_i})^{-\sigma_i^{YI}} \cdot \left((1+\tau_i^Y) \cdot \overline{PEX}_i \cdot ER \right)^{1+\sigma_i^{YI}} \Big]^{\frac{1}{1+\sigma_i^{YI}}} = 0 \\
&\perp \; YD_i^{CET} > 0 \qquad (6.16)
\end{aligned}$$

where and YT_i^{CET} is the associated complementary variable.

- The unit zero-profit condition for private consumption states that, if the consumption activity is positive, the value of one unit of utility must be equal to the unit expenditure function (cost of buying one unit of utility under the given commodity prices):

$$\begin{aligned}
\pi^H &= PU_H - \left[\alpha_{S_H} \cdot PS^{1-\sigma^{S_H}} + (1-\alpha_{S_H}) \cdot PC_H{}^{1-\sigma^{S_H}} \right]^{\frac{1}{1-\sigma^{S_H}}} = 0 \qquad (6.17) \\
&\perp \; U_H > 0 \qquad (6.18)
\end{aligned}$$

where U_H is the associated complementary variable.

- For public consumption, the zero-profit condition for the provision of one unit of public good specifies that:

$$\begin{aligned}
\pi^{GOV} &= PC_{GOV} - \left[\sum_{i=1}^{m=28} \left(1+\tau_i^{VAT}\right) \cdot PYT_i^{ARM} \cdot \frac{C_{GOV,i}}{C_{GOV}} \right] = 0 \qquad (6.19) \\
&\perp \; C_{GOV} > 0 \qquad (6.20)
\end{aligned}$$

where C_{GOV} is the associated complementary variable which indicates the activity level of providing a public good.

- For the NPISH, the zero-profit condition for the provision of one unit of non-public good serving households is given by:

$$\begin{aligned} \pi^{NP} &= PC_{NP} - \left[\sum_{i=1}^{m=28} \left(1 + \tau_i^{VAT}\right) \cdot PYT_i^{ARM} \cdot \frac{C_{NP,i}}{C_{NP}} \right] = 0 && (6.21) \\ &\perp \; C_{NP} > 0 && (6.22) \end{aligned}$$

- For private capital formation, the zero-profit condition is given by:

$$\begin{aligned} \pi^{INV} &= PS - \sum_{i=1}^{m=28} PYT_i^{ARM} \cdot idpv_i = 0 && (6.23) \\ &\perp \; INVP > 0 && (6.24) \end{aligned}$$

where $INVP$ is the associated complementary variable which indicates the activity level of providing a private investment good.

6.1.2 Market clearance conditions

In the previous sections, it has been shown how agents determine demand and supply from their optimization behaviour under given prices. However, the conditions derived from their optimal behaviours do not guarantee that demands and supplies of each market are in equilibrium. For general equilibrium to be ensured, the model must solve for the set of prices that clear the markets. In terms of the MCP approach, the market clearance condition requires that the market of any good or any factor of production with a positive price must be balanced. And for any good or production factor with excess supply, its price must be zero. The price vector of final goods, intermediate goods and factors of production is therefore the associated variable. The equations for the market clearance conditions can be divided into two groups, one for the product markets and the other for the factor markets.

Products Markets Clearance

The products markets clearance condition says that, in equilibrium, for any positive price, the supply of that good must balance the demand by agents. Since there is three goods markets, we have three market clearing conditions: for the domestically produced good, for the imported good and for the exported good. On the domestic market, we have that domestic output of the i-th commodity must be equal to its demand in quantity as the sum of intermediate demand, and final demand (private consumption, NPISH consumption, public consumption, gross capital formation and exports). For the import market, we have that import supply is equal to import demand; whereas for the export market the condition that export supply is equivalent to export demand must be satisfied.

The market clearance condition in the products market for each commodity i implies that there is a vector of prices such that total supply equals total demand. The total supply for the j-th commodity, YT_j, is equivalent to the total amount of domestic supplies sold on the domestic territory plus imports; whereas total market demand is made up of the sum of domestic and foreign demand:

$$YT_j = \sum_{j=1}^{m=28} X_{i,j} + C_{H,j} + C_{NP,j} + C_{GOV,j} + IDPV_j + IDPB_j + \sum_{r=1}^{n=2} X_{r,j} \quad (6.25)$$

Factors Markets Clearance

In this model we specify a capital market in equilibrium where the factor price adjusts so that supply equals demand. However, in the labour market we consider also the possibility of involuntary unemployment, such that total labour demand equals “effective” labour supply. Labour and capital are assumed to be homogeneous goods, mobile across industries but internationally immobile.

For the labour market, total labour demand equals effective labour supply in Spain, from residents and non-residents:

$$\left(\overline{L_H} - \overline{L_{HX}} + \overline{L_{NR}}\right)(1-u) = \sum_{i=1}^{m} L_i^d \quad (6.26)$$

$$w > 0 \quad (6.27)$$

where

L_i^d	:	labour demand for sector i
$\overline{L_H}$	:	total labour endowment of residents
$\overline{L_{HX}}$	:	labour endowment of residents supplied abroad
$\overline{L_{NR}}$	:	labour endowment of non-residents working in Spain

Note that the difference between $\overline{L_H}$ and $\overline{L_{HX}}$, this last variable being considered exogenous, is equivalent to the labour endowment of residents supplied domestically, $\overline{L_{HI}}$. From the SAM, we get benchmark data for L_i^d, $\overline{L_H}$, $\overline{L_{NR}}$ and $\overline{L_{HX}}$. To impose an initial unemployment rate $(u > 0)$ that calibrates with our benchmark data, we must divide $\overline{L_{HI}}$ and $\overline{L_{NR}}$ by $(1-u)$, such that:

$$\left(\frac{\left(\overline{L_H} - \overline{L_{HX}}\right)}{(1-u)} + \frac{\overline{L_{NR}}}{(1-u)}\right)(1-u) = \sum_{i=1}^{m} L_i^d \quad (6.28)$$

The market-clearing condition for the capital market requires that total demand for capital is equal to the total capital endowments available. The price of capital services, r, is the variable that balance factor supply and factor demand.

$$\begin{aligned} K_H + K_{NP} + K_F + K_H &= \sum_{i=1}^{m} K_i && (6.29) \\ r &> 0 && (6.30) \end{aligned}$$

6.1.3 Income balances conditions

The income balance condition states that, in equilibrium, the value of each agent's income (household, government, NPISH) must equal the value of factor endowments, transfers and tax revenues. Regarding the household, this condition just says that the consumer's expenditures cannot increase above his income. And given that local non-satiation is assumed for the utility function, the household always satisfies his budget constraint by exhausting all his disposable income on current consumption and saving. The value of his excess demand will therefore always be equal to zero. And the value of the sum of the excess demands will also be zero for any set of prices and Walras' law will be satisfied.

As previously said, the equilibrium in all markets does not warrant the necessary identity between savings and investment. Solving a general equilibrium system requires to close the model by describing which variables in the model must be considered exogenous and which are endogenous. These macroeconomic closures allow to clear all the macroeconomic balances of the model: the government closure and the equilibrium condition on the balance of payments are combined with the the savings-investment closure rule so that the model can be globally balanced.

Regarding the benchmark specification of our model, we know that the government savings is endogenous and that the investment is savings driven. General equilibrium is therefore ensured by specifying as a residual the balance of payments that is set to satisfy the domestic current account constraint. For this trade balance, we have assumed that foreign saving is fixed while the exchange rate is variable to fulfill the balance-of-payments constraint.

6.2 Walras' law and price normalisation

Once the equilibrium conditions of the model have been specified, and before calculating the calibrated parameters from the benchmark SAM database, the calibration procedure requires first to identify information about prices and quantities separately from the benchmark transactions data. The data of the SAM are indeed monetary values, defined as the products of prices and quantities, while the information needed for model estimation is both prices and quantities of the initial equilibrium.

To separate information on price-quantity combinations into components parts, the most convenient way is to adopt the "Harberger Convention" by treating prices as indices: all prices, except those which include taxes or subsidies, are set equal to unity and thus measure quantities in terms of base year values[3]. Since this price normalisation applies to all commodities prices and to all factor prices, net of taxes or subsidies, the observed equilibrium corresponds therefore to an equilibrium prices vector of unity for both goods and factors.

This price normalisation is allowed by the property of homogeneity of degree zero with respect to prices, assumed for all supply and demand functions in the model. In a CGE model, this property implies that absolute prices are not important. Units of measurement of quantities are essentially arbitrary because only relatives prices are relevant for the specification of the quantities of goods supplied and demanded. Quantities are adjusted accordingly to reflect the ratio of factor prices, such that the resulting volumes ratio does not correspond anymore to the observed physical units. With all prices equal to unity, factors quantities are implicitly measured in "efficiency units" and changes in factor quantities must therefore be understood as changes in efficiency units[4].

Given that the model only determines relative prices, we can choose any good or factor as the numéraire and fix its price at unity. All price and income changes are therefore relative price changes vis-à-vis this numéraire price index. The choice of numéraire should not bring any differences in simulation results[5]. If the numéraire is the consumer price index for example, then a proportional change of all product and factor prices and the CPI does not affect the equilibrium conditions. In this study, the numeraire chosen is the gross wage.

With the price normalisation, the model has now n equations but only $n-1$ endogenous variables. However, the n equations are not independent of each other.

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[3] Normalizing prices allows to impute the value P_0X_0 to the volume X_0.

[4] A unit of primary input (labour and capital) is defined as the amount of factor that, in equilibrium, generates a return of 1 currency unit, net of taxes and gross of subsidies. This unit convention implies that the amount of labour in an industry is not measured anymore by the number of workers in that industry, since this normalisation implicitly assumes that more productive workers are endowed with a greater number of effective labour units [Ballard et al, 1985].

[5] Note that when price fixity is assumed in CGE models, the choice of a numéraire can affect seriously the simulation results because the zero homogeneity of the system does not hold. In that case the implications of the choice of the numéraire should be carefully examined trough sensitivity analysis.

One of the market clearing conditions in this system is redundant because the Walras' law always holds[6]. According to Walras law, there cannot be a situation of aggregate excess demand over all markets. In equilibrium, if one market presents positive excess demand, another must have excess supply, such that in value terms they cancel out. In other words, Walras' law says that equilibrium on $n-1$ of the n markets of the model economy leads to equilibrium also on the $n-$th market. According to the dependence of the equilibrium conditions, one is superfluous and has to be dropped.

6.3 Computational procedure and solution search

Given that the price-endogenous equilibrium framework represents the central characteristic of the CGE models and the general equilibrium is characterised by the three equilibrium conditions mentioned above, the model is solved by finding a vector of prices that satisfy these three classes of conditions. The computational order of the model is based on the prices nesting, as described in *Figure* 5.2. At each iteration, the computations are based on a trial wage rate, price of capital services, tax scalar and basic prices. Given the basic prices, the prices of labour and capital and all tax rates, the structure of the model determines all other goods prices. The description of the price computation is the following :

1. Starting with the bottom of the production tree structure, we look for estimates of the price simplex: the wage rate (w), the price of capital services (r), total tax revenue, the prices of the energy goods ($POIL$, $PGAS$, $PCOAL$, $PElec$) and the non energy goods ($PX_{i,j}$).

2. Given the estimates of the factor prices and basic prices, and the assumptions of constant returns to scale and perfect competition, it is then possible to work the way up in the production prices structure until we compute the Armington prices at the top of the tree nesting.

3. These Armington prices are the ones that enter the bottom of the utility structure in *Figure* 5.3. From them, we can obtain the different aggregate commodity prices. Then, given the net wage rate and the price of aggregate goods, we obtain the price for present consumption, which is related to the price of private savings to give the top price of the utility structure.

4. Once at the top of the utility structure, all the prices for that iteration are known. Given factor returns and government transfers, it is possible to calculate

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[6] If the total value of output and the total value of expenditures balance, Walras' law should always holds. This will be the case if all economic agents meet their budget constraints because, at equilibrium, the budget constraint will also hold in the aggregate for any possible price vector.

the value of consumer available income. Then, given available income, prices and exogenous parameters, we can compute sequentially the following demands of the consumer from the top of the tree structure back down to the bottom.

5. The factor demands that come out at the bottom of the tree are compared with the fixed-factor supplies for that period, and prices are revised in the appropriate directions to reduce the excess supplies or demands.
6. This process is repeated until factor prices yield quantities demanded that equal quantities supplied and the factors market and products market are balanced. To do this, a numerical search algorithm is used to locate the general equilibrium price vector by iterative evaluation of the excess demand system.

Once the benchmark equilibrium is replicated, a so-called "counterfactual" scenario is imposed on the model, such as reduction in payroll taxes. By comparing the results of the benchmark equilibrium with the ones of the counterfactual equilibrium it is possible to evaluate the impacts of an alternative policy measure.

The model is programmed in GAMS [Brooke *et al.*, 1992], using MPSGE as a subsystem [Rutherford, 1994]. The combination of GAMS/MPSGE languages for programming allows to separate conveniently the economic model from the solution algorithm. This helps to specify easily changes in the model structure and assumptions.

6.4 Equilibrium and parameters calibration

Once the behaviour of the economic agents has been analytically formulated, and before solving the model for alternative equilibria associated with changes in policy variables, the following step consists in specifying the parameters of the model through a calibration procedure. To perform the calibration, a fundamental assumption must be made. It consists in supposing that the model economy is in equilibrium in a particular year, the one of the benchmark SAM. This equilibrium assumption allows us to determine the values of the parameters in the model as the ones that will replicate the base values of the variables in the benchmark year and the original steady-state values (such as capital/output ratios and income shares). This is done by solving the equations (derived from the set of equations described above) that represent the equilibrium conditions of the model, using the data on prices and quantities of the benchmark year.

We can differentiate two types of parameters: the calibrated parameters and the free parameters. The calibrated parameters are the ones that are computed directly from the benchmark database, as point estimates at the benchmark equilibrium. On the contrary, the free parameters are independent of the data from the SAM. They are usually assigned values borrowed from outside the model, based on estimates found by literature search, in econometric studies, or directly econometrically estimated. The free parameters to be estimated are usually so many that when the econometric estimation method is used, it focus only on the most relevant parameters. When literature search offers only limited, uncertain or no information about the free parameters, sensitivity analysis is used, in which alternative values for key parameters are proposed. Sensitivity analysis is also used for parameters whose values are pivotal to results in order to analyze the model robustness.

The computation of free parameters depends upon the functional forms used. In this model, the only free parameters are the elasticities of substitution of the CES and CET functions. The Cobb-Douglas and the Leontief functions present the advantage of not requiring information on the free parameters. Cobb-Douglas specification imposes constant returns to scale, constant expenditure shares, unitary elasticity of substitution[7], unit income elasticities, uncompensated own-price elasticities equal to -1 and zero cross-price elasticities. Finally, Cobb-Douglas exponents are given from data on expenditure shares by dividing the consumer's expenditure on each good by the consumer's total expenditure on all goods. So, to calibrate the parameters of Cobb-Douglas functions, only reference data for the base year from a SAM is needed.

Among the most commonly used functional forms, the CES structure presents the advantage to relax some of the constraints of the Cobb-Douglas specification, by assuming a constant non-unit own-price elasticity while maintaining the restriction of unitary income elasticity (that for some policy issues may appear inappropriate) and imposing a constant elasticity of substitution for all goods. But CES functions, as opposed to Cobb-Douglas and Leontief functions, require the pre-specification of the substitution elasticities before proceding with the calibration. The CES production function has indeed three parameters but, from the SAM, we only have information for the share parameter and the shift parameter. Therefore, we need to rely on an additional data source for the last parameter. Usually, a priori assumptions about the values of these elasticities are made by using other econometric studies. Then, on the basis of our SAM for Spain (SPAM00) and the properties of CES production and utility functions, it is possible to determine the numerical values of all the parameters of the model.

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[7] A unitary elasticity of substitution means that at any place of an isoquant, the total payment to both inputs remains the same.

6.4.1 Production

A description of the calibration of production and trade parameters follows. Calibration usually starts by first assigning values to the free parameters. We start from the bottom-level nest of the oil-gas aggregate as an example of the calibration process that can be used for the other nesting levels.

Elasticities

To assign a value to the free parameters constitutes the first step of the calibration process. In the "production" part, the only free parameters are the elasticities of substitution of the CES, CET and Armington functions. Following a standard practice common to CGE models, we select elasticity parameters close to literature based estimates. Values are displayed in *table* (6.1). First, the elasticities σ_i^{OIL} are taken from the survey of Burniaux and Truong [2002] and the GREEN model of Burniaux *et al.* [1992]. The coal - oil/gas elasticities, σ_i^{OG}, and the substitution elasticities between electricity and the fossil fuels, σ_i^{Elec}, follows the estimates of Paltsev et al. [2005], Burniaux and Truong [2002] and Burniaux *et al.* [1992].

The elasticity between energy and capital, σ_i^K, has both a sign and a magnitude that tend to vary significantly between different empirical studies (see Burniaux and Truong [2002]). One of the reasons is that energy-capital substitution is a long-term adjustment process, and therefore, empirical estimates of σ_i^K differ between the short and long run. A widely held opinion in this area is that perhaps energy and capital are complements in the short-run, but substitutes in the long-run[8]. This observation suggests that increases in energy prices stimulate factor substitution towards "energy saving" capital but that this is a long run process. The substitution elasticity between capital and the energy composite follows different studies, depending on the sectoral disaggregation proposed. As a lower bound of 0.5, we follow the meta-regression analysis for estimated elasticities on capital-energy substitution performed by Koetse et al. [2006]. We use also more precise sectoral data from the GTAP-E model [Burniaux and Truong, 2002], Kemfert and Welsch [2000] and Okagawa and Ban [2008]. All indicate energy and capital are substitutes.

The substitution elasticities between labour and the capital-energy aggregate σ_i^{KE} are also taken from Kemfert and Welsch [2000], Burniaux and Truong [2002] and Okagawa and Ban [2008]. The Armington elasticities of substitution between the domestic and imported goods,σ_i^{YD}, come from GTAP [Hertel, 1997] and are therefore

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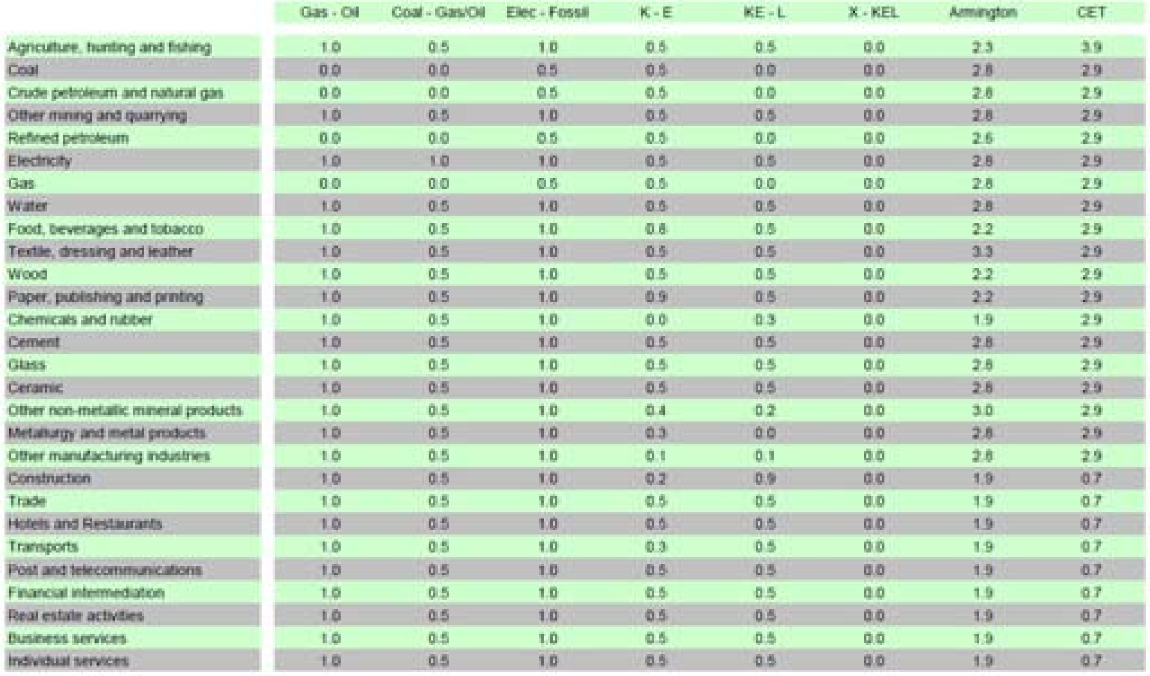
[8] The GREEN model [Burniaux et al., 1992] for example incorporate a "vintage capital" structure, so that short run substitution between "old" capital and energy can be low, while long-run substitution between "new" capital and energy can be high. The net effect will then depend on the capital vintage structure.

similar to those from Blake [2000] and Rodriguez [2003]. Finally, the elasticities of transformation between domestically supplied and exported goods, σ_i^{YI}, come from de Melo and Tarr [1992].

Table 6.1: Elasticities of substitution - Production function



	Gas - Oil	Coal - Gas/Oil	Elec - Fossil	K - E	KE - L	X - KEL	Armington	CET
Agriculture, hunting and fishing	1.0	0.5	1.0	0.5	0.5	0.0	2.3	3.9
Coal	0.0	0.0	0.5	0.5	0.0	0.0	2.8	2.9
Crude petroleum and natural gas	0.0	0.0	0.5	0.5	0.0	0.0	2.8	2.9
Other mining and quarrying	1.0	0.5	1.0	0.5	0.5	0.0	2.8	2.9
Refined petroleum	0.0	0.0	0.5	0.5	0.0	0.0	2.6	2.9
Electricity	1.0	1.0	1.0	0.5	0.5	0.0	2.8	2.9
Gas	0.0	0.0	0.5	0.5	0.0	0.0	2.8	2.9
Water	1.0	0.5	1.0	0.5	0.5	0.0	2.8	2.9
Food, beverages and tobacco	1.0	0.5	1.0	0.8	0.5	0.0	2.2	2.9
Textile, dressing and leather	1.0	0.5	1.0	0.5	0.5	0.0	3.3	2.9
Wood	1.0	0.5	1.0	0.5	0.5	0.0	2.2	2.9
Paper, publishing and printing	1.0	0.5	1.0	0.9	0.5	0.0	2.2	2.9
Chemicals and rubber	1.0	0.5	1.0	0.0	0.3	0.0	1.9	2.9
Cement	1.0	0.5	1.0	0.5	0.5	0.0	2.8	2.9
Glass	1.0	0.5	1.0	0.5	0.5	0.0	2.8	2.9
Ceramic	1.0	0.5	1.0	0.5	0.5	0.0	2.8	2.9
Other non-metallic mineral products	1.0	0.5	1.0	0.4	0.2	0.0	3.0	2.9
Metallurgy and metal products	1.0	0.5	1.0	0.3	0.0	0.0	2.8	2.9
Other manufacturing industries	1.0	0.5	1.0	0.1	0.1	0.0	2.8	2.9
Construction	1.0	0.5	1.0	0.2	0.9	0.0	1.9	0.7
Trade	1.0	0.5	1.0	0.5	0.5	0.0	1.9	0.7
Hotels and Restaurants	1.0	0.5	1.0	0.5	0.5	0.0	1.9	0.7
Transports	1.0	0.5	1.0	0.3	0.5	0.0	1.9	0.7
Post and telecommunications	1.0	0.5	1.0	0.5	0.5	0.0	1.9	0.7
Financial intermediation	1.0	0.5	1.0	0.5	0.5	0.0	1.9	0.7
Real estate activities	1.0	0.5	1.0	0.5	0.5	0.0	1.9	0.7
Business services	1.0	0.5	1.0	0.5	0.5	0.0	1.9	0.7
Individual services	1.0	0.5	1.0	0.5	0.5	0.0	1.9	0.7

Share parameters

Once we have specified the values for the substitution elasticities we can use them, together with the base values of the variables obtained from the SAM database, to calculate the shift parameters in the CES and CET functions. For the CES case, the share parameter ($\widehat{\alpha}$) is recovered, given the substitution elasticity between them and taking into account the normalisation assumption imposed on the base-year prices. This procedure applies to all the shares parameters of the CES and Armington functions. As an example, the share parameter for the oil composite in the OG_i aggregate is given by:

$$\widehat{\alpha}_{OIL_i} = \frac{\frac{POIL\left(1+\tau_{OIL}^{CO_2}+\tau_{OIL}^{ENE}\right)}{PGAS\left(1+\tau_{GAS}^{CO_2}+\tau_{GAS}^{ENE}\right)}\left(\frac{OIL_{i,0}}{GAS_{i,0}}\right)^{\frac{1}{\widehat{\sigma_i^{OIL}}}}}{1+\frac{POIL\left(1+\tau_{OIL}^{CO_2}+\tau_{OIL}^{ENE}\right)}{PGAS\left(1+\tau_{GAS}^{CO_2}+\tau_{GAS}^{ENE}\right)}\left(\frac{OIL_{i,0}}{GAS_{i,0}}\right)^{\frac{1}{\widehat{\sigma_i^{OIL}}}}} \tag{6.31}$$

For the CET case, the calibration procedure is similar to that for CES functions. The CET share parameter, $\widehat{\alpha_{YI_i}}$, is recovered, given revenue shares and the transformation elasticity between domestic sales and exports. From equation (5.41), we obtain:

$$\widehat{\alpha_{YI_i}} = \frac{\frac{PYI_i}{PEX_i \cdot ER}\left(\frac{YI_i}{EX_i}\right)^{-\frac{1}{\widehat{\sigma_i^{YI}}}}}{1+\frac{PYI_i}{PEX_i \cdot ER}\left(\frac{YI_i}{EX_i}\right)^{-\frac{1}{\widehat{\sigma_i^{YI}}}}} \tag{6.32}$$

Scale parameters

Once we know the values of the substitution elasticity ($\widehat{\sigma_i^{OIL}}$) and the share parameter ($\widehat{\alpha_{OIL_i}}$), we can use them to calibrate the value of the scale parameter, $\widehat{b_{OG,i}}$. If the output of the sector OG_i and the quantities used of the two inputs are known from the benchmark data, we may calibrate the scale parameter directly from the equation (5.2):

$$\widehat{b_{OG,i}} = \frac{OG_i}{\left[\widehat{\alpha_{OIL_i}} OIL_i^{1-\frac{1}{\widehat{\sigma_i^{OIL}}}} + (1-\widehat{\alpha_{OIL_i}}) GAS_i^{1-\frac{1}{\widehat{\sigma_i^{OIL}}}}\right]^{\frac{\widehat{\sigma_i^{OIL}}}{\widehat{\sigma_i^{OIL}}-1}}} \tag{6.33}$$

Alternatively, it may be convenient to recover a value for $b_{OG,i}$ so that the price of OG_i is unity when the price of OIL_i and GAS_i are also unity. Rearranging expression (**??**), we obtain:

$$b_{OG,i} = \left[\widehat{\alpha}_{OIL_i}^{\widehat{\sigma_i^{OIL}}} + (1-\widehat{\alpha}_{OIL_i})^{\widehat{\sigma_i^{OIL}}}\right]^{\frac{1}{1-\widehat{\sigma_i^{OIL}}}} \tag{6.34}$$

6.4.2 Household Consumption

The first set of parameters of the household consumption nesting we need to specify are the free parameters, gathered from literature search.

Lower-nest elasticities of substitution

The elasticities of substitution for the energy demand demand nesting follow the proposition of Rutherford and Palstev [2000] and Paltsev et al. [2004] and are set to $\sigma^{OIL_H} = 0.4$, $\sigma^{OG_H} = 0.5$, and $\sigma^{Elec_H} = 0.2$. The substitution elasticity between the energy aggregate and the non-energy consumption goods aggregate is set to $\sigma^{X_H} = 0.4$, according to the same authors.

Intertemporal elasticity of substitution.

The next step is to obtain an estimate of σ^{S_H}, the elasticity of substitution between savings and present consumption, and the share parameter α_{S_H}. The idea would be to solve σ^{S_H} as a function of the elasticity of saving with respect to the real after-tax rate of return, η_S. This would require to differentiate the demand for S_H, in equation

(5.55), with respect to the rate of return r. However, as confirmed by Ballard *et al.* [1985, 130], it is “exceedingly difficult to evaluate $\partial S_H/\partial r$ analytically”[9].

Empirical evidence on the magnitude of the intertemporal elasticity of substitution is not clear. Moreover, some evidence suggests that the intertemporal elasticity of substitution may vary with the level of consumption and should not be constant [Attanasio and Browning, 1995]. Earlier studies found values around 1.0 and possibly higher than unity. Based on more rigorous estimation techniques, Hall [1988] gets point estimates equal to 0.1 or 0.2 that are not significantly different from zero statistically. Barsky *et al.* [1997] find similar values. In empirical simulations models, Auerbach and Kotlikoff [1987] assume that this elasticity is 0.25, while Engen and Gale [1996] consider a value of 0.33, but in the context of a model with uncertainty and precautionary savings. Also, Attannasio and Weber [1995] estimate a range of 0.6 to 0.7, while Fullerton and Rogers [1996] estimate it to be in the range of 0.15 to 0.50. More recent work by Mulligan [2002] and Gruber [2006] obtain an elasticity of substitution greater than unity.

For Spain, different studies have been realised with macroeconomic (e.g. Rodríguez López [1997]) and microeconomic data (e.g. López Salido [1993], Cutanda y Labeaga [2001]) in order to estimate the intertemporal elasticity of substitution. Overall, the estimated values based on macroeconomic data are lower than the ones based on microeconomic data, as argued by López Salido [1995]. Pou Garcias et al. [2006] indicate also how the estimated elasticity value tends to differ significantly with respect to the consumption goods category studied (higher elasticity for durable goods vs. non-durable goods) and the level of cyclical variables such as the economic cycle periods and the interest rate.

In general, by using the Euler consumption equation as an estimation framework, empirical evidence from microeconomic data for Spain presents an intertemporal elasticity with positive sign and inferior to unity. However, results may vary widely between studies, depending on the sample data used. For example, using cohort data from the Spanish Encuesta Continua de Presupuestos Familiares, López Salido [1993] obtains estimated elasticity values between 2.8 and 6 for the period 1985-89, whereas Garcia Garcia [1999] obtains elasticities between 0.574 and 0.995 for the years 1985-1992. Márquez de la Cruz [2005] obtains also considerable differences in intertemporal elasticity values (between 0.0065 and 2.29) when performing estimations from models with one or two separable goods. Cutanda [2002] observes that estimation results

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[9] The solution proposed by Ballard et al. [1985] is to evaluate $\partial S_H/\partial r$ numerically, on the basis of an iterative procedure. By assuming a particular value for the saving elasticity, the aim of the procedure is to find by iteration a value of σ^{S_H} that "generates" this value for the saving elasticity.

tend to show different intertemporal consumption behaviours between socioeconomic groups. He concludes however that models based on microeconomic data offer much more reasonable results, with parameter values for the Spanish economy being positive and slightly superior to 0.5, possibly around 0.6 or 0.7. Based on this empirical evidence for Spain, we use an intertemporal elasticity of substitution of 0.6 in our model.

Share parameters

Given the above mentioned elasticities of substitution, it is possible to recover the related share parameters of the CES functions. As an example, the share parameter for the oil composite in the OG_H aggregate is given by:

$$\widehat{\alpha}_{OIL_H} = \frac{\frac{OIL_H}{GAS_H}\left(\frac{\left(1+\tau_{Oil}^{VAT}+\tau_{Oil}^{CO_2}+\tau_{Oil}^{ENE}\right)PYT_{oil}^{ARM}}{\left(1+\tau_{Gas}^{VAT}+\tau_{Gas}^{CO_2}+\tau_{Gas}^{ENE}\right)PYT_{gas}^{ARM}}\right)^{\sigma^{\widehat{OIL_H}}}}{1+\frac{OIL_H}{GAS_H}\left(\frac{\left(1+\tau_{Oil}^{VAT}+\tau_{Oil}^{CO_2}+\tau_{Oil}^{ENE}\right)PYT_{oil}^{ARM}}{\left(1+\tau_{Gas}^{VAT}+\tau_{Gas}^{CO_2}+\tau_{Gas}^{ENE}\right)PYT_{gas}^{ARM}}\right)^{\sigma^{\widehat{OIL_H}}}} \tag{6.35}$$

6.4.3 Economic Policy Instruments

The model includes a variety of instruments of economic policy which must be calibrated, such as direct and indirect taxes. As a generic rule, tax rates are computed as the ratio of taxes paid to their tax bases. Tax rates are declared as parameters that can be controlled and altered directly by the government.

Direct Taxes

- The employer's Social Security tax rate is computed by dividing social security tax revenues as reported by the SAM by labour income. The social security taxes reported by the SAM are a broad measure that includes payments to the social security system, taxes for health care benefits through the government, and unemployment insurance. The labour income estimate is simply the wage times labour demand.

$$\theta_{ESSC,i} = \frac{ESSC_i}{w \cdot L_i} \tag{6.36}$$

- The household's Social Security tax rate on the labour income is, in the same way, a sectoral rate computed as contributions paid divided by sectoral labour income:

$$\theta_{HSSC,i} = \frac{HSSC_i}{w \cdot L_i} \tag{6.37}$$

- The tax rate on household's income is computed as domestic income taxes paid divided by the household's income earned in the domestic territory:

$$\tau^{Y_H} = \frac{RTY_H}{(1-\lambda_{TYH})\cdot Y_H} \tag{6.38}$$

- The corporate tax rate on the corporations income:

$$\tau^{Y_F} = \frac{RTY_F}{(1-\lambda_{TYF})\cdot Y_F} \tag{6.39}$$

Indirect taxes

- The net tax rate on production is computed as the total revenues from net taxes on production divided by total domestic output:

$$\tau_i^{Y} = \frac{RTYD_i}{PYD_i \cdot YD_i} \tag{6.40}$$

- The VAT is assumed to be a flat tax where the marginal tax rate can typically be well approximated by the average tax rate. It is computed as total consumer sales tax payments divided by total consumer expenditures net of indirect taxes

$$\tau_i^{VAT} = \frac{RTYVAT_i}{PYT_i^{ARM}\cdot (C_{H,i}+C_{NP,i}+C_{GOV,i})} \tag{6.41}$$

- The net tax on products is equally approximated by the average tax rate:

$$\tau_i^{X} = \frac{RTYT_i}{(PYI_i\cdot YI_i + \overline{PYM}_{i,r}\cdot ER \cdot YM_{i,r})} \tag{6.42}$$

- The tariff rate on imports is the ratio of import tariff revenue to the value of imports from the "rest of the world" sector:

$$\tau_i^{YM} = \frac{RTYM_i}{\overline{PYM}_i \cdot ER \cdot YM_{i,ROW}} \tag{6.43}$$

- The ad-valorem tax on CO_2 emissions

The policy instrument related to the control of emissions is initially an excise tax on the carbon content of fuels, specified as a monetary amount (in 2000 euros) per ton of carbon. This carbon tax system allows a corresponding system of emissions permits if the emissions permits are assumed to be hold by the government. The carbon tax can be therefore interpreted as the shadow price of CO_2 emissions and should be determined as part of the equilibrium solution of the model[10].

Though the carbon tax is implemented as an ad quantum tax, it is expressed as an ad valorem tax for convenience in the CGE model. The excise tax on the carbon content of fuels is considered as a supplement cost to the price paid for the consumption of fuel f. To see this, suppose that the consumption of fuel f for sector i (in TJ) is $F_{i,f}$, the fuel price is P_f and $CO_{2,i,f}$ is the emission level of sector i due to the use of the fuel f. With an excise tax on the carbon content of fuels εt^{CO_2}, the cost of using the fuel f will be the following for the producer of sector i:

$$\begin{aligned} P_f \cdot F_{i,f} + \varepsilon t^{CO_2} \cdot CO_{2,i,f} &= P_f \cdot F_{i,f} + \varepsilon t^{CO_2} \cdot \Phi_f \cdot F_{i,f} \\ &= (P_f + \varepsilon t^{CO_2} \cdot \Phi_f) \cdot F_{i,f} \\ &= P_f \cdot (1 + \tau_f^{CO_2}) \cdot F_{i,f} \end{aligned} \tag{6.44}$$

where $\tau_f^{CO_2}$ is the ad-valorem carbon tax[11] on consumption of fuel f and Φ_f is a carbon emission fuel factor corresponding to the emission coefficients defined in *table* 4.4. Assigning a benchmark carbon emission fuel factor of unity to petrol fuel, we then obtain the relative coefficients factors for coal (5.464) and gas (1.843) for the activity sectors and coal (5.715) and gas (1.437) for the household.

The specification of the carbon tax as an ad-valorem tax rate on the consumption of fuel f is therefore endogenous and given by the following expression[12]:

$$\tau_f^{CO_2} = \frac{\varepsilon t^{CO_2} \cdot \Phi_f}{P_f} \tag{6.45}$$

As it appears, although the same ad-quantum carbon tax is imposed in each scenario, ad-valorem tax rates can differ considerably among different types of fossil fuels, depending on both the carbon content and the price of fuel in the absence of carbon taxes. Also, inflation reduces the impact of an ad-quantum tax. This effect might be very important in the long run and, under this situation, a periodic reevaluation of the tax level might become necessary.

- The ad-valorem tax on energy use

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[10] Within the perfect competition framework, theory shows that there is a correspondence between the negotiated price of the emission permit and the tax level allowing to reach the objective emission level. The GREEN model [Burniaux et al., 1992] for example uses this dual approach to perform simulations either with restrictions on the emissions levels (once permits exchanges are allowed between the agents) or by introducing taxes.

[11] Ad quantum taxes are levied on a quantity basis while ad valorem taxes are imposed on a value basis.

[12] See van der Mensbrugghe [1994, 76].

The ad-valorem tax on energy use is calculated in a similar way as the ad-valorem tax on carbon emissions. Again, the excise tax on the energy content of final energy sources is considered as a supplement cost to the price paid for the consumption of energy *ene*. Assume that the consumption of final energy *ene* for sector i is $FE_{i,ene}$ when expressed in *ktoe* and $FTJ_{i,ene}$ when expressed in *TJ,* the relationship between the two aggregate is given by:

$$fe_{oil} \cdot FE_{i,ene} = FTJ_{i,ene}$$

where fe_{oil} is the energy conversion factor from kilotons of oil equivalent to Terajoules on a net calorific value basis (TJ/ktoe). If the fuel price is P_{ene} and the excise tax on the energy content of final energy inputs is εt^{ENE}, the cost of consuming the final energy *ene* will be the following for the sector i:

$$\begin{aligned} P_{ene} \cdot FE_{i,ene} + \varepsilon t^{ENE} \cdot FTJ_{i,ene} &= P_{ene} \cdot FE_{i,ene} + \varepsilon t^{ENE} \cdot fe_{oil} \cdot FE_{i,ene} \quad (6.46) \\ &= (P_{ene} + \varepsilon t^{ENE} \cdot fe_{oil}) \cdot FE_{i,ene} \\ &= P_{ene} \cdot (1 + \tau\varepsilon_{ene}^{ENE}) \cdot FE_{i,ene} \end{aligned}$$

The specification of the energy tax as an ad-valorem tax rate, $\tau\varepsilon_{ene}^{ENE}$, is thus given by:

$$\tau\varepsilon_{ene}^{ENE} = \frac{\varepsilon t^{ENE} \cdot fe_{oil}}{P_{ene}} \tag{6.47}$$

Under the benchmark assumption of unitary prices ($P_{ene} = 1$), the ad-valorem tax is equivalent to the ad-quantum tax. But this tax rate applies for final energy sources valued in physical units (ktoe) whereas, our benchmark data are given in monetary units. In our tax analysis, we have to take into account that change in the valuation of the ad-valorem tax rate. Indeed, the tax rate will become energy-specific, as we pass from monetary units to physical units (ktoe). Data for physical consumption of final energy in Spain for the year 2000 can be found in equivalent physical units of kilotons of oil equivalents (ktoe) [Foro Nuclear, 2010]. For each final energy source, we obtain the ratio ck_{ene} of total consumption in physical units (ktoe), FE_{ene}, to total consumption in euros, CF_{ene}, such that $FE_{ene} = CF_{ene} \cdot ck_{ene}$. This includes imports, both from the EU and the rest of the world, obtained from the imports use table (cif) from the INE. The values for the ratio ck_{ene} are 0.9153, 1.2902, 2.9558 and 0.7615 for coal, gas, oil and electricity respectively. Given that *equation* (6.46) can be rewritten as:

$$P_{ene} \cdot (1 + \tau\varepsilon_{ene}^{ENE}) \cdot FE_{i,ene} = P_{ene} \cdot (1 + \tau\varepsilon_{ene}^{ENE}) \cdot CF_{ene} \cdot ck_{ene} \tag{6.48}$$

we obtain an effective ad-valorem tax rate, τ_{ene}^{ENE}, to be readily applied on our benchmark data (CF_{ene}), and computed as:

$$\tau_{ene}^{ENE} = \varepsilon t^{ENE} \cdot fe_{oil} \cdot ck_{ene} \tag{6.49}$$

Again, we are interested in specifying the relative value (between energy sources) of the effective ad-valorem tax rate, τ_{ene}^{ENE}. Given that the only variable parameter between energy sources is ck_{ene}, we assign a benchmark energy factor of unity (1) to electricity. We then obtain the relative coefficients factors for coal (1.202), gas (1.6942) and oil (3.8815). In the computation process, these relative values are multiplied by the endogenous ad-valorem tax rate to obtain a tax rate specific to each final energy source.

Chapter 7

Simulations and Results

This chapter presents the results of the different fiscal policy simulations. As already stated, we simulate an ex-ante reduction in *current* tax rates, generating a decrease in corresponding tax revenues equivalent to a 1% reduction of GDP. In parallel with these initial tax policies, we propose two fiscal compensation alternatives and two alternatives without fiscal compensation. With respect to the former, we impose two sub-cases of alternative financing options: a *new* carbon tax or a *new* carbon/energy tax to cover the ex-ante tax revenue losses, and ensure in this way a fiscally-neutral policy. Hence, the CO_2/energy tax rates are calibrated *ex-post*, in order to compensate the revenue losses from the initial tax policies. Instead of determining an initial level of CO_2 emissions or energy efficiency to be reached, this method allows to compare the economic efficiency of different tax policies with an equivalent *ex-ante* fiscal cost.

7.1 Modalities of the variants

The initial tax policy changes are described in *table* (2.30). They consist of an ex-ante reduction in four different tax rates from the Spanish tax system: the employers Social Security contributions (ESSC), the value-added tax (VAT), the personal income tax (PIT) and the corporate income tax (CIT). As mentioned in chapter 2, for each policy scenario, the fiscal policy that will be used as starting point will be the same: the simulation of an ex-ante reduction in tax rate, generating a decrease in corresponding tax revenues equivalent to a 1% reduction of GDP.

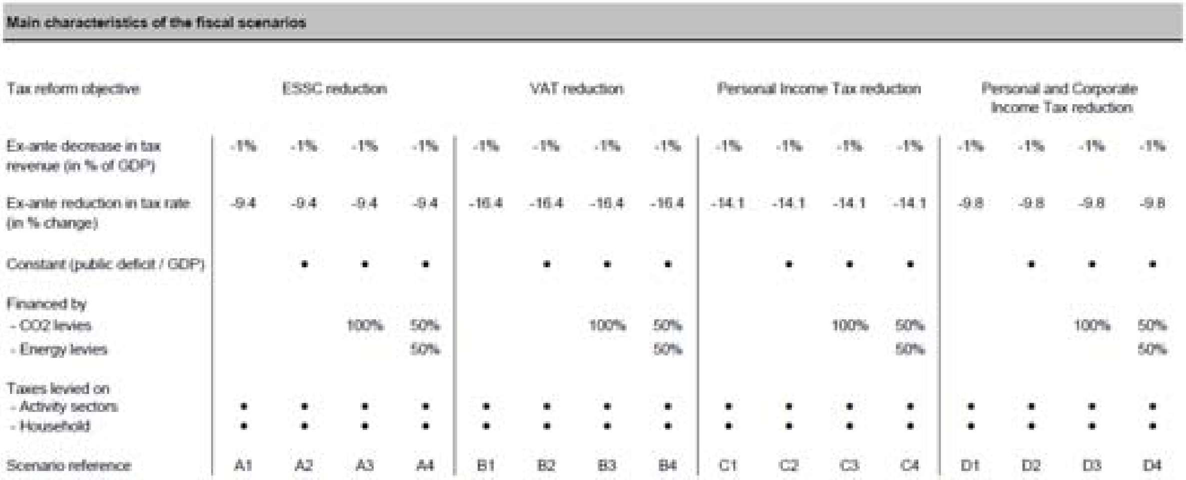
In the first variant, a decrease in ESSC, the tax policy is intended to lower production costs, trough lower labour costs, and eventually promote labour demand. By targeting the production costs, it affects in a similar way the production prices and consumption prices to the downside. These lower prices generate an increase in real disposable incomes for the household and the corporate sector. The household is thus able to consume more and save more for private investment, with allocations depending on the relative prices of consumption and private investment. At the same time, the corporate sector also benefits from higher real savings, fueling private investment. Hence, as household savings and corporate savings sum, the variant A tends to favour slightly more private investment than private consumption. It could also temper the increase in production costs resulting from the higher energy prices.

In the second variant, the VAT rate decrease should directly impact on the consumption price levels and reduce the negative impact of higher energy prices on consumption prices. If the result is a higher real disposable income, private consumption and private investment might pick up. But by reducing the VAT rate, and therefore the relative price of consumption goods with respect to private investment price, the variant B favours systematically more private consumption than private investment, for a given real household disposable income. The potential higher aggregate demand might lead to higher output and higher labour demand by firms, with a positive impact on employment.

The third and fourth variants concentrate on reduction of income taxes for both the household and the corporate sector. Since any income tax tends to reduce disposable income, it also dampens private consumption as well as savings and investment. Therefore, the focus of these variants will help to evaluate the economic impacts of an income tax reduction trough the specific results on consumption and capital accumulation. Variant C increases the household disposable income, without generating any specific bias towards consumption or private investment. Both variables can benefit from the tax policy, but the overall effect on private investment will depend also significantly on the change in corporate savings. Finally, variant D tends to favour slightly more private investment than private consumption, by improving the real disposable incomes of both the household and the corporate sector.

Of course, if the public revenue lost from the decrease in the tax rates is not compensated by another tax policy to fund the initial tax reduction, the public deficit would be severely affected, as the government would presumably suffer from a drop in its financing capacity. Now, instead of generating a larger public deficit, the restriction of a “savings driven” public investment ensures that a lower public savings would turn to a lower public investment level. The consequence of the public revenue loss is thus either a larger public deficit to GDP ratio (alternative 1 - without “savings driven” closure rule) or a lower public investment level (alternative 2). On the other hand, the imposition of fiscal neutrality, as advocated in the draft European Directive on the CO_2/energy tax, is implemented trough two different options: either a new tax on CO_2 emissions (carbon content of fossil fuels) (alternative 3), or an equally weighted CO_2/energy tax on energy inputs (including electricity) (alternative 4). The different scenarios are presented in *table* (7.1).

Table 7.1: Main characteristics of the scenarios simulated



Main characteristics of the fiscal scenarios

Tax reform objective	ESSC reduction				VAT reduction				Personal Income Tax reduction				Personal and Corporate Income Tax reduction			
Ex-ante decrease in tax revenue (in % of GDP)	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%
Ex-ante reduction in tax rate (in % change)	-9.4	-9.4	-9.4	-9.4	-16.4	-16.4	-16.4	-16.4	-14.1	-14.1	-14.1	-14.1	-9.8	-9.8	-9.8	-9.8
Constant (public deficit / GDP)		●	●	●		●	●	●		●	●	●		●	●	●
Financed by																
- CO2 levies			100%	50%			100%	50%			100%	50%			100%	50%
- Energy levies				50%				50%				50%				50%
Taxes levied on																
- Activity sectors	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
- Household	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Scenario reference	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4

We start by presenting some sectoral results for selected variables such as prices, quantities, labour and carbon emissions. We follow by showing how the sectoral effects reverberate into some key macroeconomic variables in the next section. We finally discuss some policy implications that can be derived from the simulation results.

7.2 Sectoral results

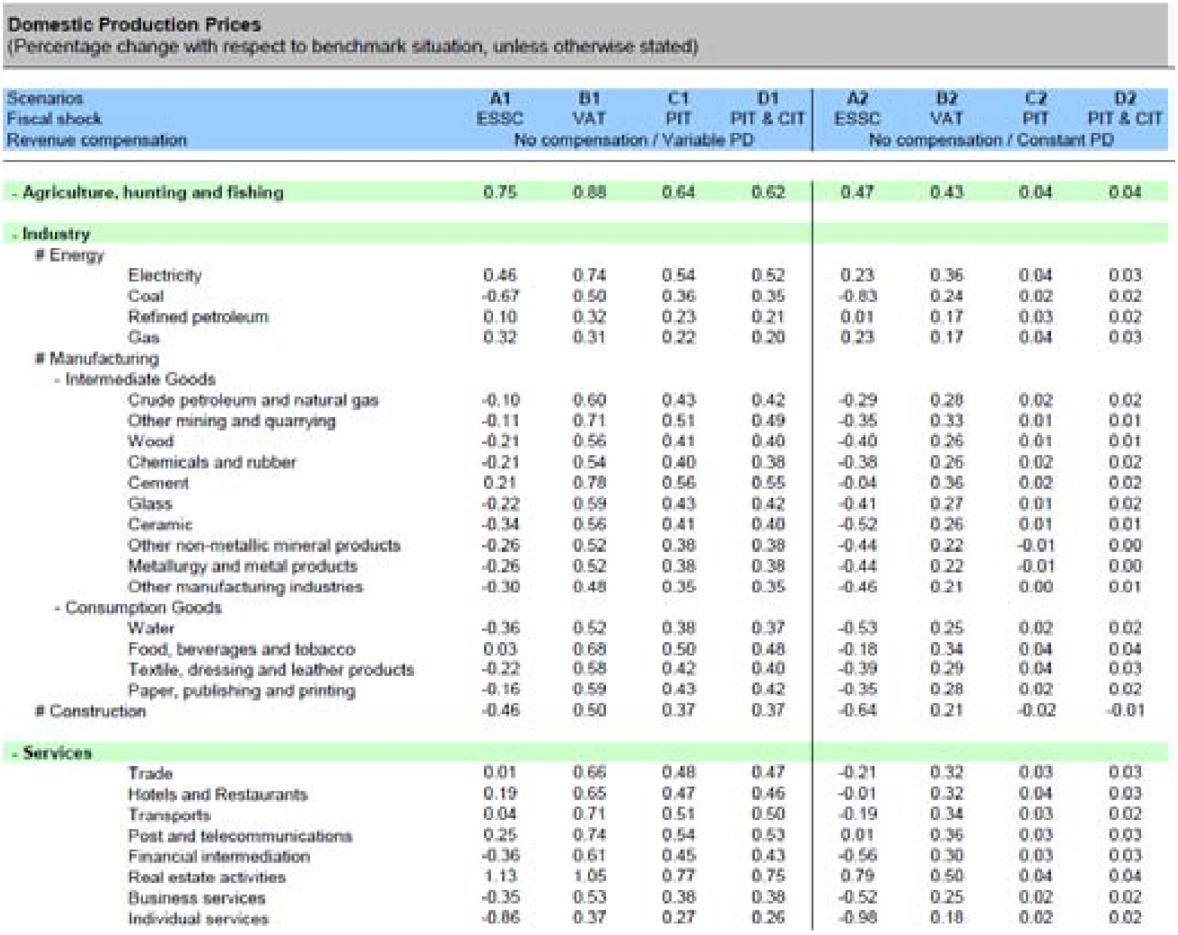
7.2.1 Production

Domestic production prices

Tables (7.2) and (7.3) show the change in domestic production prices for the selected 28 domestic sectors in Spain. It is important to emphasize again that the model only determines relative prices. As a consequence, all price and income changes are relative price changes vis-à-vis this numéraire price index, which is defined here as the gross wage. For all the four variants, results show some noticeable differences among financing alternatives.

When no fiscal compensation is in place and the public deficit is allowed to increase (alternative I), sectoral production prices increase for the last three variants. This increase in production prices is quite homogeneous across all sectors and is mainly the result of a higher price of capital services. The second variant (reduction in VAT rate) shows the highest change in domestic production prices, with a domestic production that expands more than for the last two variants. However, the variant that presents the highest increase in domestic production is also the only one that shows broad-based

Table 7.2: Domestic production prices (no fiscal compensation)



Domestic Production Prices
(Percentage change with respect to benchmark situation, unless otherwise stated)

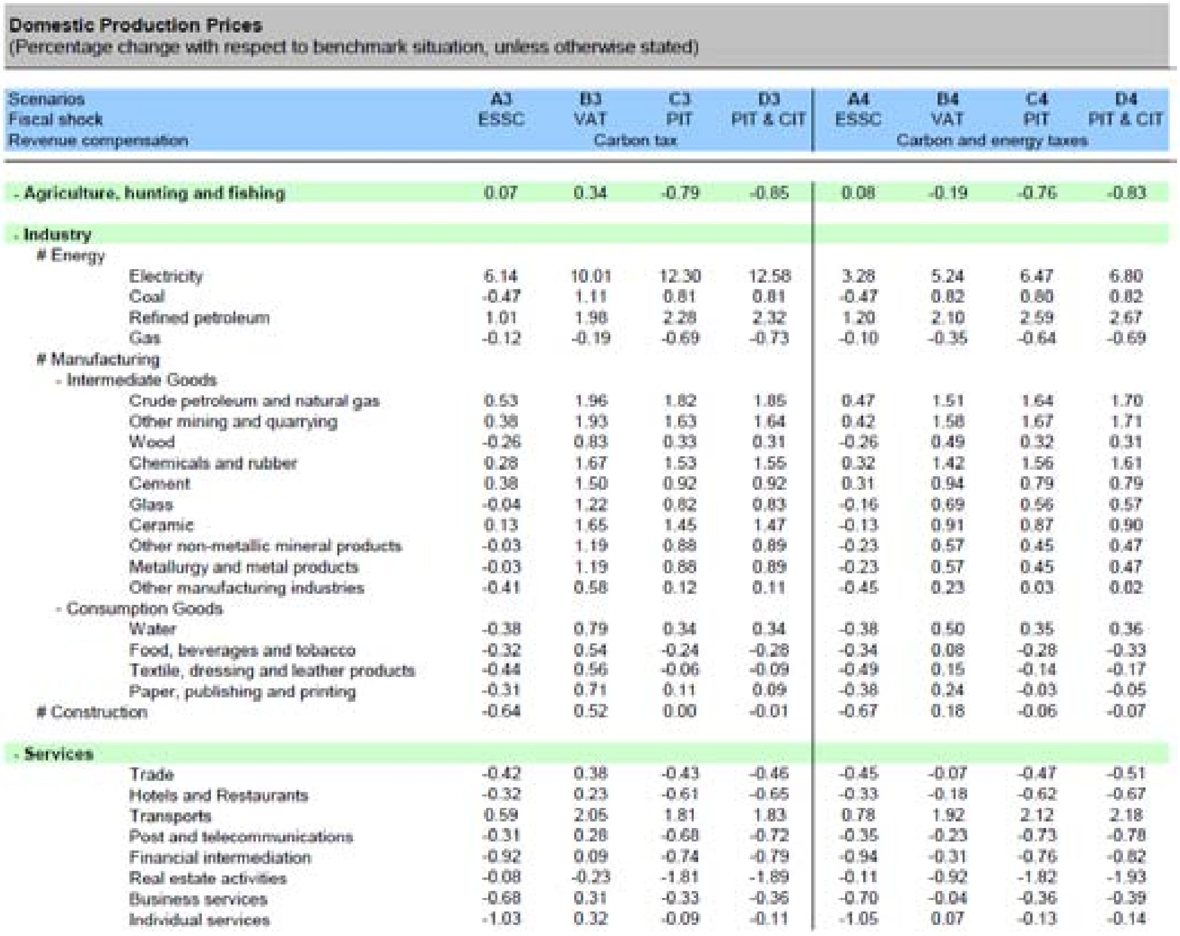
Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	0.75	0.88	0.64	0.62	0.47	0.43	0.04	0.04
- Industry								
# Energy								
Electricity	0.46	0.74	0.54	0.52	0.23	0.36	0.04	0.03
Coal	-0.67	0.50	0.36	0.35	-0.83	0.24	0.02	0.02
Refined petroleum	0.10	0.32	0.23	0.21	0.01	0.17	0.03	0.02
Gas	0.32	0.31	0.22	0.20	0.23	0.17	0.04	0.03
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-0.10	0.60	0.43	0.42	-0.29	0.28	0.02	0.02
Other mining and quarrying	-0.11	0.71	0.51	0.49	-0.35	0.33	0.01	0.01
Wood	-0.21	0.56	0.41	0.40	-0.40	0.26	0.01	0.01
Chemicals and rubber	-0.21	0.54	0.40	0.38	-0.38	0.26	0.02	0.02
Cement	0.21	0.78	0.56	0.55	-0.04	0.36	0.02	0.02
Glass	-0.22	0.59	0.43	0.42	-0.41	0.27	0.01	0.02
Ceramic	-0.34	0.56	0.41	0.40	-0.52	0.26	0.01	0.01
Other non-metallic mineral products	-0.26	0.52	0.38	0.38	-0.44	0.22	-0.01	0.00
Metallurgy and metal products	-0.26	0.52	0.38	0.38	-0.44	0.22	-0.01	0.00
Other manufacturing industries	-0.30	0.48	0.35	0.35	-0.46	0.21	0.00	0.01
- Consumption Goods								
Water	-0.36	0.52	0.38	0.37	-0.53	0.25	0.02	0.02
Food, beverages and tobacco	0.03	0.68	0.50	0.48	-0.18	0.34	0.04	0.04
Textile, dressing and leather products	-0.22	0.58	0.42	0.40	-0.39	0.29	0.04	0.03
Paper, publishing and printing	-0.16	0.59	0.43	0.42	-0.35	0.28	0.02	0.02
# Construction	-0.46	0.50	0.37	0.37	-0.64	0.21	-0.02	-0.01
- Services								
Trade	0.01	0.66	0.48	0.47	-0.21	0.32	0.03	0.03
Hotels and Restaurants	0.19	0.65	0.47	0.46	-0.01	0.32	0.04	0.03
Transports	0.04	0.71	0.51	0.50	-0.19	0.34	0.03	0.02
Post and telecommunications	0.25	0.74	0.54	0.53	0.01	0.36	0.03	0.03
Financial intermediation	-0.36	0.61	0.45	0.43	-0.56	0.30	0.03	0.03
Real estate activities	1.13	1.05	0.77	0.75	0.79	0.50	0.04	0.04
Business services	-0.35	0.53	0.38	0.38	-0.52	0.25	0.02	0.02
Individual services	-0.86	0.37	0.27	0.26	-0.98	0.18	0.02	0.02

reductions in production prices. The reduction in ESSC rate offers indeed the benefit of increasing domestic production while at the same time reducing the production prices across almost all economic sectors, by exerting a downward pressure on production costs. In other words, the reduction in labour cost is strong enough to counterbalance the increase in the price of capital services and lower the overall productions costs, that producers pass trough their final products prices.

The second financing alternative, when the public deficit to GDP ratio is restricted to be constant and no fiscal compensation is promoted, shows results in the same vein than the first one. However, with a more modest rise in the price of capital services, the increase in production prices for the last three variants is much less significant, being barely positive for the last two variants. This fact allows to reduce even further the production prices in the first variant, which benefits from lower labour costs and a moderate increase in the price of capital services. For all variants, no significant sectoral differences are noted.

When fiscal compensation is granted (alternatives III and IV), results show some

Table 7.3: Domestic production prices (fiscal compensation)



Domestic Production Prices
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	0.07	0.34	-0.79	-0.85	0.08	-0.19	-0.76	-0.83
- Industry								
# Energy								
Electricity	6.14	10.01	12.30	12.58	3.28	5.24	6.47	6.80
Coal	-0.47	1.11	0.81	0.81	-0.47	0.82	0.80	0.82
Refined petroleum	1.01	1.98	2.28	2.32	1.20	2.10	2.59	2.67
Gas	-0.12	-0.19	-0.69	-0.73	-0.10	-0.35	-0.64	-0.69
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	0.53	1.96	1.82	1.85	0.47	1.51	1.64	1.70
Other mining and quarrying	0.38	1.93	1.63	1.64	0.42	1.58	1.67	1.71
Wood	-0.26	0.83	0.33	0.31	-0.26	0.49	0.32	0.31
Chemicals and rubber	0.28	1.67	1.53	1.55	0.32	1.42	1.56	1.61
Cement	0.38	1.50	0.92	0.92	0.31	0.94	0.79	0.79
Glass	-0.04	1.22	0.82	0.83	-0.16	0.69	0.56	0.57
Ceramic	0.13	1.65	1.45	1.47	-0.13	0.91	0.87	0.90
Other non-metallic mineral products	-0.03	1.19	0.88	0.89	-0.23	0.57	0.45	0.47
Metallurgy and metal products	-0.03	1.19	0.88	0.89	-0.23	0.57	0.45	0.47
Other manufacturing industries	-0.41	0.58	0.12	0.11	-0.45	0.23	0.03	0.02
- Consumption Goods								
Water	-0.38	0.79	0.34	0.34	-0.38	0.50	0.35	0.36
Food, beverages and tobacco	-0.32	0.54	-0.24	-0.28	-0.34	0.08	-0.28	-0.33
Textile, dressing and leather products	-0.44	0.56	-0.06	-0.09	-0.49	0.15	-0.14	-0.17
Paper, publishing and printing	-0.31	0.71	0.11	0.09	-0.38	0.24	-0.03	-0.05
# Construction	-0.64	0.52	0.00	-0.01	-0.67	0.18	-0.06	-0.07
- Services								
Trade	-0.42	0.38	-0.43	-0.46	-0.45	-0.07	-0.47	-0.51
Hotels and Restaurants	-0.32	0.23	-0.61	-0.65	-0.33	-0.18	-0.62	-0.67
Transports	0.59	2.05	1.81	1.83	0.78	1.92	2.12	2.18
Post and telecommunications	-0.31	0.28	-0.68	-0.72	-0.35	-0.23	-0.73	-0.78
Financial intermediation	-0.92	0.09	-0.74	-0.79	-0.94	-0.31	-0.76	-0.82
Real estate activities	-0.08	-0.23	-1.81	-1.89	-0.11	-0.92	-1.82	-1.93
Business services	-0.68	0.31	-0.33	-0.36	-0.70	-0.04	-0.36	-0.39
Individual services	-1.03	0.32	-0.09	-0.11	-1.05	0.07	-0.13	-0.14

common traits to the first two alternatives (e.g. the different price patterns between variants), but with the additional impacts generated by the taxes on carbon and energy content. Unsurprisingly, the energy intensive sectors show the highest increase in production prices. The electric sector is particularly hurt, as it uses fossil fuels heavily for its energy generating production. Refined petroleum sector comes second. Other sectors relatively energy intensive, such as the manufacturing intermediate goods and the transport sector, show also a strong impact of higher energy prices on production prices.

It is worth mentioning that not all "energy sectors" display higher production prices. As the target of the taxes are fossil fuels and final energy inputs, economic sectors should suffer higher production costs if their intermediary inputs contain high proportions of these goods. This is obviously the case for the electric sector. However, the gas providing sector, for example, does not use much fossil fuels that are taxed as intermediary inputs. Hence, its production prices do not reflect a particular impact of the new carbon/energy tax.

On the other hand, the more labour intensive sectors, such as the services sectors, tend to show a slight increase or even a decline in production prices, after the abatement in the price of capital services. However, this is not the case for all labour intensive sectors. Indeed, some manufacturing sectors also present a high labour share in production (including "construction", "water", "ceramic" or "coal"), but they tend to be at the same time quite energy intensive in their production process.

Like for the first two alternatives, variant A shows again an extended sectoral decrease in production prices, except for the very energy intensive sectors. This is due to the tax policy implemented, aimed at reducing the employees compensation cost and, consequently, the total production cost. This reduction in production cost allows to contain the effects of the higher prices for energy inputs. As observed for the energy intensive sectors, higher energy prices are still an important burden on production costs. But the concomitant reduction of labour cost leads eventually to a weaker increase in production prices.

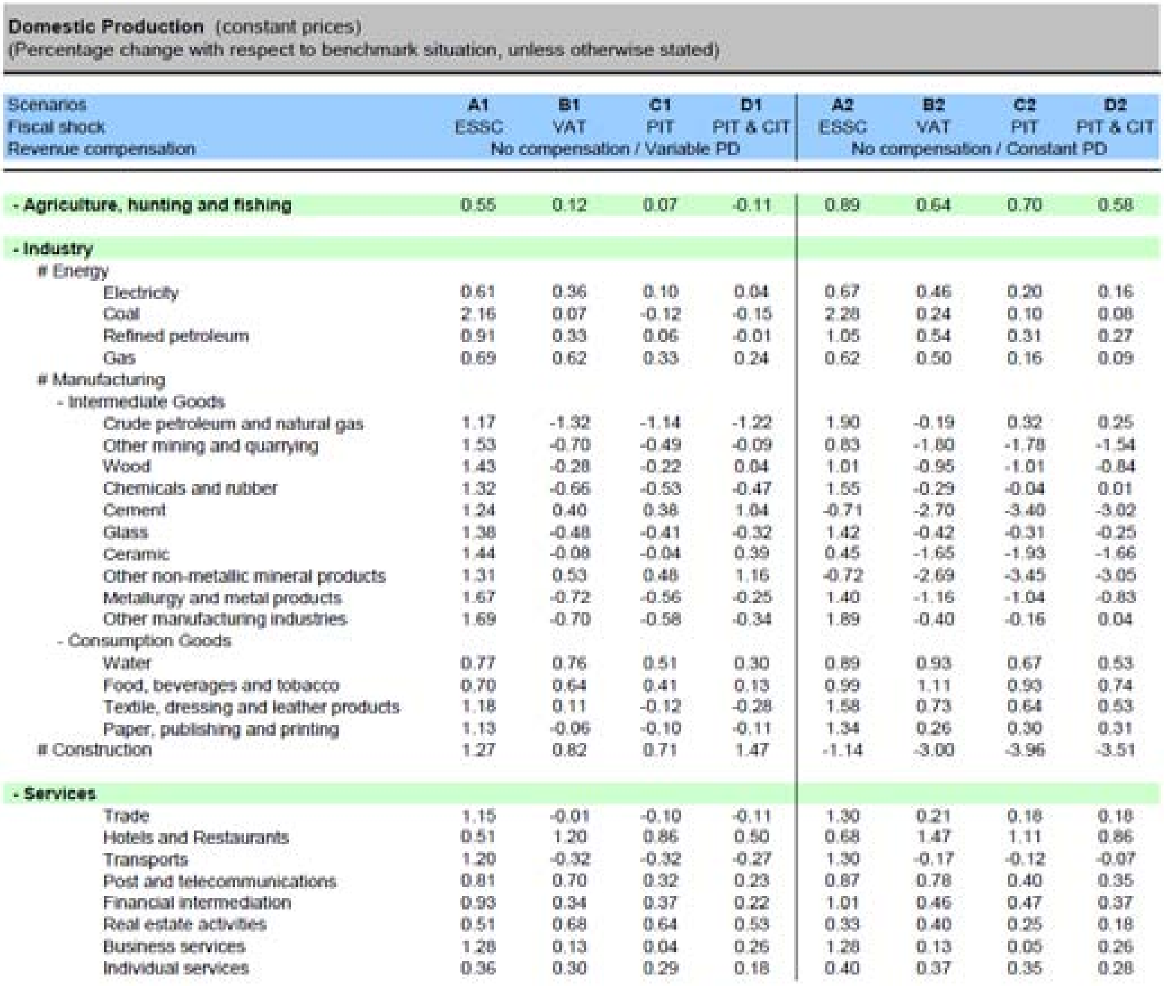
Sectoral production

Tables (7.4) and (7.5) illustrate the percent change in sectoral production. Across the different financing alternatives, variant A stands out clearly as the most effective for increasing domestic production. The reduction in ESSC rate outperforms systematically the other three variants because it is the only policy variant to benefit at the same time from higher domestic demand and higher foreign demand. As lower domestic production prices represents an improvement in external competitiveness, the economic sectors are able to take advantage of their lower production costs for increasing their exports and augment their production levels.

For the first financing alternative, the different impacts of the initial tax reductions can be observed in the macroeconomic results: variants A and D show higher increases in private investment than private consumption, while the contrary is true for variants B and C. These differences replicate at the sectoral level for domestic production: variants A and D show better results for the sectors more oriented towards capital formation (construction, manufacturing intermediate goods), whereas variants B and C demonstrate a positive bias for sectors more oriented towards private consumption (services sectors, manufacturing consumption goods).

The second financing alternative shows less convincing results in terms of sectoral production, even tough several sectors continue to present positive changes across all variants. Overall, it is now the sectors more oriented towards private consumption (consumption goods and services) that benefit from the boost in private consumption for all variants. On the contrary, gross capital formation suffers very clearly from the

Table 7.4: Domestic production (no fiscal compensation)



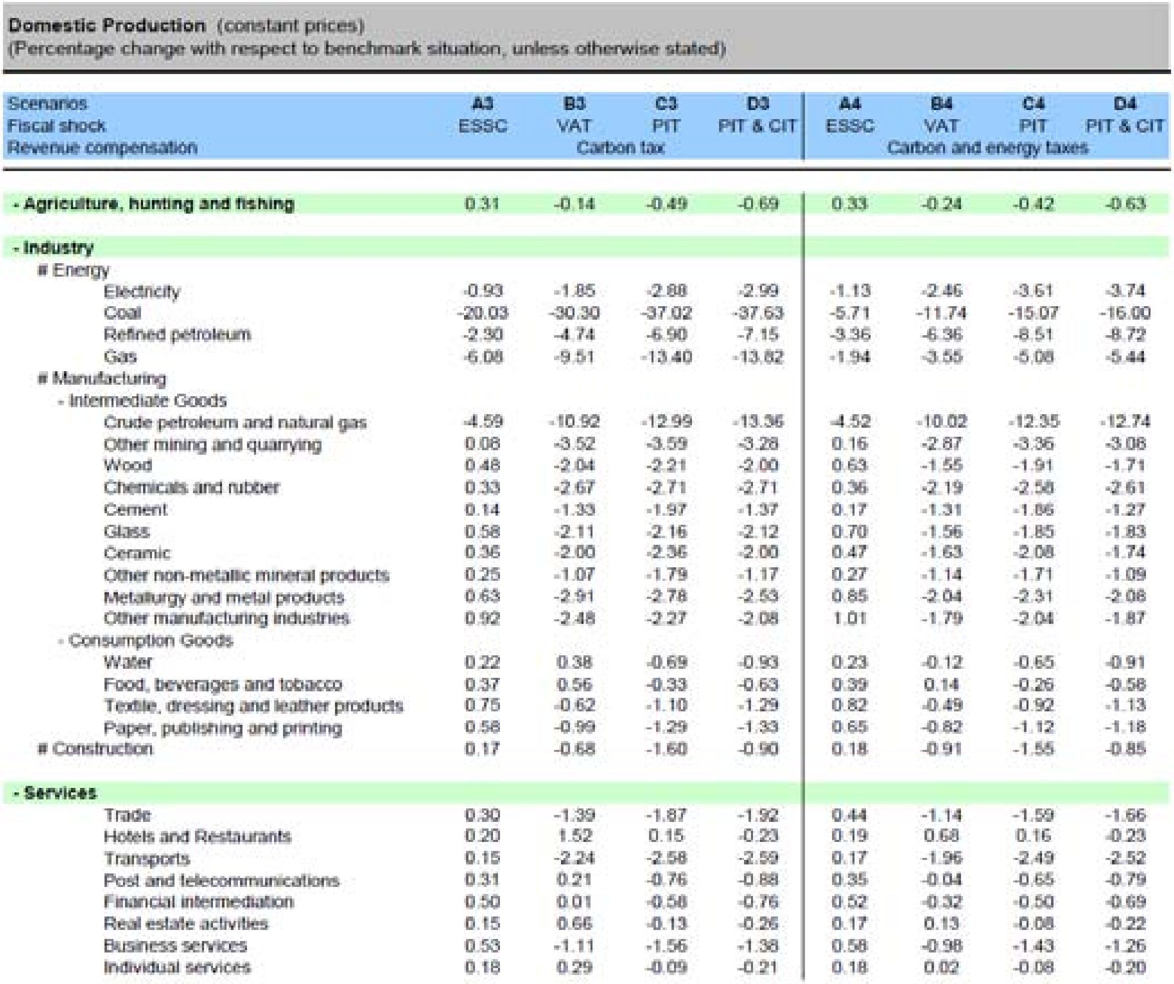
Domestic Production (constant prices)
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	0.55	0.12	0.07	-0.11	0.89	0.64	0.70	0.58
- Industry								
# Energy								
Electricity	0.61	0.36	0.10	0.04	0.67	0.46	0.20	0.16
Coal	2.16	0.07	-0.12	-0.15	2.28	0.24	0.10	0.08
Refined petroleum	0.91	0.33	0.06	-0.01	1.05	0.54	0.31	0.27
Gas	0.69	0.62	0.33	0.24	0.62	0.50	0.16	0.09
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	1.17	-1.32	-1.14	-1.22	1.90	-0.19	0.32	0.25
Other mining and quarrying	1.53	-0.70	-0.49	-0.09	0.83	-1.80	-1.78	-1.54
Wood	1.43	-0.28	-0.22	0.04	1.01	-0.95	-1.01	-0.84
Chemicals and rubber	1.32	-0.66	-0.53	-0.47	1.55	-0.29	-0.04	0.01
Cement	1.24	0.40	0.38	1.04	-0.71	-2.70	-3.40	-3.02
Glass	1.38	-0.48	-0.41	-0.32	1.42	-0.42	-0.31	-0.25
Ceramic	1.44	-0.08	-0.04	0.39	0.45	-1.65	-1.93	-1.66
Other non-metallic mineral products	1.31	0.53	0.48	1.16	-0.72	-2.69	-3.45	-3.05
Metallurgy and metal products	1.67	-0.72	-0.56	-0.25	1.40	-1.16	-1.04	-0.83
Other manufacturing industries	1.69	-0.70	-0.58	-0.34	1.89	-0.40	-0.16	0.04
- Consumption Goods								
Water	0.77	0.76	0.51	0.30	0.89	0.93	0.67	0.53
Food, beverages and tobacco	0.70	0.64	0.41	0.13	0.99	1.11	0.93	0.74
Textile, dressing and leather products	1.18	0.11	-0.12	-0.28	1.58	0.73	0.64	0.53
Paper, publishing and printing	1.13	-0.06	-0.10	-0.11	1.34	0.26	0.30	0.31
# Construction	1.27	0.82	0.71	1.47	-1.14	-3.00	-3.96	-3.51
- Services								
Trade	1.15	-0.01	-0.10	-0.11	1.30	0.21	0.18	0.18
Hotels and Restaurants	0.51	1.20	0.86	0.50	0.68	1.47	1.11	0.86
Transports	1.20	-0.32	-0.32	-0.27	1.30	-0.17	-0.12	-0.07
Post and telecommunications	0.81	0.70	0.32	0.23	0.87	0.78	0.40	0.35
Financial intermediation	0.93	0.34	0.37	0.22	1.01	0.46	0.47	0.37
Real estate activities	0.51	0.68	0.64	0.53	0.33	0.40	0.25	0.18
Business services	1.28	0.13	0.04	0.26	1.28	0.13	0.05	0.26
Individual services	0.36	0.30	0.29	0.18	0.40	0.37	0.35	0.28

drop in public investment, due to the restriction imposing a constant public deficit to GDP ratio. As a consequence, the sectors providing inputs for capital formation tend to reduce their production levels.

When fiscal compensation is implemented, the effect on production sectors change significantly. The sectors which provide directly the primary energy inputs see their production drop significantly. These sectors include the ones producing the fossil fuels on which the carbon tax is based: coal, gas and refined petroleum. Next, the sectors having an intensive use of these energy inputs are also severely affected. This is the case for the electric sector, but also for the manufacturing intermediate goods sectors and the transport sector. As expected, these sectors tend to reduce their production levels, as their production costs increase significantly. If the electricity producing sector suffers from higher inputs costs, its decline in production appears contained: its output remains indeed an important substitute for other fossil fuel energies which are taxed. When a joint carbon/energy tax is enforced (alternative IV), the better results in coal and gas production are then counterbalanced by lower production levels

Table 7.5: Domestic production (fiscal compensation)



Domestic Production (constant prices)
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	0.31	-0.14	-0.49	-0.69	0.33	-0.24	-0.42	-0.63
- Industry								
# Energy								
Electricity	-0.93	-1.85	-2.88	-2.99	-1.13	-2.46	-3.61	-3.74
Coal	-20.03	-30.30	-37.02	-37.63	-5.71	-11.74	-15.07	-16.00
Refined petroleum	-2.30	-4.74	-6.90	-7.15	-3.36	-6.36	-8.51	-8.72
Gas	-6.08	-9.51	-13.40	-13.82	-1.94	-3.55	-5.08	-5.44
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-4.59	-10.92	-12.99	-13.36	-4.52	-10.02	-12.35	-12.74
Other mining and quarrying	0.08	-3.52	-3.59	-3.28	0.16	-2.87	-3.36	-3.08
Wood	0.48	-2.04	-2.21	-2.00	0.63	-1.55	-1.91	-1.71
Chemicals and rubber	0.33	-2.67	-2.71	-2.71	0.36	-2.19	-2.58	-2.61
Cement	0.14	-1.33	-1.97	-1.37	0.17	-1.31	-1.86	-1.27
Glass	0.58	-2.11	-2.16	-2.12	0.70	-1.56	-1.85	-1.83
Ceramic	0.36	-2.00	-2.36	-2.00	0.47	-1.63	-2.08	-1.74
Other non-metallic mineral products	0.25	-1.07	-1.79	-1.17	0.27	-1.14	-1.71	-1.09
Metallurgy and metal products	0.63	-2.91	-2.78	-2.53	0.85	-2.04	-2.31	-2.08
Other manufacturing industries	0.92	-2.48	-2.27	-2.08	1.01	-1.79	-2.04	-1.87
- Consumption Goods								
Water	0.22	0.38	-0.69	-0.93	0.23	-0.12	-0.65	-0.91
Food, beverages and tobacco	0.37	0.56	-0.33	-0.63	0.39	0.14	-0.26	-0.58
Textile, dressing and leather products	0.75	-0.62	-1.10	-1.29	0.82	-0.49	-0.92	-1.13
Paper, publishing and printing	0.58	-0.99	-1.29	-1.33	0.65	-0.82	-1.12	-1.18
# Construction	0.17	-0.68	-1.60	-0.90	0.18	-0.91	-1.55	-0.85
- Services								
Trade	0.30	-1.39	-1.87	-1.92	0.44	-1.14	-1.59	-1.66
Hotels and Restaurants	0.20	1.52	0.15	-0.23	0.19	0.68	0.16	-0.23
Transports	0.15	-2.24	-2.58	-2.59	0.17	-1.96	-2.49	-2.52
Post and telecommunications	0.31	0.21	-0.76	-0.88	0.35	-0.04	-0.65	-0.79
Financial intermediation	0.50	0.01	-0.58	-0.76	0.52	-0.32	-0.50	-0.69
Real estate activities	0.15	0.66	-0.13	-0.26	0.17	0.13	-0.08	-0.22
Business services	0.53	-1.11	-1.56	-1.38	0.58	-0.98	-1.43	-1.26
Individual services	0.18	0.29	-0.09	-0.21	0.18	0.02	-0.08	-0.20

for refined petroleum and electricity (the introduction of a tax on the energy content of energy products affects petrol much more negatively than the other final energy inputs).

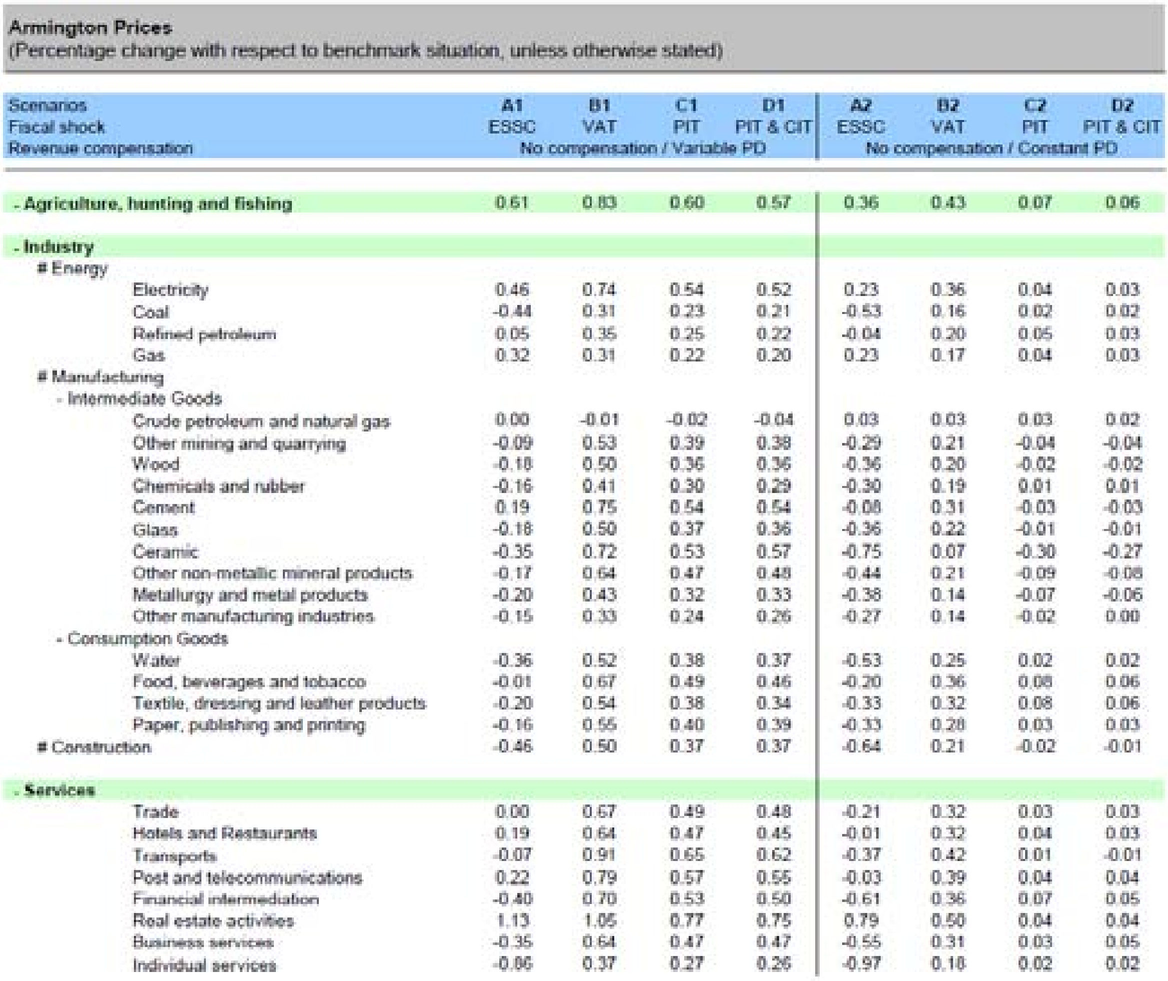
Some manufacturing intermediate goods sectors are also the sectors that are more export-oriented (having a larger ratio of total exports to production) and, therefore, suffer more from the decrease in exports that emerge for the last three variants. On the other hand, sectors more oriented towards the domestic market, such as consumption goods and services, show somewhat better results.

7.2.2 Domestic demand

Armington prices

Tables (7.6) and (7.7) illustrate the change in the Armington unit prices for the selected 28 domestic sectors in Spain. The Armington prices refer to aggregate prices of total domestic demand for each product, as a composite of the locally produced goods sold

Table 7.6: Armington prices (no fiscal compensation)



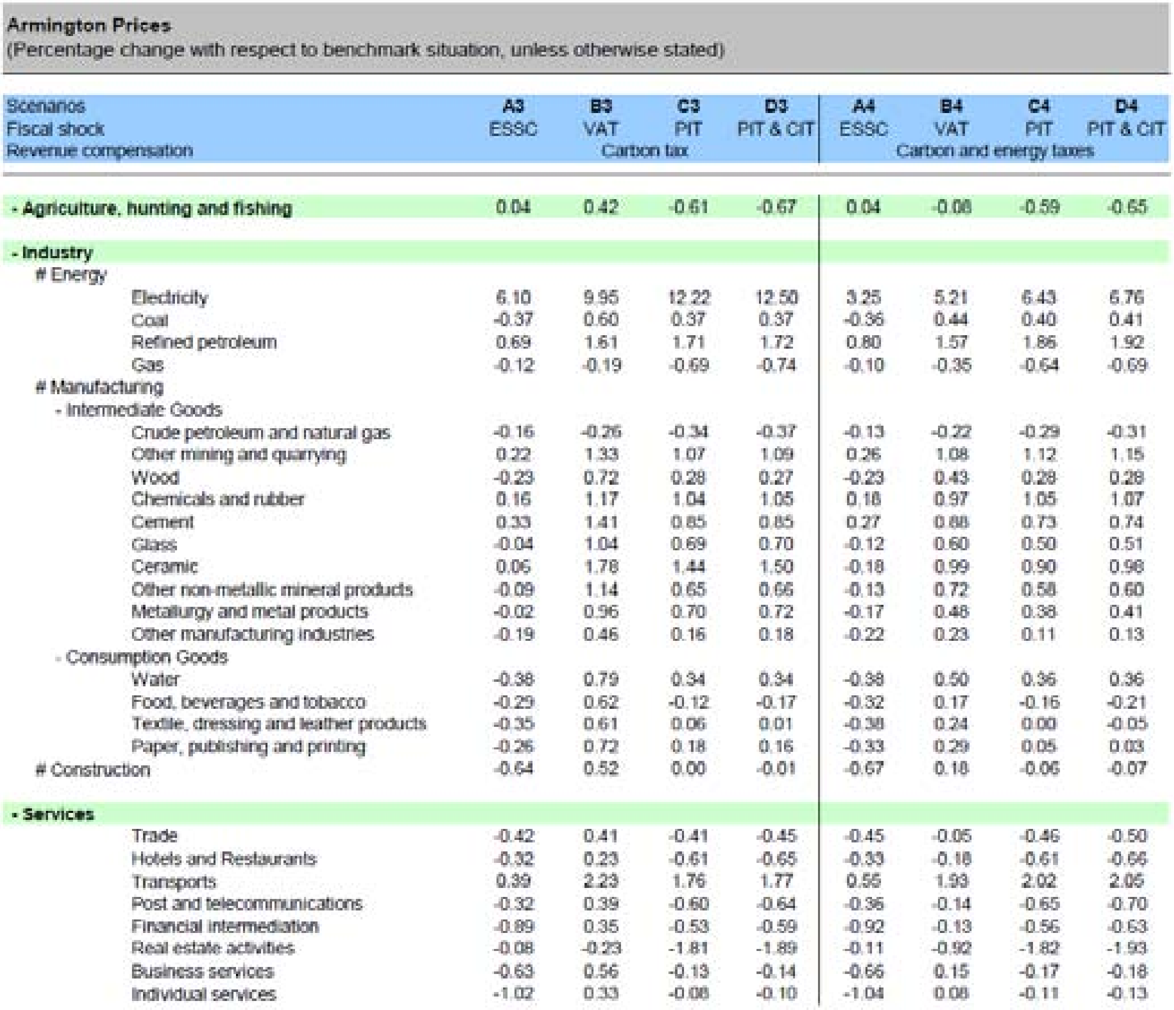
Armington Prices
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	0.61	0.83	0.60	0.57	0.36	0.43	0.07	0.06
- Industry								
# Energy								
Electricity	0.46	0.74	0.54	0.52	0.23	0.36	0.04	0.03
Coal	-0.44	0.31	0.23	0.21	-0.53	0.16	0.02	0.02
Refined petroleum	0.05	0.35	0.25	0.22	-0.04	0.20	0.05	0.03
Gas	0.32	0.31	0.22	0.20	0.23	0.17	0.04	0.03
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	0.00	-0.01	-0.02	-0.04	0.03	0.03	0.03	0.02
Other mining and quarrying	-0.09	0.53	0.39	0.38	-0.29	0.21	-0.04	-0.04
Wood	-0.18	0.50	0.36	0.36	-0.36	0.20	-0.02	-0.02
Chemicals and rubber	-0.16	0.41	0.30	0.29	-0.30	0.19	0.01	0.01
Cement	0.19	0.75	0.54	0.54	-0.08	0.31	-0.03	-0.03
Glass	-0.18	0.50	0.37	0.36	-0.36	0.22	-0.01	-0.01
Ceramic	-0.35	0.72	0.53	0.57	-0.75	0.07	-0.30	-0.27
Other non-metallic mineral products	-0.17	0.64	0.47	0.48	-0.44	0.21	-0.09	-0.08
Metallurgy and metal products	-0.20	0.43	0.32	0.33	-0.38	0.14	-0.07	-0.06
Other manufacturing industries	-0.15	0.33	0.24	0.26	-0.27	0.14	-0.02	0.00
- Consumption Goods								
Water	-0.36	0.52	0.38	0.37	-0.53	0.25	0.02	0.02
Food, beverages and tobacco	-0.01	0.67	0.49	0.46	-0.20	0.36	0.08	0.06
Textile, dressing and leather products	-0.20	0.54	0.38	0.34	-0.33	0.32	0.08	0.06
Paper, publishing and printing	-0.16	0.55	0.40	0.39	-0.33	0.28	0.03	0.03
# Construction	-0.46	0.50	0.37	0.37	-0.64	0.21	-0.02	-0.01
- Services								
Trade	0.00	0.67	0.49	0.48	-0.21	0.32	0.03	0.03
Hotels and Restaurants	0.19	0.64	0.47	0.45	-0.01	0.32	0.04	0.03
Transports	-0.07	0.91	0.65	0.62	-0.37	0.42	0.01	-0.01
Post and telecommunications	0.22	0.79	0.57	0.55	-0.03	0.39	0.04	0.04
Financial intermediation	-0.40	0.70	0.53	0.50	-0.61	0.36	0.07	0.05
Real estate activities	1.13	1.05	0.77	0.75	0.79	0.50	0.04	0.04
Business services	-0.35	0.64	0.47	0.47	-0.55	0.31	0.03	0.05
Individual services	-0.86	0.37	0.27	0.26	-0.97	0.18	0.02	0.02

in the domestic market and the imports aggregate. Unsurprisingly, results show a similar pattern to domestic production prices for most of the variants. However, some noticeable differences may be observed when fiscal financing alternatives are imposed, either trough a carbon content tax or trough a combined carbon/energy content tax.

For the energy intensive sectors in particular, results indicate that Armington prices tend to be lower than domestic production prices. This is the case for most of the manufacturing intermediate goods sectors. This discrepancy derives from the trade-off offered to domestic sectors to use more domestic or imported goods, depending on their relative prices. For most sectors, this means that higher domestic production prices may be tempered by lower prices for imported goods, as agents are not constrained to demand specifically domestic goods. So when a new carbon/energy tax is imposed on some intermediary inputs use, the resulting increase in production costs and production prices of energy intensive sectors is managed partly by increasing imports. Being less energy intensive, services sectors and manufacturing consumption goods sectors do not present such differences between domestic production prices and Armington

Table 7.7: Armington prices (fiscal compensation)



Armington Prices
(Percentage change with respect to benchmark situation, unless otherwise stated)

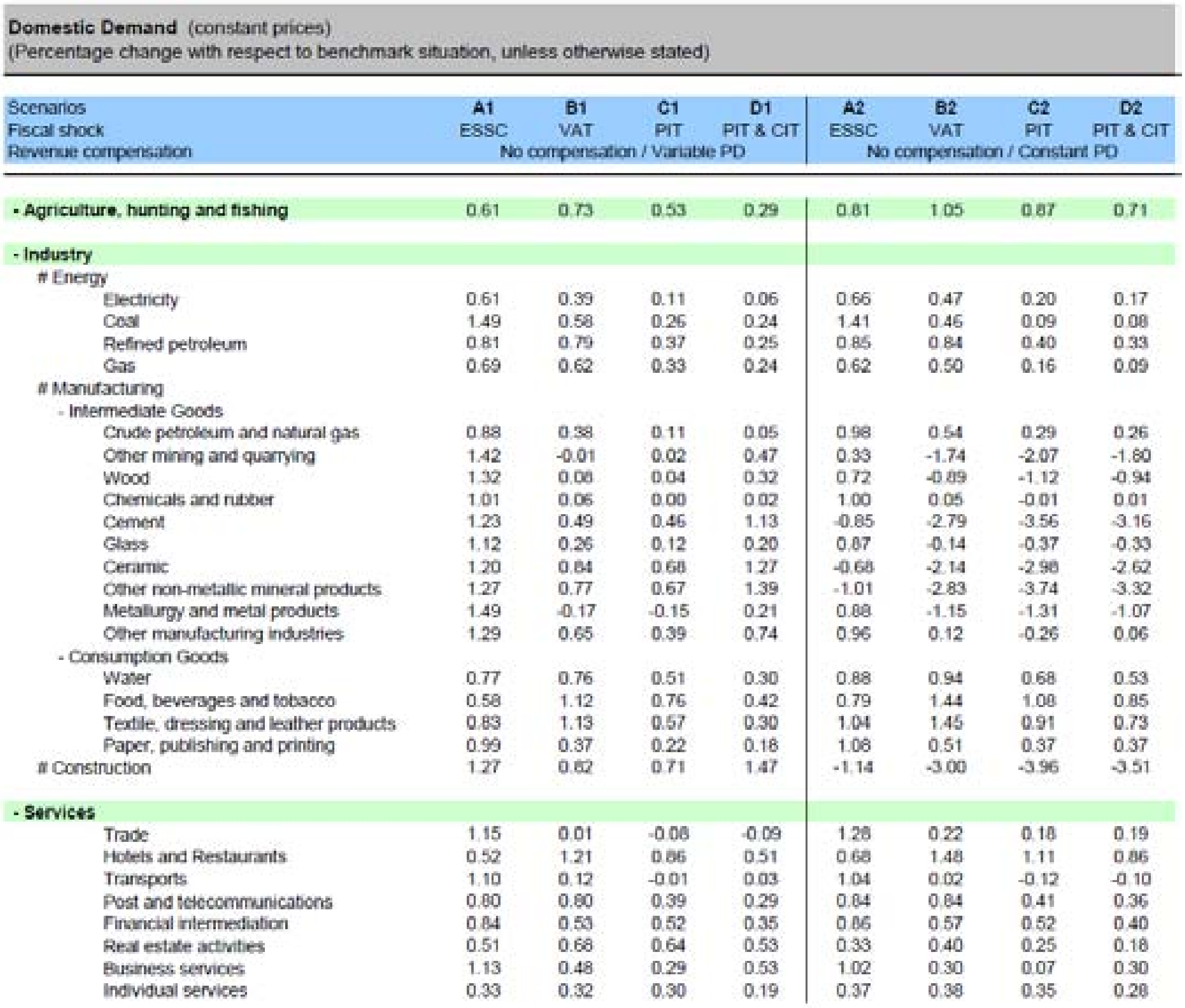
Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	0.04	0.42	-0.61	-0.67	0.04	-0.08	-0.59	-0.65
- Industry								
# Energy								
Electricity	6.10	9.95	12.22	12.50	3.25	5.21	6.43	6.76
Coal	-0.37	0.60	0.37	0.37	-0.36	0.44	0.40	0.41
Refined petroleum	0.69	1.61	1.71	1.72	0.80	1.57	1.86	1.92
Gas	-0.12	-0.19	-0.69	-0.74	-0.10	-0.35	-0.64	-0.69
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-0.16	-0.26	-0.34	-0.37	-0.13	-0.22	-0.29	-0.31
Other mining and quarrying	0.22	1.33	1.07	1.09	0.26	1.08	1.12	1.15
Wood	-0.23	0.72	0.28	0.27	-0.23	0.43	0.28	0.28
Chemicals and rubber	0.16	1.17	1.04	1.05	0.18	0.97	1.05	1.07
Cement	0.33	1.41	0.85	0.85	0.27	0.88	0.73	0.74
Glass	-0.04	1.04	0.69	0.70	-0.12	0.60	0.50	0.51
Ceramic	0.06	1.78	1.44	1.50	-0.18	0.99	0.90	0.98
Other non-metallic mineral products	-0.09	1.14	0.65	0.66	-0.13	0.72	0.58	0.60
Metallurgy and metal products	-0.02	0.96	0.70	0.72	-0.17	0.48	0.38	0.41
Other manufacturing industries	-0.19	0.46	0.16	0.18	-0.22	0.23	0.11	0.13
- Consumption Goods								
Water	-0.38	0.79	0.34	0.34	-0.38	0.50	0.36	0.36
Food, beverages and tobacco	-0.29	0.62	-0.12	-0.17	-0.32	0.17	-0.16	-0.21
Textile, dressing and leather products	-0.35	0.61	0.06	0.01	-0.38	0.24	0.00	-0.05
Paper, publishing and printing	-0.26	0.72	0.18	0.16	-0.33	0.29	0.05	0.03
# Construction	-0.64	0.52	0.00	-0.01	-0.67	0.18	-0.06	-0.07
- Services								
Trade	-0.42	0.41	-0.41	-0.45	-0.45	-0.05	-0.46	-0.50
Hotels and Restaurants	-0.32	0.23	-0.61	-0.65	-0.33	-0.18	-0.61	-0.66
Transports	0.39	2.23	1.76	1.77	0.55	1.93	2.02	2.06
Post and telecommunications	-0.32	0.39	-0.60	-0.64	-0.36	-0.14	-0.65	-0.70
Financial intermediation	-0.89	0.35	-0.53	-0.59	-0.92	-0.13	-0.56	-0.63
Real estate activities	-0.08	-0.23	-1.81	-1.89	-0.11	-0.92	-1.82	-1.93
Business services	-0.63	0.56	-0.13	-0.14	-0.66	0.15	-0.17	-0.18
Individual services	-1.02	0.33	-0.08	-0.10	-1.04	0.08	-0.11	-0.13

prices. Also, demand for services cannot always be accommodated by foreign supply. Being oriented more specifically towards the domestic market, services sectors tend to support slightly more the impact of higher domestic prices than other economic sectors.

Sectoral domestic demand

The sectoral effects for the change in the volume of domestic demand are shown in *tables* (7.8) and (7.9). They capture the change in the composite of the locally produced good sold in the domestic market and imports. The variations follow quite closely the ones of domestic production. As products markets clear and production matches demand, a variation in domestic demand must indeed reverberate into domestic production. However domestic demand is not only oriented towards domestically produced goods but also towards imported products. At the same time, domestic production is offered to the domestic and foreign markets. So, domestic production

Table 7.8: Domestic demand (no fiscal compensation)



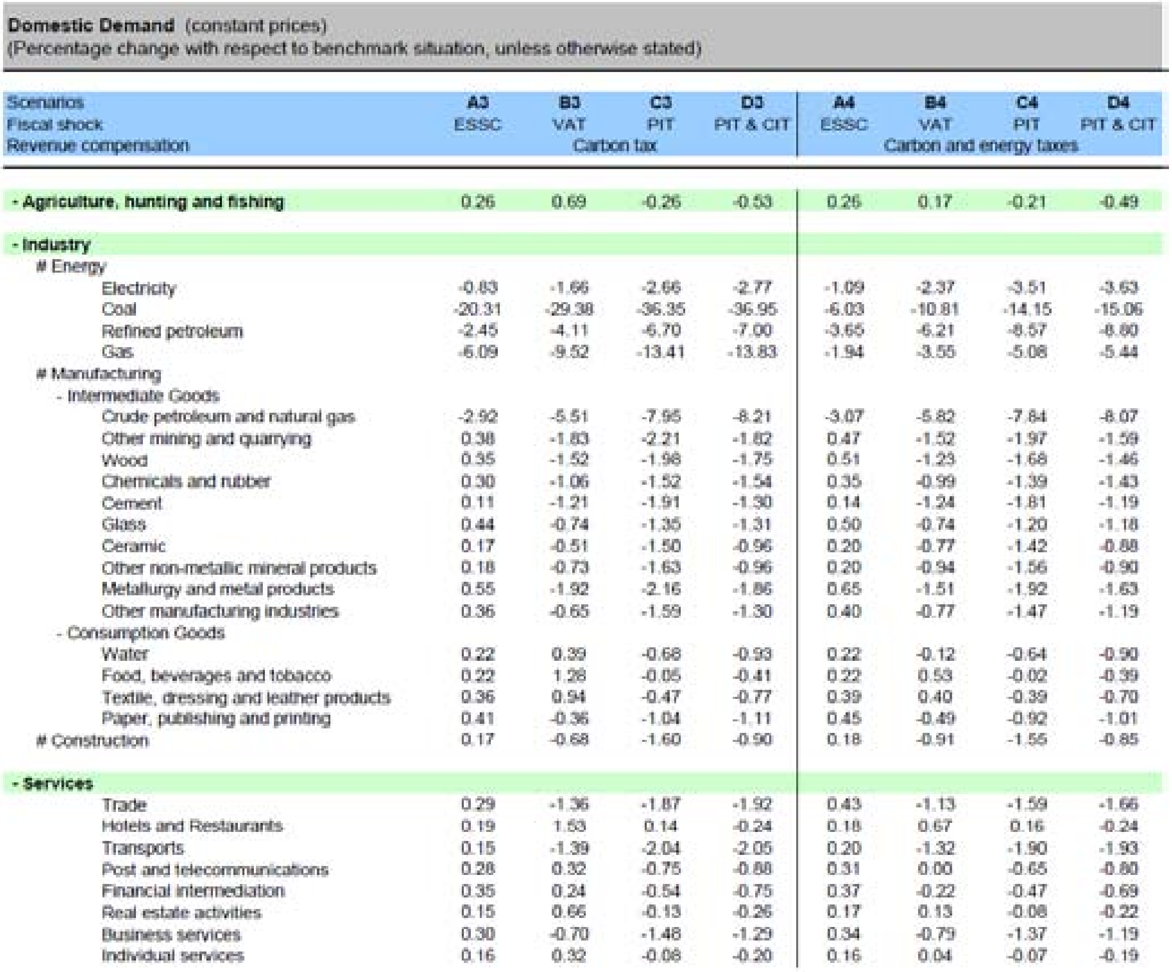
Domestic Demand (constant prices)
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	0.61	0.73	0.53	0.29	0.81	1.05	0.87	0.71
- Industry								
# Energy								
Electricity	0.61	0.39	0.11	0.06	0.66	0.47	0.20	0.17
Coal	1.49	0.58	0.26	0.24	1.41	0.46	0.09	0.08
Refined petroleum	0.81	0.79	0.37	0.25	0.85	0.84	0.40	0.33
Gas	0.69	0.62	0.33	0.24	0.62	0.50	0.16	0.09
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	0.88	0.38	0.11	0.05	0.98	0.54	0.29	0.26
Other mining and quarrying	1.42	-0.01	0.02	0.47	0.33	-1.74	-2.07	-1.80
Wood	1.32	0.08	0.04	0.32	0.72	-0.89	-1.12	-0.94
Chemicals and rubber	1.01	0.06	0.00	0.02	1.00	0.05	-0.01	0.01
Cement	1.23	0.49	0.46	1.13	-0.85	-2.79	-3.56	-3.16
Glass	1.12	0.26	0.12	0.20	0.87	-0.14	-0.37	-0.33
Ceramic	1.20	0.84	0.68	1.27	-0.68	-2.14	-2.98	-2.62
Other non-metallic mineral products	1.27	0.77	0.67	1.39	-1.01	-2.83	-3.74	-3.32
Metallurgy and metal products	1.49	-0.17	-0.15	0.21	0.88	-1.15	-1.31	-1.07
Other manufacturing industries	1.29	0.65	0.39	0.74	0.96	0.12	-0.26	0.06
- Consumption Goods								
Water	0.77	0.76	0.51	0.30	0.88	0.94	0.68	0.53
Food, beverages and tobacco	0.58	1.12	0.76	0.42	0.79	1.44	1.08	0.85
Textile, dressing and leather products	0.83	1.13	0.57	0.30	1.04	1.45	0.91	0.73
Paper, publishing and printing	0.99	0.37	0.22	0.18	1.08	0.51	0.37	0.37
# Construction	1.27	0.62	0.71	1.47	-1.14	-3.00	-3.96	-3.51
- Services								
Trade	1.15	0.01	-0.08	-0.09	1.28	0.22	0.18	0.19
Hotels and Restaurants	0.52	1.21	0.86	0.51	0.68	1.48	1.11	0.86
Transports	1.10	0.12	-0.01	0.03	1.04	0.02	-0.12	-0.10
Post and telecommunications	0.80	0.80	0.39	0.29	0.84	0.84	0.41	0.36
Financial intermediation	0.84	0.53	0.52	0.35	0.86	0.57	0.52	0.40
Real estate activities	0.51	0.68	0.64	0.53	0.33	0.40	0.25	0.18
Business services	1.13	0.48	0.29	0.53	1.02	0.30	0.07	0.30
Individual services	0.33	0.32	0.30	0.19	0.37	0.38	0.35	0.28

is obviously not constrained to match domestic demand. The differences are to be related with the corresponding changes in net exports.

In definitive, for being the only one to present an expansion in net exports, the variant A (reduction in ESSC rate) shows higher increases in domestic production levels than domestic demand. It indicates that Spain is gaining external price competitiveness by decreasing its labour cost. On the contrary, the last three variants, presenting a deterioration in their net exports, confirm that Spain is losing some external competitiveness trough these particular fiscal policies. This domestic demand "leakage" towards imported goods is particularly present for energy intensive sectors, such as manufacturing intermediate goods sectors. On the other hand, for some specific sectors more "captive" on the domestic production supply, the difference between domestic demand and domestic production is kept minimal. This is the case for most of the services sectors (or the sectors with a low ratio of imports to production), with the exception of the "transport" sector, quite energy intensive.

Table 7.9: Domestic demand (fiscal compensation)



Domestic Demand (constant prices)
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	0.26	0.69	-0.26	-0.53	0.26	0.17	-0.21	-0.49
- Industry								
# Energy								
Electricity	-0.83	-1.66	-2.66	-2.77	-1.09	-2.37	-3.51	-3.63
Coal	-20.31	-29.38	-36.35	-36.95	-6.03	-10.81	-14.15	-15.06
Refined petroleum	-2.45	-4.11	-6.70	-7.00	-3.65	-6.21	-8.57	-8.80
Gas	-6.09	-9.52	-13.41	-13.83	-1.94	-3.55	-5.08	-5.44
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-2.92	-5.51	-7.95	-8.21	-3.07	-5.82	-7.84	-8.07
Other mining and quarrying	0.38	-1.83	-2.21	-1.82	0.47	-1.52	-1.97	-1.59
Wood	0.35	-1.52	-1.98	-1.75	0.51	-1.23	-1.68	-1.46
Chemicals and rubber	0.30	-1.06	-1.52	-1.54	0.35	-0.99	-1.39	-1.43
Cement	0.11	-1.21	-1.91	-1.30	0.14	-1.24	-1.81	-1.19
Glass	0.44	-0.74	-1.35	-1.31	0.50	-0.74	-1.20	-1.18
Ceramic	0.17	-0.51	-1.50	-0.96	0.20	-0.77	-1.42	-0.88
Other non-metallic mineral products	0.18	-0.73	-1.63	-0.96	0.20	-0.94	-1.56	-0.90
Metallurgy and metal products	0.55	-1.92	-2.16	-1.86	0.65	-1.51	-1.92	-1.63
Other manufacturing industries	0.36	-0.65	-1.59	-1.30	0.40	-0.77	-1.47	-1.19
- Consumption Goods								
Water	0.22	0.39	-0.68	-0.93	0.22	-0.12	-0.64	-0.90
Food, beverages and tobacco	0.22	1.28	-0.05	-0.41	0.22	0.53	-0.02	-0.39
Textile, dressing and leather products	0.36	0.94	-0.47	-0.77	0.39	0.40	-0.39	-0.70
Paper, publishing and printing	0.41	-0.36	-1.04	-1.11	0.45	-0.49	-0.92	-1.01
# Construction	0.17	-0.68	-1.60	-0.90	0.18	-0.91	-1.55	-0.85
- Services								
Trade	0.29	-1.36	-1.87	-1.92	0.43	-1.13	-1.59	-1.66
Hotels and Restaurants	0.19	1.53	0.14	-0.24	0.18	0.67	0.16	-0.24
Transports	0.15	-1.39	-2.04	-2.05	0.20	-1.32	-1.90	-1.93
Post and telecommunications	0.28	0.32	-0.75	-0.88	0.31	0.00	-0.65	-0.80
Financial intermediation	0.35	0.24	-0.54	-0.75	0.37	-0.22	-0.47	-0.69
Real estate activities	0.15	0.66	-0.13	-0.26	0.17	0.13	-0.08	-0.22
Business services	0.30	-0.70	-1.48	-1.29	0.34	-0.79	-1.37	-1.19
Individual services	0.16	0.32	-0.08	-0.20	0.16	0.04	-0.07	-0.19

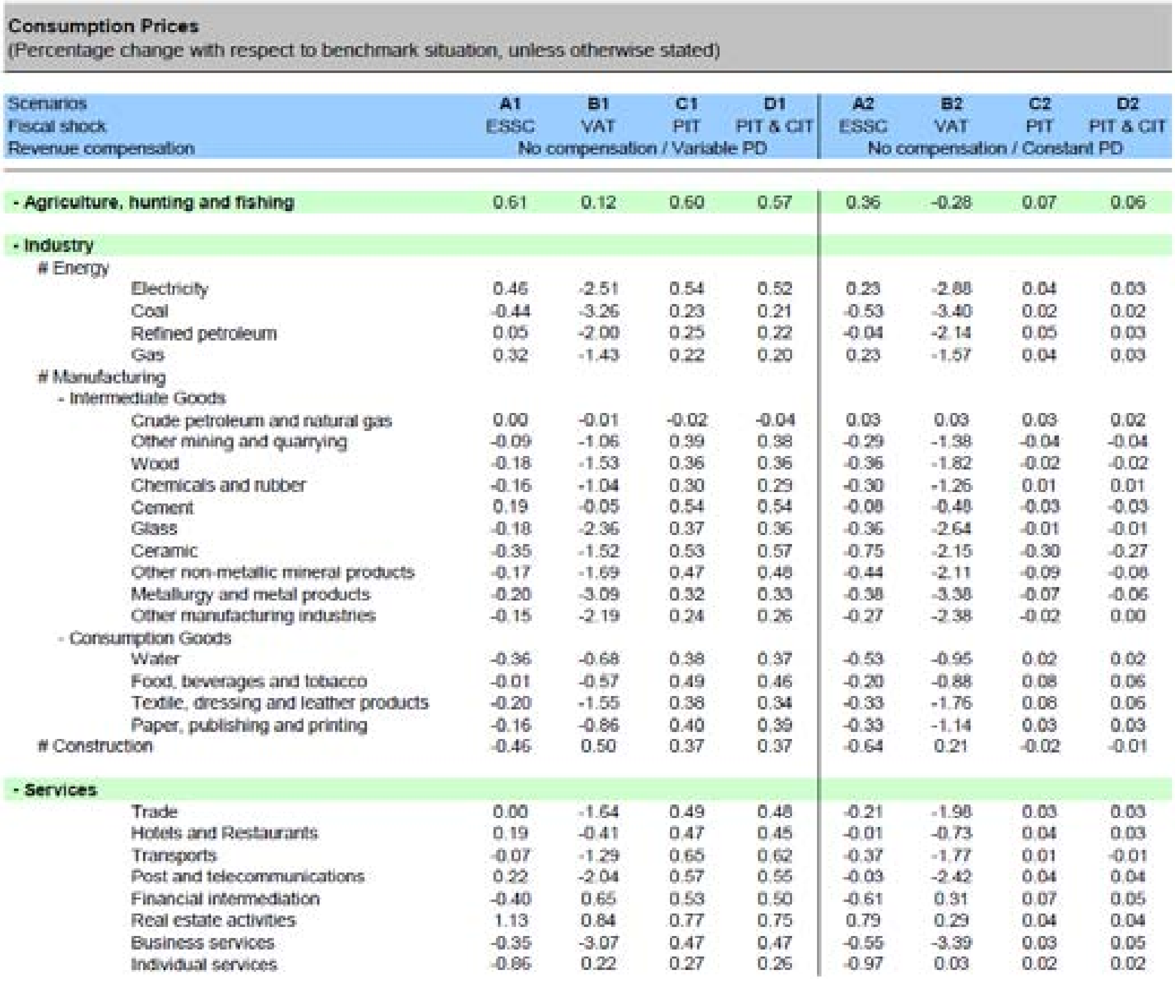
7.2.3 Consumption

Consumption prices

Results for the change in consumer prices are given in *tables* (7.10) and (7.11). Consumers prices represent the prices paid by the consumer, once all the consumption taxes have been levied. Hence, as explained previously, consumption prices are the composite of Armington prices plus all the taxes levied on consumption. These include the VAT tax, the carbon tax and the energy tax. As a result, the changes in consumption prices tend to follow the changes in Armington prices, except when appears a change in consumption tax rates.

The first source of differences with Armington prices comes from the policy variant B, which simulates a reduction in the VAT rate. This leads sectoral consumption prices to present lower percent changes than Armington prices, whether there is fiscal compensation or not. This true for almost all sectors, expect for the energy sectors when there is fiscal compensation trough the carbon and energy taxes.

Table 7.10: Consumption prices (no fiscal compensation)

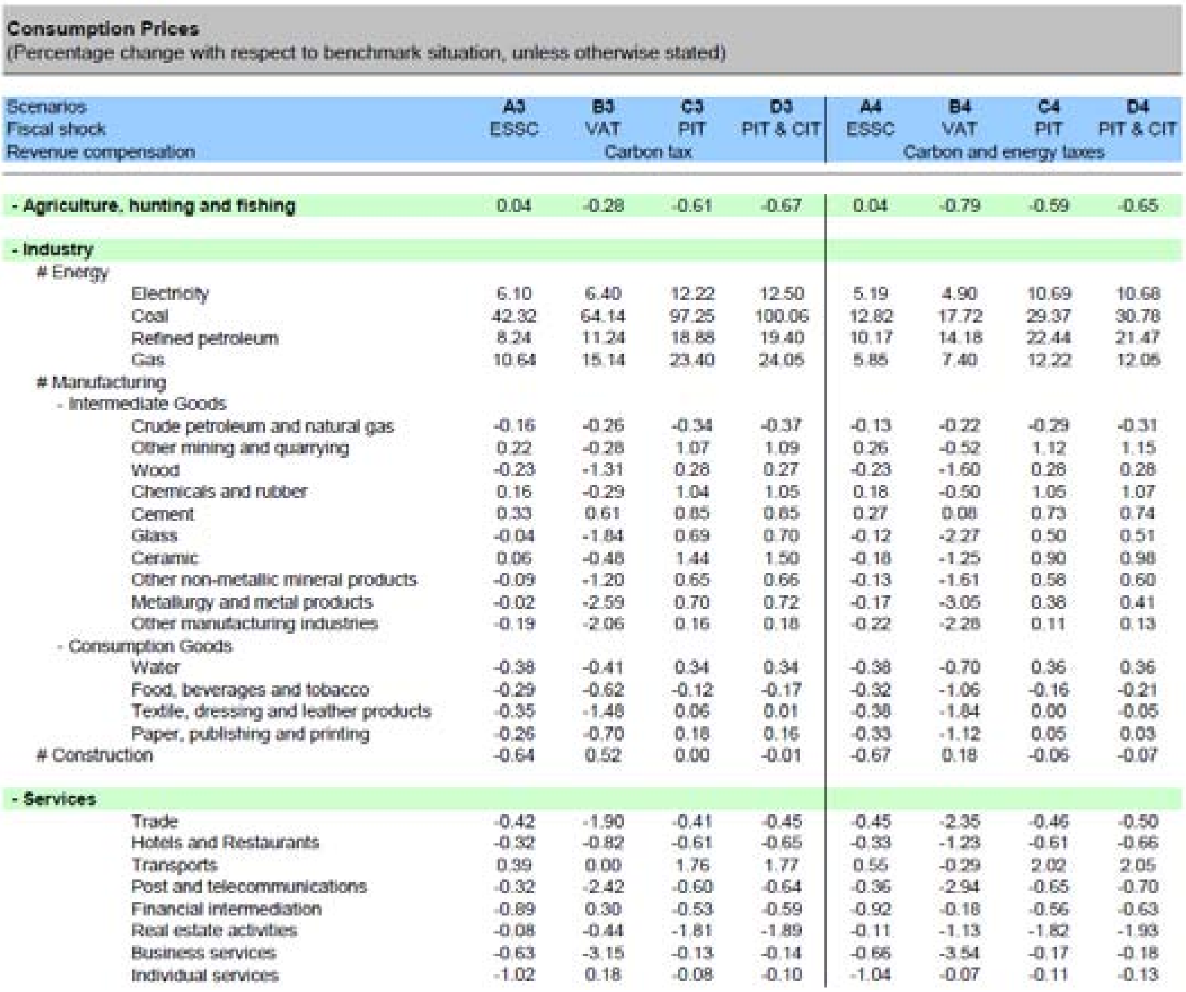


Consumption Prices
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	0.61	0.12	0.60	0.57	0.36	-0.28	0.07	0.06
- Industry								
# Energy								
Electricity	0.46	-2.51	0.54	0.52	0.23	-2.88	0.04	0.03
Coal	-0.44	-3.26	0.23	0.21	-0.53	-3.40	0.02	0.02
Refined petroleum	0.05	-2.00	0.25	0.22	-0.04	-2.14	0.05	0.03
Gas	0.32	-1.43	0.22	0.20	0.23	-1.57	0.04	0.03
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	0.00	-0.01	-0.02	-0.04	0.03	0.03	0.03	0.02
Other mining and quarrying	-0.09	-1.06	0.39	0.38	-0.29	-1.38	-0.04	-0.04
Wood	-0.18	-1.53	0.36	0.36	-0.36	-1.82	-0.02	-0.02
Chemicals and rubber	-0.16	-1.04	0.30	0.29	-0.30	-1.26	0.01	0.01
Cement	0.19	-0.05	0.54	0.54	-0.08	-0.48	-0.03	-0.03
Glass	-0.18	-2.36	0.37	0.36	-0.36	-2.64	-0.01	-0.01
Ceramic	-0.35	-1.52	0.53	0.57	-0.75	-2.15	-0.30	-0.27
Other non-metallic mineral products	-0.17	-1.69	0.47	0.48	-0.44	-2.11	-0.09	-0.08
Metallurgy and metal products	-0.20	-3.09	0.32	0.33	-0.38	-3.38	-0.07	-0.06
Other manufacturing industries	-0.15	-2.19	0.24	0.26	-0.27	-2.38	-0.02	0.00
- Consumption Goods								
Water	-0.36	-0.68	0.38	0.37	-0.53	-0.95	0.02	0.02
Food, beverages and tobacco	-0.01	-0.57	0.49	0.46	-0.20	-0.88	0.08	0.06
Textile, dressing and leather products	-0.20	-1.55	0.38	0.34	-0.33	-1.76	0.08	0.06
Paper, publishing and printing	-0.16	-0.86	0.40	0.39	-0.33	-1.14	0.03	0.03
# Construction	-0.46	0.50	0.37	0.37	-0.64	0.21	-0.02	-0.01
- Services								
Trade	0.00	-1.64	0.49	0.48	-0.21	-1.98	0.03	0.03
Hotels and Restaurants	0.19	-0.41	0.47	0.45	-0.01	-0.73	0.04	0.03
Transports	-0.07	-1.29	0.65	0.62	-0.37	-1.77	0.01	-0.01
Post and telecommunications	0.22	-2.04	0.57	0.55	-0.03	-2.42	0.04	0.04
Financial intermediation	-0.40	0.65	0.53	0.50	-0.61	0.31	0.07	0.05
Real estate activities	1.13	0.84	0.77	0.75	0.79	0.29	0.04	0.04
Business services	-0.35	-3.07	0.47	0.47	-0.55	-3.39	0.03	0.05
Individual services	-0.86	0.22	0.27	0.26	-0.97	0.03	0.02	0.02

The second source of discrepancy with Armington prices is due to the fiscal compensation scenarios, when the different initial tax reductions are compensated either by a carbon tax only (alternative III) or by a combined carbon/energy tax (alternative IV). We then observe a very significant rise in energy prices, indicating the strong impact that the carbon/energy taxes exert on energy consumption prices. Some energy prices are particularly affected when the carbon tax only is implemented. Coal consumption price almost doubles in some scenarios. But this result has very minor importance as coal represents an almost irrelevant part of household consumption. Other energy sources, such as gas, petrol and electricity have a non-trivial weight on household consumption and also show significant increases in prices. But the aggregate impact of energy goods on total private consumption is still rather limited. Indeed, according to benchmark data, the share of fossil fuels consumption represents only 4% of the total household consumption, whereas all final energy goods (including electricity) account for just above 5% of total household consumption. The largest share of private consumption is dedicated towards manufactured consumption goods

Table 7.11: Consumption prices (fiscal compensation)



Consumption Prices
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	0.04	-0.28	-0.61	-0.67	0.04	-0.79	-0.59	-0.65
- Industry								
# Energy								
Electricity	6.10	6.40	12.22	12.50	5.19	4.90	10.69	10.68
Coal	42.32	64.14	97.25	100.06	12.82	17.72	29.37	30.78
Refined petroleum	8.24	11.24	18.88	19.40	10.17	14.18	22.44	21.47
Gas	10.64	15.14	23.40	24.05	5.85	7.40	12.22	12.06
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-0.16	-0.26	-0.34	-0.37	-0.13	-0.22	-0.29	-0.31
Other mining and quarrying	0.22	-0.28	1.07	1.09	0.26	-0.52	1.12	1.15
Wood	-0.23	-1.31	0.28	0.27	-0.23	-1.60	0.28	0.28
Chemicals and rubber	0.16	-0.29	1.04	1.05	0.18	-0.50	1.05	1.07
Cement	0.33	0.61	0.85	0.85	0.27	0.08	0.73	0.74
Glass	-0.04	-1.84	0.69	0.70	-0.12	-2.27	0.50	0.51
Ceramic	0.06	-0.48	1.44	1.50	-0.18	-1.25	0.90	0.98
Other non-metallic mineral products	-0.09	-1.20	0.65	0.66	-0.13	-1.61	0.58	0.60
Metallurgy and metal products	-0.02	-2.59	0.70	0.72	-0.17	-3.05	0.38	0.41
Other manufacturing industries	-0.19	-2.06	0.16	0.18	-0.22	-2.28	0.11	0.13
- Consumption Goods								
Water	-0.38	-0.41	0.34	0.34	-0.38	-0.70	0.36	0.36
Food, beverages and tobacco	-0.29	-0.62	-0.12	-0.17	-0.32	-1.06	-0.16	-0.21
Textile, dressing and leather products	-0.35	-1.48	0.06	0.01	-0.38	-1.84	0.00	-0.05
Paper, publishing and printing	-0.26	-0.70	0.18	0.16	-0.33	-1.12	0.05	0.03
# Construction	-0.64	0.52	0.00	-0.01	-0.67	0.18	-0.06	-0.07
- Services								
Trade	-0.42	-1.90	-0.41	-0.45	-0.45	-2.35	-0.46	-0.50
Hotels and Restaurants	-0.32	-0.82	-0.61	-0.65	-0.33	-1.23	-0.61	-0.66
Transports	0.39	0.00	1.76	1.77	0.55	-0.29	2.02	2.05
Post and telecommunications	-0.32	-2.42	-0.60	-0.64	-0.36	-2.94	-0.65	-0.70
Financial intermediation	-0.89	0.30	-0.53	-0.59	-0.92	-0.18	-0.56	-0.63
Real estate activities	-0.08	-0.44	-1.81	-1.89	-0.11	-1.13	-1.82	-1.93
Business services	-0.63	-3.15	-0.13	-0.14	-0.66	-3.54	-0.17	-0.18
Individual services	-1.02	0.18	-0.08	-0.10	-1.04	-0.07	-0.11	-0.13

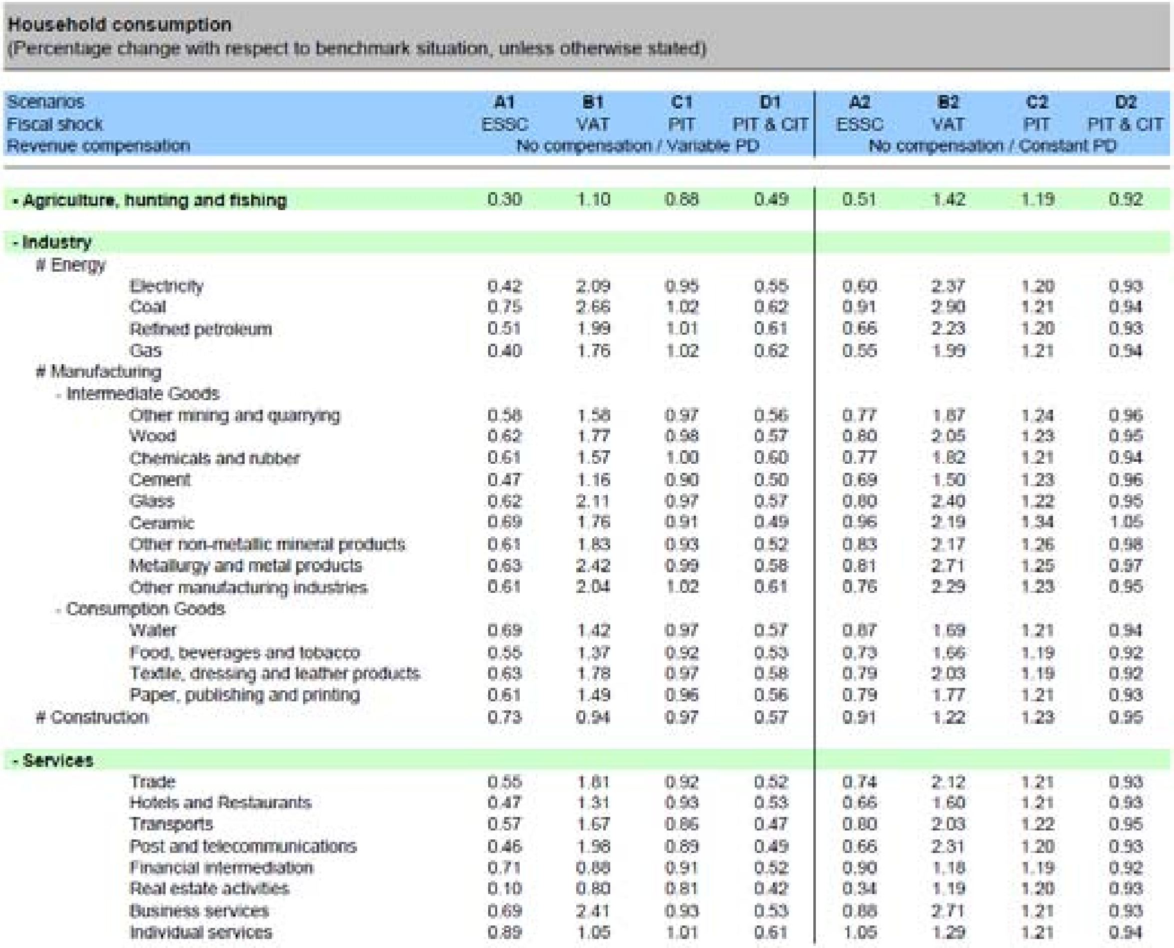
and, above all, services. The consumption prices of the remaining goods tend to show a significant impact from the lower VAT policy, with lower levels than the Armington prices, even for most of the energy intensive goods from the manufactured intermediate goods sectors.

Sectoral consumption

Changes in sectoral consumption are showed in *tables* (7.12) and (7.13). Across financing alternatives, results indicate a clear uptrend in private consumption when no fiscal compensation is required (alternatives I and II). This is particularly the case for the variants B and C, which favour explicitly private consumption by increasing significantly the household real disposable income. For these alternatives without fiscal compensation, no strong differences are noted among sectors, since the fiscal policies do no target any sector in particular but are broad-based.

When fiscal compensation is in effect, the simulation results differ significantly.

Table 7.12: Household consumption (no fiscal compensation)

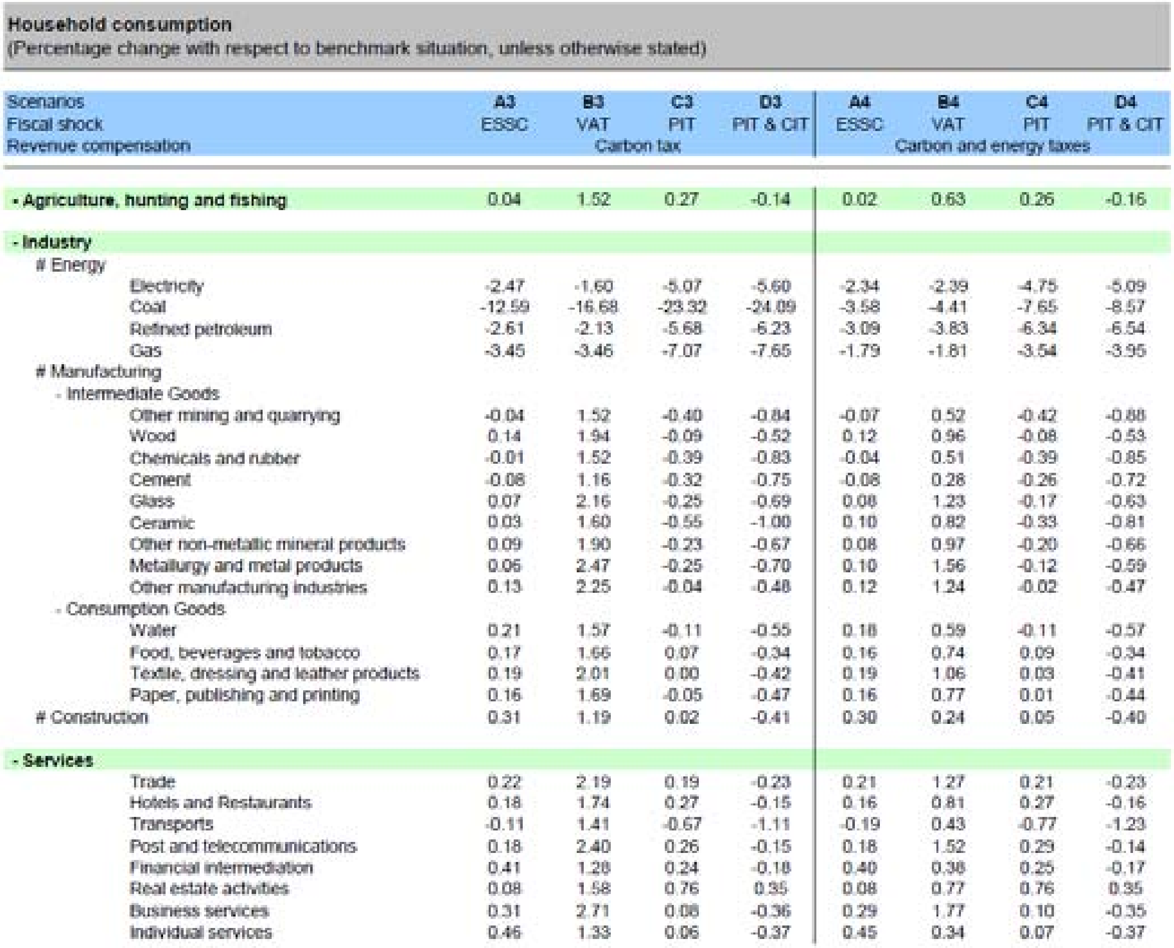


Household consumption
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	0.30	1.10	0.88	0.49	0.51	1.42	1.19	0.92
- Industry								
# Energy								
Electricity	0.42	2.09	0.95	0.55	0.60	2.37	1.20	0.93
Coal	0.75	2.66	1.02	0.62	0.91	2.90	1.21	0.94
Refined petroleum	0.51	1.99	1.01	0.61	0.66	2.23	1.20	0.93
Gas	0.40	1.76	1.02	0.62	0.55	1.99	1.21	0.94
# Manufacturing								
- Intermediate Goods								
Other mining and quarrying	0.58	1.58	0.97	0.56	0.77	1.87	1.24	0.96
Wood	0.62	1.77	0.98	0.57	0.80	2.05	1.23	0.95
Chemicals and rubber	0.61	1.57	1.00	0.60	0.77	1.82	1.21	0.94
Cement	0.47	1.16	0.90	0.50	0.69	1.50	1.23	0.96
Glass	0.62	2.11	0.97	0.57	0.80	2.40	1.22	0.95
Ceramic	0.69	1.76	0.91	0.49	0.96	2.19	1.34	1.05
Other non-metallic mineral products	0.61	1.83	0.93	0.52	0.83	2.17	1.26	0.98
Metallurgy and metal products	0.63	2.42	0.99	0.58	0.81	2.71	1.25	0.97
Other manufacturing industries	0.61	2.04	1.02	0.61	0.76	2.29	1.23	0.95
- Consumption Goods								
Water	0.69	1.42	0.97	0.57	0.87	1.69	1.21	0.94
Food, beverages and tobacco	0.55	1.37	0.92	0.53	0.73	1.66	1.19	0.92
Textile, dressing and leather products	0.63	1.78	0.97	0.58	0.79	2.03	1.19	0.92
Paper, publishing and printing	0.61	1.49	0.96	0.56	0.79	1.77	1.21	0.93
# Construction	0.73	0.94	0.97	0.57	0.91	1.22	1.23	0.95
- Services								
Trade	0.55	1.81	0.92	0.52	0.74	2.12	1.21	0.93
Hotels and Restaurants	0.47	1.31	0.93	0.53	0.66	1.60	1.21	0.93
Transports	0.57	1.67	0.86	0.47	0.80	2.03	1.22	0.95
Post and telecommunications	0.46	1.98	0.89	0.49	0.66	2.31	1.20	0.93
Financial intermediation	0.71	0.88	0.91	0.52	0.90	1.18	1.19	0.92
Real estate activities	0.10	0.80	0.81	0.42	0.34	1.19	1.20	0.93
Business services	0.69	2.41	0.93	0.53	0.88	2.71	1.21	0.93
Individual services	0.89	1.05	1.01	0.61	1.05	1.29	1.21	0.94

First, following the clear surge in consumption prices for energy products, we observe a significant reduction in consumption for energy goods. As expected, coal and gas consumption are particularly affected when only the carbon tax is levied. Second, for the rest of the sectors, variant B still shows the highest increases in household consumption, as a result of a significant rise in real disposable income. The reduction in PIT rate (variant C), which is also considered favourable to private consumption, presents worse results this time, suffering from the higher prices of consumption goods and services. Variant A shows again the advantage of reducing production costs, as they translate into lower production prices and lower consumption prices. This effect allows to contain the rise in energy prices, and benefits household consumption. Finally, variant D indicates a broad-based decline in sectoral household consumption, concomitant to the lower disposable income. The service sectors are the ones which resist the best to the this decline in real disposable income.

Table 7.13: Household consumption (fiscal compensation)



Household consumption
(Percentage change with respect to benchmark situation, unless otherwise stated)

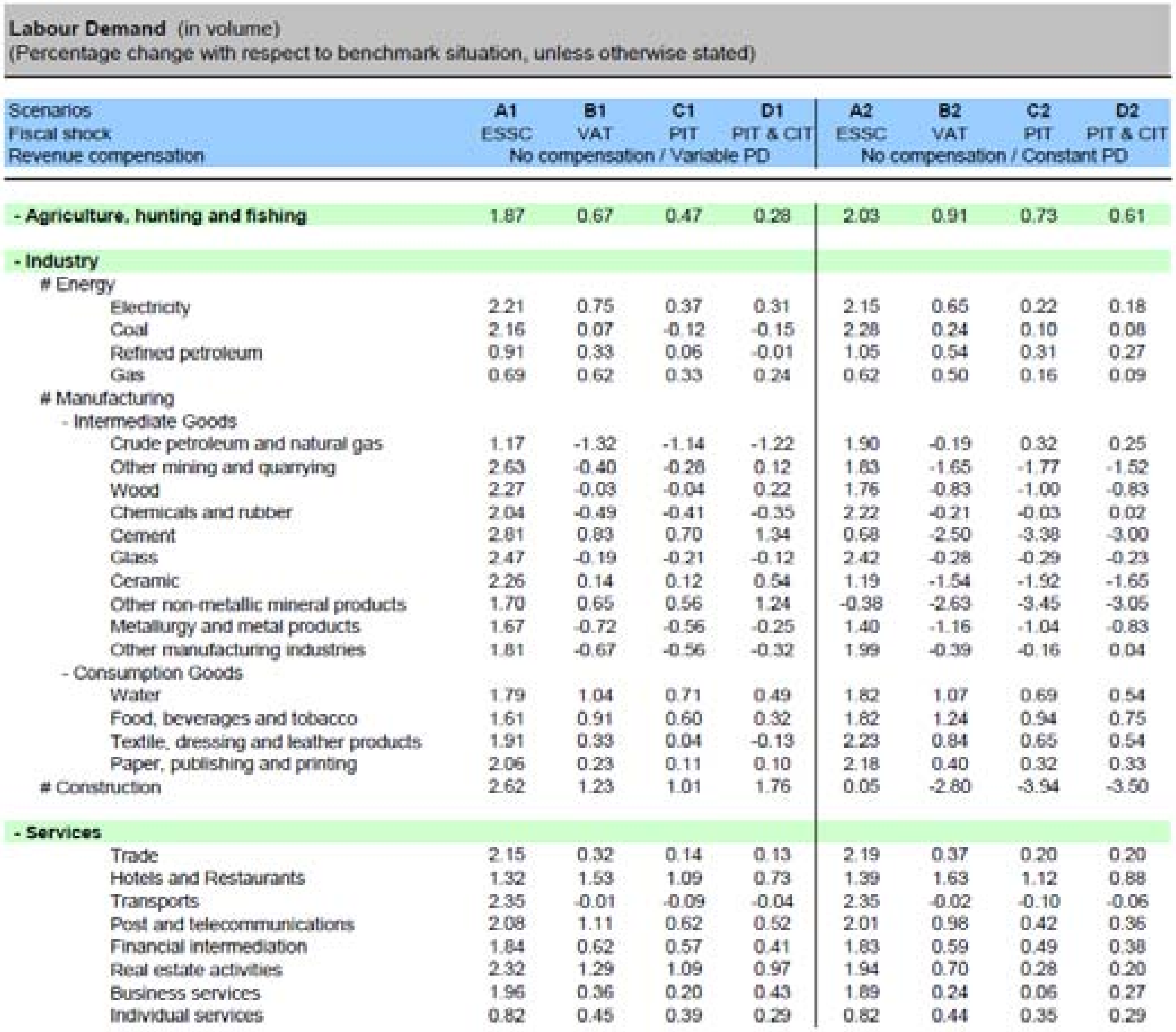
Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	0.04	1.52	0.27	-0.14	0.02	0.63	0.26	-0.16
- Industry								
# Energy								
Electricity	-2.47	-1.60	-5.07	-5.60	-2.34	-2.39	-4.75	-5.09
Coal	-12.59	-16.68	-23.32	-24.09	-3.58	-4.41	-7.65	-8.57
Refined petroleum	-2.61	-2.13	-5.68	-6.23	-3.09	-3.83	-6.34	-6.54
Gas	-3.45	-3.46	-7.07	-7.65	-1.79	-1.81	-3.54	-3.95
# Manufacturing								
- Intermediate Goods								
Other mining and quarrying	-0.04	1.52	-0.40	-0.84	-0.07	0.52	-0.42	-0.88
Wood	0.14	1.94	-0.09	-0.52	0.12	0.96	-0.08	-0.53
Chemicals and rubber	-0.01	1.52	-0.39	-0.83	-0.04	0.51	-0.39	-0.85
Cement	-0.08	1.16	-0.32	-0.75	-0.08	0.28	-0.26	-0.72
Glass	0.07	2.16	-0.25	-0.69	0.08	1.23	-0.17	-0.63
Ceramic	0.03	1.60	-0.55	-1.00	0.10	0.82	-0.33	-0.81
Other non-metallic mineral products	0.09	1.90	-0.23	-0.67	0.08	0.97	-0.20	-0.66
Metallurgy and metal products	0.06	2.47	-0.25	-0.70	0.10	1.56	-0.12	-0.59
Other manufacturing industries	0.13	2.25	-0.04	-0.48	0.12	1.24	-0.02	-0.47
- Consumption Goods								
Water	0.21	1.57	-0.11	-0.55	0.18	0.59	-0.11	-0.57
Food, beverages and tobacco	0.17	1.66	0.07	-0.34	0.16	0.74	0.09	-0.34
Textile, dressing and leather products	0.19	2.01	0.00	-0.42	0.19	1.06	0.03	-0.41
Paper, publishing and printing	0.16	1.69	-0.05	-0.47	0.16	0.77	0.01	-0.44
# Construction	0.31	1.19	0.02	-0.41	0.30	0.24	0.05	-0.40
- Services								
Trade	0.22	2.19	0.19	-0.23	0.21	1.27	0.21	-0.23
Hotels and Restaurants	0.18	1.74	0.27	-0.15	0.16	0.81	0.27	-0.16
Transports	-0.11	1.41	-0.67	-1.11	-0.19	0.43	-0.77	-1.23
Post and telecommunications	0.18	2.40	0.26	-0.15	0.18	1.52	0.29	-0.14
Financial intermediation	0.41	1.28	0.24	-0.18	0.40	0.38	0.25	-0.17
Real estate activities	0.08	1.58	0.76	0.35	0.08	0.77	0.76	0.35
Business services	0.31	2.71	0.08	-0.36	0.29	1.77	0.10	-0.35
Individual services	0.46	1.33	0.06	-0.37	0.45	0.34	0.07	-0.37

7.2.4 Labour and Value Added

Labour demand

Tables (7.14) and (7.15) present the sectoral breakdown of the change in labour demand for each policy scenario simulated. As evidenced also in the key macroeconomic results, the only variant to present an overall increase in labour demand for all alternatives is the first one (variant A). It shows the potential of decreasing ESSC rates to improve the employment situation without systematically increasing carbon emissions. Variant B comes as a second best regarding the impacts on labour demand. It generates an increase in labour demand when no fiscal compensation is in place, due to the positive impact of higher aggregate demand and domestic production. When fiscal compensation is implemented, aggregate demand and domestic production dither and labour demand follows suit. The variants implementing a reduction in PIT and CIT present similar results to variant B, but with more negative outcomes: labour demand falters in the last three financing alternatives, as domestic production is reduced more significantly. However, a positive note is given in the first financing alternative and

Table 7.14: Labour demand (no fiscal compensation)



Labour Demand (in volume)
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	1.87	0.67	0.47	0.28	2.03	0.91	0.73	0.61
- Industry								
# Energy								
Electricity	2.21	0.75	0.37	0.31	2.15	0.65	0.22	0.18
Coal	2.16	0.07	-0.12	-0.15	2.28	0.24	0.10	0.08
Refined petroleum	0.91	0.33	0.06	-0.01	1.05	0.54	0.31	0.27
Gas	0.69	0.62	0.33	0.24	0.62	0.50	0.16	0.09
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	1.17	-1.32	-1.14	-1.22	1.90	-0.19	0.32	0.25
Other mining and quarrying	2.63	-0.40	-0.28	0.12	1.83	-1.65	-1.77	-1.52
Wood	2.27	-0.03	-0.04	0.22	1.76	-0.83	-1.00	-0.83
Chemicals and rubber	2.04	-0.49	-0.41	-0.35	2.22	-0.21	-0.03	0.02
Cement	2.81	0.83	0.70	1.34	0.68	-2.50	-3.38	-3.00
Glass	2.47	-0.19	-0.21	-0.12	2.42	-0.28	-0.29	-0.23
Ceramic	2.26	0.14	0.12	0.54	1.19	-1.54	-1.92	-1.65
Other non-metallic mineral products	1.70	0.65	0.56	1.24	-0.38	-2.63	-3.45	-3.05
Metallurgy and metal products	1.67	-0.72	-0.56	-0.25	1.40	-1.16	-1.04	-0.83
Other manufacturing industries	1.81	-0.67	-0.56	-0.32	1.99	-0.39	-0.16	0.04
- Consumption Goods								
Water	1.79	1.04	0.71	0.49	1.82	1.07	0.69	0.54
Food, beverages and tobacco	1.61	0.91	0.60	0.32	1.82	1.24	0.94	0.75
Textile, dressing and leather products	1.91	0.33	0.04	-0.13	2.23	0.84	0.65	0.54
Paper, publishing and printing	2.06	0.23	0.11	0.10	2.18	0.40	0.32	0.33
# Construction	2.62	1.23	1.01	1.76	0.05	-2.80	-3.94	-3.50
- Services								
Trade	2.15	0.32	0.14	0.13	2.19	0.37	0.20	0.20
Hotels and Restaurants	1.32	1.53	1.09	0.73	1.39	1.63	1.12	0.88
Transports	2.35	-0.01	-0.09	-0.04	2.35	-0.02	-0.10	-0.06
Post and telecommunications	2.08	1.11	0.62	0.52	2.01	0.98	0.42	0.36
Financial intermediation	1.84	0.62	0.57	0.41	1.83	0.59	0.49	0.38
Real estate activities	2.32	1.29	1.09	0.97	1.94	0.70	0.28	0.20
Business services	1.96	0.36	0.20	0.43	1.89	0.24	0.06	0.27
Individual services	0.82	0.45	0.39	0.29	0.82	0.44	0.35	0.29

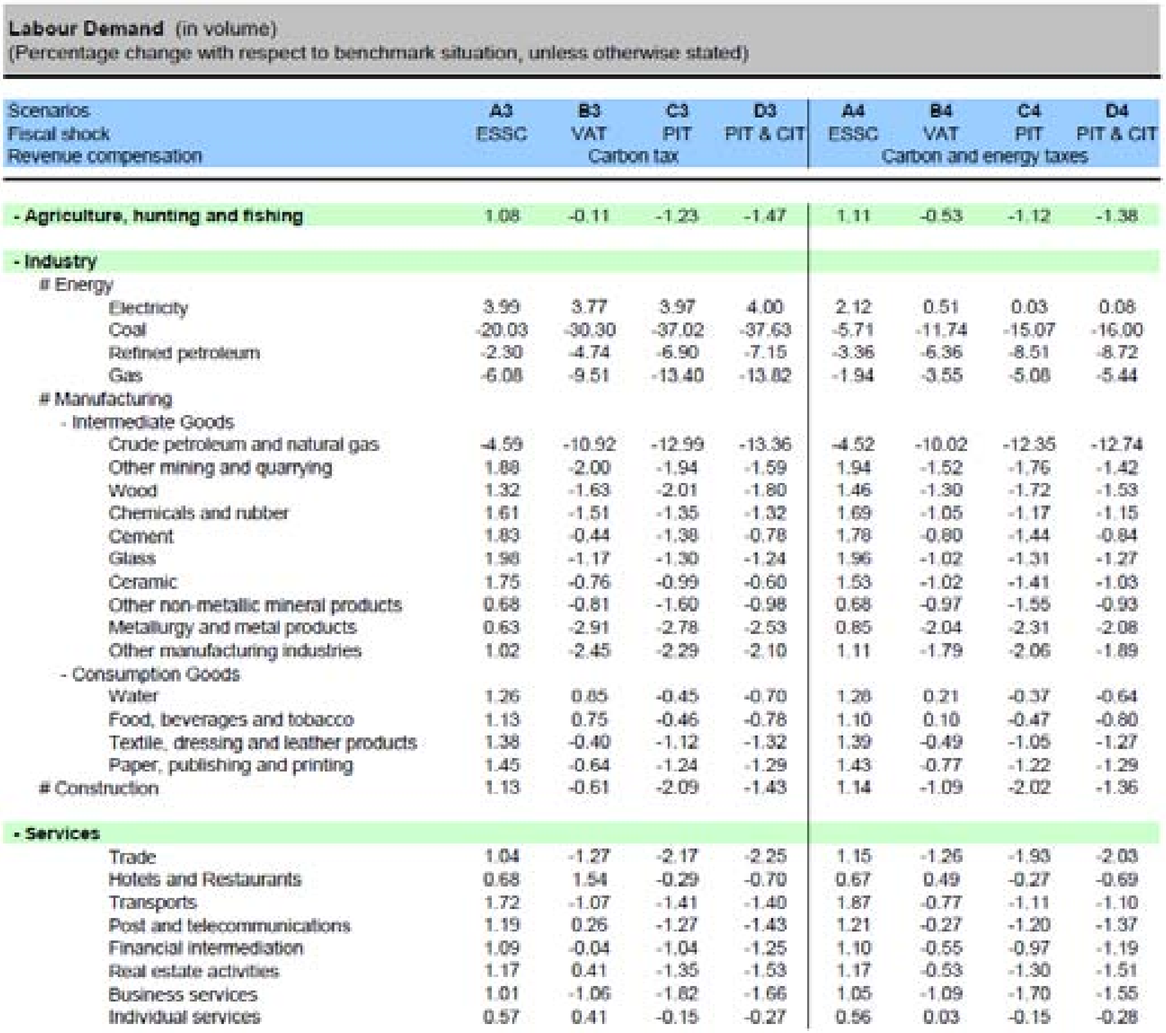
for all variants: aggregate demand being the strongest across alternatives, domestic production and, as a consequence, labour demand benefits directly from it, to the expense of a higher public deficit.

Labour share in Value Added

Value added is considered as labour income plus capital income plus indirect taxes less subsidies. The labour share is interpreted here as the product of labour demand and the compensation of employees, with the latter being composed of the gross wage and the employers Social Security contributions. The labour share in value added does not in itself indicates whether there is a shift towards more labour intensive activities in the production process. It gives some indications on the income share that labour gets from the value added in the domestic economy.

The results in *tables* (7.16) and (7.17) show that, except for variant B and for the

Table 7.15: Labour demand (fiscal compensation)



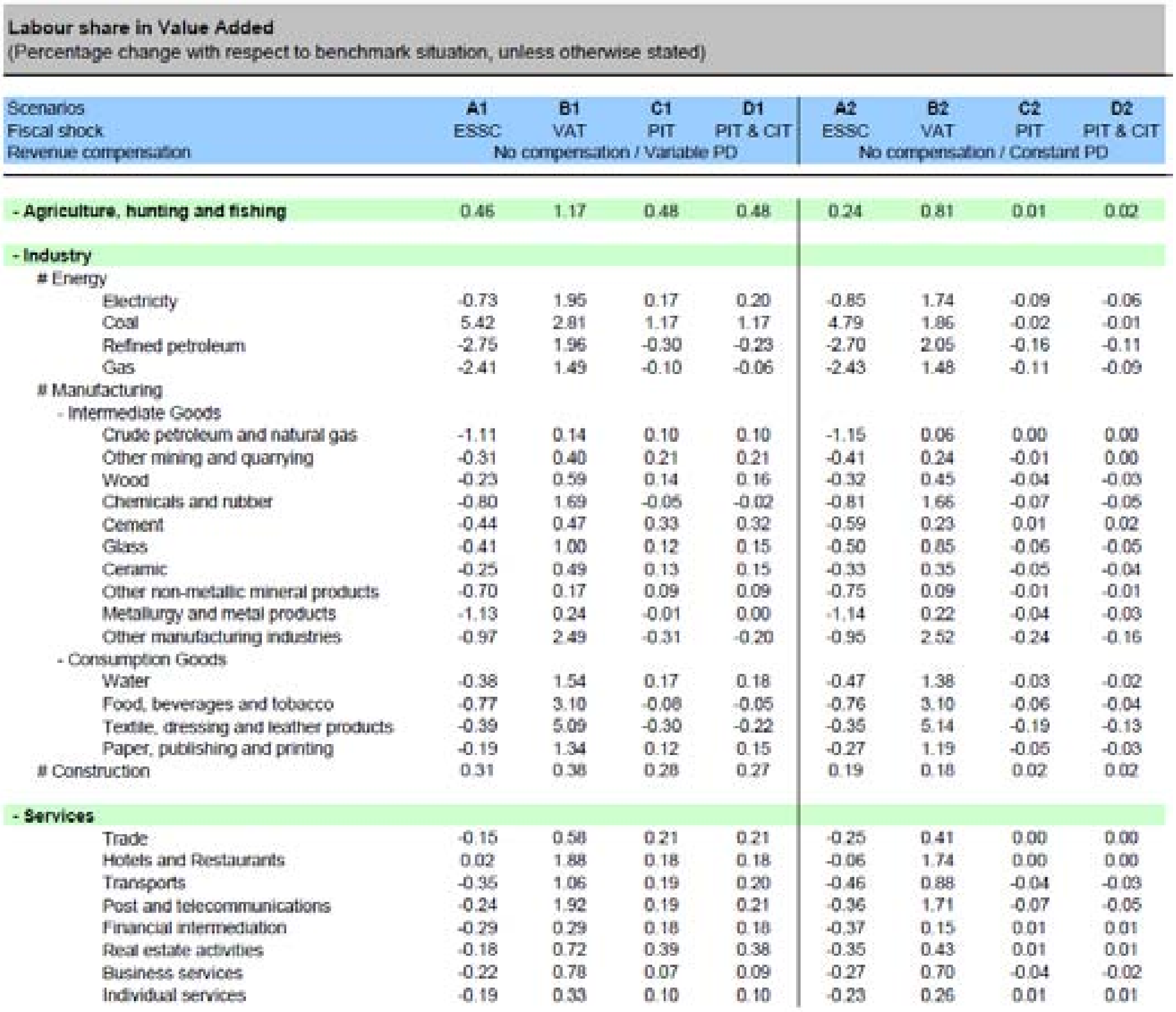
Labour Demand (in volume)
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	1.08	-0.11	-1.23	-1.47	1.11	-0.53	-1.12	-1.38
- Industry								
# Energy								
Electricity	3.99	3.77	3.97	4.00	2.12	0.51	0.03	0.08
Coal	-20.03	-30.30	-37.02	-37.63	-5.71	-11.74	-15.07	-16.00
Refined petroleum	-2.30	-4.74	-6.90	-7.15	-3.36	-6.36	-8.51	-8.72
Gas	-6.08	-9.51	-13.40	-13.82	-1.94	-3.55	-5.08	-5.44
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-4.59	-10.92	-12.99	-13.36	-4.52	-10.02	-12.35	-12.74
Other mining and quarrying	1.88	-2.00	-1.94	-1.59	1.94	-1.52	-1.76	-1.42
Wood	1.32	-1.63	-2.01	-1.80	1.46	-1.30	-1.72	-1.53
Chemicals and rubber	1.61	-1.51	-1.35	-1.32	1.69	-1.05	-1.17	-1.15
Cement	1.83	-0.44	-1.38	-0.78	1.78	-0.80	-1.44	-0.84
Glass	1.98	-1.17	-1.30	-1.24	1.96	-1.02	-1.31	-1.27
Ceramic	1.75	-0.76	-0.99	-0.60	1.53	-1.02	-1.41	-1.03
Other non-metallic mineral products	0.68	-0.81	-1.60	-0.98	0.68	-0.97	-1.55	-0.93
Metallurgy and metal products	0.63	-2.91	-2.78	-2.53	0.85	-2.04	-2.31	-2.08
Other manufacturing industries	1.02	-2.45	-2.29	-2.10	1.11	-1.79	-2.06	-1.89
- Consumption Goods								
Water	1.26	0.85	-0.45	-0.70	1.28	0.21	-0.37	-0.64
Food, beverages and tobacco	1.13	0.75	-0.46	-0.78	1.10	0.10	-0.47	-0.80
Textile, dressing and leather products	1.38	-0.40	-1.12	-1.32	1.39	-0.49	-1.05	-1.27
Paper, publishing and printing	1.45	-0.64	-1.24	-1.29	1.43	-0.77	-1.22	-1.29
# Construction	1.13	-0.61	-2.09	-1.43	1.14	-1.09	-2.02	-1.36
- Services								
Trade	1.04	-1.27	-2.17	-2.25	1.15	-1.26	-1.93	-2.03
Hotels and Restaurants	0.68	1.54	-0.29	-0.70	0.67	0.49	-0.27	-0.69
Transports	1.72	-1.07	-1.41	-1.40	1.87	-0.77	-1.11	-1.10
Post and telecommunications	1.19	0.26	-1.27	-1.43	1.21	-0.27	-1.20	-1.37
Financial intermediation	1.09	-0.04	-1.04	-1.25	1.10	-0.55	-0.97	-1.19
Real estate activities	1.17	0.41	-1.35	-1.53	1.17	-0.53	-1.30	-1.51
Business services	1.01	-1.06	-1.82	-1.66	1.05	-1.09	-1.70	-1.55
Individual services	0.57	0.41	-0.15	-0.27	0.56	0.03	-0.15	-0.28

first financing alternative, the labour share in value added tends to reduce, but not always for the same reason. For variants C and D, the reduction of labour share in value added is due mainly to a decrease in labour demand. On the other hand, the only reason why labour share in value added drops for the first variant is because of the reduction in the ESSC rate. Indeed, across all financing alternatives, variant A indicates an increase in labour demand. So, the significant decrease in the compensation of employees makes labour cost more attractive and goes along with a higher employment level, due, first, to a substitution effect towards the labour factor and, second, to the spill-over effects of higher economic activity.

Across the different scenarios, the economic sectors that present the higher decrease in the labour share in value added are the energy sectors and the manufacturing intermediate goods sectors. It suggests that the more labour intensive sectors tend to perform a stronger shift towards labour when faced with a change in relative factor prices, such as a reduction in labour cost. On the other hand, the increase in energy

Table 7.16: Labour share in Value Added (no fiscal compensation)

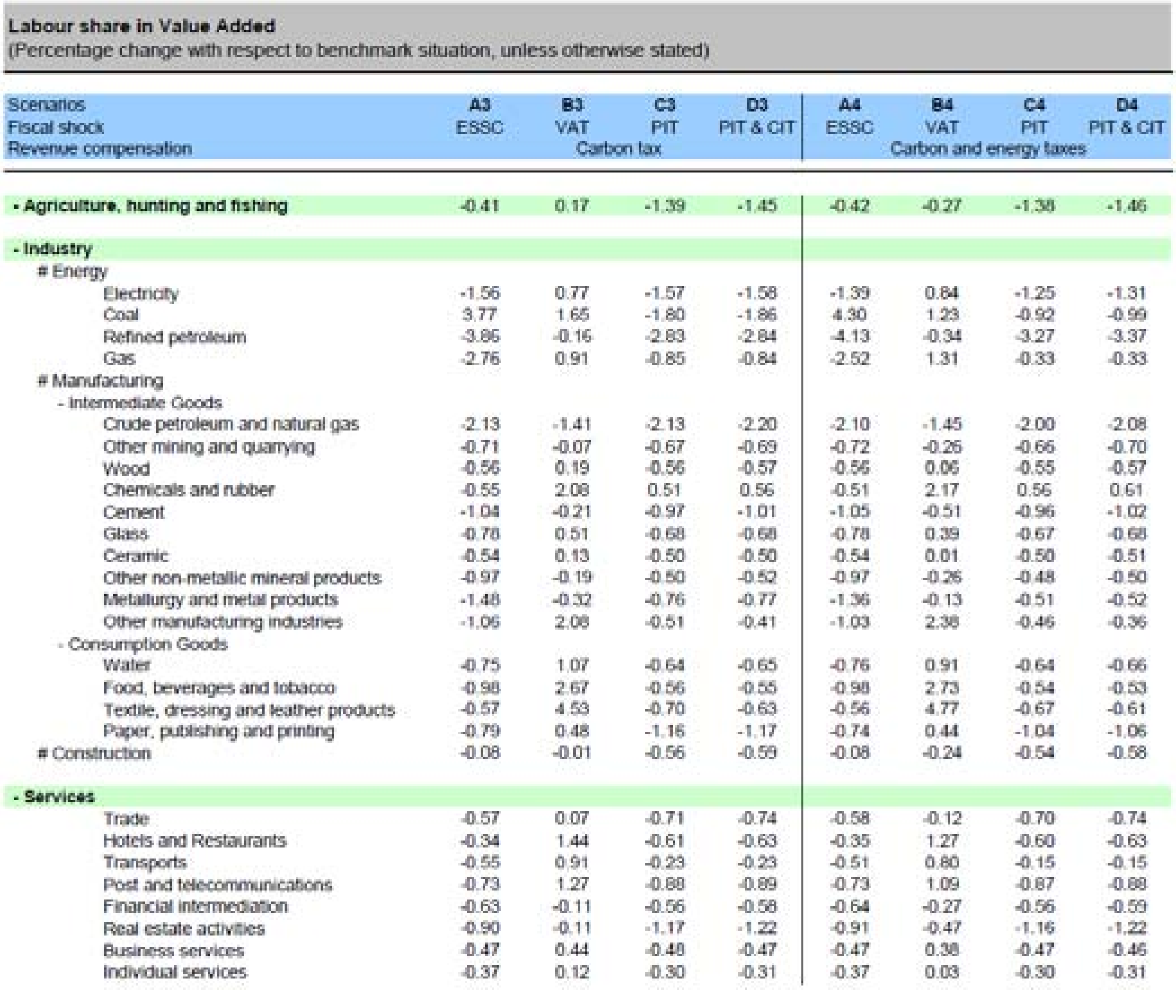


Labour share in Value Added
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	0.46	1.17	0.48	0.48	0.24	0.81	0.01	0.02
- Industry								
# Energy								
Electricity	-0.73	1.95	0.17	0.20	-0.85	1.74	-0.09	-0.06
Coal	5.42	2.81	1.17	1.17	4.79	1.86	-0.02	-0.01
Refined petroleum	-2.75	1.96	-0.30	-0.23	-2.70	2.05	-0.16	-0.11
Gas	-2.41	1.49	-0.10	-0.06	-2.43	1.48	-0.11	-0.09
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-1.11	0.14	0.10	0.10	-1.15	0.06	0.00	0.00
Other mining and quarrying	-0.31	0.40	0.21	0.21	-0.41	0.24	-0.01	0.00
Wood	-0.23	0.59	0.14	0.16	-0.32	0.45	-0.04	-0.03
Chemicals and rubber	-0.80	1.69	-0.05	-0.02	-0.81	1.66	-0.07	-0.05
Cement	-0.44	0.47	0.33	0.32	-0.59	0.23	0.01	0.02
Glass	-0.41	1.00	0.12	0.15	-0.50	0.85	-0.06	-0.05
Ceramic	-0.25	0.49	0.13	0.15	-0.33	0.35	-0.05	-0.04
Other non-metallic mineral products	-0.70	0.17	0.09	0.09	-0.75	0.09	-0.01	-0.01
Metallurgy and metal products	-1.13	0.24	-0.01	0.00	-1.14	0.22	-0.04	-0.03
Other manufacturing industries	-0.97	2.49	-0.31	-0.20	-0.95	2.52	-0.24	-0.16
- Consumption Goods								
Water	-0.38	1.54	0.17	0.18	-0.47	1.38	-0.03	-0.02
Food, beverages and tobacco	-0.77	3.10	-0.08	-0.05	-0.76	3.10	-0.06	-0.04
Textile, dressing and leather products	-0.39	5.09	-0.30	-0.22	-0.35	5.14	-0.19	-0.13
Paper, publishing and printing	-0.19	1.34	0.12	0.15	-0.27	1.19	-0.05	-0.03
# Construction	0.31	0.38	0.28	0.27	0.19	0.18	0.02	0.02
- Services								
Trade	-0.15	0.58	0.21	0.21	-0.25	0.41	0.00	0.00
Hotels and Restaurants	0.02	1.88	0.18	0.18	-0.06	1.74	0.00	0.00
Transports	-0.35	1.06	0.19	0.20	-0.46	0.88	-0.04	-0.03
Post and telecommunications	-0.24	1.92	0.19	0.21	-0.36	1.71	-0.07	-0.05
Financial intermediation	-0.29	0.29	0.18	0.18	-0.37	0.15	0.01	0.01
Real estate activities	-0.18	0.72	0.39	0.38	-0.35	0.43	0.01	0.01
Business services	-0.22	0.78	0.07	0.09	-0.27	0.70	-0.04	-0.02
Individual services	-0.19	0.33	0.10	0.10	-0.23	0.26	0.01	0.01

prices seem to favour also some substitution towards capital rather than labour for the energy- and capital-intensive sectors. The substitution effects depend of course on the substitution elasticities; but also on the production decision structure chosen. As explained previously, the choice was made to model the fuel-factor substitution structure as, first a substitution between capital and the energy aggregate and, second, between labour and the capital-energy aggregate. Given the complementarity between energy and capital, as documented by the literature review, we can expect that a significant impact of the increase in energy prices would be to generate some substitution towards capital, which would favour proportionally a higher share of capital in value added. It clarifies also why the more energy-intensive and capital-intensive manufacturing sectors tend to exhibit a stronger reduction in their labour share in value added, as they substitute energy sources for capital.

Table 7.17: Labour share in Value Added (fiscal compensation)



Labour share in Value Added
(Percentage change with respect to benchmark situation, unless otherwise stated)

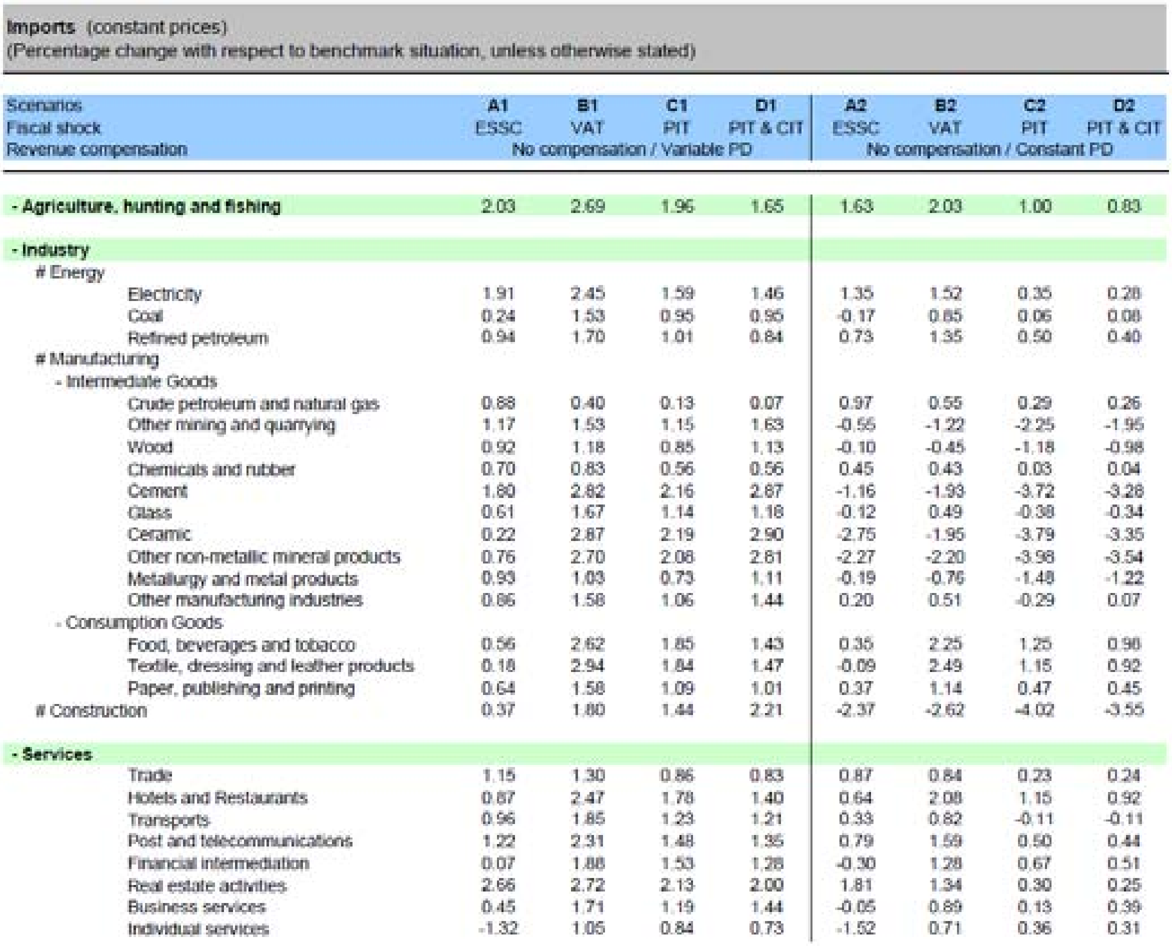
Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	-0.41	0.17	-1.39	-1.45	-0.42	-0.27	-1.38	-1.46
- Industry								
# Energy								
Electricity	-1.56	0.77	-1.57	-1.58	-1.39	0.84	-1.25	-1.31
Coal	3.77	1.65	-1.80	-1.86	4.30	1.23	-0.92	-0.99
Refined petroleum	-3.86	-0.16	-2.83	-2.84	-4.13	-0.34	-3.27	-3.37
Gas	-2.76	0.91	-0.85	-0.84	-2.52	1.31	-0.33	-0.33
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-2.13	-1.41	-2.13	-2.20	-2.10	-1.45	-2.00	-2.08
Other mining and quarrying	-0.71	-0.07	-0.67	-0.69	-0.72	-0.26	-0.66	-0.70
Wood	-0.56	0.19	-0.56	-0.57	-0.56	0.06	-0.55	-0.57
Chemicals and rubber	-0.55	2.08	0.51	0.56	-0.51	2.17	0.56	0.61
Cement	-1.04	-0.21	-0.97	-1.01	-1.05	-0.51	-0.96	-1.02
Glass	-0.78	0.51	-0.68	-0.68	-0.78	0.39	-0.67	-0.68
Ceramic	-0.54	0.13	-0.50	-0.50	-0.54	0.01	-0.50	-0.51
Other non-metallic mineral products	-0.97	-0.19	-0.50	-0.52	-0.97	-0.26	-0.48	-0.50
Metallurgy and metal products	-1.48	-0.32	-0.76	-0.77	-1.36	-0.13	-0.51	-0.52
Other manufacturing industries	-1.06	2.08	-0.51	-0.41	-1.03	2.38	-0.46	-0.36
- Consumption Goods								
Water	-0.75	1.07	-0.64	-0.65	-0.76	0.91	-0.64	-0.66
Food, beverages and tobacco	-0.98	2.67	-0.56	-0.55	-0.98	2.73	-0.54	-0.53
Textile, dressing and leather products	-0.57	4.53	-0.70	-0.63	-0.56	4.77	-0.67	-0.61
Paper, publishing and printing	-0.79	0.48	-1.16	-1.17	-0.74	0.44	-1.04	-1.06
# Construction	-0.08	-0.01	-0.56	-0.59	-0.08	-0.24	-0.54	-0.58
- Services								
Trade	-0.57	0.07	-0.71	-0.74	-0.58	-0.12	-0.70	-0.74
Hotels and Restaurants	-0.34	1.44	-0.61	-0.63	-0.35	1.27	-0.60	-0.63
Transports	-0.55	0.91	-0.23	-0.23	-0.51	0.80	-0.15	-0.15
Post and telecommunications	-0.73	1.27	-0.88	-0.89	-0.73	1.09	-0.87	-0.88
Financial intermediation	-0.63	-0.11	-0.56	-0.58	-0.64	-0.27	-0.56	-0.59
Real estate activities	-0.90	-0.11	-1.17	-1.22	-0.91	-0.47	-1.16	-1.22
Business services	-0.47	0.44	-0.48	-0.47	-0.47	0.38	-0.47	-0.46
Individual services	-0.37	0.12	-0.30	-0.31	-0.37	0.03	-0.30	-0.31

7.2.5 Trade

Imports

Imports, displayed in *tables* (7.18) and (7.19), represent aggregate products and services imports for Spanish economic sectors. Since demand for imports depends on the strength of domestic demand and the relative prices between domestic and foreign products, some noticeable divergences across policy variants, financing alternatives and economic sectors appear in the outcomes. The variant that displays the highest increase in imports is the second one (B), given that its domestic demand is stronger than the last two variants, and its production prices are higher than the first variant, manifesting a deterioration in external competitiveness. The first variant exhibits the highest increase in domestic demand, but not the highest increase in imports, due to the changes in the relative prices of domestically produced goods and imports. As production prices reduce, this variant allows to gain external competitiveness and the higher domestic demand is canalized relatively more towards domestically produced

Table 7.18: Imports (no fiscal compensation)



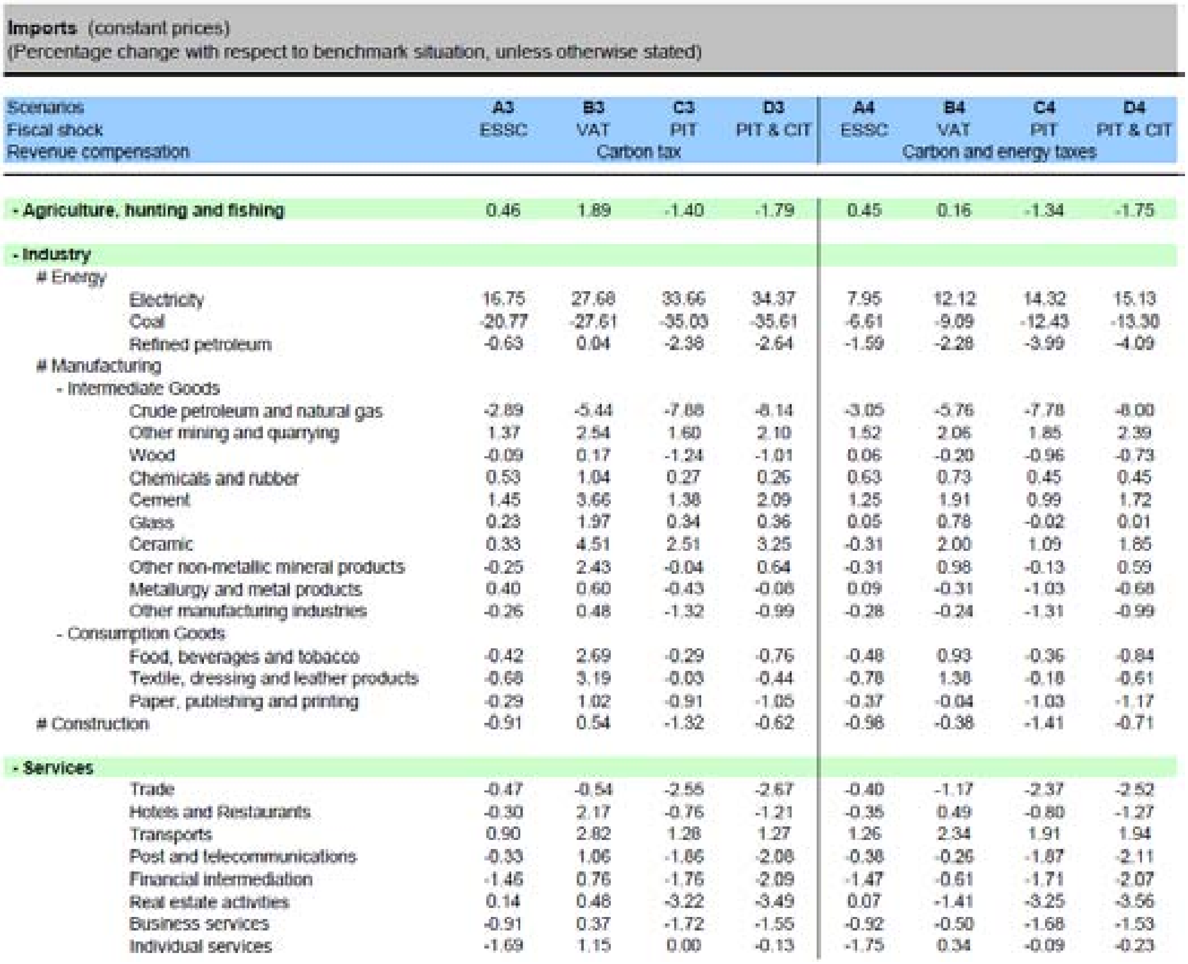
Imports (constant prices)
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	2.03	2.69	1.96	1.65	1.63	2.03	1.00	0.83
- Industry								
# Energy								
Electricity	1.91	2.45	1.59	1.46	1.35	1.52	0.35	0.28
Coal	0.24	1.53	0.95	0.95	-0.17	0.85	0.06	0.08
Refined petroleum	0.94	1.70	1.01	0.84	0.73	1.35	0.50	0.40
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	0.88	0.40	0.13	0.07	0.97	0.55	0.29	0.26
Other mining and quarrying	1.17	1.53	1.15	1.63	-0.55	-1.22	-2.25	-1.95
Wood	0.92	1.18	0.85	1.13	-0.10	-0.45	-1.18	-0.98
Chemicals and rubber	0.70	0.83	0.56	0.56	0.45	0.43	0.03	0.04
Cement	1.80	2.82	2.16	2.87	-1.16	-1.93	-3.72	-3.28
Glass	0.61	1.67	1.14	1.18	-0.12	0.49	-0.38	-0.34
Ceramic	0.22	2.87	2.19	2.90	-2.75	-1.95	-3.79	-3.35
Other non-metallic mineral products	0.76	2.70	2.08	2.81	-2.27	-2.20	-3.98	-3.54
Metallurgy and metal products	0.93	1.03	0.73	1.11	-0.19	-0.76	-1.48	-1.22
Other manufacturing industries	0.86	1.58	1.06	1.44	0.20	0.51	-0.29	0.07
- Consumption Goods								
Food, beverages and tobacco	0.56	2.62	1.85	1.43	0.35	2.25	1.25	0.98
Textile, dressing and leather products	0.18	2.94	1.84	1.47	-0.09	2.49	1.15	0.92
Paper, publishing and printing	0.64	1.58	1.09	1.01	0.37	1.14	0.47	0.45
# Construction	0.37	1.80	1.44	2.21	-2.37	-2.62	-4.02	-3.55
- Services								
Trade	1.15	1.30	0.86	0.83	0.87	0.84	0.23	0.24
Hotels and Restaurants	0.87	2.47	1.78	1.40	0.64	2.08	1.15	0.92
Transports	0.96	1.85	1.23	1.21	0.33	0.82	-0.11	-0.11
Post and telecommunications	1.22	2.31	1.48	1.35	0.79	1.59	0.50	0.44
Financial intermediation	0.07	1.88	1.53	1.28	-0.30	1.28	0.67	0.51
Real estate activities	2.66	2.72	2.13	2.00	1.81	1.34	0.30	0.25
Business services	0.45	1.71	1.19	1.44	-0.05	0.89	0.13	0.39
Individual services	-1.32	1.05	0.84	0.73	-1.52	0.71	0.36	0.31

goods than imported goods. Finally, variants C and D tend to present lower demand for imports than the other two variants, as a result of a weaker domestic demand. This is always the case except for the first financing alternative, where higher production prices and higher domestic demand combine to generate a change in imports higher than the one deriving from the variant reducing the ESSC rates.

In terms of financing alternatives, the one allowing an increase in public deficit (alternative I) shows the highest overall traction for imports as aggregate demand increases in a significant manner. With respect to economic sectors, it is when the carbon and energy content of energy sources are taxed that the differences are more striking. Demand for imported electricity tends indeed to rise significantly because domestic electricity production has to face higher production costs with the carbon/energy taxes on its production inputs. On the contrary, demand for imported fossil fuels (and coal in particular) drops as these products are now taxed when used as inputs in the production process. Also, imports for manufacturing intermediate goods are more important, as their domestic equivalents, being energy intensive, face higher costs with the new taxes. On the other hand, demand for imported services tends even to decline

Table 7.19: Imports (fiscal compensation)



Imports (constant prices)
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	0.46	1.89	-1.40	-1.79	0.45	0.16	-1.34	-1.75
- Industry								
# Energy								
Electricity	16.75	27.68	33.66	34.37	7.95	12.12	14.32	15.13
Coal	-20.77	-27.61	-35.03	-35.61	-6.61	-9.09	-12.43	-13.30
Refined petroleum	-0.63	0.04	-2.38	-2.64	-1.59	-2.28	-3.99	-4.09
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-2.89	-5.44	-7.88	-8.14	-3.05	-5.76	-7.78	-8.00
Other mining and quarrying	1.37	2.54	1.60	2.10	1.52	2.06	1.85	2.39
Wood	-0.09	0.17	-1.24	-1.01	0.06	-0.20	-0.96	-0.73
Chemicals and rubber	0.53	1.04	0.27	0.26	0.63	0.73	0.45	0.45
Cement	1.45	3.66	1.38	2.09	1.25	1.91	0.99	1.72
Glass	0.23	1.97	0.34	0.36	0.05	0.78	-0.02	0.01
Ceramic	0.33	4.51	2.51	3.25	-0.31	2.00	1.09	1.85
Other non-metallic mineral products	-0.25	2.43	-0.04	0.64	-0.31	0.98	-0.13	0.59
Metallurgy and metal products	0.40	0.60	-0.43	-0.08	0.09	-0.31	-1.03	-0.68
Other manufacturing industries	-0.26	0.48	-1.32	-0.99	-0.28	-0.24	-1.31	-0.99
- Consumption Goods								
Food, beverages and tobacco	-0.42	2.69	-0.29	-0.76	-0.48	0.93	-0.36	-0.84
Textile, dressing and leather products	-0.68	3.19	-0.03	-0.44	-0.78	1.38	-0.18	-0.61
Paper, publishing and printing	-0.29	1.02	-0.91	-1.05	-0.37	-0.04	-1.03	-1.17
# Construction	-0.91	0.54	-1.32	-0.62	-0.98	-0.38	-1.41	-0.71
- Services								
Trade	-0.47	-0.54	-2.56	-2.67	-0.40	-1.17	-2.37	-2.52
Hotels and Restaurants	-0.30	2.17	-0.76	-1.21	-0.35	0.49	-0.80	-1.27
Transports	0.90	2.82	1.28	1.27	1.26	2.34	1.91	1.94
Post and telecommunications	-0.33	1.06	-1.86	-2.08	-0.38	-0.26	-1.87	-2.11
Financial intermediation	-1.46	0.76	-1.76	-2.09	-1.47	-0.61	-1.71	-2.07
Real estate activities	0.14	0.48	-3.22	-3.49	0.07	-1.41	-3.25	-3.56
Business services	-0.91	0.37	-1.72	-1.55	-0.92	-0.50	-1.68	-1.53
Individual services	-1.69	1.15	0.00	-0.13	-1.75	0.34	-0.09	-0.23

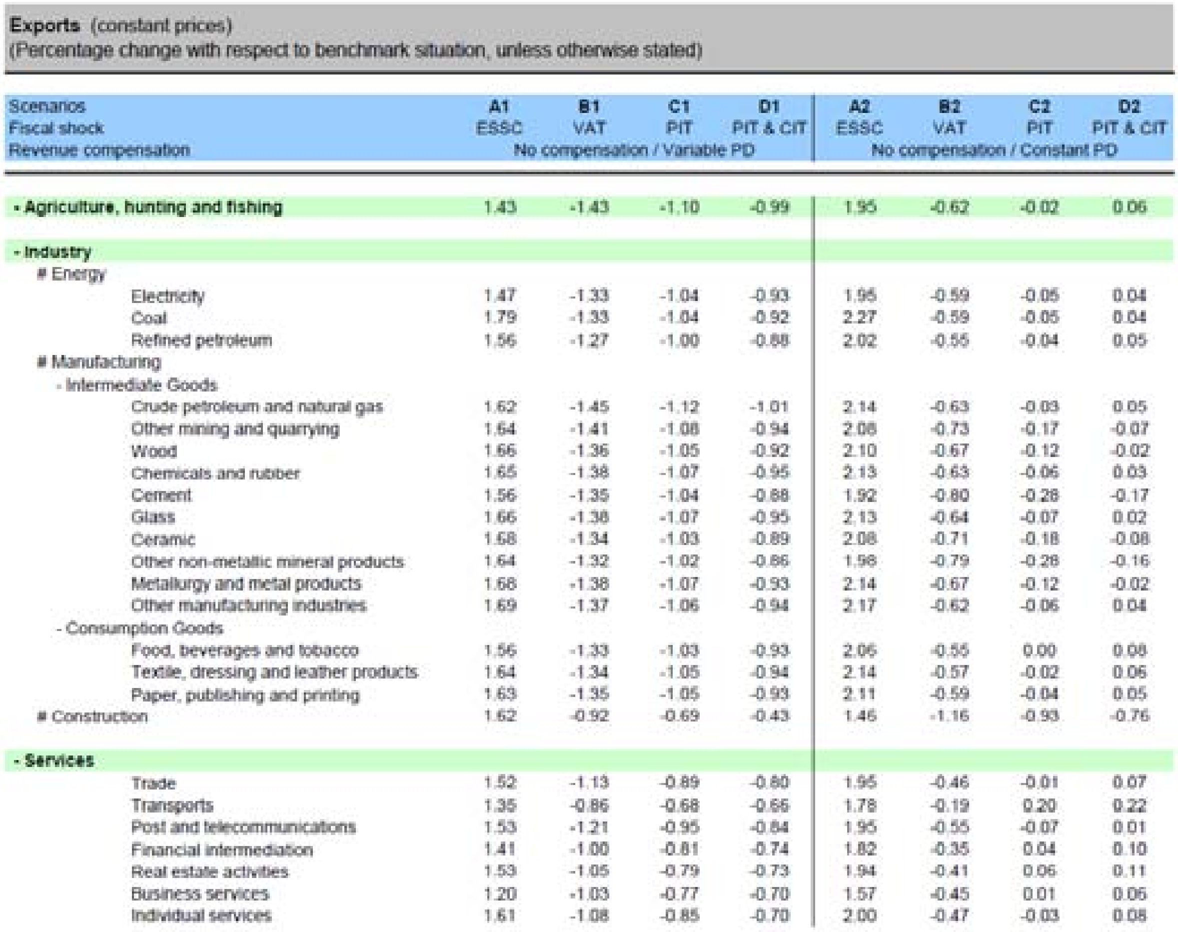
in many cases, as the domestic services sectors benefit from lower production prices changes.

Exports

Tables (7.20) and (7.21) exhibit the disaggregation for the change in sectoral exports. Exports levels are determined by equation (5.41), and are a function of the domestic production prices, the exports prices (expressed in domestic currency) and, implicitly, the Armington aggregate.

In terms of policy variants comparison, simulation outcomes indicate that variants B, C and D underperform systematically the first variant. This is mainly due to the absence of any production prices mitigation policy for these variants. Subsequently, any increase in production costs is translated readily into higher domestic production prices, undermining the external competitiveness. As a consequence, trade balances always deteriorate for these variants. In the first two financing alternatives, the increase in production costs is mainly the consequence of higher prices for production factors

Table 7.20: Exports (no fiscal compensation)



Exports (constant prices)
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	1.43	-1.43	-1.10	-0.99	1.95	-0.62	-0.02	0.06
- Industry								
# Energy								
Electricity	1.47	-1.33	-1.04	-0.93	1.96	-0.59	-0.05	0.04
Coal	1.79	-1.33	-1.04	-0.92	2.27	-0.59	-0.05	0.04
Refined petroleum	1.56	-1.27	-1.00	-0.88	2.02	-0.55	-0.04	0.05
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	1.62	-1.45	-1.12	-1.01	2.14	-0.63	-0.03	0.05
Other mining and quarrying	1.64	-1.41	-1.08	-0.94	2.08	-0.73	-0.17	-0.07
Wood	1.66	-1.36	-1.05	-0.92	2.10	-0.67	-0.12	-0.02
Chemicals and rubber	1.65	-1.38	-1.07	-0.95	2.13	-0.63	-0.06	0.03
Cement	1.56	-1.35	-1.04	-0.88	1.92	-0.80	-0.28	-0.17
Glass	1.66	-1.38	-1.07	-0.95	2.13	-0.64	-0.07	0.02
Ceramic	1.68	-1.34	-1.03	-0.89	2.08	-0.71	-0.18	-0.08
Other non-metallic mineral products	1.64	-1.32	-1.02	-0.86	1.98	-0.79	-0.28	-0.16
Metallurgy and metal products	1.68	-1.38	-1.07	-0.93	2.14	-0.67	-0.12	-0.02
Other manufacturing industries	1.69	-1.37	-1.06	-0.94	2.17	-0.62	-0.06	0.04
- Consumption Goods								
Food, beverages and tobacco	1.56	-1.33	-1.03	-0.93	2.06	-0.55	0.00	0.08
Textile, dressing and leather products	1.64	-1.34	-1.05	-0.94	2.14	-0.57	-0.02	0.06
Paper, publishing and printing	1.63	-1.35	-1.05	-0.93	2.11	-0.59	-0.04	0.05
# Construction	1.62	-0.92	-0.69	-0.43	1.46	-1.16	-0.93	-0.76
- Services								
Trade	1.52	-1.13	-0.89	-0.80	1.95	-0.46	-0.01	0.07
Transports	1.35	-0.86	-0.68	-0.66	1.78	-0.19	0.20	0.22
Post and telecommunications	1.53	-1.21	-0.95	-0.84	1.95	-0.55	-0.07	0.01
Financial intermediation	1.41	-1.00	-0.81	-0.74	1.82	-0.35	0.04	0.10
Real estate activities	1.53	-1.05	-0.79	-0.73	1.94	-0.41	0.06	0.11
Business services	1.20	-1.03	-0.77	-0.70	1.57	-0.45	0.01	0.06
Individual services	1.61	-1.08	-0.85	-0.70	2.00	-0.47	-0.03	0.08

whereas, in the last two financing alternatives (fiscal compensation, carbon/energy taxes), the higher production costs result from the higher energy prices, as energy sources are of course inputs broadly used in the production processes.

In the same way, the positive impact of the first variant policy on net exports must be stressed out. The reduction in ESSC rate allows indeed to contain in a significant manner the potential increase in domestic production prices, due to higher factor prices and higher energy prices. In doing so, it helps to curb the negative impact on external competitiveness, providing systematically the only positive results among variants in terms of exports.

Among sectors categories, results show that, when fiscal compensation is required, the sectors with the highest decline in exports are the energy-intensive sectors (energy sectors and manufacturing intermediate goods sectors). Unsurprisingly, these are the ones which suffer most from the relative increase in energy prices, echoing into higher production costs and higher production prices. As a result, their external competitiveness is particularly damaged and they have to face a lower external demand. On

Table 7.21: Exports (fiscal compensation)

Exports (constant prices)
(Percentage change with respect to benchmark situation, unless otherwise stated)

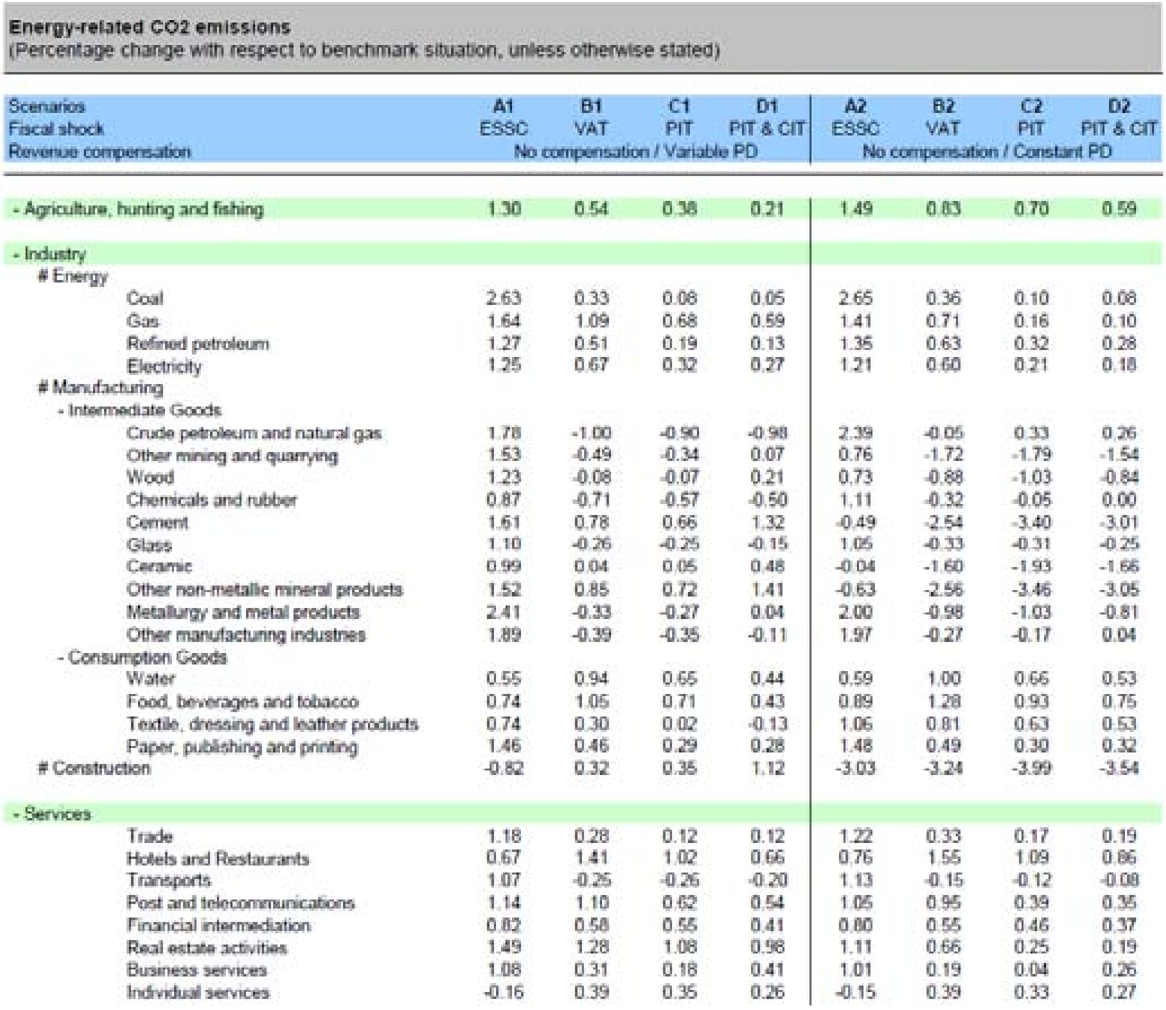
Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	0.76	-3.40	-2.61	-2.54	0.84	-2.38	-2.39	-2.35
- Industry								
# Energy								
Electricity	-0.46	-5.10	-4.99	-4.98	0.11	-3.46	-3.87	-3.90
Coal	-0.62	-5.70	-5.70	-5.69	0.52	-3.30	-3.65	-3.69
Refined petroleum	0.40	-3.93	-3.56	-3.52	0.36	-3.16	-3.51	-3.50
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	0.35	-4.34	-3.87	-3.84	0.44	-3.30	-3.58	-3.59
Other mining and quarrying	0.67	-3.84	-3.23	-3.14	0.74	-2.84	-3.01	-2.96
Wood	0.82	-3.55	-2.89	-2.81	0.91	-2.56	-2.66	-2.61
Chemicals and rubber	0.71	-3.74	-3.14	-3.08	0.78	-2.77	-2.93	-2.90
Cement	0.67	-3.63	-2.99	-2.89	0.76	-2.63	-2.75	-2.68
Glass	0.79	-3.63	-2.98	-2.91	0.89	-2.59	-2.70	-2.66
Ceramic	0.73	-3.69	-3.12	-3.04	0.86	-2.64	-2.78	-2.73
Other non-metallic mineral products	0.77	-3.54	-2.92	-2.82	0.86	-2.57	-2.69	-2.62
Metallurgy and metal products	0.79	-3.67	-3.03	-2.95	0.91	-2.60	-2.71	-2.66
Other manufacturing industries	0.88	-3.54	-2.86	-2.78	0.97	-2.52	-2.61	-2.57
- Consumption Goods								
Food, beverages and tobacco	0.82	-3.34	-2.67	-2.62	0.91	-2.38	-2.44	-2.42
Textile, dressing and leather products	0.87	-3.41	-2.76	-2.70	0.96	-2.43	-2.51	-2.49
Paper, publishing and printing	0.84	-3.46	-2.80	-2.73	0.93	-2.47	-2.55	-2.51
# Construction	0.74	-2.95	-2.61	-2.40	0.81	-2.21	-2.41	-2.23
- Services								
Trade	0.74	-3.09	-2.60	-2.55	0.84	-2.22	-2.35	-2.33
Transports	0.70	-2.44	-2.13	-2.15	0.76	-1.80	-1.95	-1.99
Post and telecommunications	0.55	-3.52	-3.09	-3.04	0.59	-2.69	-2.93	-2.92
Financial intermediation	0.73	-2.73	-2.30	-2.27	0.81	-1.95	-2.09	-2.09
Real estate activities	0.87	-2.74	-2.26	-2.23	0.94	-1.99	-2.06	-2.06
Business services	0.65	-2.55	-2.01	-1.97	0.72	-1.81	-1.82	-1.80
Individual services	0.84	-3.02	-2.54	-2.44	0.91	-2.19	-2.33	-2.26

the other side, more labour-intensive sectors, such as the service sectors, tend to outperform the rest of the economic sectors. This signals some divergent competitiveness effects that allow the sectors with high labour intensity to reduce their production costs and affect more positively their external competitiveness.

7.2.6 Carbon emissions

A sectoral breakdown of carbon emissions change is given in *tables* (7.22) and (7.23). The results show that carbon emissions decrease only when there exists the restriction of new taxes on carbon content and energy content of energy sources. When no carbon/energy taxes are levied, the decrease in VAT rate (second variant) and the decrease in ESCC rate (first variant) present the worst outcomes in terms of carbon emissions. When the carbon tax alone is levied as a fiscal compensation scheme, simulation outcomes show that all variants reduce strongly their carbon emissions levels, with a particular emphasis for the last two variants facing a substantial reduction in production. The joint carbon/energy taxes offer lower reductions in carbon emissions, even tough still very significant. This is the consequence of the partial shift of the tax

Table 7.22: Energy-related carbon emissions (no fiscal compensation)



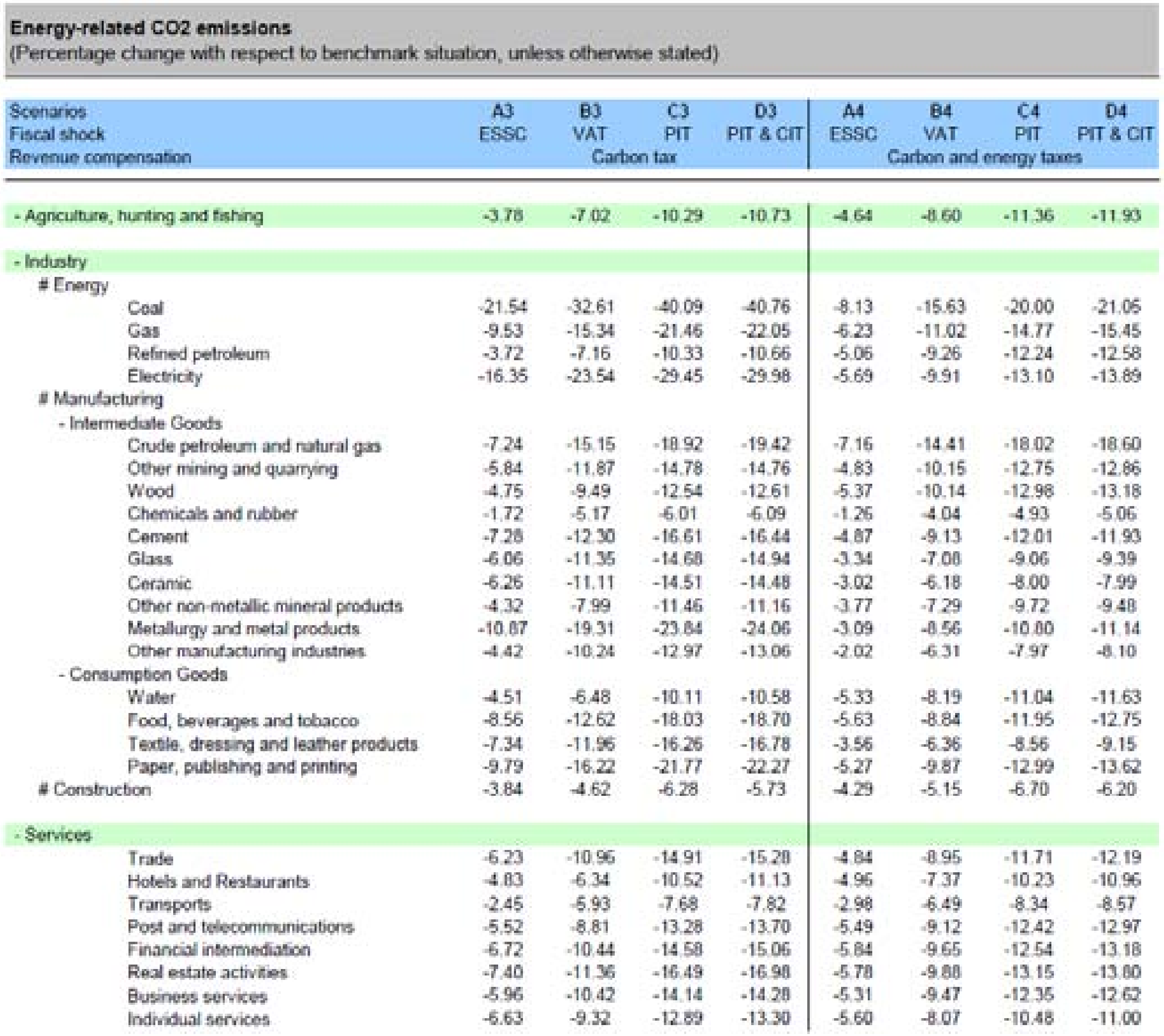
Energy-related CO2 emissions
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	No compensation / Variable PD				No compensation / Constant PD			
- Agriculture, hunting and fishing	1.30	0.54	0.38	0.21	1.49	0.83	0.70	0.59
- Industry								
# Energy								
Coal	2.63	0.33	0.08	0.05	2.65	0.36	0.10	0.08
Gas	1.64	1.09	0.68	0.59	1.41	0.71	0.16	0.10
Refined petroleum	1.27	0.51	0.19	0.13	1.35	0.63	0.32	0.28
Electricity	1.25	0.67	0.32	0.27	1.21	0.60	0.21	0.18
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	1.78	-1.00	-0.90	-0.98	2.39	-0.05	0.33	0.26
Other mining and quarrying	1.53	-0.49	-0.34	0.07	0.76	-1.72	-1.79	-1.54
Wood	1.23	-0.08	-0.07	0.21	0.73	-0.88	-1.03	-0.84
Chemicals and rubber	0.87	-0.71	-0.57	-0.50	1.11	-0.32	-0.05	0.00
Cement	1.61	0.78	0.66	1.32	-0.49	-2.54	-3.40	-3.01
Glass	1.10	-0.26	-0.25	-0.15	1.05	-0.33	-0.31	-0.25
Ceramic	0.99	0.04	0.05	0.48	-0.04	-1.60	-1.93	-1.66
Other non-metallic mineral products	1.52	0.85	0.72	1.41	-0.63	-2.56	-3.46	-3.05
Metallurgy and metal products	2.41	-0.33	-0.27	0.04	2.00	-0.98	-1.03	-0.81
Other manufacturing industries	1.89	-0.39	-0.35	-0.11	1.97	-0.27	-0.17	0.04
- Consumption Goods								
Water	0.55	0.94	0.65	0.44	0.59	1.00	0.66	0.53
Food, beverages and tobacco	0.74	1.05	0.71	0.43	0.89	1.28	0.93	0.75
Textile, dressing and leather products	0.74	0.30	0.02	-0.13	1.06	0.81	0.63	0.53
Paper, publishing and printing	1.46	0.46	0.29	0.28	1.48	0.49	0.30	0.32
# Construction	-0.82	0.32	0.35	1.12	-3.03	-3.24	-3.99	-3.54
- Services								
Trade	1.18	0.28	0.12	0.12	1.22	0.33	0.17	0.19
Hotels and Restaurants	0.67	1.41	1.02	0.66	0.76	1.55	1.09	0.86
Transports	1.07	-0.25	-0.26	-0.20	1.13	-0.15	-0.12	-0.08
Post and telecommunications	1.14	1.10	0.62	0.54	1.05	0.95	0.39	0.35
Financial intermediation	0.82	0.58	0.55	0.41	0.80	0.55	0.46	0.37
Real estate activities	1.49	1.28	1.08	0.98	1.11	0.66	0.25	0.19
Business services	1.08	0.31	0.18	0.41	1.01	0.19	0.04	0.26
Individual services	-0.16	0.39	0.35	0.26	-0.15	0.39	0.33	0.27

burden from the carbon intensive fuels (e.g. coal) towards the more energy-intensive energy sources (e.g. petrol).

In terms of economic sectors, the differences are particularly striking when the carbon and energy taxes are levied. The energy sectors appear as the primary drivers of carbon emissions reduction. But the reduction is a broad-based phenomenon, since absolutely all sectors reduce their carbon emissions levels. This indicates that there is room for some industrial sectors to become relatively more energy efficient as they take advantage of some fuel switching possibilities. However, this tradeoff does not apply to all manufacturing sectors, as certain industrial production processes are more dependent on one particular type of energy, such as petrochemicals for example. In the same vein, selected sectors demonstrate some difficulty to reduce significantly their carbon emissions levels, as fossil fuels represent crucial inputs in their process and there only exists restricted possibilities for fuel switching. This is the case for the transport sector, revealing its dependence on one particular fossil fuel, petrol.

Table 7.23: Energy-related carbon emissions (fiscal compensation)



Energy-related CO2 emissions
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation	Carbon tax				Carbon and energy taxes			
- Agriculture, hunting and fishing	-3.78	-7.02	-10.29	-10.73	-4.64	-8.60	-11.36	-11.93
- Industry								
# Energy								
Coal	-21.54	-32.61	-40.09	-40.76	-8.13	-15.63	-20.00	-21.06
Gas	-9.53	-15.34	-21.46	-22.05	-6.23	-11.02	-14.77	-15.45
Refined petroleum	-3.72	-7.16	-10.33	-10.66	-5.06	-9.26	-12.24	-12.58
Electricity	-16.35	-23.54	-29.45	-29.98	-5.69	-9.91	-13.10	-13.89
# Manufacturing								
- Intermediate Goods								
Crude petroleum and natural gas	-7.24	-15.15	-18.92	-19.42	-7.16	-14.41	-18.02	-18.60
Other mining and quarrying	-5.84	-11.87	-14.78	-14.76	-4.83	-10.15	-12.75	-12.86
Wood	-4.75	-9.49	-12.54	-12.61	-5.37	-10.14	-12.98	-13.18
Chemicals and rubber	-1.72	-5.17	-6.01	-6.09	-1.26	-4.04	-4.93	-5.06
Cement	-7.28	-12.30	-16.61	-16.44	-4.87	-9.13	-12.01	-11.93
Glass	-6.06	-11.35	-14.68	-14.94	-3.34	-7.08	-9.06	-9.39
Ceramic	-6.26	-11.11	-14.51	-14.48	-3.02	-6.18	-8.00	-7.99
Other non-metallic mineral products	-4.32	-7.99	-11.46	-11.16	-3.77	-7.29	-9.72	-9.48
Metallurgy and metal products	-10.87	-19.31	-23.84	-24.06	-3.09	-8.56	-10.80	-11.14
Other manufacturing industries	-4.42	-10.24	-12.97	-13.06	-2.02	-6.31	-7.97	-8.10
- Consumption Goods								
Water	-4.51	-6.48	-10.11	-10.58	-5.33	-8.19	-11.04	-11.63
Food, beverages and tobacco	-8.56	-12.62	-18.03	-18.70	-5.63	-8.84	-11.95	-12.75
Textile, dressing and leather products	-7.34	-11.96	-16.26	-16.78	-3.56	-6.36	-8.56	-9.15
Paper, publishing and printing	-9.79	-16.22	-21.77	-22.27	-5.27	-9.87	-12.99	-13.62
# Construction	-3.84	-4.62	-6.28	-5.73	-4.29	-5.15	-6.70	-6.20
- Services								
Trade	-6.23	-10.96	-14.91	-15.28	-4.84	-8.95	-11.71	-12.19
Hotels and Restaurants	-4.83	-6.34	-10.52	-11.13	-4.96	-7.37	-10.23	-10.96
Transports	-2.45	-5.93	-7.68	-7.82	-2.98	-6.49	-8.34	-8.57
Post and telecommunications	-5.52	-8.81	-13.28	-13.70	-5.49	-9.12	-12.42	-12.97
Financial intermediation	-6.72	-10.44	-14.58	-15.06	-5.84	-9.65	-12.54	-13.18
Real estate activities	-7.40	-11.36	-16.49	-16.98	-5.78	-9.88	-13.15	-13.80
Business services	-5.96	-10.42	-14.14	-14.28	-5.31	-9.47	-12.35	-12.62
Individual services	-6.63	-9.32	-12.89	-13.30	-5.60	-8.07	-10.48	-11.00

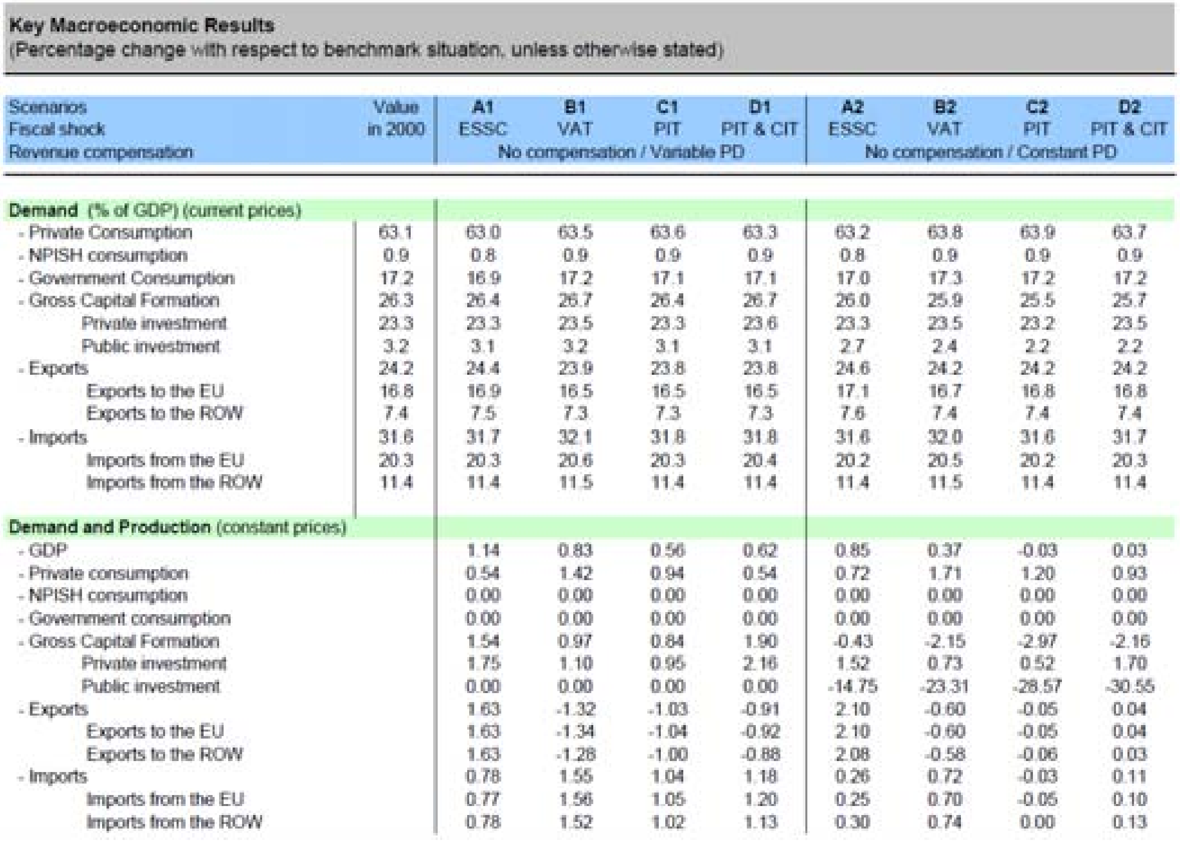
7.3 Key macroeconomic results

Tables (7.24) to (7.27) show the effects of the different policy scenarios on some key macroeconomic variables such as GDP and its components, employment, incomes and savings, prices and costs and carbon emissions by fuel sources. We discuss the results by variant type. To understand the different results, we must take into account the impacts of both the initial tax policy (e.g. reduction in ESSC) and the compensatory tax policy (e.g. carbon tax), and decompose their propagation effects.

7.3.1 First variant: a reduction in ESSC

In scenario A1, the decrease in ESSC rates reduces employees compensation cost, which lowers the labour cost per production unit and the overall production costs. This favours the labour factor in the production process. Higher labour demand and lower consumption prices lead to higher household real disposable income. This in

Table 7.24: Key macroeconomic results (no fiscal compensation)



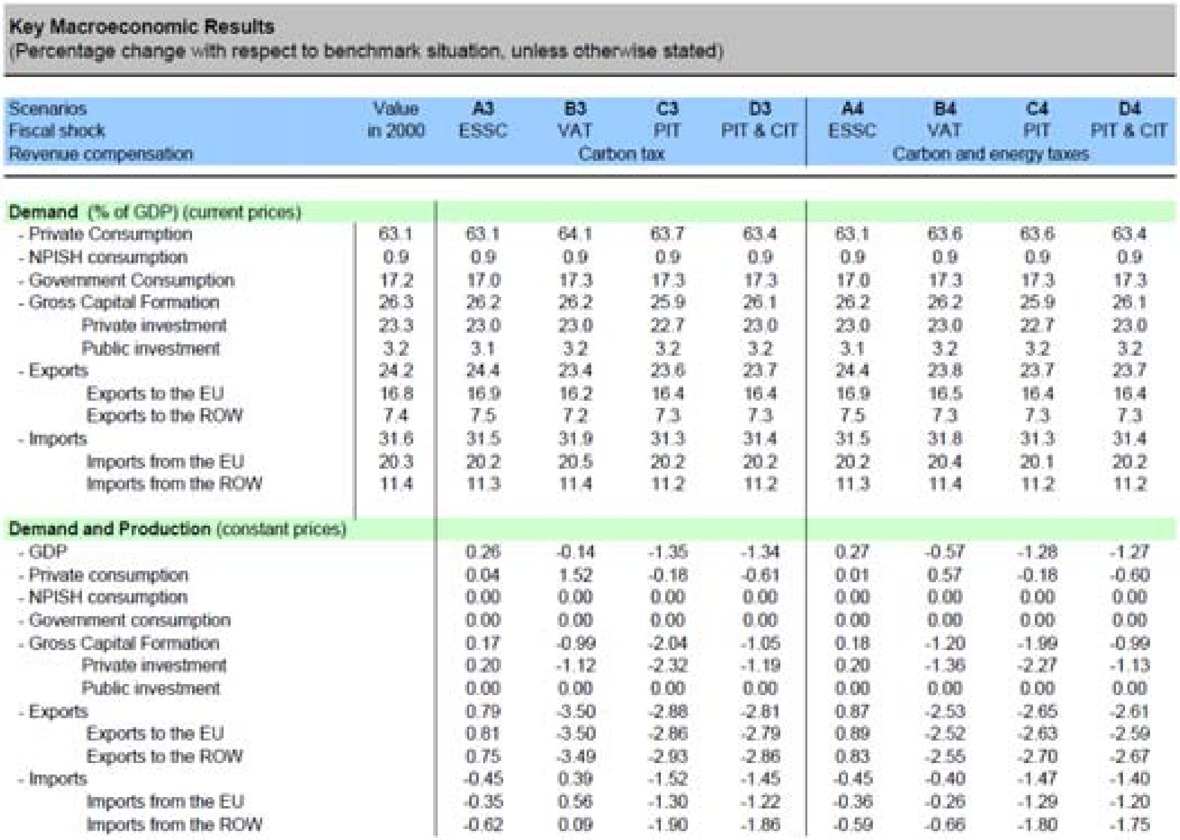
Key Macroeconomic Results
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios Fiscal shock Revenue compensation	Value in 2000	**A1** ESSC	**B1** VAT	**C1** PIT	**D1** PIT & CIT	**A2** ESSC	**B2** VAT	**C2** PIT	**D2** PIT & CIT
		No compensation / Variable PD				No compensation / Constant PD			
Demand (% of GDP) (current prices)									
- Private Consumption	63.1	63.0	63.5	63.6	63.3	63.2	63.8	63.9	63.7
- NPISH consumption	0.9	0.8	0.9	0.9	0.9	0.8	0.9	0.9	0.9
- Government Consumption	17.2	16.9	17.2	17.1	17.1	17.0	17.3	17.2	17.2
- Gross Capital Formation	26.3	26.4	26.7	26.4	26.7	26.0	25.9	25.5	25.7
Private investment	23.3	23.3	23.5	23.3	23.6	23.3	23.5	23.2	23.5
Public investment	3.2	3.1	3.2	3.1	3.1	2.7	2.4	2.2	2.2
- Exports	24.2	24.4	23.9	23.8	23.8	24.6	24.2	24.2	24.2
Exports to the EU	16.8	16.9	16.5	16.5	16.5	17.1	16.7	16.8	16.8
Exports to the ROW	7.4	7.5	7.3	7.3	7.3	7.6	7.4	7.4	7.4
- Imports	31.6	31.7	32.1	31.8	31.8	31.6	32.0	31.6	31.7
Imports from the EU	20.3	20.3	20.6	20.3	20.4	20.2	20.5	20.2	20.3
Imports from the ROW	11.4	11.4	11.5	11.4	11.4	11.4	11.5	11.4	11.4
Demand and Production (constant prices)									
- GDP		1.14	0.83	0.56	0.62	0.85	0.37	-0.03	0.03
- Private consumption		0.54	1.42	0.94	0.54	0.72	1.71	1.20	0.93
- NPISH consumption		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Government consumption		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Gross Capital Formation		1.54	0.97	0.84	1.90	-0.43	-2.15	-2.97	-2.16
Private investment		1.75	1.10	0.95	2.16	1.52	0.73	0.52	1.70
Public investment		0.00	0.00	0.00	0.00	-14.75	-23.31	-28.57	-30.55
- Exports		1.63	-1.32	-1.03	-0.91	2.10	-0.60	-0.05	0.04
Exports to the EU		1.63	-1.34	-1.04	-0.92	2.10	-0.60	-0.05	0.04
Exports to the ROW		1.63	-1.28	-1.00	-0.88	2.08	-0.58	-0.06	0.03
- Imports		0.78	1.55	1.04	1.18	0.26	0.72	-0.03	0.11
Imports from the EU		0.77	1.56	1.05	1.20	0.25	0.70	-0.05	0.10
Imports from the ROW		0.78	1.52	1.02	1.13	0.30	0.74	0.00	0.13

turn conducts into higher real private consumption and higher household savings. At the same time, the higher corporate savings helps to increase further total private savings, which elicits a higher gross capital formation. In this first alternative, the ratio of public deficit to GDP is not constant but increases, as public savings diminishes whereas public investment stays constant. The combination of higher public deficit, higher private consumption and higher gross capital formation represents a strong positive impact on domestic demand. This increase in aggregate demand leads to higher domestic production and higher imports. At the same time, the decrease in production costs induces a reduction in domestic production prices, generating a downward pressure on consumption prices. The lower domestic production prices, relative to foreign prices, also improve external competitiveness and encourage higher exports. So, while higher aggregate demand increases imports from both regions, lower production prices tend to increase exports, leading to an improvement in trade balances.

In the labour market, we observe a significant increase in employment, due to the combined effect of lower ESSC rates and stronger economic activity. The negative outcome for this scenario is mainly the result of higher carbon emissions, due to an increase in fossil fuels consumption, both from intermediary and final demand. Unsurprisingly, coal is the fuel with the highest impact on carbon emissions change,

Table 7.25: Key macroeconomic results (fiscal compensation)



Key Macroeconomic Results
(Percentage change with respect to benchmark situation, unless otherwise stated)

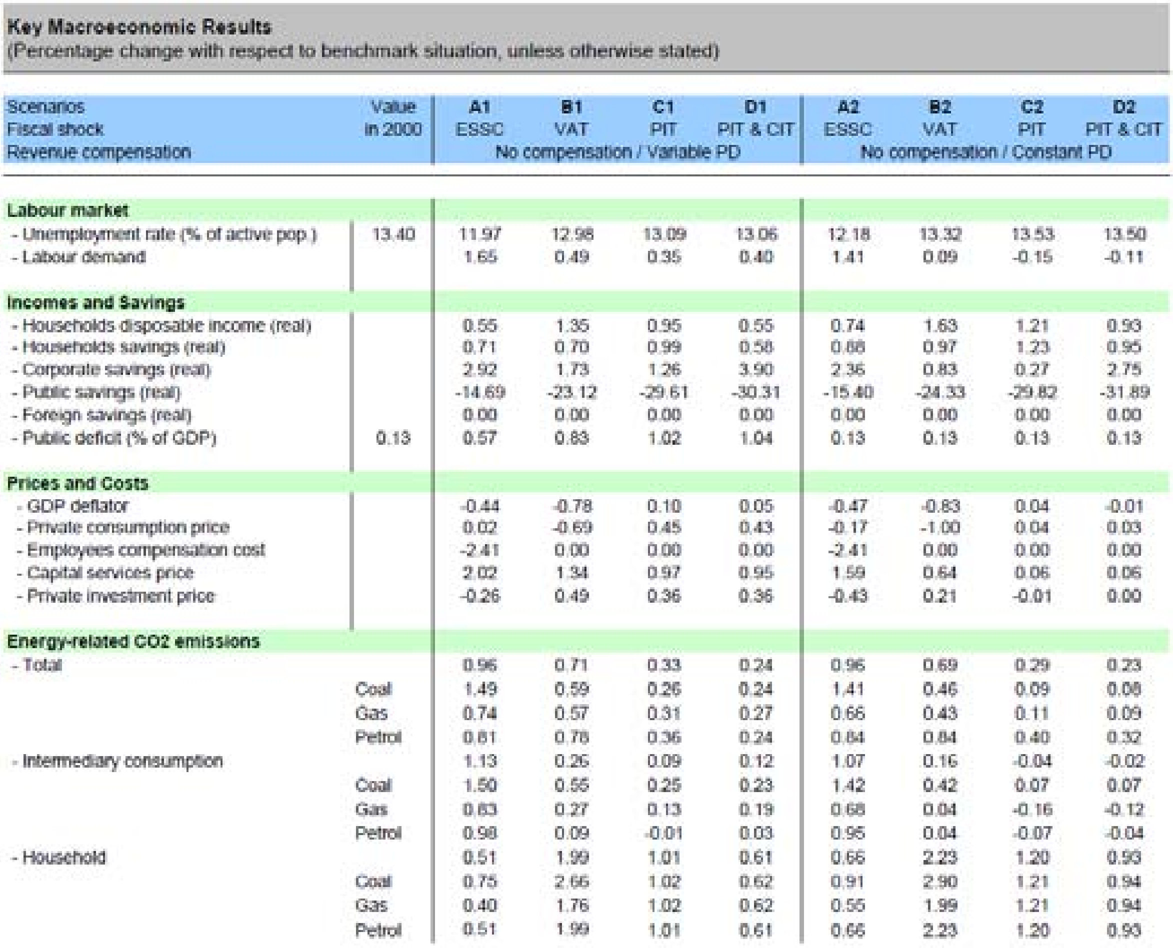
Scenarios Fiscal shock Revenue compensation	Value in 2000	A3 ESSC	B3 VAT Carbon tax	C3 PIT	D3 PIT & CIT	A4 ESSC	B4 VAT Carbon and energy taxes	C4 PIT	D4 PIT & CIT
Demand (% of GDP) (current prices)									
- Private Consumption	63.1	63.1	64.1	63.7	63.4	63.1	63.6	63.6	63.4
- NPISH consumption	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
- Government Consumption	17.2	17.0	17.3	17.3	17.3	17.0	17.3	17.3	17.3
- Gross Capital Formation	26.3	26.2	26.2	25.9	26.1	26.2	26.2	25.9	26.1
Private investment	23.3	23.0	23.0	22.7	23.0	23.0	23.0	22.7	23.0
Public investment	3.2	3.1	3.2	3.2	3.2	3.1	3.2	3.2	3.2
- Exports	24.2	24.4	23.4	23.6	23.7	24.4	23.8	23.7	23.7
Exports to the EU	16.8	16.9	16.2	16.4	16.4	16.9	16.5	16.4	16.4
Exports to the ROW	7.4	7.5	7.2	7.3	7.3	7.5	7.3	7.3	7.3
- Imports	31.6	31.5	31.9	31.3	31.4	31.5	31.8	31.3	31.4
Imports from the EU	20.3	20.2	20.5	20.2	20.2	20.2	20.4	20.1	20.2
Imports from the ROW	11.4	11.3	11.4	11.2	11.2	11.3	11.4	11.2	11.2
Demand and Production (constant prices)									
- GDP		0.26	-0.14	-1.35	-1.34	0.27	-0.57	-1.28	-1.27
- Private consumption		0.04	1.52	-0.18	-0.61	0.01	0.57	-0.18	-0.60
- NPISH consumption		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Government consumption		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Gross Capital Formation		0.17	-0.99	-2.04	-1.05	0.18	-1.20	-1.99	-0.99
Private investment		0.20	-1.12	-2.32	-1.19	0.20	-1.36	-2.27	-1.13
Public investment		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Exports		0.79	-3.50	-2.88	-2.81	0.87	-2.53	-2.65	-2.61
Exports to the EU		0.81	-3.50	-2.86	-2.79	0.89	-2.52	-2.63	-2.59
Exports to the ROW		0.75	-3.49	-2.93	-2.86	0.83	-2.55	-2.70	-2.67
- Imports		-0.45	0.39	-1.52	-1.45	-0.45	-0.40	-1.47	-1.40
Imports from the EU		-0.35	0.56	-1.30	-1.22	-0.36	-0.26	-1.29	-1.20
Imports from the ROW		-0.62	0.09	-1.90	-1.86	-0.59	-0.66	-1.80	-1.75

before petrol and gas.

For scenario A2, the major change, with respect to scenario A1, comes from public investment: it is now considered “savings driven” and shows a drop similar to the one observed for public savings. This ensures a constant ratio of public deficit to GDP. So, while private investment change stays positive, due to higher private savings, the change in total gross capital formation turns negative now. With lower increase in the price of capital services, the domestic production costs decrease even lower than in scenario A1. This generates an even higher gain in external competitiveness and net exports show their highest increase among all scenarios. In total, with a strong private consumption, we observe a significant expansion in aggregate demand, leading to an increase in economic activity and a lower unemployment level. Higher demand also elicits some higher imports even tough trade balances keep improving. The reverse of the medal is again a worsening of carbon emissions.

Focusing on scenario A3, the production sectors face a contradictory situation. On the one hand, lower ESSC rates reduce the employees compensation cost, which brings down the unit cost of labour in production. The resulting lower production cost would generate a downward impact on production prices and affect positively domestic

Table 7.26: Key macroeconomic results (no fiscal compensation) (continued)



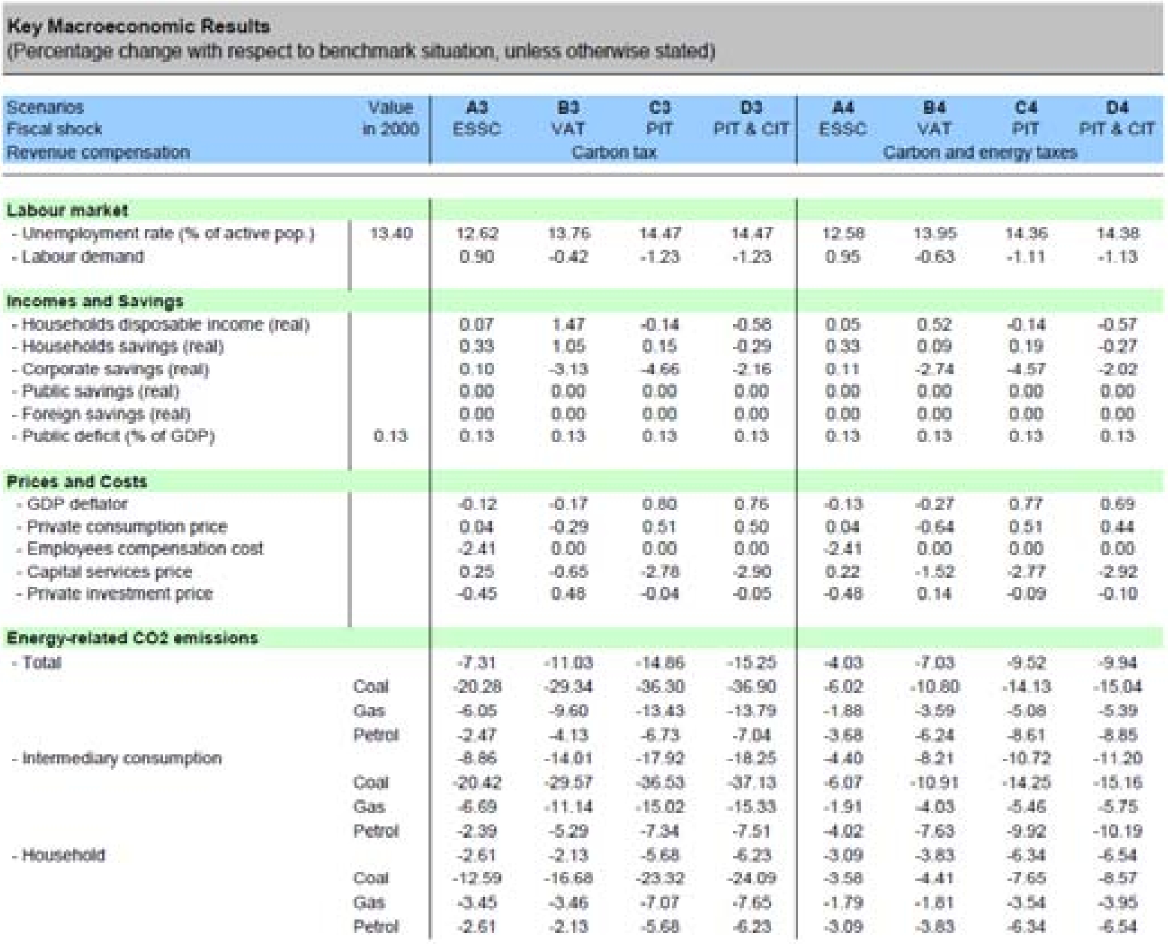
Key Macroeconomic Results
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios		Value	A1	B1	C1	D1	A2	B2	C2	D2
Fiscal shock		in 2000	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation			No compensation / Variable PD				No compensation / Constant PD			
Labour market										
- Unemployment rate (% of active pop.)		13.40	11.97	12.98	13.09	13.06	12.18	13.32	13.53	13.50
- Labour demand			1.65	0.49	0.35	0.40	1.41	0.09	-0.15	-0.11
Incomes and Savings										
- Households disposable income (real)			0.55	1.35	0.95	0.55	0.74	1.63	1.21	0.93
- Households savings (real)			0.71	0.70	0.99	0.58	0.88	0.97	1.23	0.95
- Corporate savings (real)			2.92	1.73	1.26	3.90	2.36	0.83	0.27	2.75
- Public savings (real)			-14.69	-23.12	-29.61	-30.31	-15.40	-24.33	-29.82	-31.89
- Foreign savings (real)			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Public deficit (% of GDP)		0.13	0.57	0.83	1.02	1.04	0.13	0.13	0.13	0.13
Prices and Costs										
- GDP deflator			-0.44	-0.78	0.10	0.05	-0.47	-0.83	0.04	-0.01
- Private consumption price			0.02	-0.69	0.45	0.43	-0.17	-1.00	0.04	0.03
- Employees compensation cost			-2.41	0.00	0.00	0.00	-2.41	0.00	0.00	0.00
- Capital services price			2.02	1.34	0.97	0.95	1.59	0.64	0.06	0.06
- Private investment price			-0.26	0.49	0.36	0.36	-0.43	0.21	-0.01	0.00
Energy-related CO2 emissions										
- Total			0.96	0.71	0.33	0.24	0.96	0.69	0.29	0.23
	Coal		1.49	0.59	0.26	0.24	1.41	0.46	0.09	0.08
	Gas		0.74	0.57	0.31	0.27	0.66	0.43	0.11	0.09
	Petrol		0.81	0.78	0.36	0.24	0.84	0.84	0.40	0.32
- Intermediary consumption			1.13	0.26	0.09	0.12	1.07	0.16	-0.04	-0.02
	Coal		1.50	0.55	0.25	0.23	1.42	0.42	0.07	0.07
	Gas		0.83	0.27	0.13	0.19	0.68	0.04	-0.16	-0.12
	Petrol		0.98	0.09	-0.01	0.03	0.95	0.04	-0.07	-0.04
- Household			0.51	1.99	1.01	0.61	0.66	2.23	1.20	0.93
	Coal		0.75	2.66	1.02	0.62	0.91	2.90	1.21	0.94
	Gas		0.40	1.76	1.02	0.62	0.55	1.99	1.21	0.94
	Petrol		0.51	1.99	1.01	0.61	0.66	2.23	1.20	0.93

production. On the other hand, an expansion in energy taxation augments the prices of fossil fuels and increases production costs, particularly in energy-intensive sectors. This second effect will temper, or reverse in some sectors, the first favourable effect on production prices and production levels. Overall, the lower production prices still affect positively external competitiveness and exports. With regards to imports, it is the ROW imports that decline more, as they provide most of the energy inputs (that get affected by the carbon tax) to the energy intensive sectors in the Spanish economy.

If domestic production tumbles in some energy intensive sectors, this seems no to be the case for other labour-intensive sectors. For these sectors, stronger domestic demand is reflected in higher sectoral domestic production, as they are also able to contain the higher energy prices trough lower labour costs. As a result, labour demand increases, with positive impact on household real disposable income. Household consumption and household savings expand as a consequence. The change in private investment is positive also: higher household savings coincides with higher corporate savings and both lead to an increase in gross capital formation. Under the condition of fiscal neutrality (ratio public deficit to GDP stays unchanged for this alternative), an

Table 7.27: Key macroeconomic results (fiscal compensation) (continued)



Key Macroeconomic Results
(Percentage change with respect to benchmark situation, unless otherwise stated)

Scenarios		Value	A3	B3	C3	D3	A4	B4	C4	D4
Fiscal shock		in 2000	ESSC	VAT	PIT	PIT & CIT	ESSC	VAT	PIT	PIT & CIT
Revenue compensation			Carbon tax				Carbon and energy taxes			
Labour market										
- Unemployment rate (% of active pop.)		13.40	12.62	13.76	14.47	14.47	12.58	13.95	14.36	14.38
- Labour demand			0.90	-0.42	-1.23	-1.23	0.95	-0.63	-1.11	-1.13
Incomes and Savings										
- Households disposable income (real)			0.07	1.47	-0.14	-0.58	0.05	0.52	-0.14	-0.57
- Households savings (real)			0.33	1.05	0.15	-0.29	0.33	0.09	0.19	-0.27
- Corporate savings (real)			0.10	-3.13	-4.66	-2.16	0.11	-2.74	-4.57	-2.02
- Public savings (real)			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Foreign savings (real)			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Public deficit (% of GDP)		0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Prices and Costs										
- GDP deflator			-0.12	-0.17	0.80	0.76	-0.13	-0.27	0.77	0.69
- Private consumption price			0.04	-0.29	0.51	0.50	0.04	-0.64	0.51	0.44
- Employees compensation cost			-2.41	0.00	0.00	0.00	-2.41	0.00	0.00	0.00
- Capital services price			0.25	-0.65	-2.78	-2.90	0.22	-1.52	-2.77	-2.92
- Private investment price			-0.45	0.48	-0.04	-0.05	-0.48	0.14	-0.09	-0.10
Energy-related CO2 emissions										
- Total			-7.31	-11.03	-14.86	-15.25	-4.03	-7.03	-9.52	-9.94
	Coal		-20.28	-29.34	-36.30	-36.90	-6.02	-10.60	-14.13	-15.04
	Gas		-6.05	-9.60	-13.43	-13.79	-1.88	-3.59	-5.08	-5.39
	Petrol		-2.47	-4.13	-6.73	-7.04	-3.68	-6.24	-8.61	-8.85
- Intermediary consumption			-8.86	-14.01	-17.92	-18.25	-4.40	-8.21	-10.72	-11.20
	Coal		-20.42	-29.57	-36.53	-37.13	-6.07	-10.91	-14.25	-15.16
	Gas		-6.69	-11.14	-15.02	-15.33	-1.91	-4.03	-5.46	-5.75
	Petrol		-2.39	-5.29	-7.34	-7.51	-4.02	-7.63	-9.92	-10.19
- Household			-2.61	-2.13	-5.68	-6.23	-3.09	-3.83	-6.34	-6.54
	Coal		-12.59	-16.68	-23.32	-24.09	-3.58	-4.41	-7.65	-8.57
	Gas		-3.45	-3.46	-7.07	-7.65	-1.79	-1.81	-3.54	-3.95
	Petrol		-2.61	-2.13	-5.68	-6.23	-3.09	-3.83	-6.34	-6.54

employment double dividend seems at work: at the same time, unemployment abates and carbon emissions reduce significantly. The drop in carbon emissions is striking compared to the two previous alternatives and coal related sources support the major share of this reduction.

With regard to scenario A4, the reduction in ESSC rates still exerts a downward pressure on labour cost and, by extension, on production costs. The introduction of a combined carbon/energy tax represents however a drag on producer costs and tends to increase production prices in energy intensive sectors only. Aggregate imports decline slightly, as the new taxation on energy goods incentivize domestic production sectors to reduce imports of energy goods (particularly those with the highest carbon content and energy content). The new taxes also affect negatively household consumption on energy goods, after the increase in their consumption prices. However, household's real disposable income benefits from an overall reduction in consumption prices and an increase in labour demand, which impacts positively on his purchasing power and keeps real private consumption barely unchanged. The increase in gross capital formation and, above all, net exports, are sufficient to expand economic activity. An employment double dividend takes place again, as lower unemployment combines with a clear reduction in carbon emissions, even tough to a lesser extent than in scenario A3.

7.3.2 Second variant: a reduction in VAT

Scenario B1 shows that the decrease in VAT rate reduces significantly consumption prices and increases the household real disposable income. This impacts very positively on real private consumption and household savings. However, as the private investment price augments relatively more than the consumption prices, the relative price of consumption renders now consumption more attractive for a given disposable income. As a consequence, the higher household real disposable income is directed in a larger share to private consumption. Corporate savings increase also, and the increase in private savings elicits an expansion in gross capital formation.

As we know, in this scenario public deficit increases, as the lower public savings are not compensated by a lower public investment level. The effects of higher aggregate demand are positive for economic activity, and domestic production expands as a consequence. Labour demand augments and real wages increase, both fuelling a higher household real disposable income. With higher domestic demand, imports pick up also. On the contrary, exports tend to reduce to both EU and ROW regions. This is a consequence of the initial policy: since VAT is a tax paid by all domestic and foreign products sold in Spain, but not by the domestic products sold abroad, a reduction in VAT rate tends not to be as favourable for external competitiveness than a reduction in ESSC rates (which lowers the production costs for domestic sectors). As a consequence of higher production prices, trade balances deteriorate.

Scenario B2 shows the effects of the policy when the ratio public deficit to GDP remains constant. This implies that public investment drops in parallel with public savings. Being a significant drop, this reduces the total gross capital formation. Lower consumption prices and higher labour demand and real wage lead to an increase in household real disposable income. Again, a consequence of the fiscal policy is to reduce the price of consumption relative to the price of private investment. Hence, for a given disposable income, the household shifts his real disposable income more towards consumption than savings. As a result, private consumption exhibits a significant increase. Higher domestic demand also generate higher imports and higher production levels lead to higher labour demand, which, ultimately, allows to reduce the unemployment level. However, for scenarios B1 and B2, no employment double dividend appears, as the reduction in unemployment in both cases does not come with a reduction in carbon emissions.

When fiscal compensation is allowed, trough the form of a carbon/energy tax, as in scenarios B3 and B4, no employment dividend is observed either. This time carbon emissions are clearly reduced. But unemployment increases in both scenarios. The lower VAT rate still exerts a downward pressure on consumption prices, but for energy goods consumption prices augment decisively. The higher household real disposable income keeps fueling private consumption. But gross capital formation and net exports turn negative. Indeed, the upsurge in energy prices increases production prices in almost all sectors and, as a consequence, external competitiveness deteriorates. As aggregate demand tumbles and domestic production recedes, labour demand is reduced and unemployment rises.

7.3.3 Third variant: a reduction in PIT

The major consequence of a reduction in PIT rate is to increase the household disposable income, which benefits to private consumption and gross capital formation, trough a higher private savings level. However the impact on aggregate demand is uncertain since an increase in production prices and consumption prices may very well counteracts the benefits of this policy, by generating a concomitant downward pressure on net exports and real disposable income. This is because, in this case, no mechanism for reducing producers costs and consumption prices are proposed like in the previous variants.

Scenario C1 shows this tradeoff. The higher consumption prices generate a lower increase in the household real disposable income, negating part of the positive effect of the initial tax policy. Private consumption still rises significantly and is coupled with an increase in public deficit and an expansion in the real gross capital formation, which benefits from the increase in household savings and corporate savings. Higher domestic demand leads to higher imports and higher production levels reverberate into higher labour demand. But the prices of domestic products augment also, deteriorating external competitiveness and lowering exports. No double dividend is observed, as carbon emissions go higher with the increase in economic activity.

For scenario C2, the now constant public deficit as a share of GDP reduces drastically public investment. This tends to dampen gross capital formation, as the increase in private investment is not sufficient to offset the decrease in public investment. Hence, in terms of aggregate demand, the positive effects that higher disposable incomes had on private consumption and private investment is now counterbalanced by lower public investment. However, domestic consumption prices barely increase, which now offers the household with a higher real disposable income than in scenario C1. This leads to a clear surge in private consumption and has a positive impact on household savings and private investment. Aggregate demand stays almost unchanged as the higher private consumption is not sufficient to compensate for the decline in gross capital formation. Domestic production is slightly reduced and labour demand follows suit. Lower labour demand and real wage exert a negative impact on the household disposable income and indicate, again, that no employment double dividend is obtained for this scenario.

Scenario C3 considers the impact of a reduction in PIT rate with fiscal compensation trough a carbon tax. This time, the increase in energy prices augments significantly the domestic production prices of energy intensive sectors and the consumption prices of energy goods. External competitiveness is seriously affected and exports drop as a consequence. Aggregate demand and domestic production follow this negative path. As a consequence, labour demand falls and affects negatively household disposable income. Even tough the reduction in PIT rate softens this downward effect, the result is still a reduction in real disposable income. Consequently, private consumption drops and private investment too, after a decrease in private savings. The adverse effect on aggregate demand for scenario C3 is thus stronger than for scenario C2. On the positive side, the decrease in carbon emissions looks very important in this scenario.

With scenario C4, the public revenue losses due to the decrease in PIT rate are compensated with an new carbon/energy tax. The results are somewhat similar to scenario C3. The decline in household real disposable income and corporate savings translate into a reduction in private consumption and gross capital formation. At the same time, the increase in production prices undermine net exports. The overall impact on aggregate demand is clearly negative and unemployment deteriorates again. An employment double dividend seems very uncertain in this case.

7.3.4 Fourth variant: a reduction in PIT and CIT

For the last variant, the initial shock represents a decrease in both the personal income tax (PIT) rate and the corporate income tax (CIT) rate. As in the previous variant, the household disposable income should benefit from the decrease in PIT rate, with positive impacts on purchasing power and private savings. The decrease in CIT rate increases the corporate disposable income, which, under constant transfers payments, translates into higher corporate savings and a positive effect on private investment. As the initial fiscal changes target directly disposable incomes, like in the third variant, the macroeconomic results of this last variant do not differ fundamentally from the previous one. The main difference being that the reduction in PIT rate is less important than in the third variant whereas corporations can benefit from a new reduction in CIT rate. So, the magnitude of the impacts differ for some macroeconomic variables.

Scenario D1 shows that with a lower decrease in the PIT rate than in the third variant and an equivalent increase in consumption prices, household disposable income is now increasing less, but still affecting positively household consumption and household savings. At the same time, the decrease in CIT rate boosts directly the corporate disposable income and real savings. This new effect leads to a clear surge in private investment, as total domestic savings, with its highest percent change among the four policy variants, is channeled to domestic gross capital formation. The increase in gross capital formation is due entirely to an increase in private savings, as public investment stays unchanged. Overall, the increases in household and corporate disposable incomes, coupled with a higher public deficit, generate a clear positive impact on domestic demand. Imports increase but exports decrease, as higher domestic production prices deteriorate trade competitiveness. The effects of this policy on employment are positive but no employment double dividend seems possible, as the increases in real GDP and employment are not sustained with a significant reduction in carbon emissions.

With respect to scenario D2, the restriction of constant public deficit to GDP ratio has a very clear impact on total gross capital formation: as public investment drops significantly, it pulls down total investment, despite the increase in private investment. The positive side of this scenario is a concomitant reduction in the upward pressure on domestic production prices and consumption prices. This benefits directly to the household, who sees his real disposable income rise significantly, in the face of a reduction in labour demand and slightly lower real wage. With carbon emissions and unemployment both increasing, this scenario pushes away the possibility of an employment double dividend.

Scenario D3 simulates the introduction of a carbon tax as a compensatory policy to finance the loss of public revenues from lower PIT and CIT rates. This lower PIT rate benefits the household purchasing power trough a boost to real disposable income. But, at the same time, the higher energy prices affect negatively production costs. This translates into higher production and consumption prices, which eventually reduces household real disposable income and affects negatively private consumption. Gross capital formation tumbles also, after the decline in household and corporate savings. As economic activity slows down, unemployment trends higher. On the other hand, carbon emissions present the steepest reduction across all scenarios under scrutiny.

Scenario D4 presents similar results to scenario D3, with production and consumption prices increasing in energy intensive sectors. The main difference being that the fiscal compensation takes place trough a combined carbon content/energy content tax. If the overall effect on economic activity and employment is very analogous to scenario

D3, an important contrast is related to carbon emissions. As expected, they diminish less with a combined carbon/energy tax than with a stand-alone carbon tax. So, for approximately the same changes in GDP and employment, scenario D3 offers the advantage of lowering further carbon emissions that scenario D4.

7.4 Policy implications

7.4.1 The fiscal targets for a double dividend

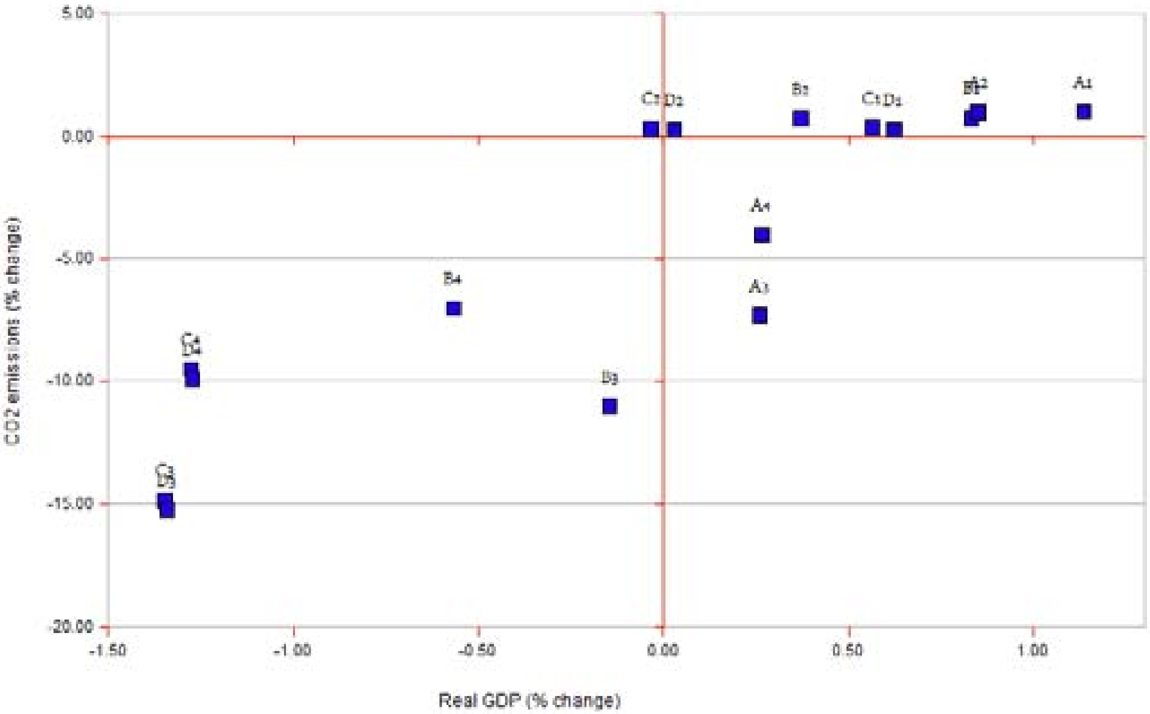
Environmental policies linked to climate change tend to face a time cost opportunity: they may generate economic short term costs to deliver environmental (and possibly economic) benefits spread out over the future. This dilemma is reinforced by the extended time-frame of climate change effects, as well as the lack of experience in regulating GHG emissions. All these uncertainties about the benefits and costs of climate change mitigation may result in indecision. An important objective of this research is thus to contribute to the discussion about the possible opportunity costs of such fiscal reforms, in terms of real GDP variation, employment and environmental targets.

For this study, we interpret the double dividend question in different ways. In the context of an environmental tax reform, a strong double dividend would require an improvement in environmental welfare (reduction in carbon emissions levels) together with an improvement in non-environmental welfare, through the reduction of fiscal distortions. With the condition of fiscal neutrality being imposed, and as indicated in the second chapter, we select two non-environmental welfare variables: the change in real GDP and the unemployment rate.

For both of these non-environmental indicators, the results suggest that a double dividend may be possible with a well targeted fiscal policy. From our simulations, and taking into account the strong limitations of the model, just a few tax scenarios appear to provide this double dividend. The key for economic efficiency is not so much in the nature of the energy taxes themselves, but rather in their tax policy counterparts.

In fact, the different (non-energy) tax policies mentioned in this study affect variables that apply to (what can be seen as) three different "economic targets". Indeed, the reduction in ESSC has a direct and initial impact on production costs (production target), the reduction in VAT has a direct impact on final consumption (expenditure target) and the reduction in income taxes (PIT and CIT) has a direct impact on disposable incomes (income target). Now, to favour the existence of a double dividend, does any of these "economic targets" represent a more effective fiscal policy aimed at counterbalancing the impacts of the new energy taxes?

Figure 7.1: Change in real GDP vs. change in carbon emissions



If we restrict the non-environmental welfare indicator to the change in real GDP, the objective is to specify which tax policy offers the highest change in real GDP coupled with the highest reduction in carbon emissions. To visualize this tradeoff, the results obtained for the sixteen scenarios are shown in a scatterplot in *figure* (7.1). As observed, the results are not absolutely unequivocal. However, depending on the weight given to environmental and non-environmental welfare, some tax policies result more interesting than others.

The first variant (A - reduction in ESSC) appears as the most favourable in terms of real GDP change. Indeed, it represents the only variant for which the impact on real GDP is always positive, with or without fiscal compensation. It also offers the clearest cases for a double dividend, with scenarios A3 and A4 showing both a non-trivial increase in real GDP and a significant reduction in carbon emissions. Scenario A3 is, in that respect, the most beneficial policy scenario, with some confidence margin. Scenarios A1 and A2 present the strongest increase in real GDP but fail to reduce carbon emissions, potentially negating the likelihood of a double dividend.

The second variant (B - reduction in VAT) appears as a kind of second best choice: it tends to lag variant A but shows some advantages, in terms of real GDP variation, with respect to the last two variants. However none of the scenarios related with variant B leads to a double dividend. Scenarios B1 and B2 provide some positive change in real GDP but fail to reduce carbon emissions. Whereas scenarios B3 and B4 reduce substantially carbon emissions but fail to ensure a positive real GDP variation.

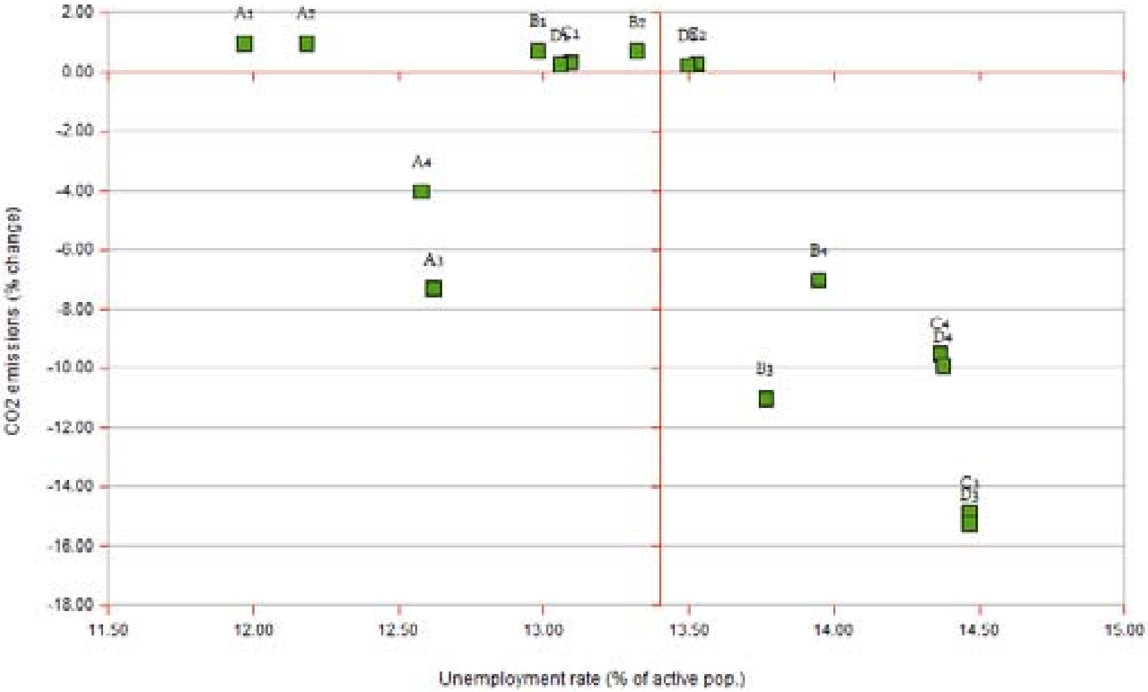
The last two variants (C - reduction in PIT - and D - reduction in PIT and CIT) present very similar outcomes as they both focus on disposable incomes. The scenarios C1 / D1 present positive changes in real GDP, but to the expense of higher carbon emissions. Scenarios C2 / D2 are mostly neutral in terms of real GDP and carbon emissions reduction. At the margin (and depending on the preferences for reducing carbon emissions vs promoting a positive change in real GDP), scenarios C1 and D1 would be preferred to scenarios C2 / D2 as they offer some better real GDP change for a slightly higher increase in carbon emissions. But all these four scenarios clearly underperform scenarios A1 and B1 in a significant manner, in terms of real GDP. The outcomes for scenarios C4 / D4 and C3 / D3 are much more clear-cut: real GDP reduces significantly and takes along carbon emissions to the downside. In total, if these scenarios present the most important decrease in overall carbon emissions, they appear also as the least likely to provide a double dividend, given the strong negative impact on real GDP.

It is worth mentioning that, among the alternatives without fiscal compensation, the first one (variable ratio public deficit to GDP) offers better results than the second alternative (constant ratio public deficit to GDP) with respect to real GDP, while generating an equivalent increase in carbon emissions. The reason is that the first financing alternative allows to boost aggregate demand with a higher public deficit. As their domestic production prices increase relatively more, Spain looses some external competitiveness and its trade deficit deteriorates. This of course has some positive effect on domestic carbon emissions, as Spain imports relatively more foreign products whose carbon emissions generated in the production process are not accounted for domestically. With respect to the alternatives with fiscal compensation, the results show again that the third alternative (carbon tax) may present better outcomes than the second alternative (joint carbon/energy taxes). Since both alternatives exhibit similar results in terms of real GDP change, the difference is mainly due to the stronger reduction in carbon emissions associated with the carbon tax.

If we consider the unemployment rate as the non-environmental welfare indicator, the question concentrates then on the existence of an employment double dividend. For such double dividend to exist, a combined reduction in carbon emissions levels together with a lower unemployment rate must be guaranteed. *Figure* (7.2) shows, for the sixteen different scenarios, the scatterplot of the unemployment rate level with the change in carbon emissions levels. The vertical bar, at 13.4 on the abscissa, represents the initial level of unemployment.

As employment is very highly correlated with gross domestic product, the results

Figure 7.2: Unemployment rate vs. change in carbon emissions



plotted show also a very similar picture to the previous one. The outcomes indicate that an employment double dividend may be possible with the scenarios A3 and A4, with a preference for scenario A3 for displaying a larger cut in carbon emissions. Scenarios A1 / A2 and B1 / B2 present a reduction in unemployment, but fail to deliver lower carbon emissions. Scenarios B3 and B4 have the substantial advantage of reducing considerably carbon emissions but remain ineffective at reducing unemployment. This situation is even more extreme with the last two alternatives, that present the strongest reductions in carbon emissions, to the expense of deteriorating even further employment. In all cases they fail to reduce unemployment, putting into question their use for targeting an employment double dividend. However, these results are encouraging as they indicate that several fiscal policies could be close to provide an employment double dividend. Again, the financing alternative I tends to outperform alternative II and alternative III tends to outperform alternative IV.

Some general conclusions on the fiscal targets can be proposed from these results. We mention three in particular.

First, the potential slowdown in economic activity that carbon and energy taxes could generate does not appear to be a systematic threat. In terms of real GDP change, the variants that target production costs (variant A) and consumption costs (variant B) appear as the most efficient fiscal policies to compensate for a rise in energy taxes. The first variant, that targets the reduction of labour costs, appears as the most attractive in terms of real GDP. It indicates that the reduction of some production costs (labour) to compensate for the increase in other production costs (energy) has the potential to generate an improvement in the efficiency of the tax system, in order to allow an increase in real GDP together with a decrease in carbon emissions. This outcome may have been even more attractive if energy presented higher substitution effects with labour, rather than with capital. In that case, the improvement in the relative costs of labour would become more decisive, when confronted with a worsening of the relative costs of energy.

The key factor of this first variant is the impact on domestic prices. The lower labour costs result in lower production costs, containing the potential upward pressures on domestic production prices exerted by higher factor prices and the increase in energy taxation. The lower production prices are matched by a higher intermediary demand for the cheaper goods and services. But lower production prices, relative to foreign prices, replicate also the effect of a currency devaluation: Spain gains in external competitiveness and is able to increase its net exports by taking advantage of foreign demand. At the same time, lower production prices entail lower consumption prices, eliciting final consumption, from the household sector mainly. So the effects of lower production prices and consumption prices allow to benefit from all sources of demand: domestic and foreign, and intermediary and final. This is an important difference with the second variant. The decrease in VAT rate allows also to reduce the consumption price levels, benefiting aggregate demand, trough higher real private consumption and tempering the negative impacts of higher energy prices for the consumer. But this second variant fails to reduce the domestic production prices and therefore lowers its possibility of taking advantage of higher intermediary demand and foreign demand.

Second, in terms of employment, the results show again a clear preference for targeting the production costs. The decrease in ESSC appears indeed as the best fiscal policy for helping and preserving employment. This is the direct consequence of rendering the labour cost more attractive, which benefits from some substitution effects among production factors. With higher real GDP, as output follows the higher aggregate demand and expands, labour demand increases too, with a positive impact on employment. However, the tax shifting process from lower payroll taxes to higher energy taxes does not imply that, due to lower labour costs, labour demand must increase. To increase employment under a fiscal neutrality condition, the key seems to be in ensuring that the increase in energy prices are more than compensated by a reduction in other production costs, in this case the labour costs. This is probably why the last three variants lag considerably the first one, as they are unable to reduce consistently the production costs.

Third, whether within the variants without fiscal compensation or with fiscal compensation, the results show no strong differences between the two scenarios involved. Within the variants with fiscal compensation, the first scenario (carbon content tax on fossil fuels) appears systematically better positioned than the second scenario (twin tax, both on carbon content of fossil fuels and energy content of final energy sources). In other words, taxing all final energy sources (including electricity) generates a pressure on real GDP and employment similar to a tax on carbon content only, but lacks the benefit of generating a very strong reduction in carbon emissions. A reasonable explanation could be that the substitution effect from fossil fuels towards electricity, that takes place in the first scenario, is reduced. In the second scenario, electricity becomes less attractive as a substitution option among final energy goods, as its relative price increases further, due to the tax on the energy content of energy sources. The results indicate also the key role played by energy inputs in the production process of other sectors. The energy sectors outputs represent indeed crucial inputs for most of the economic sectors, making the demand for these energy sources quite inelastic to price changes. In that sense, the outcomes underline the importance of petrol as a crucial energy source in the production process. Indeed, the introduction of a tax on the energy content of energy products affects petrol much more negatively than the other final energy inputs.

7.4.2 The scope of the targets

It should be remembered that Spain's ratification of the Kyoto Protocol in 2002 implied a commitment to stabilize GHG emissions for the period 2008-2012 to a maximum 15% increase in relation to the level reached in 1990. Based on recent statistics, we have shown in the second chapter that Spain has had some difficulty to comply its Kyoto GHG emissions target. Resulting, in the year 2008, with an excess of 23% with respect to its limit commitment under the Kyoto Protocol.

Based on our results, we have shown also that it is probably possible to achieve significant reductions in emissions without jeopardizing too severely real GDP and employment levels. In order to comply with the emissions reduction targets set within the Kyoto Protocol, the proposed fiscal measures to be implemented would need to be extensive and ambitious. Modest increases in relative energy prices would probably result only in marginal changes, such as fuel switching only within the most energy intensive sectors. No broad based transformation of energy efficiency would be induced.

Ambitious targets means also that carbon taxes should probably affect evenly all consumers of fossil fuels, whether the industry or the households. On the contrary, if the tax policy is restricted to a reduced number of production sectors, the taxes on carbon emissions will have to be much higher to reach the same reduction in carbon emissions. The economic prejudice to these targeted sectors may then become difficult to justify politically over the long-run.

Ambitious targets must translate also into unequivocal long term investment signals. For the production sectors to invest in low carbon technologies, there must be clear and visible long term target levels for emissions prices. Regarding the power sector for example, these long term signals would appear critical, given the cost of investment in infrastructure and technology away from the most polluting fossil fuel plants. This may require to indicate emission targets or energy efficiency targets far in advance, with a political commitment to maintain these objectives on the long run.

Ambitious targets also have their risks. In case the increase in the fossil fuel prices in intermediate consumption are passed extensively into end consumers, these may be affected in a second-round effect, as consumer prices rise first from the consumption taxes on carbon or energy content and, second, from the contagion effect of the production prices increase. In that case, it may be preferable to compensate consumers directly, trough targeted revenue recycling mechanisms, rather than downplaying the significance of the carbon/energy taxes.

Also, if a double dividend may emerge with relatively small taxes changes, it is not guaranteed that it applies to all sizes of carbon and energy taxes. Higher tax rates increase indeed the distortionary costs of revenue raising by impacting on agents choices and actions. Assuming that high carbon taxes are imposed in compensation for the reduction of other taxes with low distortionary cost, the result may be an increase in the overall distortionary cost of the tax system.

Overall, if emissions pricing can be viewed as a cornerstone of climate change mitigation policy, it could never be the unique answer to this challenge. Complementary policies are certainly required. They would include, for example, improved regulatory framework, the support on technology research for energy efficiency, and the provision of an adequate low-carbon infrastructure. In order to adjust to changing economic conditions, some flexibility in the fiscal policy may be required. Also, it may be possible to provide temporary assistance to sectors and industries particularly at risk with the burden of the initial costs. But allowing temporary support generates its own risks if it deters the transition to low-carbon technologies. Well designed complementary policies, on both the supply and demand sides, would help to overcome existing institutional and technological barriers that reduce the chance of a double dividend.

Without doubt, there will be winners and losers with an effective carbon emissions reduction policy. The losers will be those unable to adapt to a future different from the current energetic model and path of GHG emissions. The winners will be the ones who anticipate correctly the future energy markets and the costs of carbon emissions in the carbon market. In that vein, the winners will make the effort to better internalise the currently externalised costs related to GHG emissions. If Spain wants to get on the wagon, starting off as it does with an increase of almost 40% regarding the 1990 levels, then ambitious targets must be considered.

Chapter 8

Conclusions

8.1 Summing-up

8.1.1 Motivation

Climate change has emerged as one of the very important international issues over the past decades. Substantial scientific evidence suggests that increase in globally average temperatures since the mid-20th century is "unequivocal" and "very likely" due to the observed increase in anthropogenic greenhouse gas concentrations [IPCC, 2007c]. Indeed, given that concentrations of carbon dioxide, methane, nitrous oxide and halocarbons have increased markedly since the industrial revolution, one of the significant triggers of climate change is considered to be human activities.

On current trends, actual forecasts predict temperature escalations that are likely to be beyond the adaptation potential of several ecosystems. Of course, paleoclimatology indicates that changes in Earth's climate have been very important along its entire history. And life on Earth is most likely not at risk within these climatic changes. Life evolution will continue its course and the best adapted species to the changing environment will thrive. But some living species, very dependent on the current state of the atmosphere, may be at risk. Should the atmosphere of this planet change significantly, some species will be unable to adapt quickly enough and may suffer a great deal. Of course, humans have shown a remarkable ability to adjust to changes in their environment. But the 2009 Copenhagen Climate Science Congress[1] concluded with this key message regarding human societies:

> *"Recent observations show that societies are highly vulnerable to even modest levels of climate change, with poor nations and communities par-*

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[1] The International Scientific Congress on Climate Change took place in Copenhagen in March 2009 with more than 2,000 scientists registered. The congress received almost 1,600 scientific contributions from researchers from more than 70 countries.

> *ticularly at risk. Temperature rises above 2°C will be very difficult for contemporary societies to cope with, and will increase the level of climate disruption through the rest of the century."*

To change this trajectory of an increase in average global temperature, a timely and ambitious programme of mitigation measures may be required. The goal of limiting the increase in global temperature to two degrees Celsius (2°C) above pre-industrial levels would for example require to reduce GHG emissions of 50% to 95% by 2050, compared to 1990 levels. But there is disagreement about how and when to address that objective.

To motivate the discussion on the timing and magnitude of emissions mitigation policy in Europe and Spain, in particular, this study begins with an overview of the trends in global CO_2 emissions and the European position in enforcing a commitment to keep GHG emissions below 1990 levels. Among GHG emissions, we concentrate exclusively on CO_2 emissions, by far the most significant source of anthropogenic gases. The reduction in carbon emissions to 1990 levels which occurred in the industrialised countries (Annex I) is put in contrast to the emissions growth in non-industrialised countries (non-Annex I). We assert that the countries that have agreed to voluntary emission reduction commitments are important but, as a group, do not represent the major source of GHG emissions today. The exceptions to this group (the United States and the non-industrialised countries) are indeed crucial nowadays for reducing GHG in an effective manner.

As one of the countries with binding emissions reduction targets, Spain ratification of the Kyoto Protocol in 2002 implied a commitment to stabilize GHG emissions for the period 2008-2012 to a maximum 15% increase in relation to the level reached in 1990. But, apart from Cyprus and Malta, Spain became quickly the EU country with the largest growth in GHG emissions over the 1990-2008 period. As a result, in the year 2008, GHG emissions were, on average, 42% above 1990 levels, resulting with an excess of 27% with respect to its limit commitment under the Kyoto Protocol. The reasons for this distance from the targets lie in the fast and sustained economic and population growth and a share of renewable energies sources still very far from Spain's target of 20% of gross final energy demand.

To implement and control its GHG emission targets in line with its compromise to fulfill the Kyoto Protocol, Spain launched in 2005 an emission allowances market scheme, covering more than 1,000 installations in the country, accounting for more than 45% of the total GHG at that time. If this emission allowances market scheme represented an important step forward in environmental policy, the other side of the coin was a minor use of environmental taxes.

Despite the fact that Spain has adjusted its environmental legislation to European Union Directives, the use of fiscal instruments to influence “environmental behaviour” seems indeed very limited, at least at the national level. In 2008, with the lowest ratio of environmental tax revenues in percentage of GDP among all the 27 EU Member States, Spain’s environmental policy appeared quite deficient in terms of taxing environmental pollution. Of course, some of the environmental legislation in Spain is regional, which explains partly the low percentage share of environmental tax revenues in terms of total tax revenues.

Like in the majority of EU Member States, environmental taxation in Spain is mostly concentrated on transport fuels (around 70% of environmental tax revenues), even tough these taxes were not originally conceived as environmental taxes. But, unlike in other European countries, “carbon taxes” are not yet on the agenda for the moment. They could however represent an important policy instrument for helping Spain to reach its binding emissions reduction targets. To approximate the potential impacts of such taxes is one of the key objectives of this study.

8.1.2 Study objectives and methodology

This study attempts to quantify the effects on activity, employment and CO_2 emissions of an original tax policy advocated by the European authorities: the implementation of a joint tax on the carbon content of fossil fuels and the energy content of final energy sources. The declared objective of the twin carbon/energy tax is to provide a simultaneous incentive to reduce CO_2 emissions and increase energy efficiency. The fact that we exclusively concentrate on CO_2 emissions abatement is due to different reasons. First, carbon emissions represents three quarters of of global anthropogenic GHG emissions and is the most long-lived gas. Second, it is the GHG explicitly targeted by the mentioned European environmental policy. And, third, estimations of carbon emissions are precise and reliable given that they result almost entirely from the combustion of fossil fuels and do not depend on the combustion technology.

To investigate the potential disaggregated and macroeconomic impacts of a twin tax on carbon and energy content of energy sources, we use a computable general equilibrium model of the Spanish economy. In chapter 3, we introduce this CGE methodology and overviews some of its applications for environmental fiscal reforms, with a particular emphasis on CGE models applied to Spain. We then explain the main characteristics of the present model, indicating its general features and the major underlying assumptions. Emphasizing energy disaggregation, the model includes 28 economic sectors, one representative household, the public sector, one representative non-profit institution serving households and two foreign sectors representing either the EU-15 countries or the rest of the world. In chapter 5, a detailed description of the model is provided, from the behavioural equations to the macroeconomic closure rules. Chapter 6 states the equilibrium conditions of the model and the solution concept applied.

This model is calibrated to a benchmark social accounting matrix for the year 2000, derived from the Spanish National Accounts and other statistical sources. It provides a disaggregated picture of energy use for production and consumption activities. In chapter 4, we present the social accounting matrix elaborated for the purpose of this study. Great importance is indeed attached to the accounting framework which provides a detailed picture of income generation, distribution and expenditure. This enables sequential solutions to be found. In other terms, it is the social accounting matrix which sets out the flow accounts on which the general equilibrium model is based. Hence, although simplified and incomplete, the model is not arbitrary, as everything visibly goes somewhere and comes from somewhere.

8.1.3 Simulations and results

All the policy scenarios simulate an *ex-ante* reduction in *current* tax rates, generating a reduction in corresponding tax revenues equivalent to a 1% reduction of GDP. For these expansionary fiscal policies , we consider four variants, based on different tax categories from the Spanish tax system in the benchmark year:

Variant A: a reduction of the employers Social Security contributions (ESSC) rate;

Variant B: a reduction of the value added tax (VAT) rate;

Variant C: a reduction of the private income tax (PIT) rate;

Variant D: a joint and identical reduction of the private income tax (PIT) and the corporate income tax (CIT) rates.

In face of the tax revenue losses generated by the tax policies, the simulations contemplate two types of responses.

First, in order to assess the effects on prices and quantities of these four expansionary fiscal policies, we propose a first alternative where the tax reductions remain uncompensated by other tax revenues or a decrease in public investment expenditure (financing alternative 1). This first alternative (together with the second one) allows also to test the plausibility of the results obtained when taxes on energy use and carbon emissions are introduced.

Second, the same tax reductions are simulated employing three different compensatory mechanisms to guarantee a constant ratio of public deficit to GDP:

1. A cut in public investment expenditure, determined endogenously (financing alternative 2);
2. The introduction of a tax on the carbon content of fossil fuels, with its rate being endogenously determined (financing alternative 3);
3. The introduction of a twin tax on energy inputs with 50% of the tax to be based on the carbon content of the fuels and the other 50% on the energy content (financing alternative 4).

The last two alternatives follow specifically the recommendations of the European draft directive on CO_2/energy tax on fossil fuels: not to alterate the total burden of compulsory withholding taxes and, thus, to impose a fiscal neutrality restriction, by maintaining a constant ratio of public deficit to GDP. Imposing the fiscal neutrality option allows then to compare which current tax might be reduced, concomitant with the higher energy and carbon taxes, in order to minimize the economic costs and maximize the environmental benefits of the tax policy.

So, in total, there are four initial tax reductions, with each being analyzed together with four "financing alternatives", composing thus a list of sixteen simulation scenarios. Trough the sixteen simulation outcomes, we assess the impacts on prices and quantities at a disaggregated and macroeconomic level. We also investigate if any of these tax policy scenarios would allow for a double dividend, in the sense of an improvement in environmental welfare together with an improvement in non-environmental welfare, through the reduction of fiscal distortions. The environmental dividend is approximated by a reduction in carbon emissions levels whereas the non-environmental dividend is defined by an increase in real GDP or a decrease in unemployment (also mentioned as an employment double dividend). An environmental tax reform, which can not only reduce carbon emissions but also improve real GDP or reduce unemployment, by reducing the overall economic costs of the tax system, is appealing from a policy viewpoint.

In terms of variants, the decrease in ESSC rates appears as the best fiscal policy for boosting (or preserving) real GDP and employment levels, while reducing carbon emissions. The key effect of this variant is that the lower labour costs lead to lower production costs, which contain the upward pressures on domestic production prices exerted by higher factor prices and the increase in energy taxation. The lower production prices translate into lower consumption prices, eliciting private consumption. This is one of the decisive advantages of lowering ESSC rates: as the policy reduces at the same time production prices and consumption prices, it favours an increase in domestic demand and foreign demand. The higher domestic demand comes from both intermediary demand and final demand, as consumption prices are also reduced. The higher foreign demand is the result of the gain in external competitiveness: as it affects domestic production costs, a decrease in employees compensation cost is analogous to a fiscal devaluation policy that replicates, through the rebalancing of the country's tax structure, the effect of a currency devaluation.

In terms of employment, another important advantage of the decrease in ESSC rate is that, by lowering the labour cost, it favours the labour factor in the production process. Higher labour demand and real wage lead to higher household real disposable income and higher household savings. This impacts positively on private consumption and gross capital formation. However, the tax shifting process from lower payroll taxes to higher energy taxes does not imply that, due to lower labour costs, labour demand must increase. To reduce production costs and increase employment at the same time, the key is to ensure that labour costs reduction for the firms more than compensate the increase in energy prices. Here, the substitution interplay between production inputs becomes crucial. In terms of unemployment, the results may indeed have been even more favourable to this variant if the model had presented higher substitution effects between energy and labour rather than between energy and capital. The improvement in the relative costs of labour would then become more important when confronted with a worsening of the relative costs of energy. It also shows that the lack of sufficient substitution among energy inputs and between energy inputs and other production factors, such as labour and capital, represents a challenge for improving energy efficiency in Spain.

The second variant, simulating a decrease in VAT rates, also shows some constructive results. As it directly reduces consumption costs, by depressing the consumption price levels, this leads to an increase in real private consumption and tempers the negative impacts of higher energy prices. As the relative price of consumption goods decrease with respect to the price of private investment, any improvement in the household real disposable income income is preferably channeled into an increase in private consumption. A crucial difference with the first variant is that the reduction in VAT rates does not directly impact on production costs for domestic sectors. Hence, no strong counterbalancing effect is generated against the increase in energy prices, which push production prices higher, in energy intensive industries above all. At the same time, external competitiveness tends to deteriorates also, after the relative increase in domestic production prices. Hence, while this policy is favourable to private consumption, it has no clear positive impact on gross capital formation and tends to damage net exports.

The third variant, a reduction in PIT rate, increases household disposable income, which benefits private consumption and gross capital formation, trough a higher private savings level. At the same time, the increase in energy prices augments significantly the domestic production prices for energy intensive sectors and the consumption prices of energy-intensive goods. In this case again, no counteracting effect to the higher energy prices and higher factors prices is operative for reducing producers costs. Consequently, external competitiveness is negatively affected and net exports deteriorate. Higher consumption prices lead also to a reduction in real wage and household real disposable income, reducing the initial policy effect of lower PIT rate. As domestic production is reduced, the decrease in carbon emissions looks important in this variant.

The fourth variant targets also disposable incomes with a joint decrease in both the PIT and CIT rates. The main difference with the third variant is that private consumption benefits less while private investment benefits more from this policy. The overall effects on economic activity and employment are however very similar for both variants. The decrease in PIT rate increases the household real disposable income, with positive impacts on purchasing power and private savings. The decrease in CIT rate increases the corporate disposable income, which, under constant transfers payments, translates into higher corporate savings. Total domestic savings reaches its highest percent change among the four policy variants and is channeled to domestic gross capital formation. But, again, the higher energy prices affect negatively production and consumption costs, with production and consumption prices increasing in energy intensive sectors. External competitiveness deteriorates with higher domestic production prices. And the increase in consumption prices also reduces real disposable income, leading to a fall in consumption and gross capital formation. As economic activity slows down and production falls, unemployment increases. In this case, carbon emissions present the largest reduction of all variants.

Among financing alternatives, the first one (no fiscal compensation/public deficit increase) tends to outperform alternative II (no fiscal compensation/constant public deficit) and alternative III (carbon tax) tends to outperform alternative IV (carbon and energy taxes). Between the alternatives without fiscal compensation, allowing an increase in the ratio of public deficit to GDP offers systematically better results than the restriction of constant public deficit to GDP ratio. Higher public deficit boosts aggregate demand and domestic production. But higher factor prices increase also domestic production prices. This reduces Spain's external competitiveness and deteriorates its trade deficit, moderating at the same time domestically generated carbon emissions, which are now partly generated abroad. When the ratio of public deficit to GDP is restricted to be constant (trough a lower public investment), aggregate demand is now reduced but domestic prices increase much less also. As a result, Spain presents a better external competitiveness position. Carbon emissions are almost as important than in the first financing alternative, given that the improvement in net exports preserve the uptrend in domestically generated carbon emissions.

When fiscal compensation is implemented, the carbon tax alone outperforms the twin carbon/energy taxes in terms of carbon emissions outcomes. Indeed, both alternatives offer similar results in terms of real GDP change or unemployment change, but the unique tax on carbon content allows for a stronger abatement in carbon emissions. Taking also into consideration the energy efficiency of the fuels used, the twin carbon/energy taxes appear then as an interesting option, since it moderates the use of petrol, the most energy-intensive fuel. In that case, the household sector may be slightly more affected, given its particular dependence on petrol. But results show that the impacts on aggregate private consumption are not particularly worrying.

In sectoral terms, the sectors most negatively affected by the carbon tax alone are the ones which provide the energy inputs on which these taxes are based (coal, gas and refined petroleum). Their production levels drop significantly. Next, the sectors having an intensive use of these energy inputs are also severely altered. These include of course the electric sector, but also the manufacturing intermediate goods sectors and the transport sector. Facing higher production costs and lower demand for their output, these sectors tend to reduce their production levels. The electricity producing sector is able to contain somewhat the damage of its higher inputs costs by providing its output as an important substitute for other fossil fuel energies which are taxed. When a joint carbon/energy tax is enforced, the better results in coal and gas production are then counterbalanced by lower production levels for refined petroleum and electricity. Some manufacturing intermediate goods sectors are also the sectors that are more export-oriented and, therefore, suffer more from the decrease in exports that emerge for the last three variants.

On the other hand, sectors labour intensive and more dependent on internal demand are able to reduce their production prices and register lower declines in production levels or even production increases. This is the case for most of the services sectors, with the exception of the “transport” sector, quite energy intensive. They also tend to include the manufacturing consumption goods sectors. These are the sectors that, on a relative basis, show the highest increases in labour demand, when faced with higher energy prices. Being more labour intensive, they cope better the increase in energy prices. This underlines again the importance of focusing on the services sectors for preserving the employment in the Spanish economy.

With respect to the possibility of a double dividend, the results suggest that a double dividend can be obtained from some of the tax policy scenarios. In other words, for some of the policy scenarios considered, an energy tax reform could achieve significant reductions in carbon emissions without jeopardizing the level of economic activity or employment. These results complement former evidence found in previous studies for Spain and give in that sense some indications about the best compensatory policies to be considered, if a fiscal reform oriented to curb carbon emissions is to be implemented.

When the non-environmental dividend is defined by an increase in real GDP, the first variant reducing ESSC appears as the most favourable option, as it represents the only variant with scenarios involving a clear increase in real GDP, concomitant with a significant reduction in carbon emissions. The variant reducing VAT rates presents reduction in carbon emissions levels more important than the first variant, but always lags it with respect to real GDP change and, eventually, fails to generate a clear case for a double dividend. The last two variants, reducing PIT and CIT rates, present the largest decrease in overall carbon emissions, but appear as the least likely to provide a double dividend, given the strong negative impact on real GDP.

Unsurprisingly, when the non-environmental dividend is defined by a reduction in unemployment, results are similarly encouraging. They indicate the possibility of an employment double dividend when the carbon tax and the joint carbon/energy tax are coupled with a reduction in ESSC. The stimulation of labour demand is partly the consequence of rendering the labour cost more attractive, which benefits from some substitution effects among production factors. Also, with higher real GDP, as output follows the higher aggregate demand and expands, labour demand increases too, with a positive impact on employment. The variant reducing the VAT rates also provides interesting results, since the scenarios with fiscal compensation show a significant abatement in carbon emissions without inflicting significant losses to employment. Again, the variants with reduction in income taxes fail consistently to provide a second dividend. The increase in disposable incomes brought by the cut in private and corporate income taxes does not offset the unemployment cost of introducing new taxes on the carbon and energy content of energy sources.

Overall, the results are encouraging and indicate that a tax reform oriented to curb energy use and carbon emissions levels doesn't have to jeopardize excessively the level of economic activity and employment. The fact that the employment effects of taxing Spanish CO_2 emissions do not appear so dramatic indicates that carbon intensive sectors represent a low share of employment in the economy. As it appears in benchmark data, labour tends to be intensive in the services and construction sectors. In relative terms, a smaller fraction of the labour force is employed in the manufacturing sectors, which are the most negatively affected by the tax policy reforms. The distribution of production factors allows the economy to absorb the negative shocks on the energy intensive sectors through expansion in other sectors, relatively more labour intensive. This shows also the importance of preserving the activity of the services sectors, given their key role in sustaining employment. However, even for the best outcomes, the employment gains appear too small in relation with the large unemployment level present in Spain recently.

8.2 Limitations and extensions

While we believe the model adds value to the current discussion on energy tax reform in Spain, it is not without its challenges. In itself, the present model contains several limitations and leaves of course much room for extensions, as we outline in this section.

8.2.1 Methodology limitations

We mentioned that the policy scenarios discussed in this study do not reflect the current policy of emissions trading in Spain. They represent "*what if*" analyses. Hence, the simulation results serve merely as indications of potential sectoral and macroeconomic impacts, and the economic mechanisms that lead to them. Of course, believing so is accepting also a "reductionist hypothesis", on which the general equilibrium methodology is resting: we try to approximate the current system, by reducing its complexity trough a stylised representation, in order to use this reductionist semblance as a tool with predictive capacity.

In terms of methodology, the CGE modeling presents several limitations. We described some of its advantages (e.g. suitable for economy-wide reforms and long-run analysis, micro-founded) and shortcomings (e.g. theoretical abstraction, calibration uncertainty) in the third chapter. We believe the main virtue of this approach is its reliance on a consistent accounting framework which, though simplified in the form of a social accounting matrix, comprises a comprehensive system of flows in the economy. Hence, the CGE models allow to check whether factual claims make sense, given the completeness of economic flows. On the other side, CGE models are applied models and their weaknesses may arise from different sources: the quality of the data employed, the characteristics of the model used and the numerical specifications performed.

Regarding the quality of the data, social accounting matrices are demanding structures and many compromises need to be made in the construction process. Lack of consistent National Statistics may represent another important source of problem.

The characteristics of the model also incorporate some assumptions sometimes difficult to justify on an empirical and behavioural basis: the behavioural rules assumptions (the "utility-maximizing representative agents"), the market clearing assumptions or the assumption on the static nature of the model. The Walrasian framework allows to simplify things until we get to a situation where we do have uniqueness and equilibrium. The result is a closed system that appears inherently stable, because it is internally consistent, with a unique equilibrium, determined by tastes and technology.

The numerical specification entails also some limitations. If some exogenous parameters values are inferred from observed SAM values, others have to be taken from data "banks" based on econometric estimates. Hence, errors in the data are passed to the model trough the process of numerical specification. If the validation of the model is a difficult task, the robustness of the results may sometimes be tested trough sensitivity analysis and by comparing the prediction of the model to the observed economic variables.

8.2.2 Extensions

Several extensions to the present study may be proposed. First, it does not consider distributional issues, as an analysis of welfare effects is beyond its scope. But a more detailed disaggregation of households, by income groups of the distributed sampled population, could be interesting. On the one hand, this division could influence the model results if the households groups present different saving and consumption patterns. On the other hand, distributional analysis could be performed, such as the one conducted by Labandeira et al. [2006] for example.

Taxes and social security contributions do not only function as a mean of financing government expenditure (for monetarily non-sovereign countries), but also fulfill an important role in redistributing income. In that sense, direct taxation does not share the same characteristic as indirect taxes. Hence, a shift from direct to indirect taxation may therefore well be neutral for the government budget, but is not without consequences for the distribution of incomes and purchasing power, as it may increase income inequality in society. Allowing a disaggregation of households by income groups would allow to investigate the distributional impacts of such tax system differences. At the same time, it would also allow to estimate the importance of household income distribution on consumption patterns and their related impacts on carbon emissions [Duarte et al., 2010, 2012].

Second, a better linkage to the foreign sector may be interesting. As the current model cannot determine the budget constraint of the non-residents, it cannot represent explicitly their optimisation problem and an explicit modelling of international trade activities. Instead, a simple closure rule, restricted to the specification of the balance of payments, is used for representing the interaction of the Spanish economy with abroad. But since international trade may affect the consequences of the tax policy, a more realistic foreign trade structure would be particularly significant to assess the impacts of unilateral energy policies on the terms-of-trade and environmental impacts.

Third, the specification of a recursive dynamic model could be an improvement to the existing static model. The implementation of dynamic features into the model would allow to specify accumulation mechanisms in the economy and the time dependent effects of greenhouse gas emissions for example. With endogenous savings, dynamics would allow to assess investment decisions induced by policy changes over time. It may also help to model technological change, or improvement in energy efficiency, based on assumptions about how explicit energy technologies and costs will evolve in the future. The interaction between technological change and emissions control policy may then be investigated, as the new technological possibilities and energy-efficiency improvements would probably lower the tax burden by making it easier to substitute fossil fuel by a non-fossil fuel technology.

Fourth, despite its comprehensive analytical framework, the CGE approach may also present a deficiency often criticized with macroeconomic models: a lack of technological detail trough a rather abstract representation of the production and consumption structures. In the present case, the critique may well apply to the representation of the energy system. Primary energy sectors (coal, oil, and gas) may conveniently be represented at an aggregate level, by means of constant elasticities of substitution function, which emphasize substitution possibilities among fuels, capital, labor, and intermediate inputs; similar to those of most other non-energy sectors of the economy. But the electricity generation process is somewhat different.

As mentioned in the second chapter, renewable sources represent already 30% of electricity production in Spain. However, the description of the electricity production process does not explicitly incorporate non-fossil fuels inputs such as nuclear power and modern renewable energy sources (including hydro, solar, wind, geothermal, or biomass). In that sense, the model lacks the capacity to investigate the economic and environmental impacts of renewable energy promotion. The main reason to this handicap is that the explicit incorporation of these energy sources would require to specify the key technological options of bottom-up energy system models for the electricity sector. As a result, we would have to combine the top-down macroeconomic general equilibrium model with a bottom-up technology-based model of energy supply.

This hybrid framework would allow the calibration of discrete technologies in electricity generation to bottom-up engineering data. At the same time, the top-down CGE model would take into account the substitution possibilities between other goods and services, the interaction between domestic and foreign agents and the explicit treatment of a public sector with initial tax distortions, in order to assess the efficiency implications of fiscally neutral tax reforms.

Fifth, a more sophisticated update of policy instruments, other than taxes, could be proposed, as for instance quantity restrictions or a tradable emission permits system for CO_2 emissions. A convenient way to represent a permit system would be to introduce an additional constraint that holds carbon emissions from aggregate fossil fuels to a specified limit. The value on carbon associated with such a constraint would be a shadow price of carbon, readily interpretable as the price at which carbon permits would trade under such a permit system. Other gases such as methane and nitrous oxide emissions could also be taken into consideration. Also, a more reliable database on carbon emissions, at the sectoral level, would be welcomed. Based on more complete energy use and efficiency data, this would allow more reliable estimates of energy savings and carbon emission reductions potentials.

8.3 Energy policy at the crossroads

The 2007 Bali Climate Declaration was a statement signed by over 200 members of the international climate science community. It advocated for setting specific targets for greenhouse gas concentrations in the atmosphere for the 21st century. The concensus says that the goal of a new climate treaty regime must be to limit global warming to no more than 2ºC above the pre-industrial temperature, by preventing dangerous anthropogenic interference with the climate system. This is also the limit that has already been formally adopted by the European Union and a number of other countries.

The problem is that projections of coming climate change have become more worrisome over time. In 2007, the IPCC's best estimates of projected warming for this century (2090-2099 vs 1980-1999) were between 1.8°C for the low scenario (likely range of 1.1 to 2.9°C) and 4.0°C for the high scenario (likely range of 2.4 to 6.4°C). By early 2009, it was so obvious that emissions would be running at the high scenario levels that the Copenhagen Climate Science Congress warned:

> *"Recent observations confirm that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realised. For many key parameters, the climate system is already moving beyond the patterns of natural variability within which our society and economy have developed and thrived. These parameters include global mean*

> *surface temperature, sea-level rise, ocean and ice sheet dynamics, ocean acidification, and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts."*

By February 2009, scientists from the Massachusetts Institute of Technology (Joint Program on the Science and Policy of Climate Change) revised their 2003 projection of global warming with their Integrated Global System Model: by 2100, warming increases to 5.1°C, compared to 1990 levels[2] [Sokolov et al., 2009]. Under the modeling of a "no policy" scenario, the researchers obtain a 9% chance that the global average surface temperature would increase by more than 7°C by the end of this century, compared with less than 1% chance that warming would be limited to below 3°C.

In order to keep temperature increase below 2ºC, the IPCC's 2007 Fourth Assessment Report [IPCC, 2007b] states that atmospheric GHG concentrations need to be stabilised at a level below 450 ppm. But scientists such as Hansen et al. [2008] have been warning that we are already at 385 ppm and rising 2 ppm a year. Based on current scientific understanding, GHG concentrations below 450 ppm would require to reduce global GHG emissions by at least 50% below their 1990 levels by the year 2050. Recent studies even increase the required reductions up to 80% - 95% by 2050 for developed economies [Allison et al., 2009]. This implies that global emissions must peak and decline rapidly.

If we fail to reverse emissions trends, we may be headed to 800 to 1000 ppm of atmospheric carbon dioxide. Attaining concentrations higher than 450 ppm could conduct the planet to conditions when it was largely ice free and when sea levels were implying extensive coastal flooding [Kominz et al., 1998]. At 550 ppm already, the top three meters of the tundra would probably not survive and land-based vegetation and the oceans, two other key carbon sinks, would be close to saturation. At 800 to 1000 ppm, sea level may rise at a rate of 15cm a decade, all inland glaciers might disappear and desertification could affect one third of the planet and drought over half the planet. With a concomitant extreme ocean acidification, over 70% of all species might go extinct.

If a threshold of 800 ppm is a possible future, it would be very risky to believe that humans will adapt to these tipping points in the carbon cycle. Our climate efforts must therefore concentrate on staying far below these levels. And that means immediate action is required. This explains why some climate scientists looked alarmed and took

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[2] Their median projection for the atmospheric concentration of carbon dioxide in 2095 is at 866 ppm.

the remarkable step of issuing a plea at the United Nations climate change conference in Bali.

Important organisations, such as the International Energy Agency, have been advocating tirelessly for the need to set a higher price for carbon emissions. And indeed, the price will certainly have to be high for ensuring 450 ppm, and higher still for reaching 350 ppm, in the case this level can even be done through a price mechanism. The IEA [2008] also indicates that low-carbon technologies will have to be developed and deployed quickly; and participation in an international cap-and-trade system will have to very broad, covering all major emitting countries from 2020 onwards.

For the 450 ppm policy scenario, the scale of the challenge is already staggering: without even considering its political feasibility, the technology shift would have to be be unprecedented in scale and speed of deployment. The positive news is that the technology needed to cut the world's greenhouse gas emissions by 85% by 2050 already exists, according to a joint statement by eleven of the world's largest engineering organisations[3]. If achievable, the technology shift would still require increased public and private spending on research and development in the near term, to continue developing the advanced technologies needed to make the 450 ppm scenario a reality. And stimulate these investments in new capital stock would call for clear price signals (including through a broad-based carbon market), appropriate fiscal incentives and well-targeted regulation.

The risk is that, in high-polluting sectors, the technology options for emission reduction stagnate. The reason is that changing the fuel-mix we use to drive the economy is a limited tradeoff and presents high investment costs in renewable energy, which may be unaffordable for countries with desperate need for cheap energy solutions such as coal. So, the new investments must be accompanied on the demand side by large savings on energy use. Emphasis must thus be placed on boosting energy efficiency since, in the short and medium term, it represents by far the cheapest and the fastest solution to deploy.

Once the current emission-efficiency technology threshold is crossed, there is probably no direct way to reduce emissions without impacting growth. The technological

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[3] The eleven engineering institutions that signed up to the joint statement at the Future Climate 2 conference on September 2011 in London represent collectively over 1.2 million engineers spanning four continents. They include the Institution of Mechanical Engineers (UK), the Institution of Engineers (India), the Association of German Engineers (Germany), the Japanese Society of Mechanical Engineers (Japan), the Association of Professional Engineers, Scientists and Managers (Australia), the Danish Society of Engineers (Denmark), the Civil Engineer Organisation of Honduras (Honduras), the Swedish Association of Graduate Engineers (Sweden), the Norwegian Society of Engineers (Norway), the Finnish Association of Graduate Engineers (Finland) and the Union of Professional Engineers (Finland).

options for serious emission reduction are constrained in the industrial model we operate with. Hence, it is probably the growth pathway itself that must be discussed. The world has to look for new ways to cut emissions and, at the end, pay for these. There is just so much any country can do to reduce its emissions, without changing the way it does business. This is the economic challenge of climate change.

However, economic costs would probably not be excessive. In its 2007 synthesis report on the scientific literature, the IPCC [2007c] concluded that, using existing technologies and those expected to be commercialized in coming decades, global macroeconomic costs for mitigation towards stabilisation between 710 ppm and 445 ppm CO_2-eq in 2050 are between a 1% gain and 5.5% decrease of global GDP. This corresponds to slowing average annual global GDP growth by less than 0.12 percentage points. And a 20% reduction in global emissions might even be possible in a quarter century with *net economic benefits* [IPCC, 2007c, 14]:

> *"Bottom-up studies suggest that mitigation opportunities with net negative costs have the potential to reduce emissions by around 6 Gt CO2-eq/yr in 2030, realising which requires dealing with implementation barriers".*

This forecast is similar to one reported in the McKinsey Global Institute's 2008 Research in Review [Beinhocker et al., 2008], which found stabilizing at 450 ppm has a net cost near zero and that nearly 40% of the U.S. emissions reduction potential by 2030 could come from energy efficiency. This report has its own striking conclusion [*ibidem*, 8-16]:

> *" The macroeconomic costs of this carbon revolution are likely to be manageable, being in the order of 0.6–1.4 percent of global GDP by 2030. (...) To put this figure in perspective, if one were to view this spending as a form of insurance against potential damage due to climate change, it might be relevant to compare it to global spending on insurance, which was 3.3 percent of GDP in 2005."*

These conclusions are similar to those obtained in other prospective studies based on the current state of the science: at a macroeconomic level, the costs of transitioning to a low-carbon economy, even with only currently known technologies, are not all that daunting in terms of economic welfare [Patuelli et al., 2005; Labandeira et al., 2008]. This relates also to an important insight from the present study: overall economic costs from pricing emissions and energy inputs should not be overestimated, if specific revenue recycling measures are implemented. The potential losses to the Spanish economy, in terms of GDP and employment, do not appear to be highly significant.

Action for mitigating GHG emissions and global warming implies economic costs. But inaction too has its costs. Natural, economic and societal, as we mentioned already. Particularly if warming is greater than 2°C. In terms of economic costs, the net damages of global warming have been studied extensively. Climate economists such as Richard Tol [2009] and William Nordhaus [2008] find a wide range of damages, even tough these scientists do not look at warming of more than 3°C in 2100. At this temperature change, Nordhaus [2008] considers that the climate changes are estimated to increase damages by almost 3% of global output in 2100 and by close to 8% of global output in 2200 if temperature increases by 5.3°C relative to 1900. Another important study that laid out the potential economic consequences of failing to address climate pollution is the Stern Review [Stern, 2007], produced by Nicholas Stern on behalf of the British government. It concludes that strong action now to reduce GHG emissions is economically justified, since the cost of mitigation, perhaps 1% of GDP, is far less than the costs of inaction, which the author estimates as equivalent to losing 5% of GDP per year, every year.

The true costs of climate change are unknown. But since the patterns of climate determine where humans live across the globe, climate change may force massive movements of population, triggering potential conflicts as a consequence. At that level, sectoral analysis, trough CGE modelling, cannot pretend to get to grips with the kind of geographical and societal changes implied by climate change. Changes in climate patterns generate a whole-scale transformation of the relationship between human beings and the planet that can hardly be taken into account in economic models. Forecasting the dynamic and unstable changes that would come as a result of this transformation seems indeed particularly difficult.

It is remarkable how efforts to reduce public deficit and prevent climate change are often framed as a generational issue. The irony is that public debt is not so much an inter-generational issue because it is money that next generations will be paying to themselves. And the part of the debt owned by non-residents is determined by each country current account deficit, not by its budget deficit. In that sense, public debt is an intra-generational issue. On the other hand, the consequences of climate change are really an issue between generations.

The main factor that will determine the economic wellbeing of next generations will be the quality of the capital and infrastructure we pass onto them, along with the level of education offered, the state of technical knowledge we achieve, and of course the state of the environment and natural resources. Hence, climate change has everything to do with the wellbeing of next generations. It is a main threat, unlike public deficit. So, investments costs must be put in a balance with the consequences for the next generations of a threatening global warming, an ice free planet, widespread desertification, the acidification of the oceans along with the reduction in biodiversity. Investment costs do not represent economic “losses” but rather a shift in investment priorities, some of which generate important benefits that are typically unmonetized in most macroeconomic models, such as important improvements in clean air and reductions in healthcare costs.

Following current scientific concensus that climate change and global warming are largely a function of anthropogenic GHG emissions, a number of potential routes have been identified for encouraging the transition to low carbon energy systems, among other objectives. Assigning a price on carbon emissions stands as an efficient way of dealing with this challenge: once the price is raised, it is mainly the task of the private sector to find innovative ways to use less polluting energy. In Europe, the European Emissions Trading Scheme represents already an important institutional framework and a crucial step in involving industrial sectors in this effort. But it doesn’t appear to be sufficient to curb carbon emissions to a level in line with emissions targets for 2020. The introduction of carbon/energy taxes on the carbon and energy content of the fossil fuels could represent a broader policy: it would affect all production sectors and consumption sectors, trough their use of fossil fuels.

The problem is that taxing carbon emissions on a widespread scale has not had much of a political chance in most countries, with some exceptions in Europe mostly. The unwillingness to introduce broad-based carbon taxes is due to fears of adverse economic impacts, such as reducing the competitiveness of domestic industries, and intensive lobbying by some industrial sectors. But projections are not that pessimistic: several economic analyses, applied to different countries, have shown that the adjustment costs of carbon pricing are not expected to be excessively high, either economy-wide or even for most energy intensive industries. This is largely due to the fact that most schemes are designed to reduce negative economic impacts by allowing the use of economic offsets, such as tax revenue recycling used in reducing other tax burdens. This must be clearly underlined, as political will and public understanding and acceptance of such emissions control policies are important requirements to generate a broadly accepted regulatory framework. And if distributional issues associated with a carbon tax are of legitimated concern, it remains always possible to deal with those separately, with appropriate transfers and safety nets. It is probably not that costly. It isn’t that hard.

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