icta Institut de Ciència i Tecnologia Ambientals • UAB

Institut de Ciències i Tecnologia Ambientals
PhD Program in Environmental Sciences
(Ecological Economics and Environmental Management)

SOCIAL METABOLISM AND PATTERNS OF MATERIAL USE. MEXICO, SOUTH-AMERICA AND SPAIN

Ana Citlalic González Martínez

2008

SOCIAL METABOLISM AND PATTERNS OF MATERIAL USE

MEXICO, SOUTH-AMERICA AND SPAIN

Ana Citlalic González Martínez

PhD Thesis

Directors: Heinz Schandl (CSIRO, Australia)
Joan Martínez-Alier (UAB)

July 2008

icta Institut de Ciència i Tecnologia Ambientals • UAB

UAB Universitat Autònoma de Barcelona

SOCIAL METABOLISM AND PATTERNS OF MATERIAL USE MEXICO, SOUTH-AMERICA AND SPAIN

Ph.D Thesis

Ana Citlalic González Martínez

UAB Universitat Autònoma de Barcelona

icta Institut de Ciència i Tecnologia Ambientals • UAB

Institut de Ciències i Tecnologia Ambientals
PhD Program in Environmental Sciences
(Ecological Economics and Environmental Management)

Supervisors: Heinz Schandl (CSIRO, Australia)
Joan Martínez-Alier(UAB)

Date of Submission: July 2008

UNIVERSITAT AUTÒNOMA DE BARCELONA
Institut de Ciències i Tecnologia Ambientals
PhD Program in Environmental Sciences
(Ecological Economics and Environmental Management)

ABSTRACT

This thesis is composed of three published articles and a submitted one. All share the same theoretical approach: *social metabolism.* By tracing all material flows into several economic systems by means of the *Material Flows Accounting methodology (MFA)*, this thesis aims on the one hand at characterizing current metabolic profiles of different economies, identifying their main driving forces; on the other hand, it aims at providing empirical evidence on dematerialisation of the economies.

The main conclusion is that in our globalised world, countries are becoming more dependent on international trade and that the role a country plays in the international markets strongly determines its pattern of material use. This dependency followed different trajectories. On the one hand, we identify countries such as Spain that benefited from this process as it increased welfare based in an intensive use of strategic natural resources coming from other economic systems such as fossil fuels. Nevertheless, the main driving force shaping the biophysical profile of this economy was the construction sector, an internal factor. On the other hand, we identify those countries that historically have relied on the extraction of natural resources such as Chile, Ecuador, Mexico and Peru although we can no longer talk about a uniform pattern of natural resource use in the region. In Ecuador, Chile and Peru, international trade was the main driving force for material use. Ecuador remains the typical example of an *extractive economy* whereas a diversification of exports away from bulk commodities towards products with more added value could be observed to a greater extent in Chile and incipiently in Peru. Chile can be regarded as a successful example of the *staple theory of growth* as its GDP increased considerably. Mexico is a special and contradictory case. Firstly, despite being an important oil exporter, it has achieved a diversification of production, moving towards technology-intensive products due to the assembly industries. Secondly, despite it has a great potential of biomass extraction, it is undergoing a substitution process of imported biomass for national biomass, in particular, basic crops for human consumption. Instead of international trade, population growth was the main driving force for biophysical growth in this economy. Thirdly, it was observed an increasing emphasis on the use of construction materials and fossil fuels in the whole economy whereas in the countryside, rural households still rely heavily on traditional biomass flows such as fuelwood to satisfy their energetic needs.

A general conclusion is that neither absolute dematerialisation nor relative dematerialisation occurred in any of the analysed countries.

RESUMEN

La presente tesis se compone de tres artículos publicados y uno enviado para publicación. Son cuatro casos de estudio que comparten el mismo eje teórico: el *metabolismo social.* Usando la metodología *Contabilidad de Flujos de Materiales* se han medido las entradas de materiales de varias economías. Los indicadores que se obtienen aplicando esta metodología permiten caracterizar los perfiles metabólicos de las economías estudiadas, identificando los factores más importantes que los determinan. Asimismo, estos indicadores pueden considerarse como una medida indirecta de la presión que una economía ejerce en el medio ambiente. Por otra parte, esta tesis tiene como objetivo dar evidencia empírica sobre la ausencia de desmaterialización de las economías.

La principal conclusión es que en este mundo globalizado, los países son cada vez más dependientes del comercio internacional y el papel que un país juega en el concierto internacional determina en gran medida la manera como utiliza sus recursos materiales. Sin embargo, esta dependencia sigue diversas trayectorias. Por una parte, identificamos un conjunto de países como España que se ha beneficiado de este proceso. En las últimas dos décadas, este país ha logrado aumentar su bienestar económico usando intensivamente recursos provenientes de otros sistemas socioeconómicos, como el petróleo. Sin embargo, el principal factor determinante de su perfil biofísico ha sido el sector de la construcción. Por otra parte, identificamos aquellos países que históricamente han basado sus economías en la extracción de recursos naturales como Chile, Ecuador, México y Perú y que actualmente no presentan un patrón uniforme de uso de recursos naturales. En Ecuador, Chile y Perú, el comercio internacional ha sido el principal determinante del patrón e intensidad del uso de los recursos naturales. Sin embargo, Ecuador sigue siendo el ejemplo típico de *economía extractiva* mientras que Chile ha logrado una diversificación de sus exportaciones con mayor valor agregado. Este proceso se observa pero de manera muy incipiente en Perú. Chile puede considerarse como el ejemplo más exitoso en la región del modelo basado en exportaciones de materias primas al lograr un fuerte crecimiento económico. México es un caso especial y contradictorio, porque a pesar de ser un importante exportador de petróleo, ha logrado una diversificación de su producción hacía sectores con un mayor componente tecnológico debido a la creciente presencia de la industria maquiladora. Sin embargo, no son sus flujos de exportaciones ni el crecimiento económico los principales determinantes del uso que hace de sus recursos materiales sino el crecimiento de la población. Por otra parte, se observa un incremento considerable en el uso de materiales de construcción y energéticos fósiles en toda la economía mientras que al mismo tiempo, la población rural sigue dependiendo de fuentes tradicionales de energía como la leña para satisfacer sus necesidades energéticas.

Otra conclusión general es que no se observa un proceso de desmaterialización ni absoluta ni relativa en ninguno de los países analizados.

PREFACE

This thesis is the culmination of 6 years of research at the Autonomous University of Barcelona (UAB). During that time, apart from carrying out my PhD studies and research, I had the opportunity to teach a number of different subjects. One of those subjects was ecological and environmental economics, which I taught as Associated Professor at the Department of Economics and Economic History, UAB. I also had the joy and fortune of forming a nice family and of becoming a mother, in itself a pleasurable, if time-consuming endeavour!

I obtained a bachelor's degree in Economics at the Autonomous University of Mexico (UNAM) and a MSc. in Natural Resource and Environmental Economics at the University College London. My training in ecological economics has taken place at the UAB.

The origins of this thesis can be traced back in 2002, when I attended a course with other UAB colleagues at the Institute of Social Ecology (IFF-Vienna) on *Physical Accounting.* In this course, I had the chance not only to learn *Social Metabolism* and the MEFA methodology but also to meet all the IFF-Vienna team, among them my external supervisor: Heinz Schandl. These people provided me with the analytical tools that allowed me "jumping" from the weak sustainability approach to the strong sustainability field.

This thesis is submitted as a compendium of three published articles in international journals (chapter 2 on the social metabolism of Mexico was published in *Ecological Economics*, 2008; chapter 3 on material flows in Spain between 1980 and 2000 was published in *the International Journal of Global Environmental Issues*, 2004 and it is here updated; and chapter 4, which is a comparative analysis of four Latin American biophysical profiles, was published in the *Journal of Industrial Ecology*, 2008). In addition, this thesis includes one submitted typescript: Chapter 5, which discusses patterns of biomass use in Mexico and the importance of fuelwood use in rural Mexico. None of these articles has been or will be submitted as part of a PhD. Thesis by co-authors.

* * *

The original motivation of this thesis was the need to explore alternative methodologies to analyse sustainable development in developing countries. As mentioned in the preceding lines, I was first formed as an environmental economist and after obtaining the MSc degree, I worked three years for the Mexican government (at the National Institute of Ecology, INE) carrying out research on economic valuation, economic instruments and sustainability indicators. My MSc thesis aimed at developing green corporate accounting for a transnational company by means of including in its internal accounts, through economic valuation, the externalities arising from its solid waste.

I came to the Ecological Economics PhD program with the idea of exploring new ways of analysing environmental problems as I found the weak sustainability approach rather limited and controversial. I then had the chance to learn multicriteria analysis (MCA) with Giuseppe Munda and to apply this methodology and compare it with the traditional Cost-Benefit Analysis (CBA) in the case of air pollution abatement measures in Mexico City. This work allowed me to obtain the *DEA* degree. At that time, my idea for the PhD thesis was using different indicators in a MCA framework, but this time on a national scale, to evaluate sustainable development in Mexico. I was then confronted to reality as I found out that it was a lack of meaningful indicators to evaluate sustainability which made this first idea difficult to be accomplished. At that time, resource use indicators were not available neither for Mexico nor for the rest of the Latin-American countries and most of the existent work devoted to the analysis of sustainable development was based either on monetary measures or indices.

Therefore, I directed my research to explore new methodologies to develop non-monetary indicators when I had the chance in 2002 to attend the MEFA course in Vienna. This course was the last push that allowed me "jumping" to the strong sustainability approach and particularly, to the Social Metabolism theory. Since then my work has focused on developing resource use indicators, analysing biophysical profiles, discussing patterns of energy and material use, a duty often neglected by economists but absolutely necessary to complete the picture of an economy.

* * *

ACKNOWLEDGEMENTS

My enormous gratitude to Heinz Schandl, my external supervisor, for sharing his knowledge with me and for being always so patient and supportive. I really appreciated his efforts to keep me motivated and on track, even from the distance. I will always be indebted to Joan Martinez Alier who convinced me to leave my work as Environmental Economist back in Mexico and enrolled me in his PhD program converting me into an Ecological Economist. I thank Giuseppe Munda for his trust and support. I also wish to mention the IFF team for their intellectual support and friendship, in particular Nina Eisenmenger, Marina Fischer-Kowalski, Helga Weisz and Fridolin Kraussmann.

I would also like to express my gratitude to all my friends from the PhD programme for the great moments, fruitful discussions and continuous support, in particular to Daniela, Begum, Bea, Silvia, Miquel, Txus, Gonzalo, Eduardo and Christos. To Miguel Angel Alva, for keeping me company *virtually* from Bonn, during all those days of endless work in front of the computer. I want to thank him also for his technical support in the edition of this document. Thanks to Christos and Marco Raugei for their incommensurable aid in revising my English in some chapters of this work as well as Tamar and Malcolm, my old friends from my London times. Thanks also to Elsa Suárez for the artistic cover design. Back in Mexico, I want to thank all my friends who helped me in gathering quality material and data, such as Anabel Martínez, Waldino, Carlos Guevara, Héctor Iturribarría, Adolfo Cimadevilla and Francisco Aguayo. Thanks to Antonio Yunez and his team at the PRECESAM-COLMEX for providing me with the ENHRUM database. This research was partly sponsored by the Mexican National Council for Science and Technology (CONACYT), one of the very few institutions in Latin America that keeps supporting human capital formation and knowledge development, despite economic crises.

I want to dedicate this work to my dearest parents Nancy and Raymundo, to my sister Valentina and to my brother Ray for their wholehearted support. *Merci* my beloved Flo for your endless patience and love. Without your emotional support I would not have been able to “give birth” to this PhD thesis, our third child! Finally, to my two most precious treasures: *mon petit* Hugo and the little one who does not stop moving in my belly!

TABLE OF CONTENTS

Chapter 3

Material Flows and Economic Development in the North:

A Dematerialisation Analysis of Spain (1980-2004)

Chapter 4

Material Flows in Latin America: A Comparative Analysis of

Chile, Ecuador, Mexico and Peru (1980-2000)

Chapter 5

Transitions in Middle Income Economies:

Biomass Use Patterns and the Importance of Fuelwood in Mexico

Chapter 6

Conclusions

LIST OF TABLES AND FIGURES

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

DE	Domestic Extraction
DMC	Domestic Material Consumption
DMI	Domestic Material Input
EKC	Environmental Kuznets Curve
ENHRUM	Encuesta Nacional de Hogares Rurales de Mexico (Mexican National Rural Households Survey)
EUROSTAT	Statistical Office of the European Communities
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
HANPP	Human Appropriation of Net Primary Production
INEGI	Instituto Nacional de Estadística, Geografía e Informática (Mexican National Institute of Statistics)
IPAT	Environmental Impact, Population, Affluence and Technology model
MEFA	Material and Energy Flow Analysis
MFA	Material Flow Analysis
MTB	Monetary Trade Balance
NAFTA	North America Free Trade Agreement
OECD	Organisation for Economic Co-operation and Development
PTB	Physical Trade Balance
WTO	World Trade Organisation

CHAPTER 1

CONCEPTUAL BASES OF SOCIAL METABOLISM

"Prices are cultural constructions that do not
measure or reflect real material flows" (Hornborg 1998)

1. INTRODUCTION

All societies, even the most rudimentary ones, need a physical base, a biophysical infrastructure composed of living and non- living materials (livestock, buildings, artefacts, machines, roads). In addition, all societies depend on the use of materials to grow and increase their welfare. At the same time, the use of materials exerts pressures on the environment and in a world characterised by limited availability of resources, it affects future supply prospects. Every product consumed in modern societies has a long material flow story which starts with the extraction of raw materials, and continues with processing, manufacturing, packaging, and transportation to markets. It then goes on to final consumption or use, possible reuse and recycling and ends up with final disposal. Each step on this material chain has an impact on the environment: either by the extraction of materials, by the accumulation of materials within the socioeconomic system — as more land is being used — or by the release of emissions and waste.

By producing, consuming and disposing of materials into the environment, societies transform nature. At the same time, this modified natural environment determines societies. A co-evolutionary process takes place between nature and societies. The epistemological framework that analyses these interactions between society and its material environment is referred to as *social or societal metabolism (*Fischer-Kowalski 1998*)*. One of the ways proposed by this framework to analyze such interactions is to measure exchanges of matter and energy.

According to this approach, each socioeconomic system (or society) has a physical dimension or *metabolic profile* determined by the quantity and characteristics of their material and energy inputs and outputs. For instance, one can say that, in the last twenty five years, Spain's metabolic profile has been dominated by construction materials. However, predominating patterns of society-nature interactions can also remain over long periods of time; these are known as human modes of subsistence or in the social metabolism argot, *sociecological regimes* (Fischer-Kowalski and Haberl 2007). In addition, periods of *transition* take place between one socio-ecological regime and a new one. For instance, the transition that took place from agrarian to industrial society.

Metabolic profiles of countries are today constructed by using figures and indicators provided by diverse methodologies such as MEFA (Material and Energy Flow Accounting), HANPP (Human Appropriation of Net Primary Production), land use change, labour time, and virtual water. Geographical conditions, level of development, population dynamics, available technology, commercial relations with the rest of the world, and environmental policy and regulations shape the metabolic profile of a society.

This thesis focuses on metabolic profiles or biophysical patterns of resource use. By tracing all material flows in and out of several economic systems, this thesis aims on the one hand, to characterize different current metabolic profiles. Nation-wide MFA derived indicators are used with economic and population indicators.

One the other hand, this thesis wishes to provide answer to the following questions:

- What are the main driving forces shaping the biophysical profile of countries nowadays?
- What is the effect of international trade on the material and natural resources use in a country?

In the specific case of developing nations that have historically shared the role of providing raw materials to industrial economies, such as Latin American countries, this document tries to answer the following questions:

- Is there nowadays a characteristic common biophysical profile in terms of material use in this region?

- How have economic reforms implemented along this region affected the structure of physical trade?
- Are these societies moving along a path towards dematerialization? Is there an overall increase or decrease in resource use efficiency?
- Are material flows arising from subsistence activities relevant to the biophysical profile of those societies?

Therefore, this thesis intends to contribute to two main ongoing academic debates. Firstly, it wishes to provide empirical evidences on the *dematerialization hypothesis*. Dematerialization has been an important concern since the early 1970s and most of the research carried out in the industrial metabolism field has sought to test such hypothesis. Dematerialization refers to the absolute or relative reduction in the quantity of materials used and/or the quantity of waste generated in the production of a unit of economic output (Cleveland and Ruth 1999: 16). The assumptions behind such hypothesis are the same as those lying behind the *Environmental Kuznets Curve.*

The environmental Kuznets curve (EKC) hypothesis is based on the idea that economic growth will eventually redress the environmental impacts of the early stages of economic development, and growth will lead to further improvements in developed countries (Stern 2001). This process would behave as an inverted U-shaped function. Structural change towards services intensive activities, technological improvements, higher environmental expenditures, stronger environmental monitoring and enforcement, and more ecological awareness will lead to a gradual decline in environmental degradation. Empirical analysis suggests that the relationship holds for some single air pollutants such as SO_2 and suspended particles PM10 (Grossman and Krueger 1991, Shafik and Bandyopadhyay 1992) but fails for some others such as carbon emissions and water contaminants (Shafik and Bandyopadhyay 1992).

The EKC approach has been applied to material use. The thesis behind is that in early stages of development when countries have low income, material demand is low, particularly for certain materials such as metals and building materials. Once the industrialisation process takes place, material requirements will increase due to the need for building basic infrastructure: roads, buildings, pipelines, and cities. As development goes on, the need for building basic infrastructure declines as well as demand for materials and the economy shifts to services activities, which are assumed to be less material intensive. Most of the studies which have focused on analysing the intensity of use of one or several materials (metals, cement, paper and chemical compounds such as chlorine, ammonia) have found enough evidence to support the EKC hypothesis (Larson *et al.* 1986). A recent study using material aggregated indicators in the EU member states suggest that "there seems to be a relation between national trends in material use parameters and indicators for a country's relative stage of economic development" (Eurostat 2002: 44) as three countries revealed inverted U-shape patterns: Denmark, UK and the Netherlands while countries with relative low-income such as Portugal, Spain, Greece and Ireland exhibited increasing curves.

Secondly, this thesis wishes to provide empirical evidences on the international trade effects on material and natural resource use, as well as to evaluate different theories which link natural resource extraction and exports to economic growth and development prospects.

Since the theory of comparative advantage outlined by David Ricardo in 1817, economic theory has assumed that international trade leads to a win-win situation as it stimulates economic growth through a specialization process – each country must use its relatively most abundant factor - and by an intensification of export production. As for the ecological effects of trade, it has been generally assumed that given certain preconditions, economic growth and trade liberalization would improve environmental quality as tax revenues would increase. More revenues would enable governments to allocate more resources to environmental protection and to increase the institutional capacity to respond to environmental problems (Dasgupta *et al.* 2001).

Different theories linking international trade, natural resource extraction and underdevelopment have been proposed. On the one hand, the rather optimistic view is provided by the "staple theory of economic growth" (Innis 1930, 1949; Altman 2003). According to this view, exports of resource-rich economies could lead to growth and economic development. Historical examples for this type of development are Canada, Australia, and Argentina (until the mid-1920s).

On the other hand, "the enclave economy" (Levin 1960) and "the curse of natural resources" (Sachs and Warner 2001) stress the fact that abundance of natural resources is negatively correlated with economic wealth. In the former, the idea is that there are no linkages between the export sector and the national economy as in the "age of guano" in Peru (1840-1880). The latter argues that many countries rich in commodities whose price increases, i.e. oil, paradoxically have a lower GDP than resource poor western countries. The risks inherent to economies based on extraction and not on transformation have also been underlined by El Serafy (1989), who distinguishes between economic growth based on the use of exhaustible resources (a limited stock) and growth obtained through labour, capital investment, technological progress and efficient organization (flows). The latter lays the basis for a durable improvement in living conditions whereas the former simply relies on the depletion of natural capital.

In addition, the extraction of raw materials (fossil fuels, biomass, minerals and ores) in general has higher environmental impact than the production of finished products. The "ecologically unequal exchange" hypothesis (Muradian and Martínez-Alier 2001) states that increased specialization in resource intensive productions decreases welfare in the extractive countries due to the high environmental impact.

The world system theory takes a historical perspective to analyze international processes such as trade and its effects on the global distribution of environmental deterioration. It argues that the international trade structure is the result of the international division of labour arising from the 16th century (Wallerstein 1974-1989) when southern countries were assigned the role of suppliers of raw materials — *extractive economies* (Bunker 1985)- thus creating dependency and underdevelopment. Low prices for primary commodities allow industrialized countries to obtain increasing amounts of raw materials from peripheral economies while maintaining a balanced trade in monetary terms (Bunker 1998). Hornborg (1998) stresses the importance of the price system in this process as market prices are the means by which world system centres extract exergy (available energy) and cheap materials from the peripheries.

In the same line , in Latin America the "dependency theory" developed by Prebisch (1952) and in general by the structuralism school of thought, argued that the international division of labour leads some countries to specialise in exporting raw materials or primary commodities (*peripheral* countries) while other economies specialize in exporting industrial goods based on advanced technologies(*centre* countries). The main argument is that a unit of export allows peripheral countries to buy increasingly less imports because of declining terms of trade for primary commodities. This leads to an incentive to increase the amount of commodities exported, resulting in a further worsening of the terms of trade for *peripheral* countries.

Concerning the empirical evidence on the environmental effects of international trade, a number of studies have been recently published using a wide variety of indicators, ranging from monetary to biophysical (see Giljum and Eisenmenger 2004 for an excellent review of the existing studies on the topic). Most analyses taking a biophysical perspective have been carried out in the last years although there is still a lack of study cases for developing countries. Existing evidence confirms a tendency towards the unequal distribution of environmental goods and burdens between different regions in the world through international trade: Southern countries specialize on resource-intensive products while industrialized Northern countries are net-importers of natural resources. It is then evidenced that the role of a country plays in international trade strongly determines its natural resource use dynamics (Einsenmenger *et al.* 2007).

To sum up, this thesis intends to contribute to the research on social metabolism by generating biophysical information both for northern countries and, specially, southern countries, based on the MFA methodology. In addition, it aims at improving the MFA methodology by demonstrating the usefulness of using sources based on field data to account for biomass flows such as fuelwood in developing contexts.

Therefore, this is not an exhaustive analysis of the biophysical aspects of an economy as other methodologies are also useful to characterise the metabolic profile of a country like HANPP, land use change, virtual water or the tool kit MSIASEM (Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism) and the application of all these methodologies is beyond the scope of this thesis. Finally, one main contribution of this work, aside from its comparative approach, is to provide a database of material flows for Mexico (in Annex I).

2. ORGANIZATION OF THIS WORK

This document is divided into six chapters. In the first chapter, the introduction and the conceptual bases of *Social metabolism* are outlined as well as a brief explanation of the methodology used to measure the metabolism of economies: economy-wide material flow analysis (MFA). In addition, the main indicators derived from MFA are described.

Chapters 2, 3, 4 and 5 are devoted to the analysis of national case studies. In chapter 2, the biophysical profile of Mexico is analysed in the period 1970-2003. Mexico is a large country (1.9 million km^2) with a dynamic population (105 million people) and diverse climatic conditions, ranging from tropical forest in the South to dry deserts in the North. Ranked as a middle-income country (WB 2007) but with 24% of the Mexican population in extreme poverty, Mexico reached high rates of economic growth up to the 1970s. Despite structural change and the on-going liberalization of the economy, economic production has been growing modestly since the 1980s.

In chapter 3, the second case study is presented: Spain (1980-2004), a country that has experienced rapid economic growth in the last twenty five years which has led to convergence in income per capita with the older members of the European Union and is now considered as developed country. In contrast to Mexico, a key characteristic of the Spanish economy is the stability of its population until 2000.

Chapter 4 contains the third case study, a comparative analysis of the biophysical profiles of four Latin American countries: Chile, Ecuador, Mexico and Peru in the period 1980-2000. Historically, the four countries have shared a common path: their economies have been based on the intensive extraction of natural resources and all of them experienced economic crises that opened up the way to implement a set of neo-liberal reforms. Chile and Mexico are two of the largest economies in the subcontinent; while Ecuador and Peru, are smaller and are considered lower-middle income countries (WB 2007).

Chapter 5 deals with patterns of biomass use in middle income economies. In particular, it discusses changes of biomass use in Mexico, underlying the importance of accounting for material flows arising from subsistence activities, in particular fuelwood gathering. These flows are important and it is very difficult to properly account for them. The chapter also tests the "energy ladder" hypothesis for Mexico. This hypothesis is based on the idea that as income increases, dung, wood, and charcoal (biomass energy) are replaced by modern fuels such as kerosene and LPG (fossil fuel energy), which are in turn replaced by piped gas or electricity. Finally, Chapter 6 draws some general conclusions and maps future research.

3. SOCIAL METABOLISM

The notion of *society´s metabolism* or *socioeconomic metabolism* (Fischer-Kowalski 1998), sees economies as systems where materials and energy are transformed into valuable goods and services for human consumption, as well as waste, dissipated heat and other emissions that are discharged into the environment. By using and processing materials and energy, these systems are metabolizing. Their impacts on the surrounding environment can be measured by the size of the metabolic throughput —the amount of materials these "organisms" appropriate from their environment and return back to it in an altered form (EUROSTAT 2001: p.11).

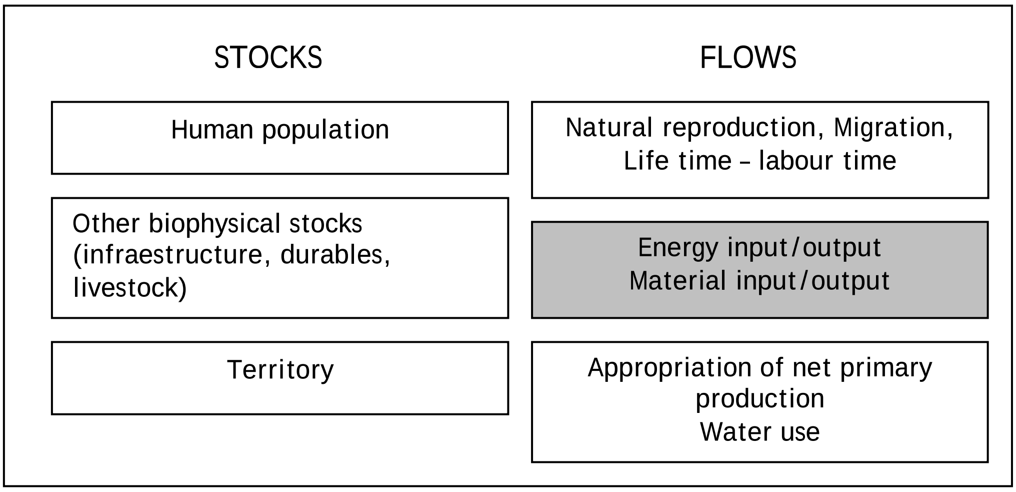
Consequently, this approach recognizes the nature of economies as open systems (Kapp 1976), that are inevitably connected with the surrounding environment and with other economic systems by means of material flows and energy. There is a continuous and mutual influence between economic processes and the environment. The analysis of this mutual influence is framed in the epistemological framework called *co-evolution*.

Unlike other social science approaches which aim at analyzing the interrelations between economy and nature, i.e. environmental economics, a key aspect of this approach is that ecological damages and wastes are not treated as *externalities* (Naredo 2006). On the contrary, they are conceived as the result of the system's normal operation. A certain amount of materials entering the system is accumulated but other amounts leave the system either as products (to other economic systems), waste, dissipated emissions or pollution.

The thermodynamics laws are fundamental in this analytical framework. That matter and energy are neither created nor destroyed, guarantees a material balance in the economy. That is to say, "human beings cannot create neither matter nor energy, only can create utilities" (Marshall 1924 in Georgescu-Roegen 1977). Therefore, the limits or physical restrictions that the environment imposes on the expansion of national economies are recognized. The second law of thermodynamics or Entropy law, highlights the finite character of natural resources and, in general, of all materials that are used in the economic system. This law establishes that energy is transformed from available energy for the human use to non-available or dissipated energy and never vice versa: "The degradation of matter-energy goes on not only continuously, but also irrevocably" (Georgescu-Roegen 1977:16). In general terms, we can say that valuable natural resources enter the economic process and waste without value is what leaves the system.

Under this approach, the biophysical dimensions of a society can be described by analyzing the physical stocks and their flows as described in Figure 1.1; this research is focused on material input flows.

Figure 1.1 Biophysical dimensions of social systems



Source: Fischer-Kowaslki and Haberl 2007

The concept of socioeconomic metabolism[1] is rooted in diverse academic disciplines—chemistry, biology, ecology and social sciences. Scientists such as Wilhelm

[1] Fischer-Kowalski (1998) and Fischer-Kowaslki and Hüttler (1998) provide a exhaustive review of the roots and history of this concept.

Ostwald (1909) attempted to interpret human history in terms of energy use while Lindemann and Odum developed models of materials and energy flows in the ecosystem. In the 19th century, Karl Marx first introduced the notion "metabolism" between humans and nature (Martinez-Alier 2005), a mutual interdependence beyond the widespread simple idea of using nature (Fischer-Kowaslki 1998: 64), after being influenced by biologists and physiological materialists of his time such as Moleschott and Liebig. Nevertheless, neither Marx nor other Marxist authors developed further this idea nor did they calculate the material and energy flows of the economies. In fact, Marx and Engels omitted S.A Podolinsky´s contributions on the energetics of agriculture and the importance of energy availability for the human population. Podolinsky was the first author to develop the concept of energy return to energy input (EROI) and he tried to combine his ecological approach with the Marxist theory of economic value. He explained that "in countries where capitalism triumphs, a great part of work goes towards the production of luxury goods, that is to say, towards a gratuitous dissipation of energy instead of towards increasing the availability of energy" (Martínez Alier 2005)

References to social metabolism are found in other fathers of modern social science such as H. Spencer, and Morgan. Otto Neurath (1882-1945) was the first author defending the idea of a democratically planned economy based on physical accounting of energy and material terms. P.Geddes is considered to be "the first scientist to approach an empirical description of societal metabolism on a macroeconomic level, (Fischer-Kowalski 1998: 65) as in 1884-85 he sought to provide a methodology to measure energy and material flows in all economic and social activities. He developed an economic input-output table in physical terms where he showed that the final product was small relative to the gross quantity of energy and materials used in its extraction, manufacture, transport and exchange. Another important contribution to the study of energy flows was provided by Lotka who in 1911 introduced the distinction between endosomatic consumption of energy and exosomatic use of energy by humans (Martinez-Alier 2005).

While the intellectual history of social metabolism can be traced back to the late 19th century and early 20th century, an increasing interest on socioeconomic metabolism took place in the late 1970s when the oil crisis and the more evident environmental side effects of economic growth first appeared. Most attention was placed on modern industrial societies and their impacts on the environment and, as a result, this field of study was first named *industrial metabolism*[2] (Ayres 1989). In 1971, Georgescu- Roegen published *The Entropy Law and the Economic Process* where he described how the economic system is limited and determined by the thermodynamics laws, setting the bases for the school of Ecological Economics, which developed afterwards. Another economist, K. Boulding (1966) pointed out the limits the biosphere poses on the economy or "econosphere" in his article *The Economics of the Coming Spaceship Earth*. In 1969, Ayres and Kneese, the pioneers of the current MFA methodology presented the first material flow analysis for the United States (1963-1965), criticizing the assumptions behind general equilibrium models.

The "second wave" of social metabolism research surged in the 1990´s, mainly in Europe, when a number of national material flow balances were published and international agreement on methodological standards was reached by bringing together experiences from several industrialized countries (Adriaanse *et al.* 1997; Matthews *et al.* 2000; Weisz *et al.* 2006). Since then, a major breakthrough in developing harmonized accounting standards has been achieved within the OECD working group on environmental information (for a review see Moriguchi 2007). More recently, material flow accounting has been applied to developing economies in Southeast Asia (Schandl *et al.* 2005), and Latin America (Giljum 2004; Pérez-Rincón 2006; Vallejo 2006, chapter 2 below), allowing for comparative studies of resource use patterns in the South (Grünbühel *et al.* 2007, Einsenmenger *et al.* 2007, Amann *et al.* 2002, chapter 4 below).

There is a burgeoning MFA literature and a large number of national case studies for European countries. For example, a range of studies have been produced for Spain at the national level (Carpintero 2005; Cañellas *et al.* 2004, Alonso y Bailón, 2003), some at the regional level and even one at provincial level (Sendra *et al.* 2006, Sastre 2007)[3]. Although the use of multi scale approaches has been recognized as an important contribution (Haberl *et al.* 2004) and there is an evident dynamism in the application of the MFA methodology at the national level, methodological constrains are still constraining analyses at the regional and local scale (Bringezu *et al.* 1997). The debate

[2] Whereas industrial metabolism focuses on "the whole of the materials and energy flows going through the industrial system" (Erkman, 1997, 1), socioeconomic metabolism goes beyond the analysis of industrial societies as it covers non-industrial modes of subsistence (Fisher-Kowalski and Hüttler, 1998).

[3] Sastre 2007 offers a very recent review of the state of the art in Spain.

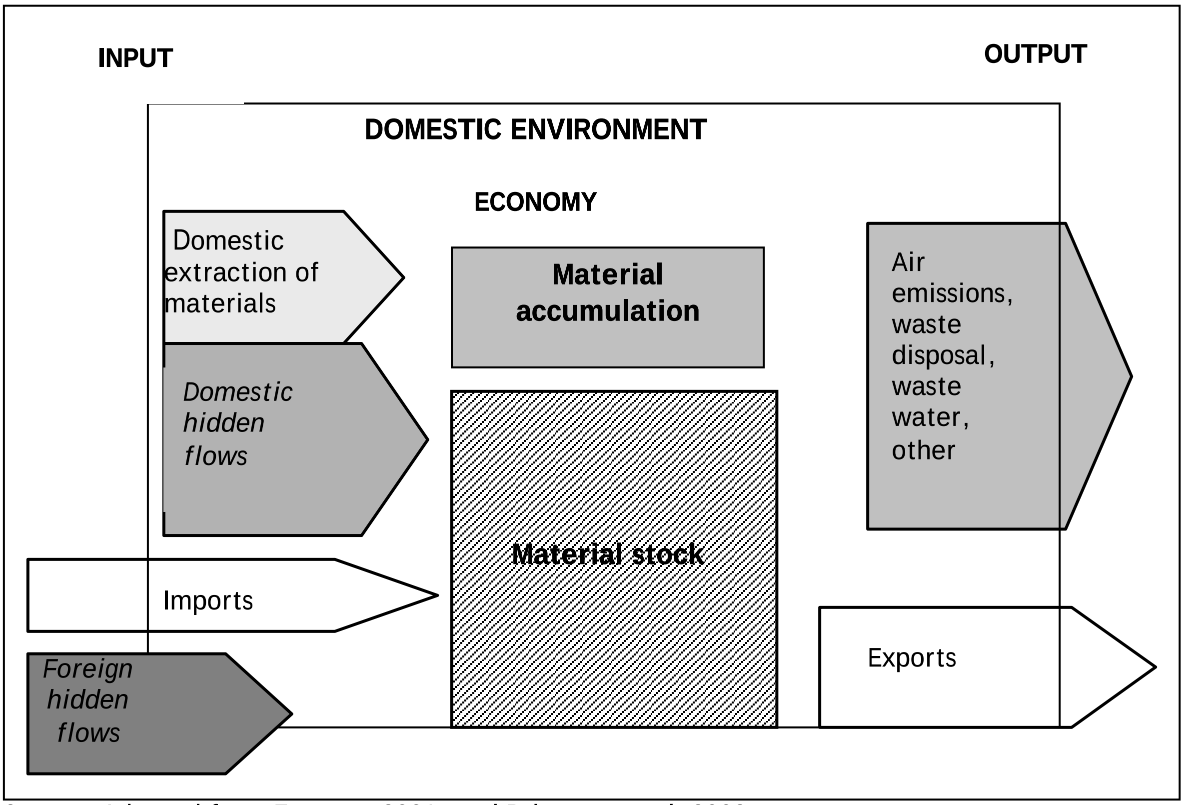
on dematerialisation of economies by a factor of 4 or even a factor of 10, that von Weiszäcker (1998) and Schmidt-Bleek (1999) started at the Wuppertal Institut already ten years ago, can nowadays leave the level of desires and go down to a solid base of empirical studies.

4. PHYSICAL ACCOUNTING METHODOLOGY

Material flow and energy accounting (MEFA) has become the standard approach in environmental accounting and reporting on the flow of materials and energy related to economic activities. By establishing a satellite account to the national accounts reporting on material and energy flows, MEFA complements the system of national accounts for resource use caused by and enabling economic activity. Therefore, this methodology establishes a link between physical flows and monetary and socioeconomic variables (i.e. GDP or population). The terminology of “satellite” accounts betrays the higher ranking socially given to the GDP. We are dealing with non-equivalent descriptions of the same realities, equally valid. Perhaps “parallel” accounts is a better terminology than “satellite accounts”.

By accounting the material inputs into an economy, the material accumulation within the economy, and transfer of outputs to other economies or back to nature, this methodological framework provides an empirical picture of the physical dimension of an economic system, usually expressed in tonnes (Figure 1.2).

Figure 1.2 Scope of economy-wide material flow accounts



Source: Adapted from Eurostat 2001, and Bringezu *et al.* 2003

Under this approach, the total turnover of a socioeconomic system in terms of matter and/or energy can be analyzed. It can be applied also to specific flows of materials or chemical substances. Therefore, it allows focusing on certain input materials in the metabolic process —such as construction minerals biomass or fossil fuels, for instance— and to determine their uses and pathways throughout the socioeconomic system. It also allows looking at output flows (exports, pollutant emissions) to determine how they were produced within the system.

Applying material flows accounting (MFA) methodology to the input side means that all material inputs of a national economy are accounted for, apart from water and air which are not directly embodied in material inputs. The basic premise of this methodology is that the amount of input flows entering the economy determines the amount of all outputs transferred to the environment (wastes and emissions). It also reveals information on the physical dimension of foreign trade (imports and exports).

This thesis focuses on the input side and not on the accumulation of stocks or the production of waste (such as carbon dioxide).

In order to obtain consistent data, the boundaries of the socio-economic system have to be clearly defined. According to the most up to date methodological standard (EUROSTAT 2001: p.17), the system boundary is defined in the following way:

I. By the extraction of primary (i.e. raw, crude, or virgin) materials from the national environment and the discharge of materials to the national environment.
II. By the political (administrative) borders that determine material flows to and from the rest of the world (imports and exports). Natural flows into and out of a geographical territory are excluded.

In this approach, raw materials comprise agriculture and harvested timber reported in national agricultural and timber statistics. Livestock is considered part of the economic system and thus, livestock production (such as meat and milk) is considered as an internal flow in the economy. As a result, uptake of grass from permanent pastures for fodder is accounted as material input.

In order to make the data sets used in this thesis internationally comparable, the standard EUROSTAT methodology for economy-wide MFA (EUROSTAT 2001) was applied. According to this methodology, material flows can be *domestic*, if extracted from the system, or from the rest of the world *(ROW)*. *ROW* material flows can be *direct or indirect* (see Figure 1.2). D*irect flows* are inflows with an economic value, namely *used flows*. *Unused and indirect flows*, are those flows that are not directly exchanged on the market but are associated with the extraction of raw materials (e.g. overburden from mining processes) as well as materials required to produce imported goods.

In this study only *direct flows* were accounted for ignoring all the *unused and indirect* flows because even if *unused and indirect* flows increase the comprehensiveness of the analysis, they can also increase arbitrariness as they are calculated by multiplying direct flows by standard coefficients. These coefficients can vary considerably depending on specific factors such as the available technology, and the natural and economic conditions of a country. In addition, including indirect flows can result in double-counting if they are counted in both the exporting and the importing country. Supporters of including these flows point out their significance in terms of magnitude as they can be one order of magnitude higher than the final product (Bringezu and Schütz 2001).

The main material sub-categories we included in our accounts were *biomass, fossil fuels and minerals*. *Biomass* comprises the subcategories of food, fodder, living animals, timber and other biomass. *Fossil fuels* comprise coal, oil, natural gas and other fossils while the category *minerals* includes industrial minerals, metal ores and construction minerals. Table 1.1 provides a straightforward classification of the materials accounted for in the MFA framework.

Table 1.1 MFA categories and subcategories

Material categories	Subcategories	Items comprised
Biomass	Food	All potentially edible biomass from cropland. All traded agricultural goods and final products from agriculture plants are included in exports and imports.
	Fodder	All biomass from cropland, permanent pastures and by-products of harvest used to feed livestock; In exports and imports all traded fodder is comprised.
	Animals	Biomass from hunting and fishing activities. In imports and exports all traded live animals and agricultural animal products (including fish) are comprised.
	Timber	Harvested timber for industrial products and fuel wood. In imports and exports the following goods are comprised: harvested timber, forestry products, wood based products such as paper, cork products and products predominantly from wood such as music instruments.
	Other biomass	Fibres and other non-timber products. In imports and exports, traded fibres products such as clothing as well as other products predominantly from biomass such as natural fertilizers are comprised.
Fossil fuels	Coal	All types of coal.
	Oil	All types of oil.
	Natural gas	All types of natural gas.
	Other fossils	Peat. In imports and exports, all manufactured traded products predominantly from fossil fuels such as plastics, pharmaceutics, and nitrogen fertilisers are also comprised.
Minerals	Industrial minerals	All non-metallic minerals used predominantly for industrial processes (excluding fossil fuels).
	Metal ores	Metal ores. In imports and exports all metal- based products and products predominantly from metals are also considered.
	Building minerals	All minerals used in construction.

5. INDICATORS

Similar to traditional National Accounts, MFA aggregated indicators are derived from material flow data sets. All the macro indicators from physical accounting presented in this analysis are input, consumption and balance indicators focusing mainly on the input side of the economy. The aggregated indicators are described as follows:

Domestic Extraction (DE) expresses the annual amount of raw materials extracted from a national territory in order to be used as material factor in the economic system. As mentioned before, water and air are not accounted for. Biomass, fossil fuels, metal ores and industrial minerals as well as construction minerals are the main categories of materials extracted in the national territory. Domestic extraction is mainly related to the activities of primary industries and refers to the step when a natural resource is transformed into a commodity.

Domestic Material Input (DMI) measures all materials of economic value used in production and consumption activities. Therefore, DMI sums up domestic extraction and imports. It is a measure of the overall material input of an economic system used to produce a certain added value.

Domestic Material Consumption (DMC) measures the total amount of material directly used in an economy. DMC equals domestic extraction plus imports minus exports. Here, the term “consumption” refers to “apparent consumption” and not “final consumption”. This consumption indicator is the closest equivalent to GDP (C+I+G+X-M) and can be considered as the physical equivalent to GDP (C+I+G+M-X). It is worth noting that the difference between monetary GDP and physical GDP is that in the monetary approach, exports are added and imports deducted whereas in the latter, imports are added and exports deducted. This is because usually “money and physical goods flow in opposite directions in economic transactions” (EUROSTAT 2001: p.38).

Physical imports and physical exports refers to all imports and exports—raw materials and final goods—expressed in tonnes of traded flows when they cross a national boundary.

Physical trade Balance (PTB) is calculated by deducting exports from imports. Thus, PTB is the reverse of the monetary trade balance. A positive figure for PTB would refer to a net importer while a negative figure would indicate a net exporter of materials.

On the output side (see Figure 1.2), four broad indicators are distinguished, namely *domestic processed output released to nature, disposal of unused domestic extraction, exports, indirect flows associated to with exports.* Considering the conservation of matter, there should be a balance between material inputs and the sum of outputs and changes in stock as described by the following equation (Fischer-Kowalski and Hüttler 1998: p.115):

The sum of material/energy inputs into a system= the sum of outputs +changes in stock

Table 1.2 provides an overview of the aggregated indicators used for the biophysical analyses provided in this study.

Table 1.2 Material categories and MFA indicators calculated in this study

Material categories	Indicators	Description
Biomass Fossil fuels Minerals	Domestic Material Extraction (DE)	Raw materials extracted within national borders.
	Direct Material Input (DMI) DMI = DE + imports	DMI comprises all materials that enter the economy for further use, either for production or consumption processes.
	Domestic Material Consumption (DMC) DMC= DMI – exports	DMC provides information on the quantity of the materials that remain within the national territory.
	Imports	All imports from raw materials to final goods, expressed in tonnes of traded flows when they cross the national boundary.
	Exports	All exports from raw materials to final goods, expressed in tonnes of traded flows when they cross the national boundary.
	Physical Trade Balance (PTB)	PTB is accounted for by deducting exports from imports. Thus, PTB is the reverse of the monetary trade balance. A positive figure for PTB would refer to a net importer while a negative figure would indicate a net exporter of materials.

Source: own elaboration

CHAPTER 2

THE BIOPHYSICAL PERSPECTIVE OF A MIDDLE INCOME ECONOMY: MATERIAL FLOWS IN MEXICO (1970-2003)[1]

ABSTRACT

We analyse natural resource use dynamics in the Mexican economy during the last three decades. Despite low and uneven economic growth, the extraction and use of materials in the Mexican economy has continuously increased during the last 30 years. In this period, population growth rather than economic growth was the main driving force for biophysical growth. In addition, fundamental changes have taken place in the primary sectors, in manufacturing, and in household consumption and these are reflected in an increasing emphasis on the use of fossil fuels and construction materials. Mexico's economy has been strongly influenced by international trade since the country commenced competing in international markets. In the 1970s, Mexico mainly exported primary resources. This pattern has changed and manufactured goods now have a much greater importance due to a boom in assembling industries. In contrast with other Latin American countries, Mexico has achieved a diversification of production, moving towards technology-intensive products and a better mix in its export portfolio. However, crude oil exports still represent the single most important export good. Mexico's material consumption is still well below the OECD average but is growing fast and the current resource use patterns may well present serious social and environmental problems to the medium and long term sustainability of Mexico's economy and community. Information on natural resource use and resource productivity could provide valuable guidance for economic policy planning in Mexico.

Keywords: *Natural resources, resource use patterns and dynamics, physical accounting, material flows, resource use efficiency, Mexico.*

[1] This chapter is an accepted paper with changes in the *Journal of Ecological Economics*. The amended and re-submitted version is included here. The full reference is: Gonzalez-Martinez, A.C and H. Schandl. 2008. The biophysical perspective of a middle income country: Material Flows in Mexico. *Ecological Economics.* doi:10.1016/j.ecolecon.2008.03.013

1. INTRODUCTION

Most of the existing work devoted to the analysis of sustainable development in developing countries, and particularly those in Latin America, has been based either on monetary measures or indices[2], while hardly any emphasis has been given to the development of resource use indicators to evaluate the resource requirements and related environmental impacts of economic activities. This paper contributes to a biophysical understanding of the economic process by providing a material flow accounts (MFA) for the Mexican Economy. By accounting for the material inputs into an economy, the material accumulation within the economy, and outputs to other economies or back to nature, material flow accounting provides an empirical assessment of the physical dimension of an economic system, usually expressed in tonnes or joules.

Material flow indicators are measures of pressure, and express a potential for environmental impact rather than environmental impact as such. Although there is always an environmental impact associated with the extraction and consumption of materials, the actual impact depends on physical quantity and the impact factor per a unit of physical material flows. The indicators we present refer to 'generic impacts' (Bringezu *et al.* 2003) and focus on material input and consumption rather than waste and emissions. Material flow analysis studies emphasise natural resource extraction activities as an important area of negative environmental impacts (Giljum *et al.* 2005) For example, the considerable environmental impacts of mining on landscapes, water use and biodiversity are well documented and have been the source of important social conflicts in Latin American countries such as e.g. Peru (Muradian *et al.* 2003). Extensive agriculture and livestock industries have been the main cause of forest degradation and of massive changes in habitat and biodiversity loss in the Amazon area (Martinez-Alier 2002). In Mexico, oil exploration and extraction, in addition to depleting a non-renewable natural resource, also have led to important environmental and social consequences as they conflict with existing property rights, force relocations and lead to hazardous living conditions (due to soil and water pollution), mobilise large amounts of material and require considerable amounts of infrastructure (Epstein and Selver 2002).

[2] For an extensive review on progress on sustainability indicators in Mexico and in Latin America in general see Quiroga (2005).

In addition, oil extraction requires ever higher amounts of energy (energy costs) to obtain the new fuel because production increasingly extends from shallow waters to more deepwater environments (Gately 2007).

Accounting for physical flows is conceptually based on the notion of social metabolism and has a long intellectual history (Fischer-Kowalski 1998). The empirical work gained momentum in the early 1990 when a number of national case studies were published (see Fischer-Kowalski and Hüttler 1998) and international agreement on methodological standards was reached by bringing together experiences from several industrialized countries (Adriaanse *et al.* 1997, Matthews *et al.* 2000, Weisz *et al.* 2006). A major breakthrough in developing harmonized accounting standards has been achieved within the OECD working group on environmental information (for a review see Moriguchi 2007). More recently, material flow accounting has been applied to Latin American economies including Chile, Colombia and Ecuador (Giljum 2004, Pérez-Rincón 2006, Vallejo 2006) and has allowed for the first comparative studies of Latin American resource use patterns (Amann *et al.* 2002, chapter 4, below).

In this paper, we provide a biophysical perspective of the Mexican economy by accounting for its material inputs during the period 1970 to 2003. Over these three decades, the Mexican economy experienced important transformations. Mexico's productive structure was modified, as a result of the implementation of radical economic reforms whose main objectives were stabilisation and growth, to be achieved through the liberalisation of the economy. The economic effects as well as the social impacts of these reforms have been thoughtfully analysed by economists (Dussel 2002, Guillén 2006, Chavez 2006) but environmental impacts and implications for natural resource use have hardly been addressed. While there is a common sense that economic growth leads to increases in resource use and impacts, a number of questions have not been addressed adequately. What has been the magnitude of changes in resource use? How has resource use changed in qualitative terms? How have economic reforms affected the structure of physical trade? Was there an overall increase or decrease in resource use efficiency in the Mexican economy over recent decades?

To address these questions we structure the paper in four parts: Part I provides the economic background for Mexico, summarising the major macro-economic reforms.

In part II we analyse the pressures that economic activities exert on the natural resource endowment of Mexico by analysing the levels and trends of domestic materials extraction. Part III describes changes in the economy's physical trade patterns as a result of the structural changes that the Mexican economy has undergone since the 1980's. Finally, part IV analyses material input and material consumption patterns in Mexico. To do this, material flows are related to macroeconomic and social indicators in order to analyse the interface between the physical and economic dimensions. From there, we provide a first take on resource constraints, and possible problems posed by current resource use patterns. It is important to mention that the methodology we applied to measure material flows and to arrive at material flow indicators is thoroughly described in Chapter 1.

2. ECONOMIC DEVELOPMENT IN MEXICO

Since the 1940s and until the second half of the 1970s, economic development in Mexico was based on import substitution[3] and state-driven industrialisation. During this period, Mexico experienced its most dynamic economic period ever. Real GDP per capita grew at an average annual rate of 3.1%. Growth in the 1970s was based on high government investment and import substitution, and since the second half of the decade it was boosted by the oil boom.

Despite the dynamic performance of the Mexican economy during the 1970s, the economy went through a hyperinflation process and multiple crises in 1982 (*debt crisis*) and in 1986-1987 (*oil crisis*). The main factor leading to the economic collapse was the deterioration of the productive structure caused by a drastic rise in the income generated during the oil boom, a phenomenon described in the literature as the *Dutch disease.*[4] High external debt and a high dependence on petroleum exports further

[3] The imports substitution policy regime focused on the provision of trade protection measures to domestic manufacturing. Under this regime, industrial policy operated through sector-specific programs, with the aim of building up a manufacturing sector capable of producing capital goods and intermediate products. This policy was complemented by strong state intervention to carry out investment projects to supply strategic or basic intermediate products. In addition, public enterprises were created for security reasons or to avert bankruptcies and maintain employment (Moreno-Brid *et al.* 2005).

[4] The core of the *Dutch disease* argument is that resource abundance in general, or resource booms in particular shift resources away from sectors of the economy that have positive externalities in growth (Sachs and Warner 1999. p. 48). In Mexico, the drastic rise in income due to the oil boom deteriorated the overall productive structure. This development in Mexico is explained by Cardenas in detail (1998, p. 112): more

contributed to the vulnerability of the economy to external shocks. During the 1980s, the economy did not grow and per capita income decreased by about 15%.

As a reaction to the crisis and in order to stabilise the economy, a neo-liberal economic programme was adopted in 1988 based on fiscal and monetary restrictive policies, multiple currency devaluations, an opening of the economy and an increasing reliance on market forces instead of government planning. In 1986, Mexico inaugurated a set of policies aiming at stimulating free trade by joining the General Agreement on Tariffs and Trade (GATT) as one of the first Latin American economies to do so. By the end of 1988, the trade liberalisation of Mexico's domestic market for manufacturers was almost completed (Ten Kate and De Mateo 1989).

Since then, Mexico has signed 12 trade agreements with 43 nations putting 90% of its trade under free trade regulations. It has also joined the OECD and the WTO. The most important trade agreement has been established with the United States and Canada (NAFTA), allowing trade to triple in monetary terms since NAFTA was ratified in 1994. Today, almost 85% of Mexico's exports are delivered to the United States, making the Mexican economy dependent on economic cycles in the US. Foreign Direct Investment (FDI) inflows have increased and helped to trigger export-oriented manufacturing, transforming Mexico's position in the world market (Moreno-Brid *et al.* 2005). During the period 1982-2003, Mexico went from being merely an oil-exporting country, to a significant exporter of manufactured goods.

Nevertheless, these economic reforms did not spare the economy from a new collapse. In 1994-1995, a financial crisis caused a 7% reduction in overall economic activity. Since then, the economy has not regained the dynamism observed in the 1970s and has been unable to create enough jobs to satisfy the growing supply of labour. From 1995 to 2003, average real GDP growth was 2.5%. As a result of the economic reforms, the economic structure was modified during the last three decades, resulting in a dominance of the services sector. In 2003, service activities accounted for 67% of the

income, more demand for national products and imports pushing internal prices upwards. The domestic industry sees their input prices abruptly increasing (labour, energy, construction) faster than the price of their products, thus driving profits downwards. As a result, Mexico's domestic industry was unable to compete against imported goods.

national product, while the industrial activities produced only 27% and the primary sector accounted for an insignificant 6% (INEGI 2006a).

In addition, the structural reforms have not led to poverty alleviation and have not improved income distribution. In 2000, 24% of the Mexican population remained in extreme poverty[5], the same level that had been observed in 1968, over thirty years earlier (Szekely 2005). The Gini index was 0.48 in 2000, almost the same as in 1977 (0.49) and today, the top 20% of income earners receive 55% of total income in the country (WB 2006). On the other hand, when compared with most other Latin America economies, Mexico still has a privileged position despite economic instability. In 2003, Mexico had the highest per capita GDP in the Latin American region ($6,770 in current US dollars in 2003) and was considered a middle- income country by the World Bank.

3. EXTRACTION OF MATERIALS IN MEXICO

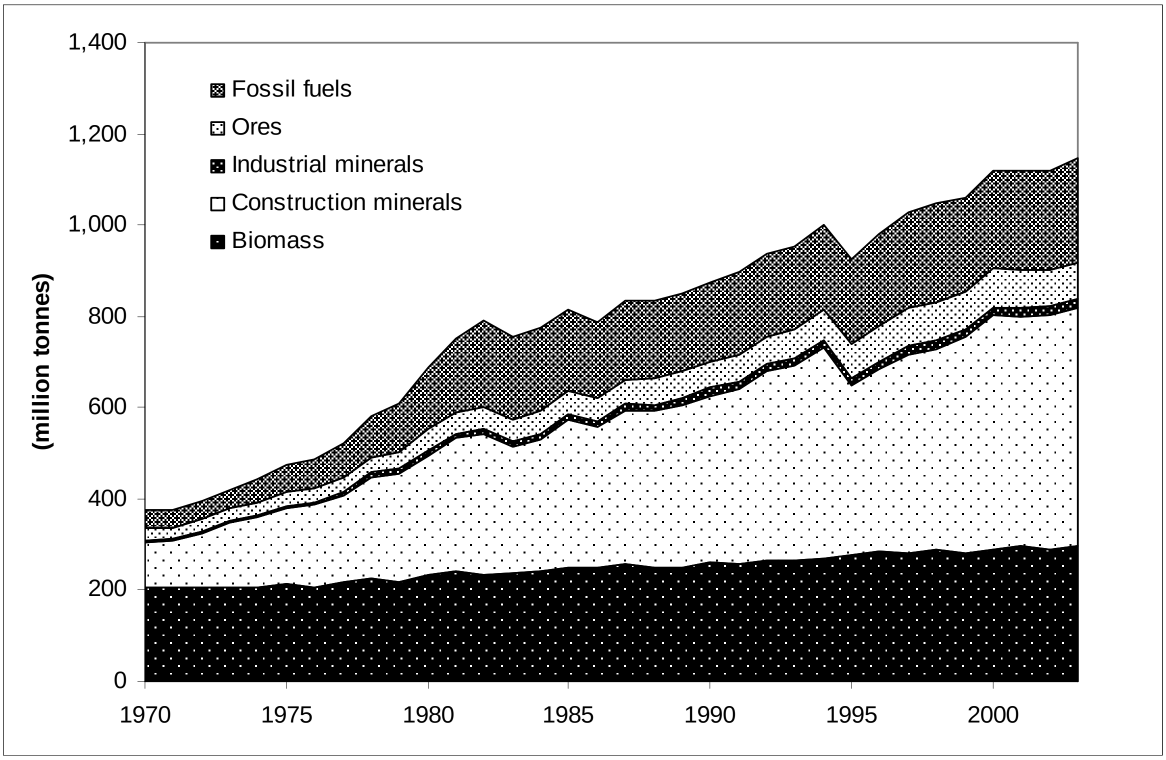
The first biophysical indicator we calculated, namely *Domestic Material Extraction (DE)* counts the amount of materials extracted within the borders of the economy. Thus, it is a straightforward indicator of pressure exerted on the domestic environment. The level of DE depends to large extent on the spatial distribution and regional availability of resources (Eurostat 2002). Mexico is a big country (1.9 million km²) with diverse climatic conditions, ranging from tropical forest in the South to dry deserts in the North, suggesting a big potential for resource extraction.

Unperturbed by the ups and downs of the economy, domestic extraction of materials in Mexico consistently increased over the last three decades. In those thirty years, domestic extraction tripled from 349 million tonnes in 1970 to 1,148 million tonnes in 2003. In per capita terms, it increased from 7.4 to 11.2 tonnes between 1970 and 2003, a considerable amount if we take into account that average global resource extraction was 8.2 tonnes per capita in 1999 (Schandl and Eisenmenger 2006).

[5] The notion of extreme poverty used here refers to poverty measured as incapacity to obtain food. In the same year, 53.7% of the population was unable to buy a house, a property (Szekely 2003) which is another indicator for lack of means.

As Figure 2.1 shows, the composition of domestic material extraction also underwent an important change between 1970 and 2003. The most pronounced feature is the considerable rise in the quantity of minerals and fossil fuels domestically extracted since 1970. The categories increased by a factor 5 and 6, respectively, during the three decades. As a consequence, the relative importance of biomass extraction dropped from 54% to 26%, marking an important change in Mexico's resource base, away from traditional, land based resources to new industrial resources. During this period, fossil fuels increased from an 11% share to a 20% share. By 2003, the largest portion, by far, of domestic materials extraction was minerals, and in particular construction minerals, with a proportion of 54% and 45% respectively. The ongoing industrialization and urbanization of the Mexican economy and a growing population went hand-in-hand with infrastructure and housing requirements (reflected by the large amounts of building materials) and energy demand (increasing extraction of fossil fuels).

Figure 2.1 Domestic extraction of materials in Mexico 1970-2003, in million tonnes



Source: Gonzalez-Martinez 2007

In Mexico, government institutions played an important role for financing the construction of dwellings. In the 1970s, public credit institutions were created

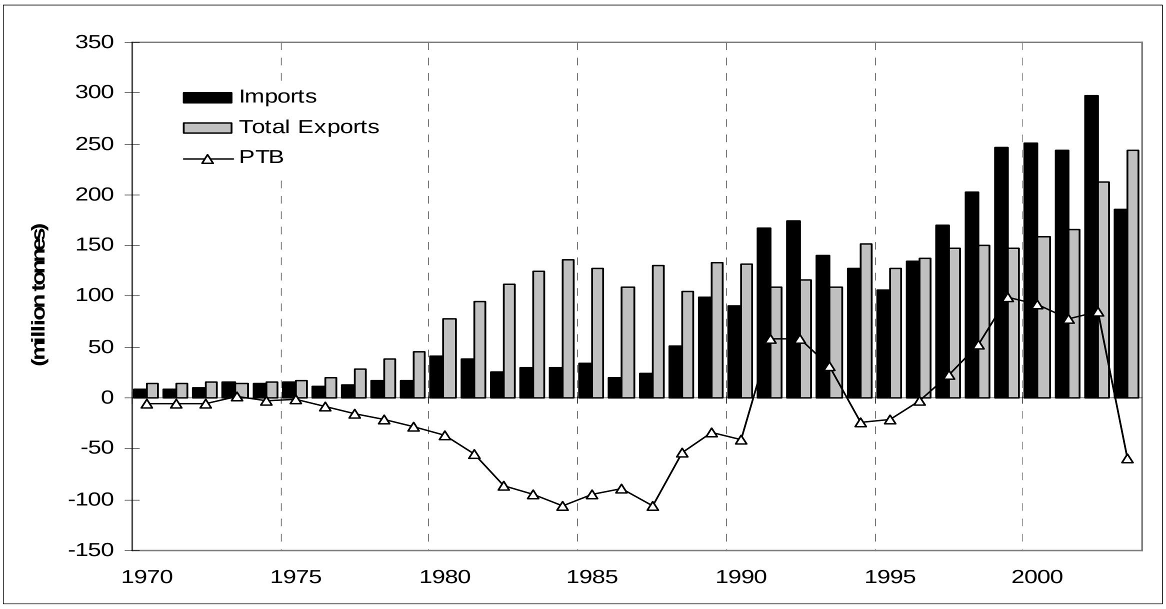
(INFONAVIT and FOVISSTE) to increase private house ownership. The year's 1970 to 1980 were the most dynamic period in house building. Dwellings increased from 8 million to 12 million during this decade (4.6% annual growth rate). The following two decades were less dynamic because of economic slowdown and crisis. The annual growth rate for new buildings during 1980-1990 was 3.3% and 3.4% in the period 1990-2000 (INEGI 2008). In the years of economic crises, credits for housing and other construction activities were constrained; for instance, GDP in the construction sector decreased by 23.5% during the economic crisis in 1994-1995 (INEGI 2006a). Investments in infrastructure construction followed a cyclic pattern as well. Government expenditure decreased during the economic crises. For instance in 1995, expenditure in infrastructure decreased by 33%.

Nevertheless, according to material flow indicators, the general growth trend for construction minerals seemed to be unaffected by economic fluctuation, although in critical years such as 1982 and 1994-1995, extraction of construction minerals decreased along with the contracting economy. This only partly confirms the findings of other case studies (Giljum *et al.* 2005, Weisz *et al.* 2006), that the absolute level of building materials extraction would be determined by GDP/capita levels and the more an economy grows, the more infrastructure it needs and therefore it would demand more building materials. It needs further investigation to disaggregate the overall trend found into its components, to identify the impact of construction activities for dwellings and infrastructure, on overall demand for construction minerals.

4. MEXICO'S TRADE PATTERNS AND THEIR PHYSICAL CONSEQUENCES

Besides of the considerable growth dynamics observed for the extraction of natural resources, the integration of Mexico into global markets, as expressed by the amount of materials traded, has been impressive. Trade flows have shown a dramatic rise in terms of weight during the period under study. Annual imports have grown from 8.5 to 185 million tonnes and exports have grown from 14 to 243 million tonnes, resulting in a yearly growth rate of 9.8% and 9.05% respectively.

Figure 2.2 Physical Imports, Exports and Physical Trade Balance (PTB) of Mexico 1970-2003, in million tonnes

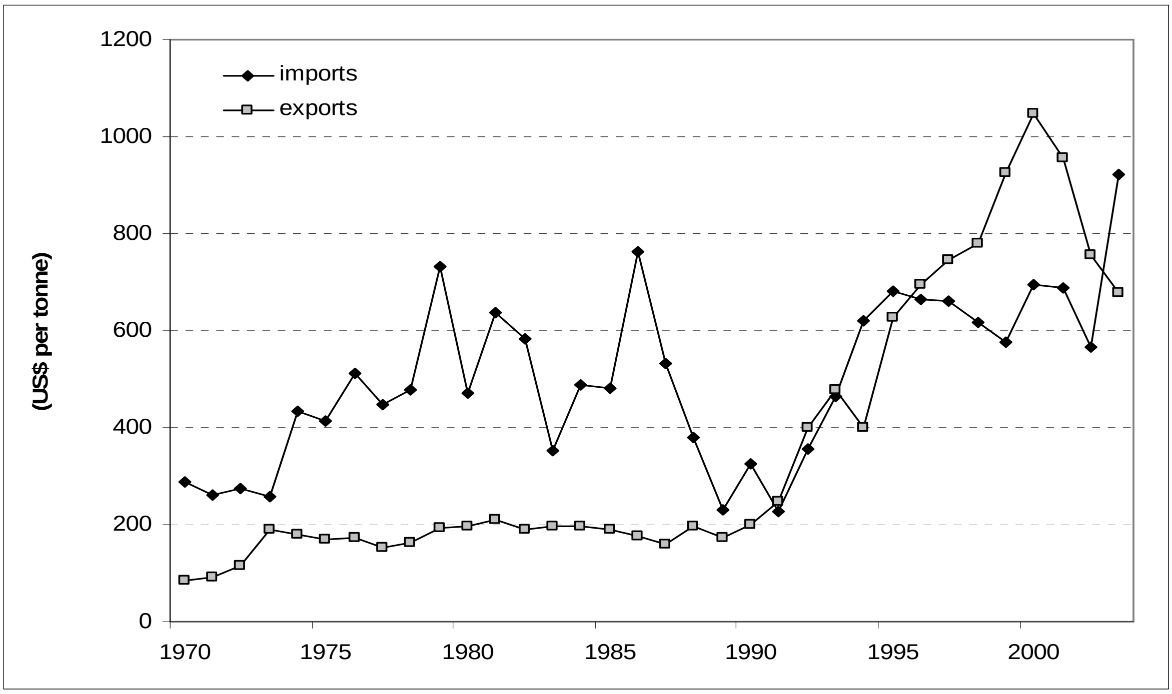


Source: Gonzalez-Martinez 2007

As Figure 2.2 shows, the development of trade should be split in two main periods with different characteristics. The first period, from 1970 to 1986, was characterised by fast growing exports boosted mainly by the oil boom while imports remained fairly constant, because Mexico's main trade policy was focussed on import substitution. The second period, from 1987 onwards, was characterised by fast growing imports, caused by reduced trade barriers and more international trading agreements. In this phase exports grew at a much slower pace. As a consequence, the physical trade balance (PTB) obtained by deducting exports from imports also underwent change in the late 1980s, from a negative balance (net exports) to a positive balance (net imports), except for the years 1994 and 1995 (when the Mexican economy experienced a financial crisis) and for the year 2003.However, the monetary trade balance (MTB) was negative for most of the period, apart from some critical years such as 1982-1989 and 1995-1996 when imports were constrained due to contractions of domestic demand (Moreno-Brid *et al.* 2005). Interestingly, during the 1970s physical exports where higher than imports while the value of exports was lower than that for imports, resulting in a negative monetary balance and a negative physical balance, indicating the unfavourable position of the Mexican economy in the World market in the 1970s.

This imbalance becomes more evident when analysing the unit prices of imports and exports. Figure 2.3 shows the price of imports and exports for Mexican trade from 1970-2003. During the 1970s and even the 1980s, the price per tonne of imports was considerably higher than the price per tonne for exports. This difference decreased markedly from 1982 on when the unit price of exports increased faster than the price of imports (from $86/tonne, to $1,046/tonne in 2000 and $676/tonne in 2003). In the 1970s, Mexico was mainly an extractive economy, selling raw materials cheaply to the world market but relying on imports of expensive finished products. The overall effect of this unfavourable position was alleviated by an import substitution policy but nevertheless could not ease the social and economic consequences of resource exports. Such an economic pattern is resource and pollution intensive, results in a lack of sufficient infrastructure development and insufficient incomes for communities and households, and is highly vulnerable to market fluctuations (Bunker 2007). For comparative purposes, note that in the EU-15 the average price for an imported tonne was $1,559 in 2000, about one third of the price for an exported tonne ($5,306), both numbers being significantly higher than those for Mexico (Eurostat 2002).

Figure 2.3 Unitary price of imports and exports in Mexico 1970-2003, in US dollars (2000 prices) per tonne



Source: Gonzalez-Martinez 2007 and World Bank 2005

The reason for this marked change in Mexico's trade can be found in the composition of traded goods, caused by structural changes in the Mexican economy. Apart from the overall growth experienced in Mexican trade, the composition of imports and exports, measured in tonnes, has also undergone important changes in the period under study. In the early 1970s, minerals (comprising raw materials, semi-manufactured products and final products) dominated imports (37%). In particular, semi-manufactured metal products and raw metals were the dominating fractions contributing three quarters of total mineral imports. The second most important import-flow was fossil fuels (36%).

By 2003, minerals increased their importance to account for 64% of all imports. However, the composition of raw materials and final products in mineral imports has changed markedly since the 1970s. Semi-manufactured products and finished products accounted for 87% of total mineral imports, while raw minerals accounted for only 10%. This shift to more processed goods in imports was the reason for increasing unit prices of imports. The fact that most of these products were used by the assembling industry ('maquila')[6] as inputs is of great relevance in understanding these trends, as will be explained later in this paper. Biomass was the second most important import (25%) in 2003, mainly because of an increasing reliance on imported food crops.

In 1970, the minerals category accounted for the biggest share of exports; in particular, raw minerals represented 49% of total exports followed by fossil fuels, accounting for 27%. This pattern rapidly changed, and in 1978, fossil fuels accounted for 53% of total exports due to the oil boom. Since then, fossil fuels have been the dominant fraction, although their relative importance has decreased in recent years. In 2003, they accounted for 50% of total export weight followed by minerals (43%) dominated now by metal-based manufactures (34% of total exports). It is also evident in monetary terms that Mexico, during the last two decades, has changed from being an oil-exporting country to an exporter of manufactured goods. In 2003, the manufacturing industry contributed 42% of all exports whereas in 1970 the share was only 10%. In addition, from 1985 to 1994 Mexico ranked fifth among the countries with the largest increases in their

[6] The Mexican term 'maquila' is used to refer to the practice of subcontracting to produce or assemble parts that will be used in other production processes.

share of world manufactured exports (measured in monetary terms), but in the period 1994-2001, Mexico moved into second place, just behind China (Moreno-Brid *et al.* 2005).

What explains this non-oil exports boom? Apart from trade liberalisation policy and foreign direct investment (FDI) inflows, a decline in internal demand forced firms to look towards external markets. Nowadays, demand from abroad is the most dynamic component of demand for Mexican products. Another key factor explaining the impressive growth in non-oil trade is the assembling industry, especially since the 1990s when this type of industry obtained economic importance. According to Dussel (2004), around 70% of Mexico's exports of manufactured goods are produced by assembling industries using imported inputs. The components that cross Mexican borders to be assembled in this industry are accounted for as imports, whereas the final goods once assembled are directly sent abroad and therefore, they are accounted for as exports. According to De la Garza (2005) 96-98% of the total inputs used in these industries are imported. Assembling activities thus were responsible not only for the remarkable increase in Mexican trade, but also for its change in composition. According to foreign trade statistics (BANCOMEXT 2004) exports from assembling activities accounted for 47.7% of total Mexican exports and 35.3% of all Mexican imports, in monetary terms. These activities are concentrated in the automobile, auto parts and electronics industries (Dussel 2004).

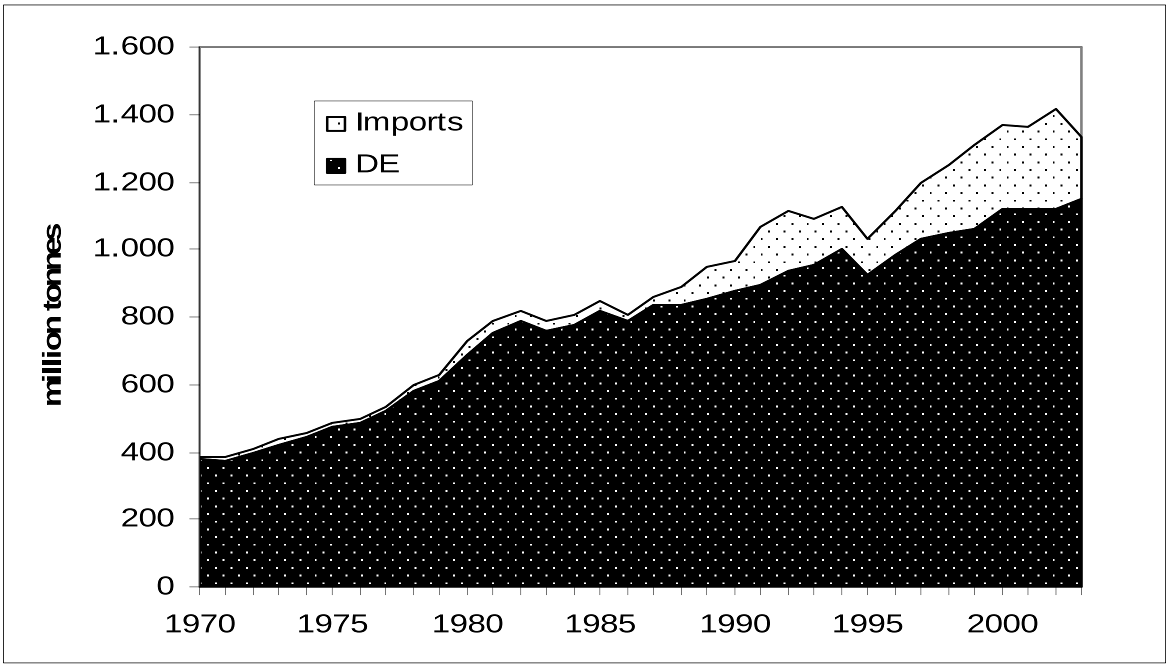
Whether the assembling industry has positive effects for the national economy has been very controversial. Salaries prevailing in the assembling industry are low, there is a serious disconnect between the assembling industry and the other domestic industries, as most of their inputs are imported, and therefore, it has not had a spill over effect on the rest of the economy. Its contribution to domestic value added is rather limited. In addition, the environmental impacts of these activities can be high due to their geographical location. The majority of the assembling plants are located in Northern Mexico's semi-arid border regions where the combination of meteorological conditions and topological disadvantages, with dynamic industrialisation and population growth, exert a growing pressure on the environment and natural resources; mainly on water. Water scarcity is becoming a crucial issue (Stromberg 2005).

With regard to physical trade patterns, the Mexican economy is different from other Latin American economies such as, for instance, Ecuador and Colombia. While the latter follow the typical pattern of 'extractive economies', Mexico's dependence on natural resource exports decreased in monetary terms in the analyzed period even though exports of raw materials increased in absolute values. This pattern places Mexico between the profile of a typical Latin American economy (characterised by low GDP and abundance of natural resources) and that of industrialized countries (based on strong industrial and service sector and a high dependence on imports for mineral ores, fossil fuels and other primary materials). The Mexican economy is at a crossroads between being an 'extractive economy' (Bunker 2007) as it keeps extracting large quantities of crude oil for exporting, and a 'productive economy' as it produces an increasing quantity of manufactured products destined mainly for international markets. Whether Mexico will be able to consolidate an economy based on high value added processes and products, is thoughtfully debated by economists (for a review see Dussel 2003).

5. MATERIAL INPUT AND CONSUMPTION PATTERNS IN THE MEXICAN ECONOMY

Material flow analysis aims to create a full description of an economy, in physical terms. The material flow-based-indicator Direct Material Input (DMI) is comprised of all materials of economic value directly used for consumption or production purposes. The indicator is calculated by adding imports to domestic extraction. In Figure 2.4 the evolution of DMI in millions of tonnes clearly shows the increasing quantity of materials entering the Mexican economy. DMI rose from 384 million to 1.3 billion tonnes in only three decades, equal to an increase from 7.6 to 13 tonnes per capita. Although imports are fast growing, domestic extraction of resources has been the main source of material inputs. Imports only gained importance in the 1980s. In 1970, imported materials represented only 2% of direct material input, but this increased to 14% by 2003.

Figure 2.4 Domestic extraction and imports in Mexico 1970-2003, in million tonnes



Source: Gonzalez-Martinez 2007

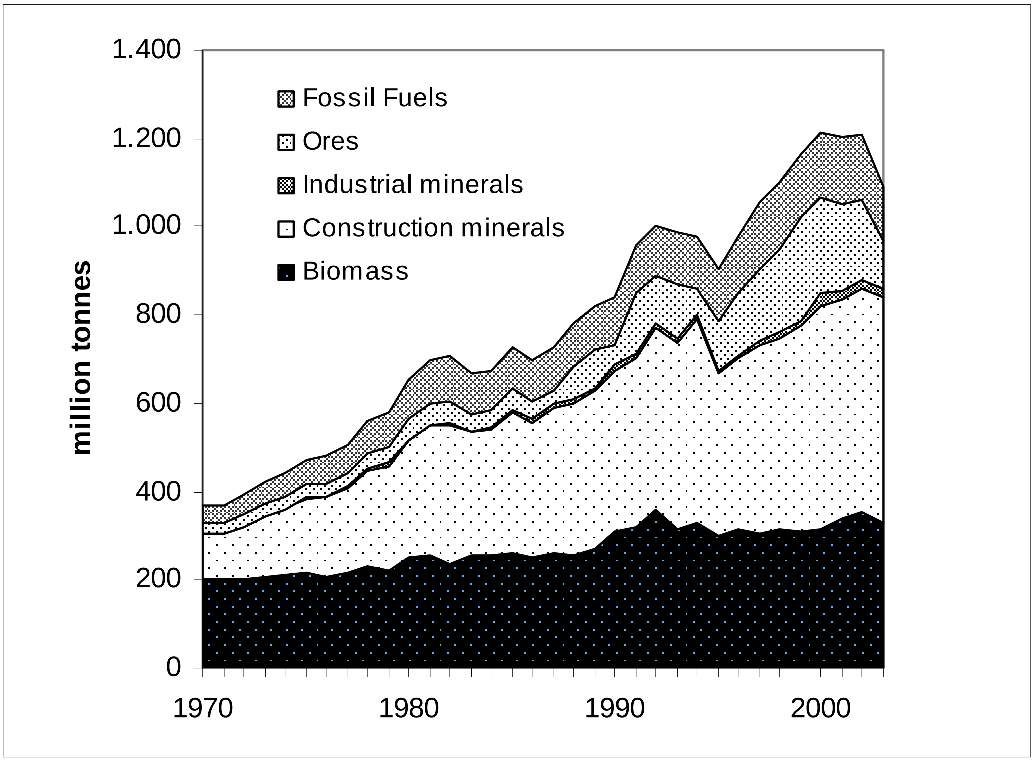
Information about the evolution of resource use is of great relevance as it allows us to complete the picture of the Mexican economy. If we based our analysis only on economic data, we might wrongly conclude that as a result of the structural change, resource use and related environmental impacts of the Mexican economy have decreased due to the increasing importance of the service sector and the fact that services need fewer resources than primary and industrial activities[7]. This misconception disappears when we gain consistent information on the physical economy, showing that despite the relative increase in services in the economy, the underlying physical flows have increased dramatically. Services do not replace material intensive production and consumption processes but add economic value on top of these. Usually an increase in service sector jobs also increases domestic consumption, due to increasing wages adding to the resource requirements of the whole economy. Moreover, material flows in Mexico rose despite periods of uneven and weak economic growth.

[7] The environmental Kuznets curve (EKC) hypothesis wrongly assumes a reduction in materials use when economies get richer. Whilst in the early stages of development, it is argued, incomes are low and so are material requirements. Industrialization drives an increase in material demand, mainly for basic infrastructure. As development continues, the need for infrastructure is met and consumer demand shifts toward services, which are assumed to be less materials intensive (Cleveland and Ruth 1999, Stern 2001). While we may see stabilization for certain industrial economies, there is not a lot of evidence for overall resource use decline (Weisz *et al.* 2006).

The growing quantity of material inputs extracted domestically coincided with the decreasing economic importance of primary activities as a source of national income and as a provider of jobs. In 1970, agriculture, forestry and fishing contributed 11.2% to gross domestic product, while mining contributed another 2.6%. Today, agriculture has decreased to 3.5% of added value, and mining to 1.2% although they went up in absolute terms allowing for increasing DE. With regard to the relative importance of agriculture and mining in the economy, Mexico represents a typical developed, industrialized pattern. Unlike Mexico, other Latin American countries specialising in natural resource exports, such as Chile and Ecuador, show an increasing relative importance of primary sectors activities (Giljum 2004, Russi *et al.* forthcoming).

While DMI focuses on the inputs side, the indicator Domestic Material Consumption (DMC) provides information on the quantity of the materials that remain within the national territory. It is calculated by subtracting exports from DMI. DMC comprises of all materials used (intermediate and final consumption) and has also been described as an indicator for the waste and emissions potential of an economy (Weisz *et al.* 2006). Because DMC includes intermediate consumption the indicator is higher when the extraction sector and industry are of greater importance. Therefore, DMC is not an indicator for final consumption.

Figure 2.5 Domestic material consumption of materials in Mexico 1970-2003, in million tonnes



Source: Gonzalez-Martinez 2007

Material consumption in Mexico has also grown similarly to material input. In 1970, the quantity of materials consumed was 370 million tonnes, and this increased to about 1 billion tonnes in 2003. In per capita terms, DMC increased from 7.3 to 10.7 tonnes. Figure 2.5 shows material consumption with breakdowns by type of material flow. Mexico has raised its material consumption mainly because of an increasing use of construction minerals while consumption of fossil fuels and biomass went up at much slower pace. In 2003, building minerals accounted for 47% of total materials (see Table 2.1). The shares of other flow categories either slightly grew, as was the case for fossil fuels (from10.8% in 1970 to 14% in 1980 and 12% in 2003), or decreased as did biomass consumption (from 55% in 1970 to 30% in 2003).

Table 2.1 Domestic material consumption by material categories (% share)

		1970	1980	1990	2003
TOTAL		100.0	100.0	100.0	100.0
Biomass		**54.9**	**38.7**	**36.9**	**30.0**
	Food crops	16.4	13.2	11.2	10.9
	Fodder	33.7	21.5	17.9	15.2
	Animals	0.1	0.2	1.4	0.3
	Timber	4.3	3.3	5.9	3.0
	Non edible biomass	0.4	0.5	0.4	0.5
Minerals		**34.3**	**47.7**	**50.5**	**58.3**
	Construction minerals	-	39.8	43.5	46.9
	Industrial minerals	-	0.1	1.3	1.8
	Ores	-	7.9	5.7	9.6
Fossil Fuels		**10.8**	**13.6**	**12.6**	**11.7**
	Coal and products	-	0.3	0.5	1.3
	Crude oil and products	-	9.5	9.0	8.0
	Natural gas and products	-	3.8	3.1	2.4

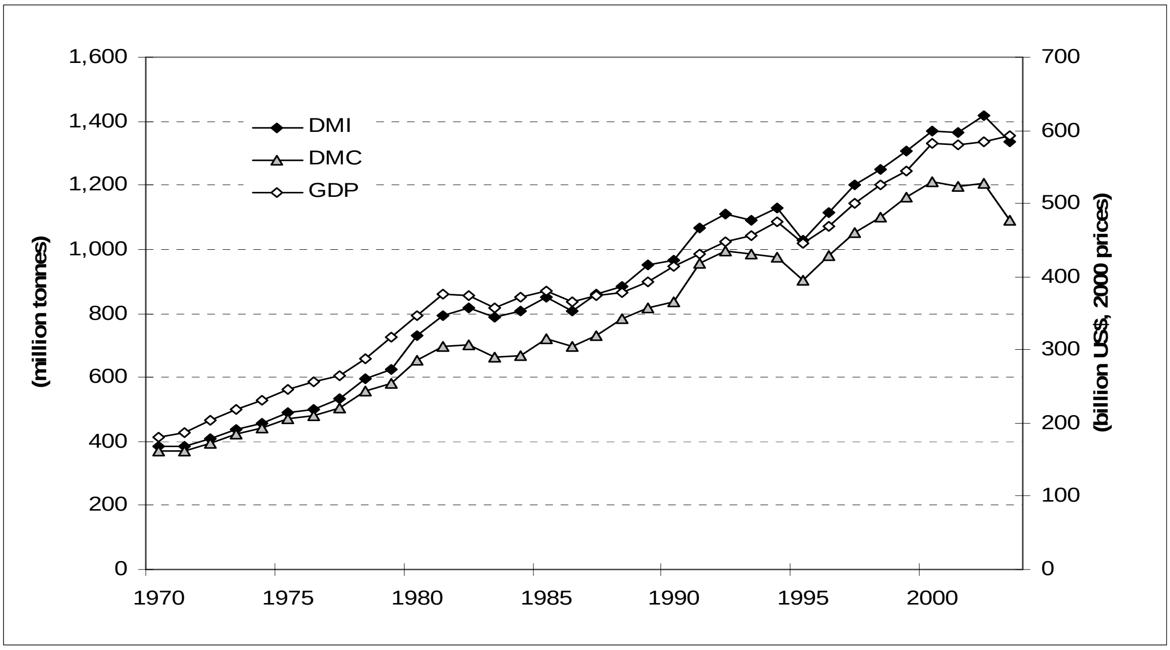
Source: Gonzalez-Martinez 2007

The marked increase in mineral use is linked to a prevalent urbanisation trend (Garza 1999) and the growing importance of manufacturing and related built infrastructure. The much slower increase in fossil fuels consumption compared to increase in industrial output suggests a decline in energy intensity in the industrial sector. In fact, energy intensity, measured in mega joules per unit of GDP, has been declining since 1988 (Aguayo and Gallagher 2005). In addition, per capita household energy consumption increased by only 13% over the last three decades, from 6,201 PJ to 7,055 PJ. Less than half of the total energy consumption of the residential sector, namely 42%, stems from fossil fuels. Fuel wood is still an important factor in household energy consumption, especially in rural areas, and accounts for 36% of residential energy use (SENER 2007). A study by Masera *et al.* (2005) suggests that 80% of the energy demand in rural areas is supplied from fuel wood. Per capita fossil fuel consumption in Mexico is similar to Chile (Giljum 2004), which also has a similar per capita GDP but lacks significant fossil fuel reserves. In the year 2000, fossil fuel consumption in the EU-15 was three times higher than in Mexico and Chile, at 3.7 tonnes per capita (Eurostat 2002).

A though there was a slight growth in biomass consumption in absolute terms, DMC per capita for biomass decreased from 4 tonnes to 3.2 per capita over the period 1970 to 2003. This decrease was related to fodder for livestock. This flow is mainly comprised of grass uptake by ruminants on permanent pastures, and it is affected by high uncertainty as it has to be estimated indirectly. Direct fodder uptake is not usually reported in agricultural statistics and, in the case of Mexico, it was estimated following the standard procedure used in Eurostat (2002) in order to narrow down the range of uncertainty. The drop per capita should not be related to technological improvements or a decrease in the land used for permanent pastures. In fact, between 1970 and 2003, permanent pastures slightly increased from 74,500 to 80,000 thousand hectares a result of increases in livestock from 45 million to 54 million heads.

Relating DMC to indicators of economic performance such as GDP or GNP allows for assessing the intensity of material use in an economy. The ratio DMC/GDP (material intensity) indicates the quantity of materials used per unit of economic output. Figure 2.7 shows that material intensity in Mexico has been fairly stable during the last three decades despite structural change and the increasing importance of manufacturing industries in GDP. Material intensity fluctuated between 1.8 and 2.2 kg of materials per USD. In addition, Figure 2.6 provides evidence that dematerialisation has not happened. In order to gain a complete picture of the overall material intensity, the indirect up-stream flows related to imports would have to be appropriately measured and included in the analysis·

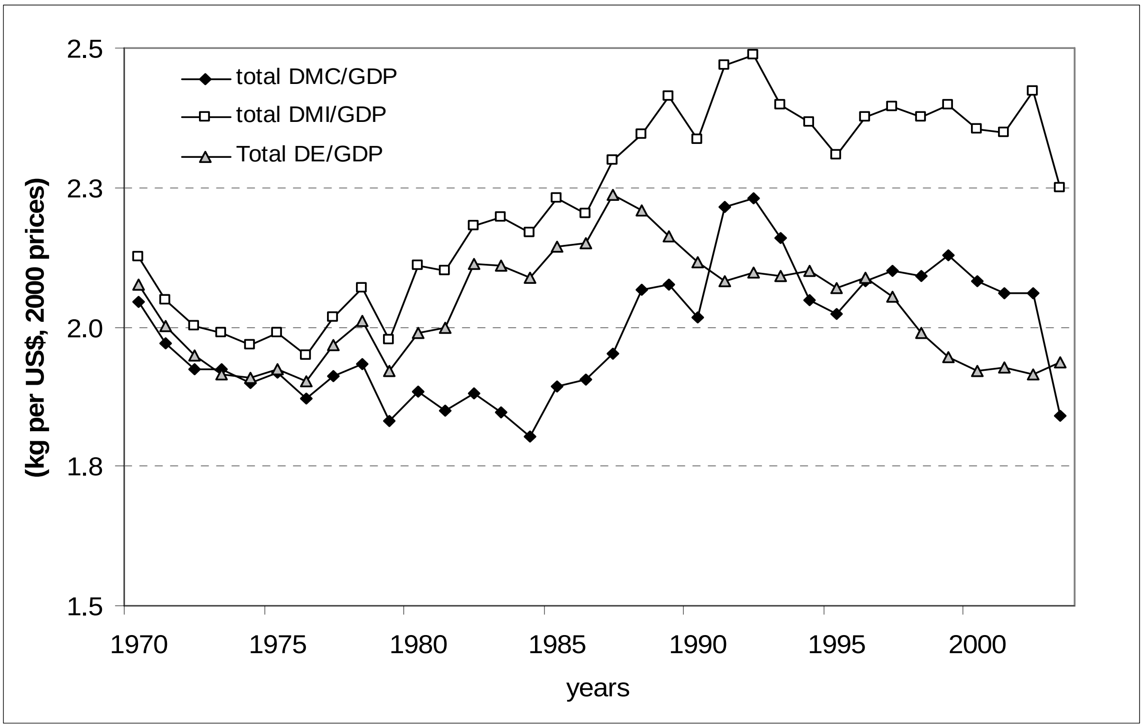
Figure 2.6 Evolution of material flow indicators and GDP 1970-2003, in million tonnes and billion US dollars, at 2000 prices



Source: Gonzalez-Martinez 2007, World Bank 2005

The reasons why there has been little progress in material efficiency in the Mexican economy is that, apart from a few privileged sectors oriented towards exports, innovation has been rare. Only few sectors have been able to close the technological gap, while the majority of the national industry has not solved the deeply-rooted structural problems. The pressing problems are a lack of long-term financial resources and insufficient investment to modernise industrial businesses. Indeed, during the eighties, fixed domestic capital formation in machinery and equipment registered an annual negative growth rate of 1%. By the end of the eighties, investment in machinery and equipment recovered to a positive growth rate. From 1988 to 2003, the annual average growth rate was 6.7%, still below the annual rate of 8% during the 1970s (Banco de Mexico 2007, INEGI 2007). Although the Mexican economy has not achieved a consistent delinking between resource use and economic growth, the overall material efficiency is more favourable than in many other Latin American countries such as Ecuador, Chile and Peru. Compared to these economies, Mexico is more material-efficient (Russi *et al.* forthcoming) but still by far below the EU-15 material-efficiency level, which was at 1.2 kg per USD in 1980 and further improved to 0.8 kg per USD in 2000 (Eurostat 2002).

Figure 2.7 Material intensity of the Mexican economy 1970-2003, in kg per US dollar



Source: Gonzalez-Martinez 2007, World Bank 2005

We apply the IPAT model (Holdren and Ehrlich 1971) in order to analyse the main socio-economic driving forces of material consumption. We interpret DMC as a proxy for environmental impact (I) and use a mathematical formula with three variables: population (P), GDP per capita to indicate affluence (A), and DMC/GDP as a technology indicator (T). Our objective is to determine which of these three variables explains the material consumption trends in Mexico. The IPAT equation using the material consumption indicator has been formulated as follows (Eurostat 2002):

$$DMC = (Population) * (GDP/Population) * (DMC/GDP)$$

Table 2.2 shows the evolution of the relevant variables over different sub-periods. During the whole period 1970-2003, domestic material consumption increased by 194%. This growth was influenced by a population growth of 102%, a growth in affluence of 62% and an efficiency gain of 10%.

Table 2.2 Evolution of main components of the IPAT equation

	DMC	POP	GDP/POP	DMC/GDP
1970-2003	2.94	2.02	1.62	0.90
1970-1980	1.76	1.34	1.43	0.92
1980-1990	1.28	1.23	0.97	1.10
1990-2003	1.30	1.23	1.16	0.91

Source: Gonzalez-Martinez 2007

Population growth was the main driving force for material consumption over the whole period. In the 1970s, per capita GDP was the fastest growing factor, supported by the oil boom. The efficiency of resource use increased although at a lower pace (8%). In the following two decades population growth was the main driving factor. In the 1980s, when the economy was in recession, both per capita GDP and efficiency of resource use decreased. In the most recent period (1990-2003), GDP grew slowly and resource use improvements increased by 9%.

6. CONCLUSIONS

This study presents information on material inputs into the Mexican economy for the first time and adds evidence to other studies done for the region of Latin America. Information on the biophysical aspects of the Mexican economy have been gathered by applying standard methods for material flow accounting, and results are therefore internationally comparable. In particular, the MFA indicators obtained for Mexico are helpful to analyse the pressure this economy exerts on its natural resource endowment. In this sense, our first finding is that the quantity of materials entering into the economy constantly increased, despite structural change and modest economic growth. Over the last three decades, population growth and export industries were the main driving forces for the increasing use of natural resources in Mexico. Efficiency gains were relatively small, and despite rapid growth in resource use, increases in the material standard of living have been slower and unevenly distributed.

The economic reforms implemented in Mexico in the 1980s were based on an intensive use of natural resources: firstly, domestic extraction of materials in Mexico tripled due to a rapid increase of construction minerals and fossil fuels extraction. Secondly, the amount of materials traded increased considerably from the late eighties when Mexico drastically reduced all trade barriers: imports grew by a factor of 22 during the period while exports increased by a factor of 17. The impressive growth of exports occurring in the late 1970s was solely based on fossil fuels. From the late 1980s onwards this pattern changed as manufactured products gained importance. Using MFA indicators, it was noted that Mexico has moved away from being an oil-exporting country to become an exporter of mainly manufactured goods. The assembly industry has played a crucial role in this process. While the oil based boom was based on the exploitation of a natural resource, the new export boom based on the assembling industries results from comparably low labour costs in Mexico. In this sense, the Mexican economy represents a different pattern when compared with other Latin American economies. Its dependence on exports of bulk commodities in the monetary trade balance decreased during the period analyzed, which situates Mexico between an 'extractive' and a 'productive economy' (Bunker 2007).

Nevertheless, material intensity in Mexico has not improved during the last three decades, despite structural change and the increasing importance of manufacturing industries in the national product. The reason is that most national industries have not improved production processes and technology, apart from a few sectors oriented towards exports.

Despite efforts to diversify exports, crude oil exports still represent 50% of total exports in weight. The fact that Mexico is still basing its economic growth to a large extent on the depletion of a non-renewable natural resource, namely oil, will raise problems for the mid and long term sustainability of the Mexican economy. Already, the *weak* environmental accounting literature[8] has extensively discussed how ephemeral

[8] The risks of economies based on extraction and not on transformation was underlined by El Serafy (1989), who differences between economic growth based on the use of exhaustible resources (a finished stock) and growth obtained through labour, capital investment, technological progress and efficient organization (flows). The latter lays the basis for a durable improvement of life conditions whereas the former can be linked to the liquidation of a natural capital. Authors such as El Serafy (1989) and Repetto (1989) propose methodologies based on monetary measures to include natural resources depreciation into national accounts. Environmental accounting based on monetary measures of natural resources can be regarded as

economic prosperity built on depletion of natural resources can be. The biophysical analysis of the Mexican economy adds information on real amounts of resources used in economic processes, about the efficiency of resource use and has a potential to inform policy planning.

belonging to the weak sustainability approach assuming a potential substitution between different types of capital.

CHAPTER 3

MATERIAL FLOWS AND ECONOMIC DEVELOPMENT IN THE NORTH: A DEMATERIALISATION ANALYSIS OF SPAIN (1980-2004)[1]

ABSTRACT

Material flow analysis (MFA) is a means of measuring the social metabolism, or physical dimensions of a society's consumption, and can be taken as an indirect and approximate indicator of sustainability. This methodology can be used to test the dematerialisation hypothesis, the idea that technological progress causes a decrease in total material used (strong dematerialisation) or material used per monetary unit of output (weak dematerialisation). This paper provides the results of a material flow analysis for Spain for the period from 1980 to 2004. In addition, the environmental Kuznets curve hypothesis is tested in this paper, using material consumption as an indicator of global environmental impact. The analysis reveals that neither strong nor weak dematerialisation took place during the period analysed. Although the population did not increase considerably, materials mobilised by the Spanish economy (DMI) increased by a factor 2. DMI average growth rate was 3.4% per year, surpassing GDP growth rate (3%). In addition, Spain became more dependent on external trade in physical terms. In fact, its imports are more than twice the amount of its exports in terms of weight.

Keywords: *Spain, dematerialisation, sustainability, environmental Kuznets curve (EKC), material flow analysis (MFA)*

---

[1] An earlier version of this manuscript was published in 2004 covering the period 1980-2000: Cañellas, S. Gonzalez. A.C., Puig, I., Russi, D., Sendra, C., Sojo, A. (2004). Material Flow Accounting of Spain. International *Journal of Global Environmental Issues*. Vol. 4. No. 4. An updated version in Spanish covering the period 1980-2004 has been submitted to *Revista Iberoamericana de Economía Ecológica* (REVIBEC).

1. INTRODUCTION

There is burgeoning literature on the topic of *Environmental Kuznets Curve*, a hypothesis based on the idea that economic growth will eventually redress the environmental impacts of early stages of economic development and growth will lead to further improvements in the developed countries (Stern 2001). Structural change towards services intensive activities, technological improvements, higher environmental expenditures, stronger environmental monitoring and enforcement and more ecological awareness[2] will lead to a gradual decline of environmental degradation.

If verified, this hypothesis would lead to important political consequences, in the sense that following the present development path, far from being a threat to the environment and human survival, as argued in the report *Meadows: the Limits of Growth* (1972), will lead to a more sustainable economic system. This would mean that environmental measures are not necessary, and that instead the environment would benefit from policies that aim at stimulating the economic growth.

Several studies have tried to empirically test such hypothesis. While most of the studies used a single polluter – mainly atmospheric pollutants such as SO_2 and CO_2 – as environmental impact indicator; little work has been carried out to analyse impacts globally. In this sense, studies such as that carried out by Suri and Chapman (1998) use energetic consumption as global impact indicator.

An interesting way to test this hypothesis is to analyse the amount of material used by a country in physical terms. The total amount of material used by an economy can give insights into its “social metabolism”[3]. In fact, materials must be extracted and processed in order to produce goods that are then transported, exchanged, used and finally, discharged. All these activities have environmental impacts: the more the material used in an economy, the higher the environmental impacts.

[2] This hypothesis assumes that environmental quality is a luxury good and the more the income, the demand for better environmental quality increases more than proportionally. Therefore, under this analytical framework, environmental awareness depends on income level.

[3] This metaphor is used to express that an economy is seen as an organism that takes resources from the environment and discharges wastes. For a bibliographical review of the origins and application of this biological concept on social sciences see Fischer-Kowalski (1998) and Fischer-Kowalski and Hüttler (1998).

Material flow accounting can be used to test the dematerialisation hypothesis (Cleveland and Ruth 1998). According to this theory, countries tend to use less material in absolute terms (*strong dematerialisation*) or at least per unit of service produced (*weak dematerialisation* or *decoupling*) due to technological progress, which is in turn made possible by economic growth. The dematerialisation hypothesis can be seen as a different formulation of the *Environmental Kuznets Curve.* In addition, information about a country's level of dependence on materials coming from other economic systems can be of use.

This chapter analyses material flows associated with the Spanish economy between 1980 and 2004, a time period when important structural changes took place. In addition, the environmental Kuznets Curve is estimated using material consumption as a environmental pressure indicator. The aim is to analyse how economic growth and physical growth are related in the case of Spain.

The Eurostat methodology (Eurostat 2001) has been followed in order to ensure comparability with other similar analyses conducted for different countries. Much research has already been carried out in this direction on an international scale for industrial countries (Bringezu and Schütz 2001, Adriaanse *et al*. 1997, Matthews *et al*. 2000, Weisz *et al*. 2006) and more recently, for developing countries (Amann *et al*. 2002, Giljum 2004, Pérez-Rincón 2006, Vallejo 2006, Silva-Macher 2007; González-Martínez and Schandl 2008). The Eurostat methodology produces quite adequate and easy-obtained indicators, providing a first overview on the physical dimension of a country.

In Spain, several studies on material flows have been conducted already: at national scale (Carpintero 2005, Cañellas *et al.* 2004; Alonso and Bailon 2003) and at regional level although these do not allow comparability between them (Naredo and Frias 1988, 2003; Almenar *et al.* 1998, Arto 2003, Doldán 2003, Hercowitz 2003, Sendra 2006). The most recent material analysis for Spain is Sastre (2007), where a homogeneous database at province scale is provided for the period 1996-2003.

In the Eurostat methodological guide (Eurostat 2001) material flows are classified into three main material groups (**minerals**, **energy** and **biomass)** and into three main categories (**imports**, **exports** and **domestic extraction**), which are used to structure the indicators calculated in this study:

- **Domestic Extraction**: materials extracted in the national territory per year.
- **Direct Material Input** (DMI): Domestic Extraction (DE) plus Direct Material Imports (I) (DMI=DE+I).
- **Domestic Material Consumption** (DMC): DMI minus Direct Material Exports (E) (DMC=DMI-E=DE+I-E).

This chapter focuses on direct material inputs (i.e. inflows with an economic value, namely used flows), ignoring all *unused* and i*ndirect flows s*, i.e. those flows that are not directly exchanged on the market but are associated with the extraction of raw materials (e.g. overburden from mining processes) as well as materials required to produce imported goods. The inclusion of these flows can increase the comprehensiveness of the analysis but they also increase its arbitrariness. This is because indirect flows are calculated by multiplying direct flows by standard coefficients (Bringezu and Schütz 2001). However, in reality they vary considerably depending on many factors, such as the state of technology and the economic conditions of a country. Moreover, if indirect flows are accounted for, comparisons between countries may imply double-counting internationally traded goods since indirect flows are accounted for twice –in both the exporting and the importing country. It should be noted as well, that water and air are excluded (although the water and air content present in materials are included), as they represent nearly 95% of the entire metabolism of an industrial society (Schandl *et al.* 2000).

2. IS SPAIN DEMATERIALIZING?[4]

In the last twenty five years, the Spanish economy has experienced a strong growth and a positive evolution of all its macroeconomic indicators, in a path of convergence in income per capita with the older members of the European Union. For instance, the difference between income per capita in Spain and the Euro zone average income per capita decreased from 20% in 1990 to 10% in 2004 (Eurostat 2007a).

[4] For data sources and detailed tables see Annex II

The period 1980-2004 is characterised by:

1) A structural change due to an increasing predominance of the service sector in terms of employment and economic added value. In 2004, the service sector produced 67% of total value added while the industry sector comprising energy and construction accounted for 29%. The primary sector contributed with the remaining 4% (OECD 2007).

2) Cycles of recession, stagnation and recuperation following a GDP growing trend in the long term, as can be observed in Figure 3.1

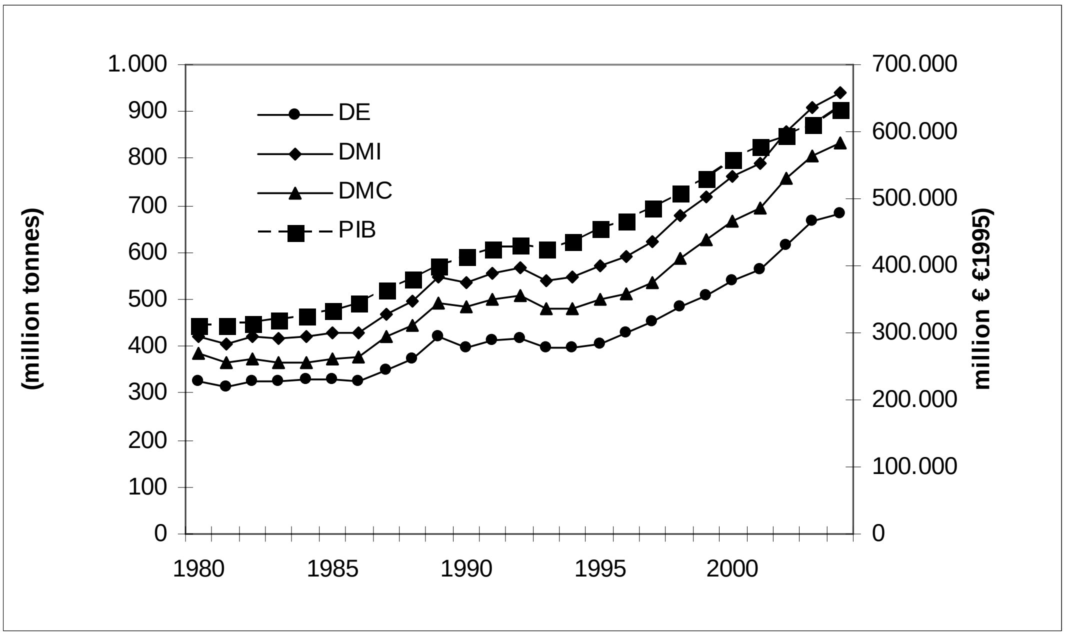
3) An increasing material and natural resources use.

This section analyses the impact of this economic performance on material use. Firstly, the use of materials steadily increased in the period 1980-2004 (Figure 3.1). For instance, the material moved by the economy, expressed by the Direct Material Input (DMI), two-folded, from 420 to 940 million tonnes. The DMI average annual growth rate was 3.4 during this period. As can be observed in Figure 3.1, all the material use indicators (domestic extraction [DE], domestic consumption [DMC] and domestic input [DMI]), followed a similar path. Similarly, the quantity of material consumed in Spain (DMC) doubled during this period, having an average annual growth rate of 3.3%. When comparing these data with evolution of real GDP, whose annual growth rate was 3% in average (Eurostat 2008), we conclude that material use and consumption in Spain increased even more than income. In consequence, strong dematerialisation did not take place.

This tendency has also been observed in the long term. Carpintero (2005) gave figures for the Total Material Requirement (TMR)[5] of the Spanish economy showing that had become 5.6 times larger in the period 1955-1990.

[5] It measures the total “material base”of an economy and it is constituted by Direct Material Input + unused material extraction + indirect flows associated with imports (Eurostat 2001).

Figure 3.1 DE, DMI y DMC versus GDP in Spain (1980–2004)



Source: own calculations

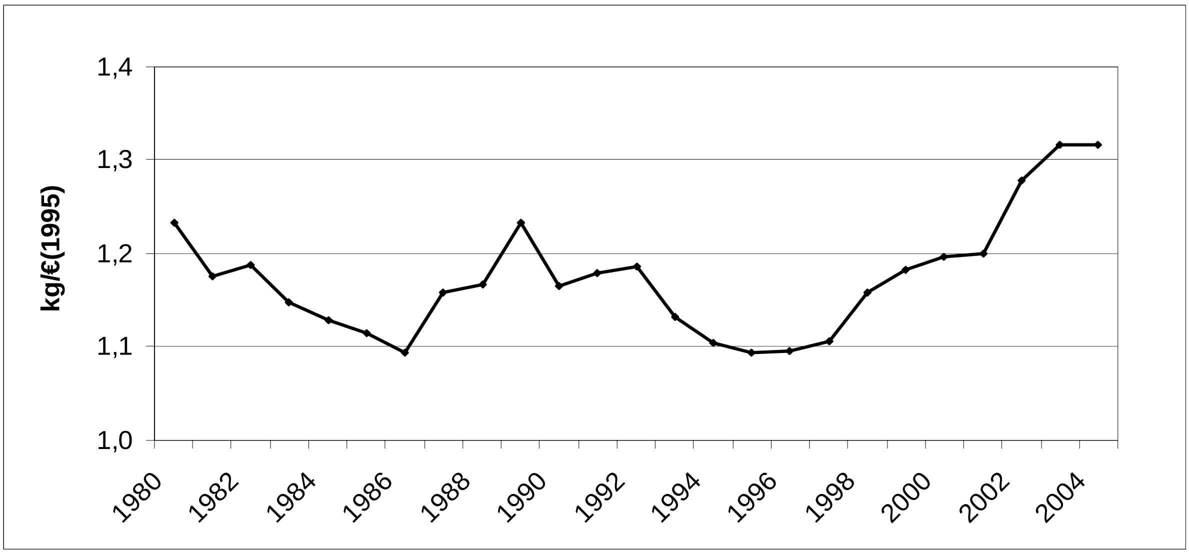
In addition, Figure 3.1 shows that the three material use indicators (DE, DMI and DMC) followed the country's economic cycles: stagnation in the early eighties, followed by a cyclic expansion from 1985 to 1990, a halt from 1992 to 1995, after which a new period of expansion began again. In other words, there are no signs of material consumption that differ from the economic evolution.

Material consumption measured in per capita terms increased from 10.3 tonne/person in 1990 to 19,6 tonne/person in 2004. While material consumption dynamically increased, population remained almost stable until 2000. From 1980 to 2000, population annual growth rate was 0.3%. From 2001, population rate shows a slight dynamism as it rose to 1.4%, a growth rate still slower than the material use growth rate (Eurostat 2007a).

Secondly, analysing intensity of material use (material consumed per unit of economic output), we are able to find out if weak dematerialisation did take place in Spain. According to the dematerialisation hypothesis, once reached certain level of wealth, an economy should be more material efficient as it should require less material to produce one unit of economic output. In Spain, this phenomenon did not take place.

In 1980, 1.2 kg were required to produce one euro of economic output while in 2004, it increased to 1.3 kg. Figure 3.2 shows the material intensity oscillations from 1980 to 1995 and how from 1996 the general trend has been upwards.

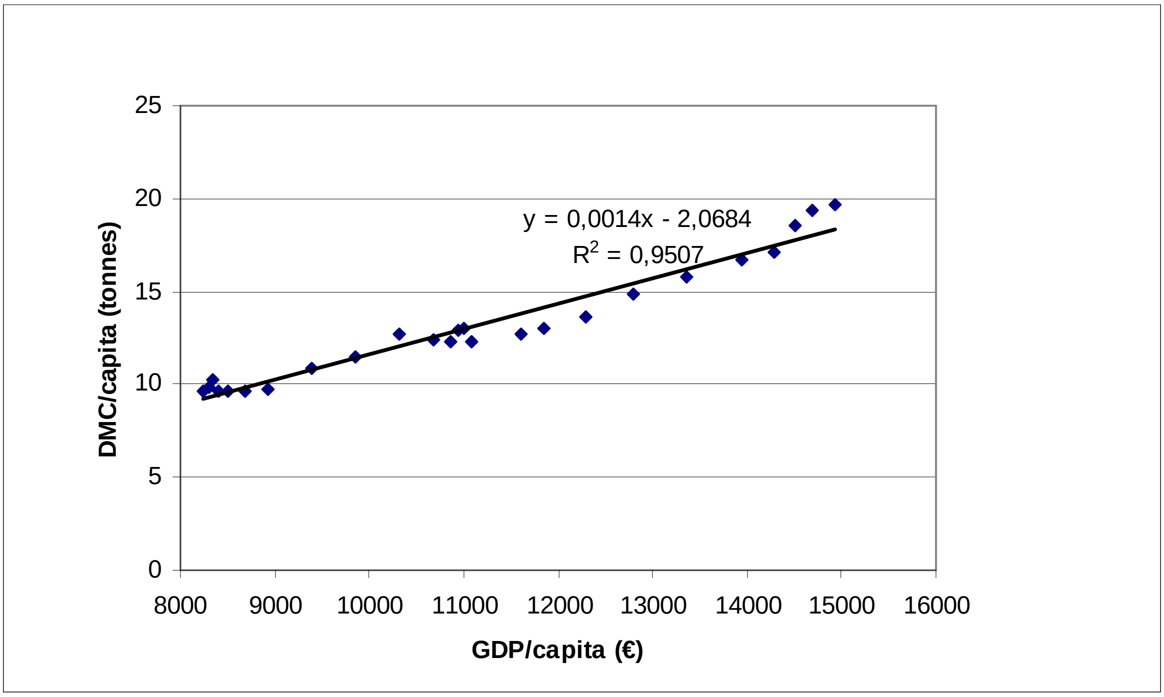
Figure 3.2 Material intensity in Spain Kg/€ (1995)



Source: Own calculations

We investigate the Environmental Kuznets Curve (EKC) hypothesis using material domestic consumption (DMC) as environmental pressure indicator and GDP per capita (1995 constant) as wealth indicator. The estimated function (Figure 3.3) represents changes in variable Y (tonnes of per capita material consumption) explained by changes in variable X (GDP per capita). Results show that material consumption grows considerably as per capita income improves. No inflexion point is observed during the period under analysis. In addition, the Spanish economy increases material consumption in 1.4 tonnes when income per capita increases 1000 euros. The R^2 =0.9 means that the regression model fits the data. It is also observed that between 14,000 and 15,000 euros per capita intensity of material use considerably rose.

Figure 3.3 Environmental Kuznets Curve for Spain using material consumption



Source: own calculations

This trend does not follow the performance of other industrialised countries. In fact, previous analyses have proven that in some industrialised countries such as Denmark, The Netherlands and U.K a decoupling between GDP and material use took place notwithstanding an increase in material flows in absolute terms. On the contrary, Spain has followed the performance of other European countries with lower income levels as it is the case of Greece, Ireland and Portugal (Eurostat 2002).

As regards the material flows between Spain and the rest of the world, an important growth is observed. Exports grew faster than imports throughout the whole period. As a matter of fact, they increased 2.8 times (from 38 to 109 million tonnes) whereas imports increased 2.6 times (from 97 to 258 million tonnes). However, since imports weighed more than twice the exports, net imports (X-M) increased 2.2 times. This underlines the fact that the Spanish economy has become more dependent on international trade. The analysis of these figures suggests that Spain is importing a large amount of primary natural resources, which are characterised by high weight, low price and low added value. These types of imports might also imply high levels of pollution and environmental degradation in the countries from which these materials are extracted (Muradian *et al.* 2002). These hypotheses are to be confirmed in further analyses.

3. ANALYSIS BY MATERIAL GROUPS

In this section, composition of material flows is analysed by categories: biomass, fossil fuels and minerals.

3.1 Fossil fuels

Fossil fuels have played an important role as energy source in Spain, despite the fact that this country does not have important oil reserves. At the beginning of the 1980s most of the primary energy consumed was obtained from oil and coal, representing more than 90% of the primary energy consumed (Ministerio de Economia y Hacienda 2005). Between 1980 and 2000, energy production composition in Spain changed with the increase of other energetic sources. Nuclear power production began to rise in 1984, as well as natural gas at the end of the 1980s. Nevertheless, by 2000, coal and oil still represented 82.1% of primary energy consumed (measured in thousand toe) while renewable sources constituted 6.4% and nuclear energy 11.7% (Ministerio de Industria, Comercio y Turismo 2005).

Renewable energy sources, including hydropower, were not considered in the MFA since they do not imply material transformation. Nuclear power is not considered either, due to the relatively small amount of mass needed to produce energy. Thus the analysis focuses on the use of fossil fuels, the most significant mass energy sources, which represent the overall material flows related to the energy sector. In this analysis three main categories of fuels are taken into account: coal, crude oil and natural gas[6].

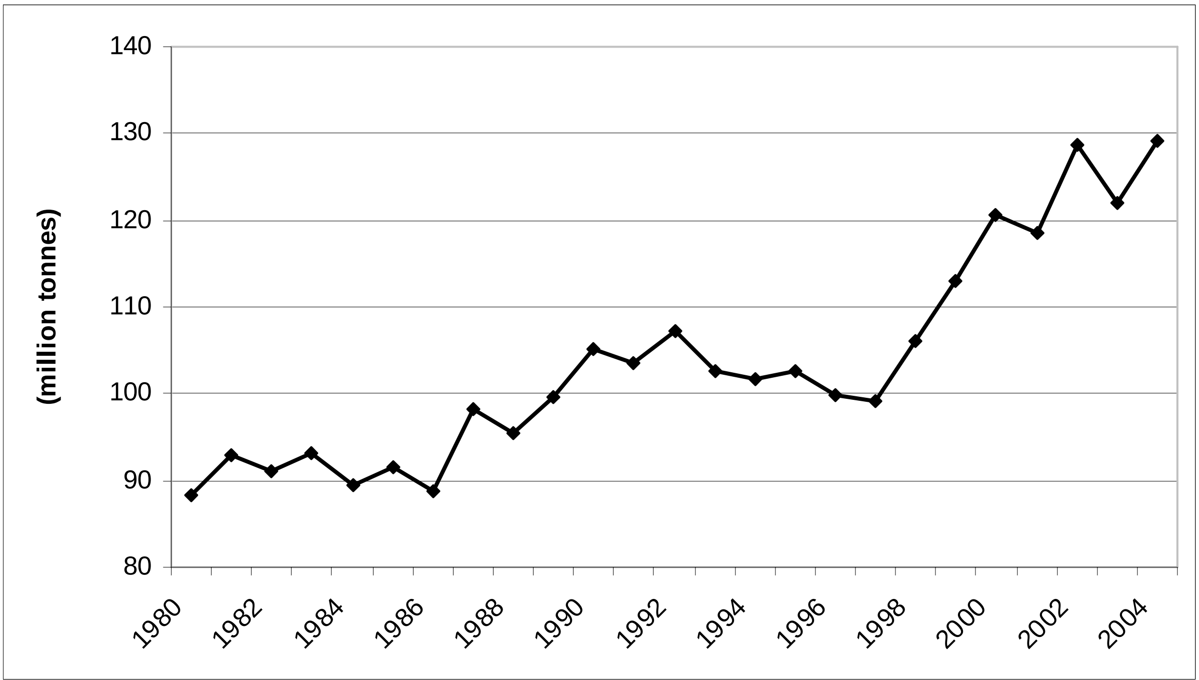
Coal represents the largest share of domestic extraction of energetic resources in Spain. In fact, it accounts for 98% of total energy extraction in 2004. Spain has few oil and gas reserves, each source accounting for approximately one percent of the total in 2000. Domestic extraction of energetic resources has declined since the early 1980s. This

[6] An energy flow accounting (EFA) includes all energetic sources (comprising i.e. renewable energy sources). The standard methodology to carry out such accountability is similar to the MFA.

could be due to: 1) geographical displacement of energy production abroad[7], 2) improvements in energy efficiency, and 3) the substitution of coal by oil imports and gas and domestic nuclear power. In the case of oil and natural gas, although new oil and gas deposits were discovered, domestic extraction decreased (especially since 1990), due to the depletion of previous sites. In any case, the contribution of domestic oil and gas to the total energy production is minimal.

Historically, Spain has been a net importer of energy given the few oil and gas reserves. Fossil fuel imports have always been larger than exports and they have increased over the period studied. More than 52% of total imports by weight were energy carriers in 2004. Figure 3.4 shows the large, increasing consumption of fossil fuels.

Figure 3.4 Fossil fuels consumption in Spain (million tonnes)



Source: own calculations

3.2 Biomass

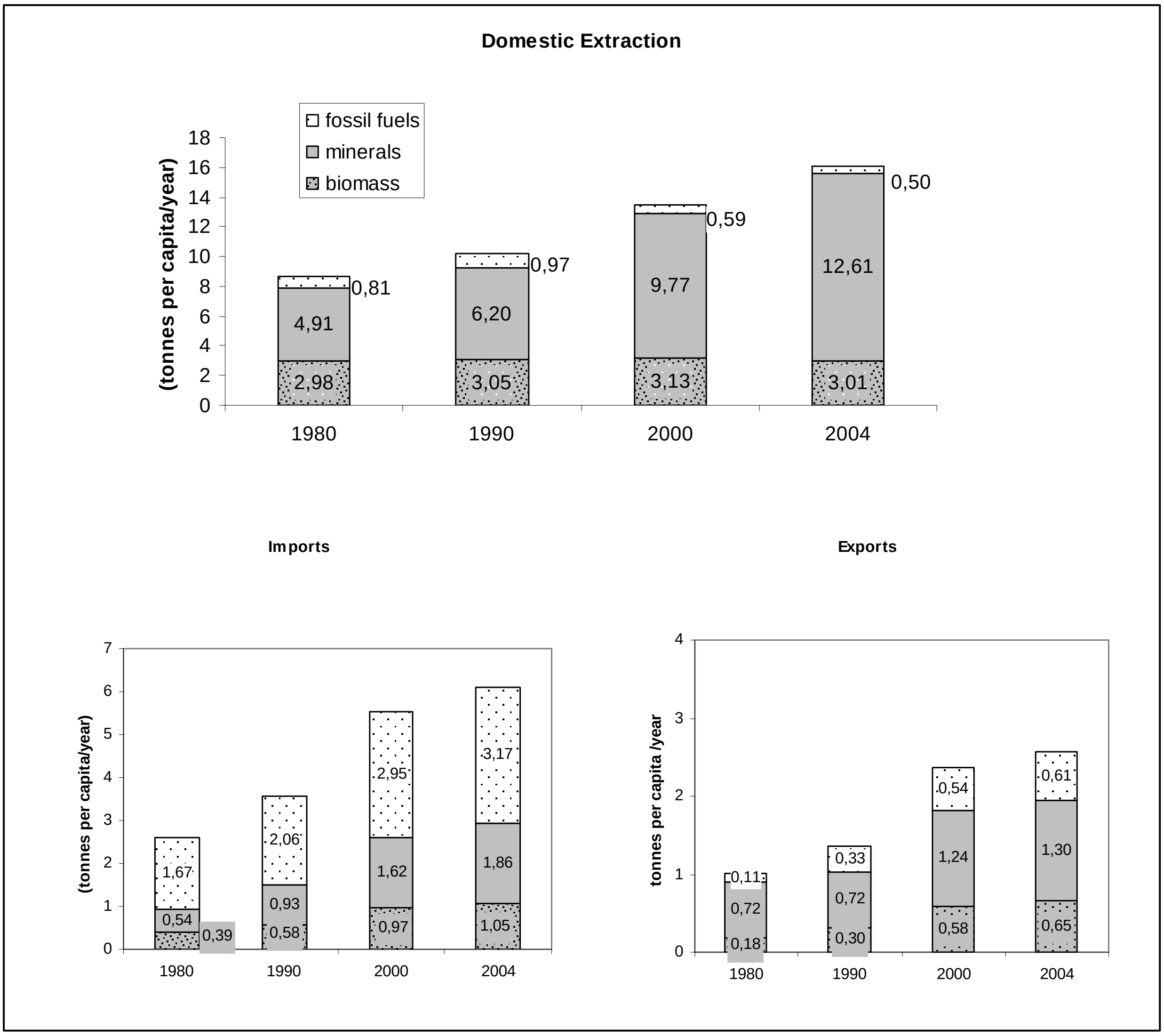
Four main types of biomass are considered in this study: agriculture products for human consumption, fodder, forestry and fishing. Agriculture products have accounted for most of the biomass extraction throughout the period analysed (57% in 2004). In 1995 a sharp

[7] This is a current general trend observed in a globalised world according to several authors (Muradian and Martínez-Alier 2001, Giljum and Eisenmenger 2004).

decline of total biomass extraction occurred, due to the droughts in the winter of 1994/1995, which implied a strong decrease in cereal and oil crop production. In 2004, 89% of total extraction of used biomass was constituted by agriculture products and fodder. In this same year, domestic extraction of agricultural products was headed by cereals, which represented 20%.

Domestic Extraction of biomass remained almost stable over the period, in contrast to energy and mineral materials, as can be observed in per capita terms (Figure 3.5). Direct Material Input of biomass increased due to imports, which also increased steadily during the period. Domestic Material Consumption of biomass increased in absolute terms and slightly in per capita terms (from 3.2 to 3.4 ton/capita) all along the analysed period, but the change in consumption in this sector was smaller than for the mineral and energetic ones. This indicates that the increased use of materials and energy in Spain concomitant with economic growth has certainly not been satisfied by domestic or imported biomass.

Figure 3.5 Domestic extraction, imports and exports per capita in Spain by material categories



Source: own calculations

3.3 Minerals

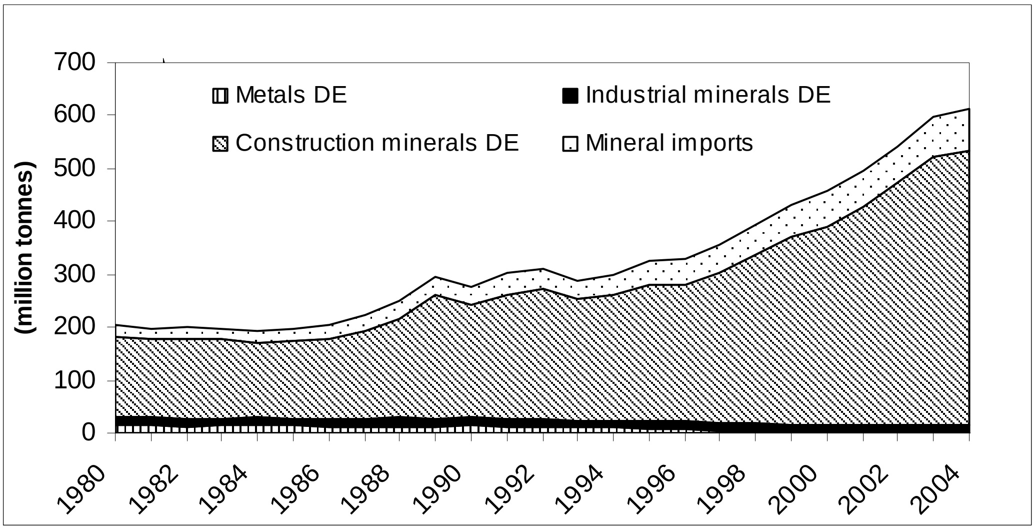
Mineral data were aggregated into three main categories: ores (metals), industrial minerals, and construction minerals. Industrial minerals and construction minerals comprise non-metallic minerals. Historically, minerals constitute the most important material group, with a higher proportion and higher growth rate. In 1980, this material group accounted for 56% of total extraction. By 2004, its share considerably increased to 78%. In the period under analysis, mineral domestic extraction grew by a factor 2 and mineral consumption tripled. Average annual growth rates were 4.7% for DE and 5.1% for DMC.

This impressive minerals growth consumption is mainly due to the dynamism of the construction sector. During the period 1980-2004, GDP in the construction sector experienced an average annual growth rate of 3.7%(INE 2005, 2000, 1998, 1988), a higher rate than that registered for the whole economy. Even in episodes of economic downturn such as the beginning of the 90´s, the building sector experienced strong growth due to the development of important infrastructures such as those for the Olympic Games in Barcelona and the World Exhibition in Seville in 1992. This fact is clearly reflected in the extraction and minerals use (see graph 6). 85 to 90% of minerals used in the Spanish economy were extracted domestically. The imports weight is relatively low comparing to DE. Therefore, DMI indicator does not differ from domestic extraction.

As previously stated, the DE trend is dominated by the demand of construction minerals. However, industrial minerals and metal ores each followed a very different trend. While industrial minerals remained approximately steady throughout the whole period of time considered, metal ores clearly declined, going from 14.6 million tonnes in 1980 to only 17 thousand tonnes in the year 2004. The decrease experienced by this sector is not related to any economic crisis but to the structural change of the metal sector in Spain that began in the 1980s. During this period, a number of mines and ironworks were shut down and, since then, extraction of metal ores in Spain has become irrelevant.

An analysis of the data from mineral imports and exports for the period 1980 to 2004 shows that Spain shifts from being a net exporter to being a net importer (Figure 3.6). Unlike in the case of DE, industrial minerals and metal ores account for the majority of imports and exports in this sector. The main single contributors to imports nowadays are iron and steel (as raw materials or in the form of processed goods). Imports of these materials have more than doubled between 1980 and 2004, which is coherent with the decline of their domestic extraction. We are again facing with the displacement of environmental loads to other countries.

Figure 3.6 Minerals: domestic extraction (DE) and imports (1980–2004)



Source: own calculations

4. CONCLUSIONS

A number of conclusions concerning the relationship between the Spanish economy and its surrounding environment can be drawn from this analysis. Firstly, despite structural change and dynamic income growth, the Spanish economy has shown no signs of dematerialisation in neither relative nor absolute terms. On the contrary, the total mass of material moved by the Spanish economy (i.e. DMI = domestic extraction plus direct material imports) increased 2,8 times from 1980 to 2004, whereas GDP increased 2 times. Thus, Spain's trend towards convergence of income per capita within the European Union is matched by its "race to the top" in terms of materials.

The relation between material use and GDP clearly shows that Spain increases material consumption not only in absolute terms but also per unit of economic output. No inflection point is foreseen in the short term. Material intensity (DMC/GDP) has increased. Therefore, Spain locked itself into a technological pattern of increased use of materials.

Secondly, domestic extraction (DE), consumption (DMC) and material input (DMI) in the economy has evolved in line with the economic cycles. The growth of construction materials is comparatively remarkable as also the increase in energy materials (despite the decline of domestic coal extraction).

Thirdly, the Spanish economy has become increasingly dependent on international trade. Imports are more than twice as much as exports in terms of weight. Net imports (X-M) increased 2.2 times in the period under analysis. In other words, Spain was using more and more natural resources from other economic systems to increase its welfare displacing environmental loads to other countries. The dependence on energy imports has been a key characteristic of the Spanish economy. Also, metals that used to be domestically produced are now imported.

As aforementioned, the quantitative analysis performed here does not deal with qualitative aspects of material flows such as toxicity. In this sense, MFA should not be seen as a comprehensive assessment of the environmental impact of an economy. However, it is clear that the increase in material flows reveals an increase in the consumption of internal and external resources, some of them causing high environmental impacts during extraction, transport, use or waste disposal.

Other environmental indicators show trends that are similar to the MFA. For example, CO_2 emissions rose from 5.43 in 1980 to 9.35 metric tonnes CO_2/person in 2000 (INE 2007a), an increase of almost 72%. The importance of the construction sector in material flows is also seen in other indicators, such as the number of finished houses and flats constructed per year, which doubled (it increased from 368 thousand to 740 thousand dwellings) between 1994 and 20004 (INE 2007b). In addition, the importance of the construction sector can be shown by the comparatively rapid rates of soil sealing in Spain. Between 1987 and 2000, soil sealing in Spain has increased 29.5%, including soil sealing for new transport infrastructures (Observatorio de la sostenibilidad en España 2006).

Therefore, this paper should be seen as one of the first attempts to analyse the Spanish economy in terms of material use. Further improvements should be done by exploring the relationship between MFA and assessment of environmental impacts. Definite conclusions on historical trends would need an analysis of broader historical data as well as further evidence from socio-economic, political and technological fields that allow explaining the interrelated dynamics between material flows and the socio-economic system.

Our finding that Spain has not reached in 2004 a stage of “weak dematerialisation” should not be construed as agreement on our part to the use of environmental indicators based on intensive variables such as energy intensity or carbon emissions intensity or volume of transport relative to GDP or indeed material intensity (materials per unit of GDP). The environment so to speak, does not care about GDP.

CHAPTER 4

MATERIAL FLOWS IN LATIN AMERICA: A COMPARATIVE ANALYSIS OF CHILE, ECUADOR, MEXICO AND PERU (1980-2000)[1]

ABSTRACT

In this chapter we compare the resource flows of Chile, Ecuador, Mexico and Peru between 1980 and 2000. Our objective is to analyze the structure of social metabolism of extractive countries and the consequences of the neo liberal economic structural reforms on the use of natural resources. In two decades, the domestic extraction of materials increased considerably in the four countries, mainly due to the mining sector in Chile and Peru, biomass and oil in Ecuador and construction minerals in Mexico. Imports and exports also increased, because of the deeper integration in international markets, prompted by liberalization policies implemented in the four countries between the late 1970s and the late 1990s. All four countries had a negative physical trade balance for most of the period analyzed, with exports exceeding imports in terms of weight. However, parallel growth of imports reduced the physical deficit in Chile, Mexico and Peru. Ecuador's physical deficit was the highest and did not decrease during the last two decades. A diversification of exports away from bulk commodities could be observed in Chile and Mexico, and to a lesser extent in Peru, whereas in Ecuador the export sector remained mainly based on oil and biomass. More research is needed to explore the environmental and social impacts of the neo liberal economic reforms Also, the indirect flows associated with direct physical imports and exports deserve to be subject to further analysis.

Keywords: *physical accounting, material flows, social metabolism, extractive economies, material intensity*

---

[1] This chapter is the amended version of a forthcoming paper accepted in the *Journal of Industrial Ecology*. The full reference is: Russi, D.; Gonzalez-Martinez A.C,; Silva-Macher, J.C., Giljum, S,; Martínez-Alier, J.; Vallejo, M.C. (2008). Material Flow Accounting in Chile, Ecuador, Mexico and Peru (1980-2000). *Journal of Industrial Ecology*.12 (5).

1. INTRODUCTION

Between the late 1970s and the early 1990s, a set of neoliberal reforms was implemented in the majority of Latin American countries. The main cornerstones of these reforms were privatization of public enterprises, reduction of public expenditure and progressive opening of the economy to foreign investment and international trade. These policies and their consequences have already been extensively analyzed using economic and social indicators; see, for example, Herzer and Nowak-Lehnmann (2006), Dussel (2002), Pascó-Font (2000). However, the effects on the biophysical dimension were mostly neglected by economists.

A particularly helpful methodology for investigating patterns of biophysical change is Material Flow Analysis (MFA), which assesses flows of materials through socio-economic systems. This methodology is based on the concept of *social metabolism* (Fischer-Kowalski and Hüttler 1998). According to this approach, an economy in a biophysical sense is seen in analogy to an organism, which extracts high quality materials and energy from the environment, processes them and then returns them back to the environment as low quality residues.

Material flow indicators have been regarded as pressure indicators and express a potential for environmental impact. In fact, materials must be extracted and processed in order to produce goods that are then transported, exchanged, used and, finally, discharged. Environmental pressures are associated to all these activities.

Accounting for physical flows already has a long intellectual history (Fischer-Kowalski 1998; Fischer-Kowalski and Hüttler 1998) and has been applied to most industrialized countries (Adriaanse *et al.* 1997, Matthews *et al.* 2000, Weisz *et al.* 2006). More recently, the methodology of material flow accounting was used to discuss the social metabolism of some Latin American countries (Fischer-Kowalski and Amann 2001, Amann *et al.* 2002, Giljum 2004, Gonzalez-Martínez 2007, Pérez-Rincón 2006, and Vallejo 2006).

This chapter provides the first comparison of material flows in four selected Latin American countries, for which MFA data are available. On the one hand, Chile and Mexico, two of the largest economies in the subcontinent and part of the group of upper-middle income economies; on the other hand, Ecuador and Peru, two countries that are considered to be of lower-middle income level (WB 2007). Historically, the four countries have shared a common pattern: their economies have been based on an intensive extraction of natural resources.

Therefore, our objective is to analyze the structure of social metabolism of extractive countries. Bunker (1985) introduced the term "extractive economies". According to Bunker, capitalism produces a polarization between extractive economies – based on extraction of resources for trade- and productive economies- based on production of goods. The increasing flow of raw materials and energy from extractive to productive economies (from the periphery to the core of power) is responsible for the deterioration of natural resources in extractive economies together with an increasing vulnerability to world market price fluctuations. Similarly, Eisenmenger and Giljum (2007, p299) argue that extractive economies should be defined as those specialized in extracting resources for export rather than for domestic use.

We focus on the period 1980-2000 because of the availability of statistics. This period coincides with the implementation of the neo liberal structural reforms (early Eighties), freeing the access to natural resources.

By doing so, we will answer two related questions:

1) How did the development strategy of these four countries change towards increasing integration into world markets through international trade and what were the consequences for material flows in these countries?

2) Are the four analyzed countries moving along a path towards dematerialisation as a result of the economic reforms implemented? According to the dematerialisation hypothesis (Cleveland and Ruth 1998) countries tend to use less material in absolute terms *(absolute dematerialisation)* or at least per unit of economic product (*relative dematerialisation*) due to technological progress, which is in turn made possible by economic growth.

Furthermore, we aim to empirically evaluate different theories, which link natural resource extraction and export to economic growth and development prospects, such as the "staple theory of economic growth" (Altman 2003; Innis 1930, 1949) or the theory of the "deterioration of terms of trade" (Prebisch 1952).

Chilean, Ecuadorian, Mexican and Peruvian social metabolisms were analyzed thoroughly in Giljum (2004), Vallejo (2006), Gonzalez-Martinez (2007) and Silva-Macher (2007). MFA indicators for the first three countries were mainly built using information from national institutions and statistics. Where necessary, data sets were complemented with statistics from international organizations. The MFA dataset for Peru is solely based on international sources.

Nevertheless, the data sets are highly comparable, because all four country studies applied the standard methodology for economy-wide MFA published by the European Statistical Office (Eurostat 2001). The main material indicators used are:

- **Domestic Material Extraction (DE)**: Raw materials extracted within national borders.
- **Direct Material Input (DMI)**: **DMI = DE + imports**. DMI comprises all materials that enter the economy for further use, either in production or consumption processes.
- **Domestic Material Consumption (DMC): DMC= DMI - exports**. DMC provides information on the quantity of the materials that remain within the national territory.
- **Physical Trade Balance (PTB)**: **Imports – exports**. The PTB reveals whether a country is net-importer or net-exporter in physical terms.

It is important to emphasize that only inflows that are used in the economy namely *used flows*, are taken into account, leaving out the *unused extraction*, i.e. those materials that are moved without intention of using them in the economy (e.g. overburden from mining).

The main material categories considered in this analytical framework are: biomass, fossil fuels and minerals. A fourth category, “other industrial products”, comprises final goods that have not been included in one of the other material categories.

The chapter is structured as follows. Firstly, we provide an overview of the main physical, social and economic features of the four Latin American countries. Secondly, we analyze material use in these four economies, putting special emphasis on physical trade balances; and, thirdly, we illustrate the different material intensities of imports and exports. Finally, we provide a discussion of the results and draw our conclusions.

2. COUNTRIES OVERVIEW

Table 4.1 provides an overview on the main structural indicators for the four Latin American countries. In order to compare the data with those of an industrialized region, we additionally list data for the EU-15. This region was selected as it is the only one for which MFA for the period of 1980 to 2000 exists[2]. Total area and population vary greatly among the four countries. Mexico is the largest and most populated country and Ecuador the smallest and least populated one. All four Latin American countries are by far less densely populated than Europe, as their geography includes large deserts, mountain ranges and tropical forests and they developed through a much shorter agricultural history than Europe. Final energy use per capita is also significantly lower in these Latin American countries than in the EU-15. European population on the average uses more than twice the energy per capita than Chile, which has the highest energy use per capita among the four countries.

With regard to economic indicators, Mexico has the largest volume of economic activity, both in absolute and per capita terms. Still, the per capita income in the EU-15 is much higher. When expressing GDP per capita using Purchasing Power Parities (PPP), the Chilean economy increased markedly in the period under analysis and surpassed

[2] Schematically, EU-15 is a sample of “Northern countries” whereas Chile, Ecuador, Mexico and Peru belong to the “Southern” group of countries.

average Mexican income in 1995 (see Figure 4.1). By 2000, the Chilean GDP per capita in PPP was the highest (9,115 US$), followed by Mexico (9,046 US$).

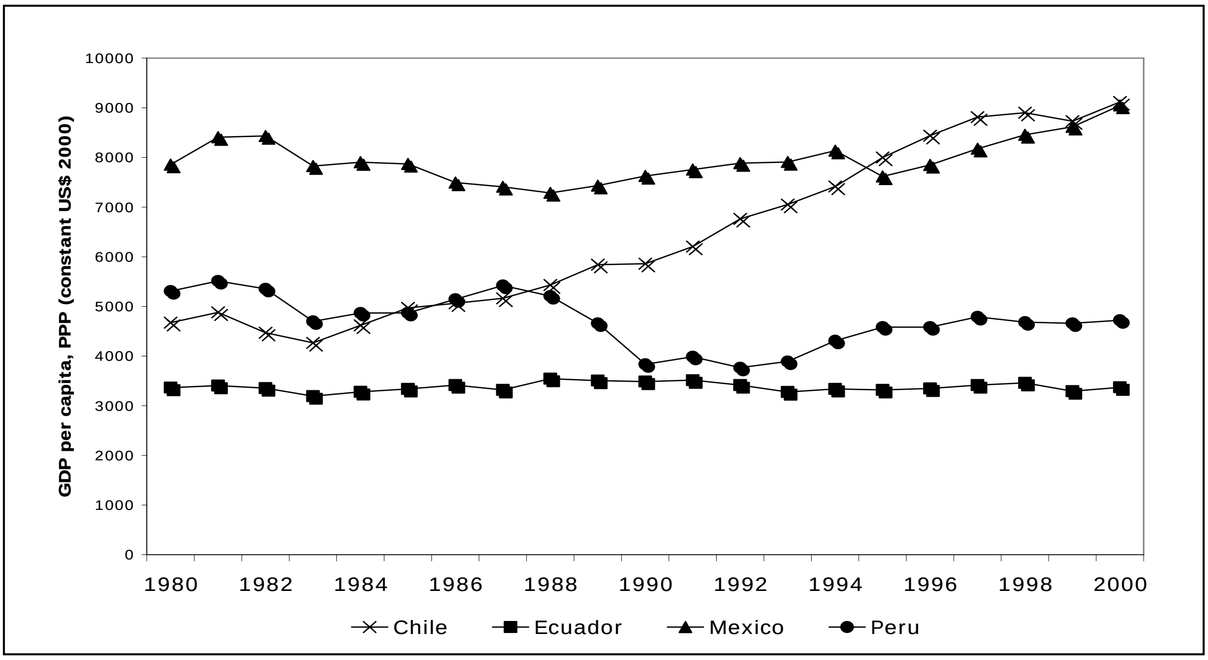
Another relevant feature of the four countries is the high income inequality: the richest 10% of the population hold between one third and one half of the total income, while in EU-15 the wealthiest 10% hold only one fourth of total income.

Table 4.1 Structural parameters, 2000

Year 2000	Population	Population density	Area	Energy use per capita	GDP	GDP per capita	Income share held by highest 10%
	Thousands	inhab/km^2	km^2	toe per capita	Million USD	USD/inhab	%
Chile	15,412	20.4	756,630	1.68	75,775	4,917	47.0%
Ecuador	12,306	43.4	283,560	0.68	15,942	1,295	41.6%
Mexico	97,966	50.0	1,958,200	1.53	581,426	5,935	41.7%
Peru	25,952	20.2	1,285,220	0.48	53,086	2,046	35.4%
EU-15*	376,462	116.1	3,242,601	3.90	7,965,639	21,159	25.2%

Source: World Bank 2007, (*) Eurostat 2002

Figure 4.1 GDP per capita evolution in Chile, Ecuador, Mexico and Peru. 1980-2000 (PPP, constant US$ 2000)



Source: World Bank 2007

As a result of a regional economic crisis in the 1980's, characterized by economic stagnation, high rates of inflation, net capital outflows and a huge external debt, important structural reforms were applied in Latin America. These reforms mainly consisted of a progressive opening of the economies to foreign capital and international trade and an increasing privatization of crucial sectors, such as infrastructures, energy and education.

Chile was the first country in Latin America to adopt a market-oriented set of policy measures in 1974. The reforms deeply modified an economy which had been mainly based on import substitution and protectionism (the average tariff rate was almost 100 per cent). One of the main objectives of the military regime was to fuel economic growth through an increase in exports, stimulated by a strong devaluation and a drastic reduction of trade tariffs. Earnings from exports rose and also a diversification of exports took place: the relative importance of copper as the main export product decreased from 80% to 40% (in monetary terms) between 1973 and 2000. In the 1990's, Chile signed several free trade agreements with Canada, the United States, Central American and Mercosur countries.

After Chile's reforms started to bear fruit in terms of economic growth, neoliberal policies were fully embraced also by other Latin America countries. Mexico, after a period of devaluation, hyperinflation and economic collapse (-0.6% GDP growth rate in 1982 and an additional -4.2% in 1983), implemented a neoliberal economic program in 1988. Also in 1986, Mexico inaugurated a set of policies aimed at stimulating free trade joining GATT (the General Agreement on Tariffs and Trade). Since then, it signed 12 trade agreements with 43 nations putting 90% of its trade under free trade regulations. The most important trade agreement has been established with the United States and Canada (North American Free Trade Agreement- NAFTA), allowing trade to triple in monetary terms since NAFTA was ratified in 1994. Today, almost 85% of Mexico's exports are delivered to the United States, making the Mexican economy highly dependent on the economic cycles in the US.

In Peru, president Fujimori introduced a neoliberal reform package to alleviate the economic crisis of 1988-90, when GDP decreased by 20% and the accumulated inflation rate was 4,778% in 1990, partly caused by internal armed unrest (Diaz *et al.* 2000). Beginning in 1990, trade reforms gradually reduced import tariffs. Also, the export sector was promoted through elimination of export tariff duties. As a result, exports grew in monetary terms by 80% between 1990 and 1997.

Ecuador, later than other countries in the region, implemented market-oriented reforms in 1992. The 'Stabilization Plan' restructured the economy towards liberalization of trade and capital flows. During the 1980's, adjustment policies were focused on short-term stabilization rather than structural change (Taylor and Vos 2000). As a result, inflation reached historical rates (75%) in 1989 and fiscal and current accounts registered high deficits, which the government tried to reduce by means of stabilization reforms.

The results of these reforms were not homogeneous. Clearly, Chile saw its economy and standard of living boosted (see Figure 4.1), while Mexico, Peru and Ecuador were not able to sustain a similarly dynamic growth. Nevertheless, in Latin America, economic growth did not translate into a more equitable income distribution.

One main reason is that growth in Latin American became more technology- and skill-intensive in 2000 than it was in the past (Morley 2000). Therefore, the positive effects of market opening were concentrated in capital-intensive industries with high productivity such as those processing natural resources, and the automotive and electronic industries. By comparison, labour-intensive industries producing final consumption products were negatively affected (Katz 2000).

3. RESOURCE USE IN CHILE, ECUADOR, MEXICO AND PERU

The economic development of Latin American countries and their specialization pattern on international markets have clear consequences for the social metabolism. Chile's material input of more than 46 tonnes per capita in the year 2000 was among the highest in the world (see Behrens *et al.* 2007). For instance, in the same year in Finland, the country with the highest per capita material input in Europe, DMI was 42 tonnes per capita (Eurostat 2002). Ecuador shows the lowest indicators, while Peru and Mexico are situated in between (see Table 4.2).

Table 4.2 Indicators of material use (tonne per capita) in 1980 and 2000

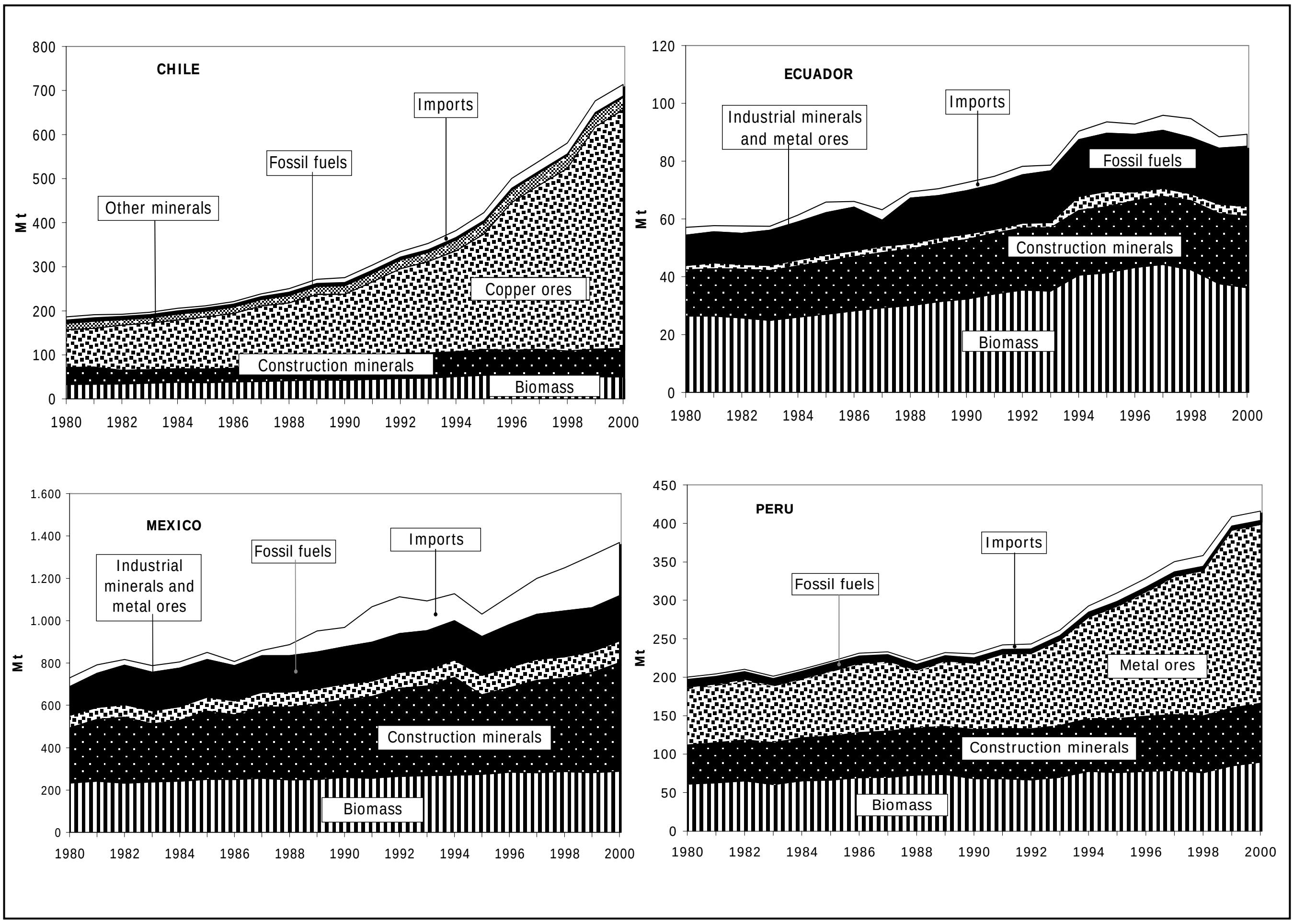
	Domestic Extraction (DE)		Imports (I)		Domestic Material Input (DMI): DE + I		Exports (E)		Domestic Material Consumption (DMC): DMI - E	
	1980	2000	1980	2000	1980	2000	1980	2000	1980	2000
Chile	16.0	44.6	0.7	1.7	16.7	46.3	1.2	1.8	15.5	44.5
Ecuador	6.8	6.9	0.3	0.3	7.2	7.3	1.1	1.6	6.1	5.6
Mexico	10.2	11.4	0.6	2.6	10.8	14.0	1.2	1.6	9.6	12.3
Peru	11.4	15.6	0.2	0.5	11.6	16.0	0.6	0.5	11.0	15.5
EU-15 *	13.8	13.0	3.1	3.8	16.9	16.8	0.8	1.1	16.1	15.6

Source: Giljum 2004, Vallejo 2006, González-Martínez 2007, Silva-Macher, 2007 (*)Eurostat 2002

3.1 Direct Material Input

Figure 4.2 shows the Direct Material Input (DMI) of the four selected countries, with breakdowns by type of material flow. DMI includes all materials entering the economy for use and is obtained by adding up tonnes of domestic extraction and tonnes of imports. The DMI of the four countries increased between 1980 and 2000, although at very different rates. Most of the increase was due to intensified domestic extraction, while imports provided a growing but still small share. Only in Ecuador, the import share did not increase in the last twenty years.

Figure 4.2 DMI in Chile, Ecuador, Mexico and Peru 1980-2000 (million tonnes)



Source: Giljum 2004, Vallejo 2006, González-Martínez 2007, Silva-Macher 2007

Chilean DMI rose from 186 million tonnes in 1980 to 700 million tonnes in 2000. This is mainly explained by the high rate of metal ore extraction (in particular, copper), which increased more than threefold. In 1980, ores represented 50% of DMI while in 2000 their share rose to 78%. Construction minerals rank second (9%), followed by biomass (7%).[3]

The Peruvian DMI only increased at a low rate between 1980 and 1992 because of severe economic recession. After 1993, the slope of DMI was steeper as a consequence of President Fujimori's neoliberal policies and the end of the armed unrest in 1992. Like

[3] The high share of minerals in DMI can be explained by the very low extraction ore grades for copper, see below.

Chile, Peru is an economy based on mineral extraction (Kuramoto and Glave 2002). Growing material input in Peru is driven by the domestic extraction of metal ores such as gold, silver, copper, zinc and lead. The ore extraction share of DMI increased from 30% in 1980 to 55% in 2000 (the accumulated growth rate was 145%).

Ecuador has negligible metal ore production but it is a substantial exporter of crude oil (23% of DMI in 2000). In terms of weight, the Ecuadorian economy is mainly based on biomass (bananas and sugar cane), which accounted for 43% of DMI in 2000 (accumulated growth rate was 37%). The second main flow was construction minerals (28%), followed by fossil fuels (23%). The share of imports in Ecuador's DMI is very small.

Among the four countries, Mexico is the economy with the highest absolute DMI, due to its large territory and population. Between 1980 and 2000 DMI increased unevenly, although the general trend was upwards. A different DMI composition is observed if compared to the other three countries: as a result of building-up infrastructure and related construction activities, construction minerals are the main material flow (42% share of DMI in 2000) followed by biomass (24%), mainly animal fodder. Fossil fuels rank third (18%). In addition, Mexico shows the highest imports share in DMI, which considerably increased during the last two decades due to trade liberalization.

The increase in material extraction has both environmental and social consequences. In Chile copper mining takes place in largely uninhabited regions and thus social conflicts rarely appear. However, in Peru, mining conflicts arise regularly due to the proximity to populated areas, as pollution and the intensive use of the scarce water resources directly affect the local population. In Ecuador, there are complaints because of environmental liabilities of oil and gas extraction in the Amazon. The distinction between 'preciosities' (high economic value per unit of weight) and 'bulk commodities', introduced by Wallerstein (Hornborg *et al.* 2007; Wallerstein 1974, 1980, 1989), is relevant here. Conflicts might arise against gold mining, as was the case of the successful resistance movement in Tambogrande (Piura, Peru) because of the threats of local pollution. However, for the importing countries' metabolism, imports of refined gold matter little when compared for instance to crude oil or copper.

3.2 Trade balances

In the MFA method, the physical trade balance (PTB) is the most widely used indicator to analyze biophysical aspects of international trade. The PTB is calculated as the inverse of the monetary trade balance (MTB), i.e. by subtracting exports from imports. In the PTB, we only included direct flows, i.e. direct weight of imports and exports. A summary of the data referring to international trade is presented in Tables 4.3 and 4.4

Table 4.3 Physical and monetary trade per capita, 1980

	Imports		Exports		Trade Balances	
	Tonnes	$ (*)	Tonnes	$ (*)	PTB (imp.-exp.), tonnes	MTB (exp.-imp.), $
Ecuador	0.3	283	1.1	312	-0.8	29
Peru	0.2	149	0.6	191	-0.4	42
Chile	0.7	458	1.2	410	-0.5	-48
Mexico	0.6	290	1.2	229	-0.6	-61
EU-15	3.1 (**)	1,060	0.8 (**)	868	2.3	-192

Source: (*)UN 2007 ; (**) Eurostat 2002 ; (+) Eurostat 2007

Table 4.4 Physical and monetary trade per capita, 2000

	Imports		Exports		Trade Balances	
	Tonnes	$ (*)	Tonnes	$ (*)	PTB (imp.-exp.), tonnes	MTB (exp.-imp.), $
Ecuador	0.3	280	1.6	392	-1.3	112
Peru	0.5	286	0.5	265	0	-21
Chile	1.7	1,078	1.8	1,182	-0.1	104
Mexico	2.6	1,780	1.6	1,696	1	-84
EU-15	3.8 (**)	2,514 (+)	1.1 (**)	2,297 (+)	2.7	-218

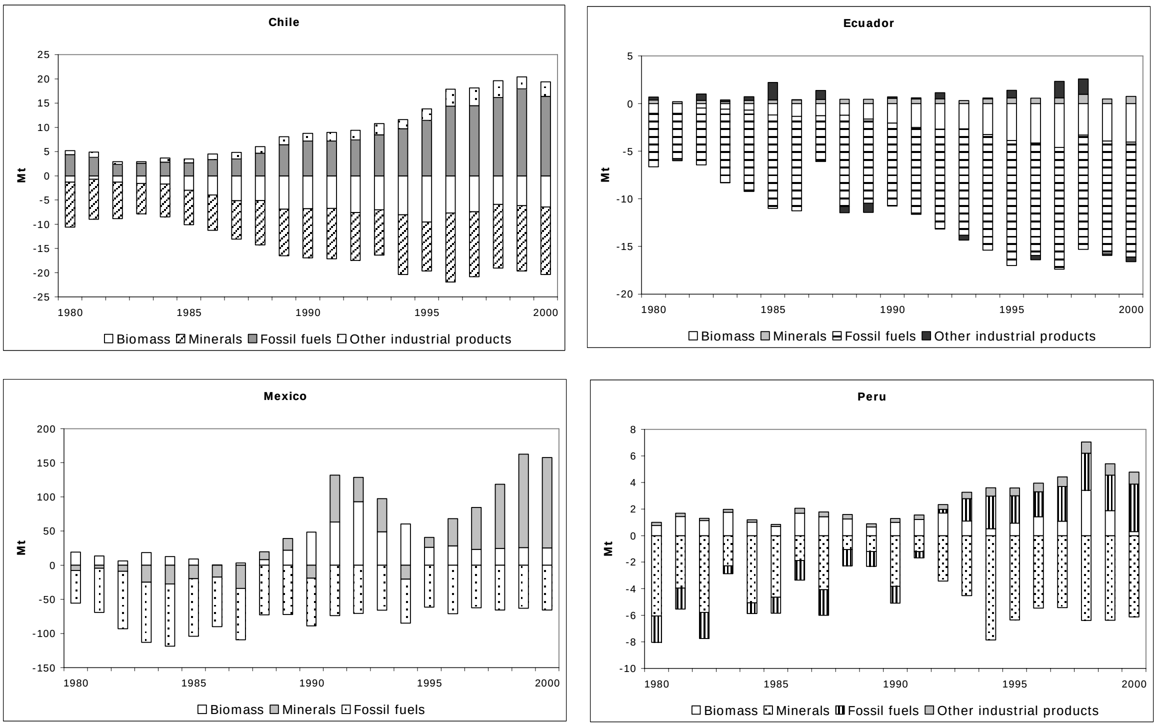
Source: (*)UN 2007 ; (**) Eurostat 2002 ; (+) Eurostat 2007.

The physical trade balance of the four countries was in deficit in 1980 and more goods were exported than imported. As a consequence of the liberalization policies and the opening of the domestic economy, the four countries became increasingly integrated in international trade between 1980 and 2000. In particular, imports per capita increased more than exports in Peru, Chile and Mexico, whereas in Ecuador an opposite trend could be observed.

In the EU-15, imports per capita are almost three times higher than exports in terms of weight. European imports per capita were already 4 to 16 times higher than those of the four analyzed countries in 1980, and the gap became more pronounced in the following years, leading to an increasingly positive physical trade balance in the EU-15. In other words, the EU is a net importer and relies on resources from other parts in the world. Figure 4.3 shows a detailed picture of PTB in absolute terms, disaggregated in the four macro-categories: biomass, minerals, fossil fuels and other industrial products.

The PTB of Chile, Peru and Ecuador were negative for most of the analyzed years. However, in Chile and Peru imports grew faster than exports, and the PTB became more balanced from 1994 on, despite remaining negative most of the period. On the contrary, in Ecuador, exports grew faster than imports, leading to an increasingly negative PTB. The increase in imports was particularly dramatic in Mexico, resulting in a positive physical trade balance in the last decade (with the exception of the years between 1994 and 1996, when a severe economic crisis abruptly reduced the imports).

Figure 4.3 Physical Trade Balance (PTB) in Chile, Ecuador, Mexico and Peru 1980-2000 (million tonnes)



Source: Own calculations with data from Giljum 2004, Vallejo 2006, González-Martínez 2007, and Silva-Macher 2007

Chile was a significant net exporter of minerals and biomass at the beginning of the analyzed period. In Chile, even though the government carried out a policy of export diversification, in 2000 exports were still largely dominated by copper and other mining products (52% in terms of weight). Another 37% of Chilean trade in terms of weight was made up of biomass and biomass products. In addition, a dramatic increase in net fossil fuel imports could be observed in particular in the 1990s, driven by rapid economic growth. As a consequence, fossil fuels were the most important import category in terms of weight (70% in 2000). Consequently, a reduction of the physical deficit could be observed from 1994 on, leading even to a positive PTB in 1998 and 1999. However, this picture would change, if the indirect material flows associated with imports and exports were also considered. Some studies of Chile's external trade (Giljum 2004, Munoz and Hubacek 2007) illustrate that in particular the production of concentrated metals require huge amounts of primary materials and processing energy. As a result, waste and emissions related to the production of exports remain in Chile, while the refined products are exported.

Peru was a net exporter of minerals and a net importer of biomass during the whole period. At the beginning of the 1990's, Peru turned from a net oil exporter into a net oil importer. In 2000, 55% of exports in terms of weight consisted of minerals and ores (27% of which were iron ores and concentrates), 18% of fossil fuels and 27% of biomass (mainly fishmeal). In the same year, imports were mainly composed of fossil fuels (49%) and biomass (33%, mainly wheat and flour). Like in Chile, a reduction of the physical deficit could be observed from 1994 on. In fact, between 1980 and 2000 Peruvian imports dramatically increased from 3.0 to 12.2 million tonnes but exports grew modestly from 10.0 to 13.5 million tonnes. However, the physical deficit of Peru will increase again as soon as the Camisea gas project (with reserves of about 390 million TOE) will be completed.

Ecuador showed a high and increasing material deficit due to the booming export of crude oil. Also, Ecuador was a net biomass exporter for the entire period. In 2000, fossil fuel products accounted for 60% of total exports in terms of weight. Agricultural and fishery products accounted for 24%, whereas imports were dominated by industrial products (64%). Ecuador is by far the smallest among the four analyzed countries both in terms of territory and population (see Table 4.1) but its physical deficit was the highest. The reason can be found in the low economic growth, which is connected to low imports, whereas exports increased considerably in terms of weight due to the specialization in raw materials (oil and biomass products).

Mexico was a net exporter of fossil fuels and a net importer of biomass and metallic final products. In 2000, 58% of its exports in weight were represented by crude oil, 16% by non-metallic materials including construction materials and 10% by biomass. As regards imports, 12% were fossil fuels, mainly refined oil and basic petrochemical products. Imports were dominated by finished products (56% of total imports), including the assembly parts for the 'maquila' industry.[4]

[4] The term "maquila" is a medieval Spanish word that indicated the practice of bringing grain to a miller and paying him with part of the obtained flour (the "miller's portion", or "maquila"). Nowadays, this term is used

Although the maquila industry started at the end of the 1960s, it was not until the 1990s that it became a mass phenomenon, gaining relevance in the Mexican economy (Carrillo and De la O 2003). The components that cross Mexican borders to be assembled in the maquila industries are accounted as inputs, and were decisive for the remarkable increase in Mexican imports. However, the assembly industry has not had a spill over effect on the rest of the economy as they use cheap labor force and there is a delinking from the domestic suppliers as most of the assembly inputs are imported (De la Garza 2005).

The Mexican economy is different from the other three countries insofar as the dependence on exports of raw materials in the monetary trade balance decreased in the analyzed period (even though exports of raw materials increased in absolute values). Consequently, from 1992 to 2000, the Mexican PTB was positive. This can be explained by the 'hybrid' nature of Mexico, whose pattern of development places it between that of a typical Latin American economy (characterized by low GDP and abundance of natural resources)[5] and that of industrialized countries (based on strong industrial and service sector and a high dependence on imports for mineral ores, fossil fuels and other primary materials).

There has been a long discussion in Latin America about the negative consequences of exports of raw materials for economic growth. This is very much present in popular awareness (Galeano 1971). Sachs and Warner (2001) introduced the idea of the 'curse of natural resources', i.e. the fact that abundance of natural resources is often negatively correlated with economic growth.

Much before the proposal of the "resource curse", there had been debates on the relationship between natural resource exports and economic development. At one extreme, along the lines of the Sachs and Warner theory, there was the "enclave economy" view, of which Peru of the "guano age" (1880-1880) provided an example

---

to refer to the practice of subcontracting to produce or put together parts that will be used in other production processes.

[5] Mexico, despite the economic fluctuations, reached a certain level of industrialization and is nowadays considered as an advanced middle income country.

according to Levin (1960). The idea was that there were no linkages between the export sector and the national economy: the country came out of the period of guano exports with a much depleted resource, with a lost war with Chile over the nitrates of Tarapacá, and more indebted than ever (Martinez-Alier 2002). At the other extreme, the optimistic conclusions drawn from Harold Innis' analysis of exports from Canada (Innis 1930, 1949; Altman 2003), have given rise to a so-called "staple theory of growth". In this view, exports of resource-rich economies could lead to growth and economic development. Examples for this type of development are Canada, Australia, and Argentina (until the mid-1920s).

The Sachs and Warner thesis holds true for Ecuador for the whole period analyzed and for Peru in the 1980's, but it does not provide an appropriate analysis for Chile and Mexico. The economy of Chile could instead be regarded as a successful example of Innis' 'staple theory of growth' at least as long as copper reserves of good quality can be exploited and copper prices on world markets remain high.

3.3 Domestic Material Consumption and resource intensity

Domestic Material Consumption (DMC) provides information about the quantity of materials that remain within the national territory. It is calculated by subtracting direct physical exports from Direct Material Input (DMI). Considering that the materials accumulated will turn into emissions and waste at some point in the future, DMC has recently been proposed as an indicator of *potential waste* (Weisz *et al.* 2006). DMC reflects the size of the industrial production (intermediary consumption) and final domestic consumption.

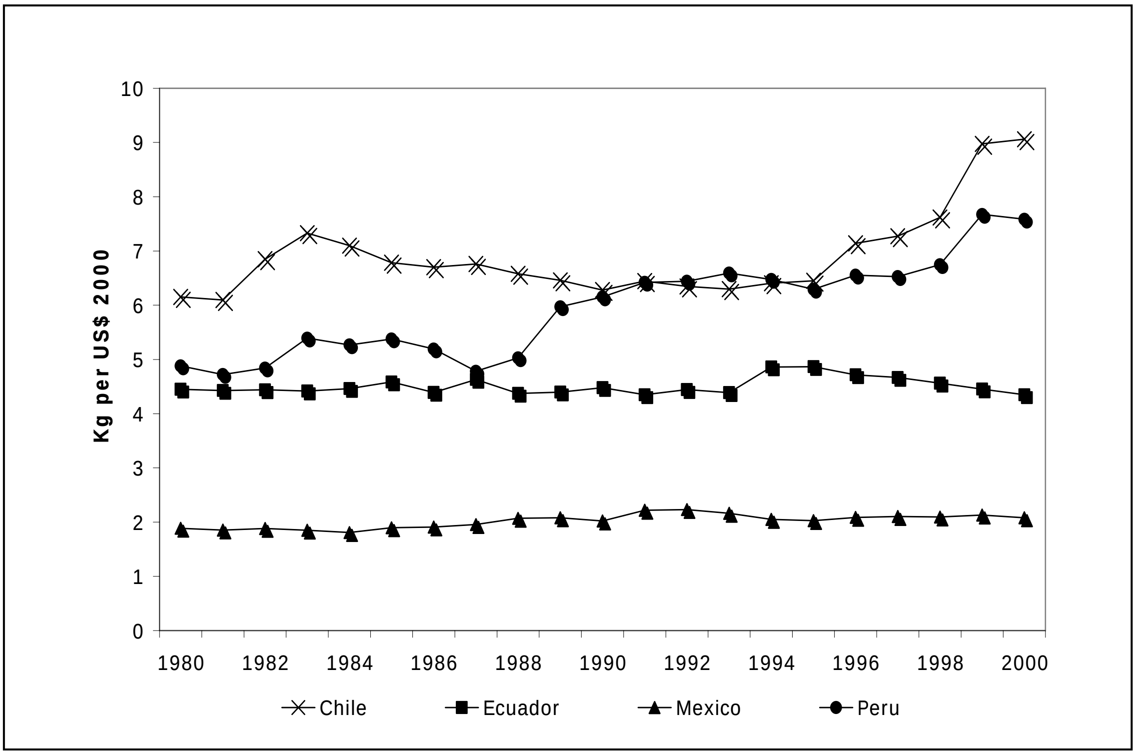
DMC per capita in the four countries increased between 1980 and 2000 (see Table 4.2). In particular, Chile had the highest DMC per capita in 1980 (15.5 tonnes), close to the EU-15 average by then. By 2000 the DMC of Chile increased by a factor of three. By contrast, Ecuador had the lowest DMC in 1980 (6.1 tonnes), and by 2000 it even decreased to 5.6 tonnes, which might be related to a decrease in material standards of living. When compared to a global average of resource consumption in 1999 of 8.5 tonnes per capita (Schandl and Eisenmenger 2006), only Ecuador is below the average, because of a low level of economic development, while the other Latin American economies show much higher levels.

DMC per capita can give a misleading indication of an average standard of living particularly in economies based on mineral extraction, like those of Chile and Peru. In fact, in these economies an important share of DMC ends up as waste of the mineral industry. For instance in Chile, where copper represents a large share of domestic extraction, copper is mined at a very low extraction grade of around 1%, whereas the highly concentrated copper metal is exported. Therefore, large quantities of ancillary copper mineral, the part of the used extraction that ends up as waste along the concentration process, remains within Chile's borders. By definition, it is part of Chile's DMC, but is only 'consumed' by the Chilean mineral industry. Giljum (2004) showed that if the quantity of ancillary copper minerals is subtracted from DMC, the remaining material consumption actually grew at a very slow rate.

We relate DMC to GDP to assess the material intensity of an economy. In Latin America, two different trends can be observed (see Figure 4.4). Economies based on mineral extraction use a great amount of materials per unit of GDP. For instance Chile in 2000 required 9 kg of matter to produce one dollar of GDP and Peru nearly 8 kg. By contrast, the material intensity of Ecuador and Mexico were lower, although at different levels. Mexico shows the most favorable resource intensity of the four countries with 2 kg of materials used per US$ produced. Ecuador used twice as much material per US$. The Mexican economy is the most material-efficient among the four analyzed countries. Nevertheless, the four countries are by far above the EU-15 material-efficiency level, which was 1.2 kg/$ in 1980 and improved to 0.8 kg/$ in 2000.

While resource intensity has been stable in Mexico and Ecuador, Chile and Peru were characterized by a re-materialization process, and both countries showed an upward trend in their material intensity curves, indicating an undesirable development since less GDP is generated with more materials. Peru in particular, increased its material intensity significantly and was catching up with Chile in the 1990's. This trend is explained by the extension of material intensive mining activities. Also in the case of Peru, once the metal ores are excluded from DMC, per capita figures remain almost constant over the period (3 tonnes in 1980 and 3.2 tonnes in 2000).

Figure 4.4 Resource efficiency in Chile, Ecuador, Mexico and Peru 1980-2000 (kg per US$2000)



Source: Own calculations with data from Giljum 2004, Vallejo 2006, González-Martínez 2007, Silva-Macher 2007 and WB 2007

In Mexico, despite structural change and the increasing importance of industrial products, material intensity did not decrease in the period 1980-2000. This may be due to the fact that only some specific sectors such as the electronic and the automotive industries went through a process of technological change, while the rest of the economy did not reduce their material intensity[6].

3.4 Material intensities of imports and exports

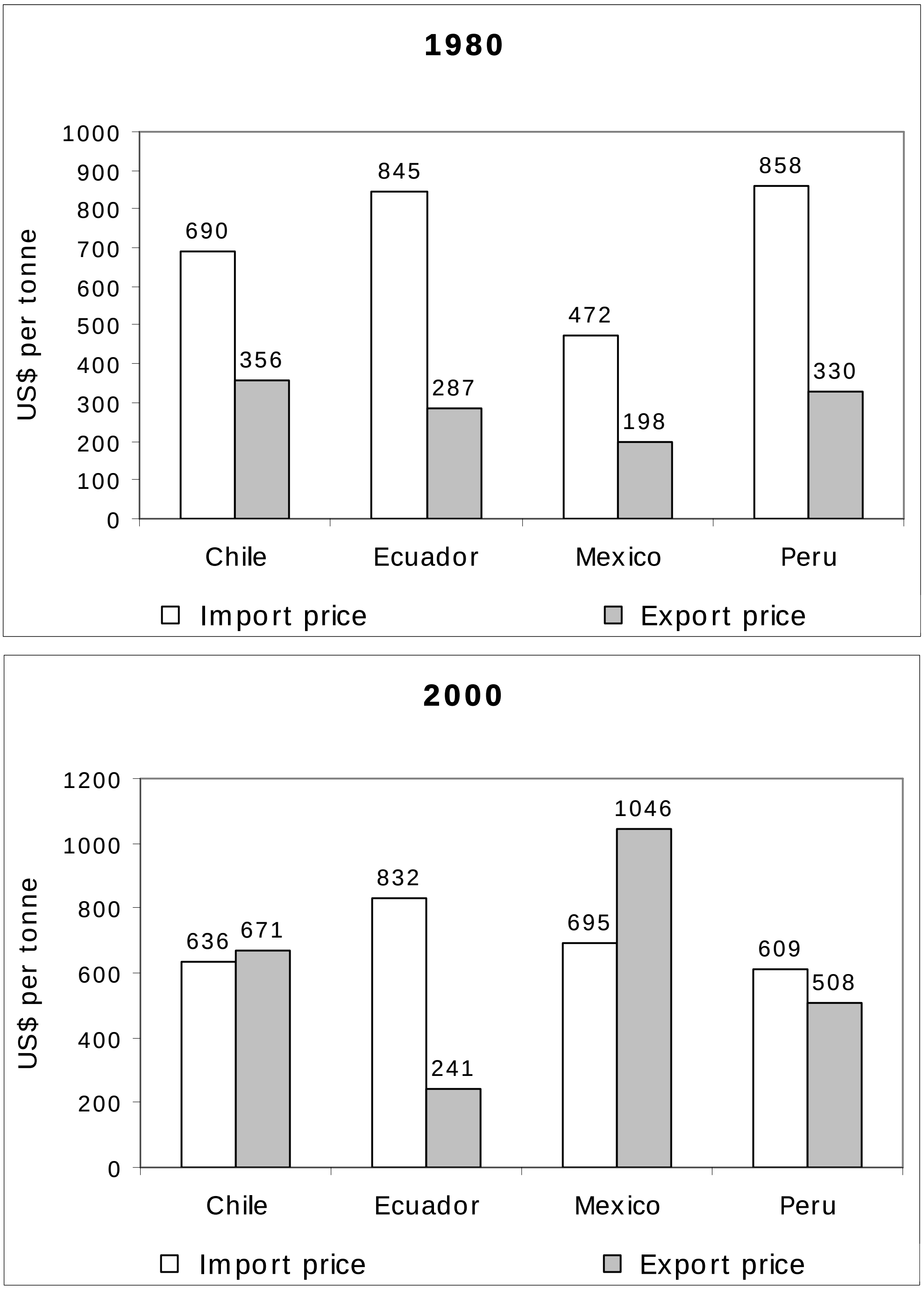
A physical trade analysis reveals that the four countries were net exporters of materials during most of the period. This is not directly reflected in the monetary terms of trade. Chilean monetary trade balance (MTB; exports minus imports) was positive until 1992 and fluctuated thereafter, mainly due to price changes on raw material markets and increasing expenditures on fossil fuel imports. Ecuadorian MTB was positive during most

[6] However, in order to have a complete picture of the overall material intensity of an economy, the unused material flows should be measured and included in the analysis.

of the analyzed period due to crude oil exports and raising prices at international oil markets. If these exports had been absent, the MTB would have been negative during the entire period with the exception of the year 1999. The Peruvian and Mexican MTBs were negative most of the 1990s, due to the increasing imports of finished and semi processed products, and also oil imports in the case of Peru.

Another way of analyzing the position a country holds in the international division of labour is to calculate unit prices of imports and exports. Figure 4.5 compares the unit prices of imports and exports in 1980 and 2000. In 1980, the price per tonne of imports was considerably higher than that for exports in all four countries. They were importing capital intensive, high price commodities and exporting low value added primary commodities. However, this difference markedly decreased during the last two decades in Mexico, Peru and Chile, with the unit price of exports increasing faster than the price of imports. Still, in 2000, the price of an average tonne of import was higher than the price of an average tonne of export in Ecuador and Peru, but certainly not in Mexico. The case of Mexico is particularly remarkable, with the unit price of exports increasing from 198 $/tonne to 1,046 $/tonne. The main reasons for such a tremendous increase are structural changes and the diversification of exports, which significantly increased the share of industrial products in total exports (from 4% to 59% in monetary terms). The assembly industry played a key role in this process. In fact, in 2000 according to foreign trade statistics (BANCOMEXT 2002) the maquila share of exports was 47.7% of the total Mexican exports and 35.3% of the total Mexican imports in monetary terms, the latter including raw materials and semi-manufactured products for further processing and assembly.

Figure 4.5 Price per exported and imported tonne in Chile, Ecuador, Mexico and Peru 1980 and 2000 (US$ per tonne)



Source: Own calculations with data from Giljum 2004, Vallejo 2006, González-Martínez 2007, Silva-Macher 2007 and UN 2007

It is interesting to compare these Latin American data with European trends, where a reverse situation can be observed. In 2000, the EU-15 imported 3.4 times more materials than it exported, whereas the monetary trade balance was approximately balanced (Eurostat 2002). Also, the average price (1,559$) for an imported tonne in the year 2000 was about one third of the price (5,306$) for an exported tonne, both numbers being significantly higher than those for Latin America. This reflects the position of this industrialized region in the upper value added segment of the world market.

For Latin American countries, the relative prices of the commodities exchanged on international markets determine that the contribution of raw materials to the generation of added value is remarkably lower than their share in weight. The common pattern is that primary activities such as agriculture, forestry and mining extract large amounts of materials to obtain little added value. The mining sector's share of GDP in Chile is 8% (Banco Central de Chile 2007) and in Peru it was only 4.5% in 2000 (Ministerio de Economia y Finanzas de Peru 2007.) In Mexico, the importance of resource extraction-based activities in the production of added value is very small: the share of the whole oil sector (comprising oil extraction, refining and basic petrochemical) of the national GDP was only 1.3% in 2000 (INEGI 2007). In Ecuador, the biomass-related activities (agriculture, fishing, forestry) accounted for 10% of GDP on average. Banana production alone accounted for a comparatively large 2% of GDP. Fossil fuels, a strategic material flow in the Ecuadorian economy, provided only 13% of added value.

4. DISCUSSION AND CONCLUSIONS

We have compared trends in natural resource use in four Latin American countries, i.e. Chile, Ecuador, Mexico and Peru, between 1980 and 2000 to explore whether these economies follow a uniform pattern in natural resource extraction, trade and consumption. By comparing the economies in terms of material flows we have been able to identify characteristic structures and trends.

In the analysed period, domestic material extraction increased constantly in the four countries. The important role of the mining sector in the economies of Chile and Peru and the role of agriculture and crude oil extraction in Ecuador appears very clearly in the physical accounts. Similarly, although Mexico is an important oil exporter, material flow analysis reveals the very relevant role of construction materials caused by infrastructure projects and an increase in material standards of living reflected in construction activities.

MFA indicators shed light on the discussion on the 'deterioration of terms of trade' coined by the Argentinean economist Raul Prebisch (1952). His idea was that a unit of exports allows peripheral (extractive) countries to purchase lower and lower amounts of imports, leading to the vicious circle requiring increased amounts of commodity exports. This phenomenon may apply to some Latin American countries (see for example Pérez-Rincón 2006, for a recent study on Colombia). Many Latin American countries, with their comparably low population densities and rich natural resources seem to be among the regions, which provide resources, but economically gain comparably little by doing so (Bunker 1985, Eisenmenger *et al.* 2007).

These theories hold for Ecuador, with its main focus on crude oil and agricultural products. In Chile, Mexico and Peru they only held in the 1980's, when the price per imported tonne was much higher than the price per exported tonne. However, in the year 2000, this pattern changed in these countries, due to a diversification of exports and a subsequent reduction of the difference between the price per tonne of imports and exports.

The increase in material flows not only has an effect on the environment but also on the social situation, as a cause of environmental conflicts, as explained above. Also, the increase in extraction and exports of raw materials does not necessarily create economic growth. This may sometimes be the case, as in Chile, but in some other instances this equation does not apply. As a matter of fact, the economy of Ecuador did not grow between 1980 and 2000, despite the high and increasing exports of oil and biomass.

In the case of Chile and Mexico, and even Peru, there was a diversification of exports away from bulk commodities increasing the added value (and the price) per tonne of exported product. This development can be regarded as positive from a development point of view, as more added value is created within the domestic economy which should create employment opportunities and contribute to local household income. The environmental implications, on the other hand, largely depend on the applied production technologies and the environmental regulations in place. If produced with high environmental standards, then such a development path could be both economically and environmentally rewarding. However, diversification of exports can also be a blessing in disguise, when considering for example the pollution and health hazards deriving from the maquila industry in Mexico (Stromberg 2005).

One main and obvious conclusion of our analysis is that relative dematerialisation (decrease of the relation between use of materials and GDP) has certainly not occurred during the period of study. Further research is needed to investigate to what extent the re-location of resource-intensive productions outside the borders of industrialized countries is at the roots of the relative dematerialisation process taking place in many European countries (Adriansee *et al.* 1997, Weisz *et al.* 2006), as claimed for example by Rothman (1998). From this point of view, a careful and comprehensive analysis of the indirect flows associated with imports and exports is required, in order to attribute to the final consumers all natural resources required in the entire production chain (Weisz 2007).

CHAPTER 5

TRANSITIONS IN MIDDLE INCOME ECONOMIES:

BIOMASS USE PATTERNS AND THE IMPORTANCE OF FUELWOOD IN MEXICO

ABSTRACT

This chapter analyses the biomass flows of the Mexican economy in the last thirty three years by applying the material flow accounting methodology (MFA). Extraction and consumption of biomass in the national territory have continuously increased in absolute terms but have decreased in per capita terms. Biomass extraction per capita decreased more than domestic consumption whereas biomass imports rose considerably during the analysed period. These findings evidence a substitution process of imported biomass for national biomass, in particular, basic crops for human consumption. Undoubtedly, this fact poses problems for food security in the medium and long term. In addition, this paper discusses the importance of accounting for material flows arising from subsistence activities in rural Mexico, focusing on fuelwood. An estimation of the amount of fuelwood collected directly by rural users in the year 2002 is provided. It was three times higher than industrial timber production in the same year; evidencing the importance of such flows in physical terms and the need of including these flows in material flow accounting. Finally, the paper discusses the hypothesis that fuelwood use goes down as income grows.

Keywords: *Physical accounting, biomass flows, biomass imports, Mexico, fuelwood, energy ladder.*

1. INTRODUCTION

The term biomass can be defined as the set of non-fossil organic matter that composes an ecosystem. Biomass plays a fundamental role in the metabolism of societies as food supplier for sustaining human populations and animals and it is still the most important energy carrier for a large part of the population in the developing world. Biomass is also used as raw material in industrial processes or for construction. Simply, without the existence of biomass, societies could not exist, which is the reason why it is considered as an irreplaceable socioeconomic flow (Weisz *et al.* 2006).

Economic activities based on biomass extraction are agriculture, cattle rising, forestry, hunting and fishing. Certain forms of biomass extraction have important environmental consequences. For instance, modern agriculture, apart from being a human activity competing with other non human species for land occupation (Haberl *et al.* 2004), it degrades the natural resources on which it depends, as land and water. Besides, it creates a strong dependency on fossil fuels (Gliessman 1998:3). Cattle raising and tree plantations are related to deforestation, ecosystem degradation and biodiversity loss. Biomass demand is expected to grow considerably in the future due to the expected growth of global population (Lutz *et al.* 2004) and to the expected substitution of biomass for fossil fuels encouraged as a strategy to reduce greenhouse emissions (Malhi *et al.* 2008, OECD-FAO 2007).

The general objective of this article is to identify changes of biomass use patterns in the Mexican economy between 1970 and 2003. During this period, the Mexican economy underwent important transformations towards an industry -led economy steered by international trade. These structural changes constitute a stage of the *transition* (Fischer-Kowalski and Haberl 2007) from a traditional agrarian regime to the industrial mode initiated in the 1940s. We know that socio-ecological transitions increase energy and material use per capita/year (from 50 GJ to 300 GJ, from 5 tonnes to 25 tonnes). Fossil fuels do go up. Does biomass per capita use increase or decline? In order to elucidate how these transformations affected biomass use, physical indicators derived from Material Flow Accounts (MFA) were used. In addition, biomass use changes take place in subsistence activities such as fuelwood gathering. This article discusses such changes and the importance that fuelwood may still have as energy carrier in rural economies of middle income countries such as Mexico. According to the "energy ladder" hypothesis, there seems to be a 'natural' and universal hierarchy in the use of domestic fuel which was first proposed by Foley (1985). As income increases, dung, wood, charcoal are replaced by kerosene and LPG (in bottles), which are in turn replaced by piped gas or electricity. Nevertheless, field studies in rural Mexico have evidenced that fuelwood still accounts for more than 80% of the energy demand (Masera *et al.* 2005), and apart from being an important source of income and employment it is also an important physical flow. Since most of the fuelwood used in rural households is gathered directly by users, it tends to be omitted or underestimated in national statistics. We provide an estimation of fuelwood use in 2002, based on a national representative rural survey, named *Rural Households National Survey* (ENHRUM). In addition, the "energy ladder" hypothesis will be tested based on data provided by this survey.

This document is organized as follows. In section 2 structural changes in the Mexican economy and in biomass extraction related activities are described. In section 3 patterns of biomass use are analysed using MFA biophysical indicators. In this section, the main physical and policy related driving forces determining such evolution are discussed. In section 4 the importance of fuelwood use in the rural Mexican households is discussed. Physical flows arising from this activity are of important magnitude and are very difficult to be properly accounted for. In this section, a fuelwood national estimation for 2002 is provided and the methodology for obtaining such estimation is explained. With this data, the energy ladder hypothesis is tested. Finally, some conclusions and future lines of research are drawn in section 5.

2. A BRIEF OVERVIEW OF MEXICO RECENT DEVELOPMENT

With a geographical extension of 1,958,200km^2 and 102 million of habitants, Mexico is one of the largest and most populated countries in Latin America although with a low population density. This country's geography includes large deserts in the North, mountain ranges and tropical evergreen forests in the South. The complex topography of the country, together with its broad climatological diversity along the latitudinal continuum create an enormous number of environmental variants which make Mexico the second country in the world in terms of number of ecosystem types and the fourth largest in terms of species (CONABIO 2007). These characteristics suggest a great potential of biomass extraction in the country.

The most dynamic period ever experienced in the Mexican economy took place in from 1940 until the second half of the 1970s. Some years before, from 1934 the bases of the industrialisation process were settled by President Cardenas by providing infrastructures and assuring provision of strategic inputs such as oil at subsidised prices to the national industry. The take off phase of the transition process from an economy based on agriculture production to an industrialised economy took place in this period.

From 1940 until the second half of the 1970s, real GDP per capita grew at an average annual rate of 3.1%. The general model of development was based on two main policy lines: import substitution[1] and state-driven industrialisation. Agriculture and in general primary related activities were boosted by a strong state intervention in the production and distribution chains. During this period, agricultural policy was characterized by State influence in the production by means of setting guaranteed prices for basic grains, the provision of financial aid for harvest commercialization and of subsidized credits. In addition, during this period, the Mexican government influenced the inputs market by producing and selling subsidized fertilizers and seeds. Most important, the State controlled the basic grain imports i.e. maize and beans. The result was a vigorous primary sector. In the last period of the “mexican miracle” in the 1970s, agriculture was growing annually at 4% and its share in the national product was 11% (INEGI 2006a).

As a reaction to the multiple crises affecting the economy during the 1980s - resulting from the deterioration of the productive structure, a high external debt and an increasing dependency on oil exports-, a neo-liberal economic programme was adopted in 1988. This was based on fiscal and monetary restrictive policies, currency devaluations, an opening of the economy and an increasing reliance on market forces instead of government planning.

[1] The imports substitution policy regime focused on the provision of trade protection measures to domestic manufacturing. This policy was complemented by strong state intervention to carry out investment projects to supply strategic or basic intermediate products. In addition, public enterprises were created (Moreno-Brid et al. 2005).

The agricultural sector was severely affected by this stabilisation programme as public aids and subsidies were cut substantially and governmental institutions like CONASUPO[2], an entity that established and guaranteed prices and commercialized agricultural products were dismantled (Appendini 2001). As in the national economy, the agricultural reforms were aimed to eliminate state intervention and to consolidate free market.

The fast commercial opening was an important part of this strategy, beginning in 1986 when Mexico joined the GATT (the General Agreement on Tariffs and Trade). Since then, Mexico signed 12 trade agreements with 43 nations putting 90% of its trade under free trade regulations. The most important trade agreement was established with the United States and Canada (North American Free Trade Agreement- NAFTA). Since then, fossil fuels have been the main export flow, although its relative importance has decreased in recent years due to the increasing contribution of the assembly industries. In 2003, fossil fuels accounted for 50% of total export weight followed by minerals (43%) dominated now by metal-based manufactures (34% of total exports).

Under the NAFTA commercial frame, trade tariffs for basic grains almost disappeared. For instance, maize imports tariffs were cut and by 2008 they will be reduced to zero (Nadal 2002). As a consequence, maize imports rose from three million tonnes in 1993 to almost six million tonnes in 2003.

Along with this tendency to lower subsidies and to open commercial barriers, a key factor affecting Mexican agrarian life was the reform of land tenure and the end of the agrarian distribution initiated as a result of the Mexican Revolution of 1910. The *Ejido* has been the base of the land tenure system in Mexico since the end of the Revolution. It consists of a communal land shared among several heads of families. Any individual family has right to an *ejido* share of crop land for usufruct. The land cannot be sold, leased, mortgaged and the right to these lands can be passed on to heirs. But land may be lost if is not under cultivation for two consecutive years (Whetten 1948:142).

[2] CONASUPO stands for the National Company for Popular Subsistance (Compañía Nacional de Subsistencias Populares).

The modification of article 27 of the Constitution, made in February 1992, totally liberalized the form of land possession opening way to a model sustained by the free market. Since then, *ejido* land can be sold. The goal of this reform was the reactivation of an agriculture based on private investment and the reorientation of the production structure to competitive crops in the international market (Appendini 1996).

From 1995 to 2003, average real GDP growth was 2.5%, insufficient to create enough jobs to satisfy the growing supply of labour. As a result of the economic reforms, the economic structure was modified during the last three decades, resulting in a dominance of the services sector. In 2003, service activities accounted for 67% of the national product, while the industrial activities produced only 27% and the primary sector accounted for only 6% (INEGI 2006a).

3. PATTERNS OF BIOMASS CONSUMPTION AND EXTRACTION IN MEXICO (1970-2003)

The biomass flow estimates used here are parts of an overall material flow account (MFA) database for Mexico provided in Gonzalez-Martinez (2007). The MFA methodology provides an empirical picture of the physical dimension of an economic system by accounting the material inputs into an economy, the material accumulation within the economy and outputs to other economies or back to nature. In this analysis, the focus is on the input side and specifically on the biomass inputs. Therefore only the biomass inputs of the national economy are accounted for, apart from water and air. Table 5.1 provides the subcategories constituting the biomass flow.

Table 5.1 Subcategories comprised in biomass

Subcategories	Description
Food	It includes primary crops. In exports and imports all traded agricultural goods and final products from agriculture plants are included.
Fodder	It includes biomass harvested from grassland and grazed biomass plus primary crops cultivated for animals consumption e g. alfalfa. Used crops residues are also included. In exports and imports all traded final and semi-manufactured products destined to feed animals.
Animals	Biomass from hunting and fishing activities. In imports and exports all traded live animals and agricultural animal products (including fish) are comprised.
Wood	Harvested timber for industrial products and fuel wood. In imports and exports the following goods are comprised: harvested timber, forestry products, wood based products such as paper, cork products and products predominantly from wood such as music instruments.
Other biomass	Fibres and other non-timber products. In imports and exports, traded fibres products such as clothing as well as other products predominantly from biomass such as natural fertilizers are comprised.

Source: Adapted from Weisz *et al.* 2006

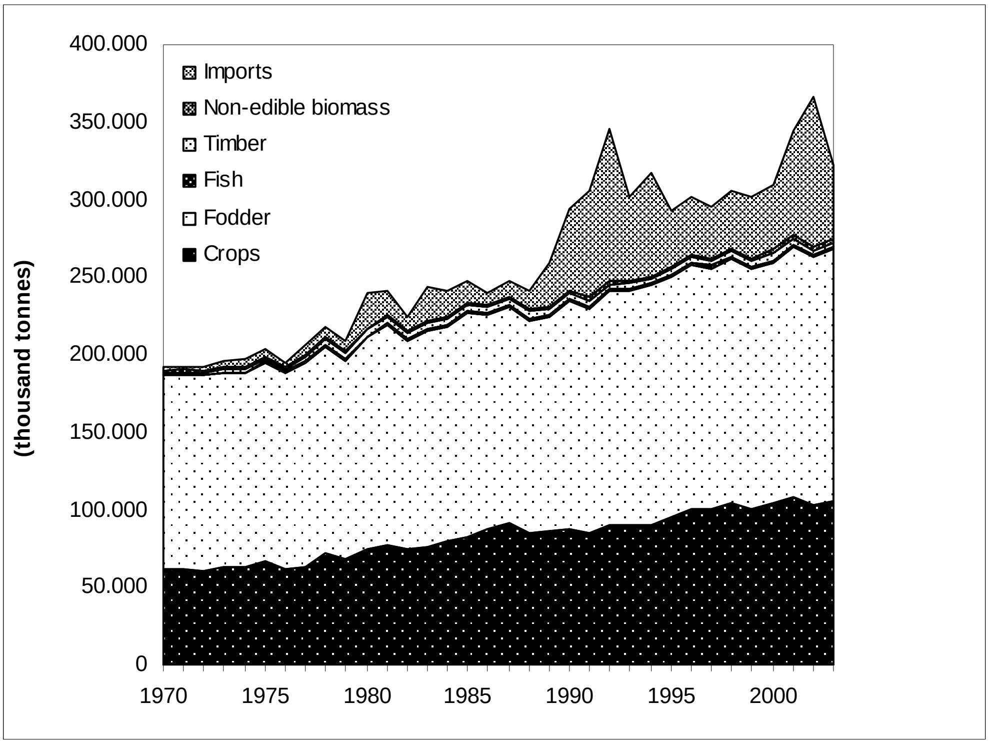
In order to make the data sets used in this paper internationally comparable, the standard Eurostat methodology for economy-wide MFA (Eurostat 2001) was consistently applied. Only d*irect flows* were accounted for ignoring all the *unused and indirect* flows since their inclusion can increase the arbitrariness as they are calculated by multiplying direct flows by standard coefficients. In biomass flow analyses, unused extraction is defined as “biomass that is killed through harvest but not economically used thereafter” (Krausmann *et al.* 2007:3). It includes three major fractions (a) unrecovered crop residues and residues from wood harvest, (b) belowground biomass of harvested primary crops and felled trees and, (c) biomass destroyed in human induced fires.

The level of biomass per capita that an economy uses depends firstly on several physical factors but also on policy-related factors that have an influence on the economic activities related to biomass extraction. As for the physical factors, the most important is undoubtedly, land availability which basically depends on the geographical area and population density. Mexico's population density was 50 inhab/km^2 in 2000. This country has a low population density compared to Europe or South Asia i. e. average population density in EU-15 was 116.2 in 2000 (Weisz *et al.* 2006), in Thailand 122 and in Korea 471 (Krausmann *et al.* 2007). But it has a high population density compared with other Latin American countries such as Peru, 20.4, Chile, 20.2 and in Ecuador 43.4 inhab/km2 (Russi *et al.* 2007). In addition, Mexico has a considerable potential for biomass production due to the great extensions of permanent pastures that guarantee a high supply of fodder, approximately 80 million hectares (SEMARNAT 2006) which is 41% of Mexico's total land area.

Other important factors are the climatic conditions as well as technological factors that can affect productivity. Also, agricultural productivity varies much between different zones. According to own calculations using SAGARPA (2006b) sources, only 25% of the land extension dedicated to agriculture is irrigated, which is the reason why food production in Mexico depends mainly on changing rainfall with periods of hydric stress.

According to the MFA indicator domestic extraction (DE), 170 million tonnes of biomass were annually extracted in the Mexican economy in 1970. By 2003, this quantity increases of 60%, rising to 276 million tonnes. The average annual growth rate of extraction was 1,2%. During the whole period, the predominant flow was fodder accounting in average for 62% of total biomass extraction (see Figure 5.1). The second most important flow was crops for human consumption (referred to as crops throughout the rest of the paper) with 36% share in average. Both together, fodder and crops constituted 98% of total biomass extracted in the country. The three remaining biomass flows together accounted for only 3%: timber including fuelwood (1.3%), non edible biomass (1.3%) and fishing (0.4%).

Figure 5.1 Biomass extraction and imports in Mexico, 1970-2003 (Thousand tonnes)



Source: Gonzalez-Martinez 2007

Materials extraction plus imports compose domestic material input (DMI). This indicator counts all materials with economic value that enter the economy without taking into account whether they are consumed in the country or in other economic systems. Biomass DMI growth was more dynamic than domestic extraction as its average growth rate was 1.8%. This is due to the impressive imports growth started in the 1990s (see Figure 5.1).

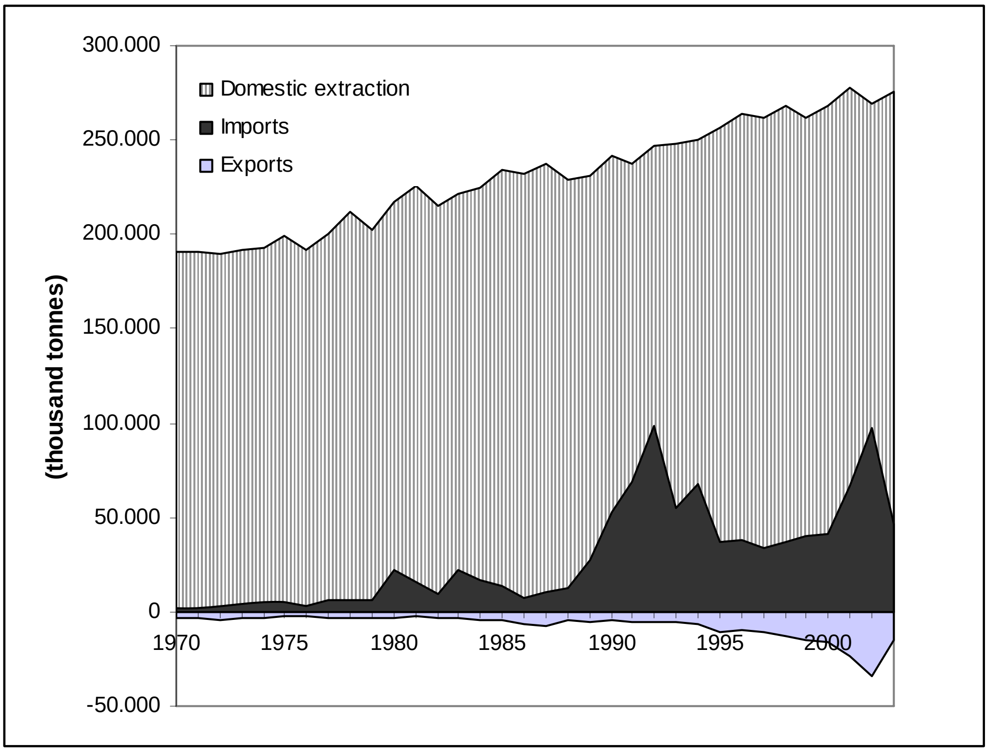
To what extent biomass input is actually consumed by the inhabitants of this country? The MFA indicator, domestic material consumption (DMC) expresses the amount of materials consumed within the economy and it is obtained by subtracting exports from DMI. Biomass consumption is directly related to population growth since biomass constitutes the main food supplier in the economy. During the period under analysis, population doubled, registering 2.2% annual growth rate.

Following population growth, biomass consumption nearly doubled as it passed from 195 million in 1970 to 337 million in 2003, registering an annual growth rate of 2%. Since extraction increased at lower pace than consumption, the lacking part was completed with biomass imports. During the period under analysis, imports grew by a factor of 20 and exports by a factor of 5. In contrast, domestic extraction grew only by a factor of 1.5. Given the increasing importance of biomass imports, this flow accounted for 14% of biomass input in 2003, as opposed to 1% in 1970. The increasing dependency on biomass imports is more evident when calculating the ratio DE/DMC, which expresses the degree of self-sufficiency. This ratio fell from 0.97 in 1970 to 0.61 in 2003. These results clearly reflect the opening of the commercial barriers. Mexico had become a biomass importing country and an oil and manufactures exporting country.

Although imports composition varied considerably, the increasing biomass imports consumed in the Mexican economy were dominated by crops during the whole period, as it can be seen in Figure 5.3 with the exception of 1990, crops imports[3] (raw materials) accounted for up to 60% of biomass imports. Timber was the second most imported biomass flow. This flow was basically constituted by commercial timber products. In the exceptional year of 1990, wood constituted up to 50% of biomass imports.

[3] Exports and imports are composed by all traded raw materials and final products.

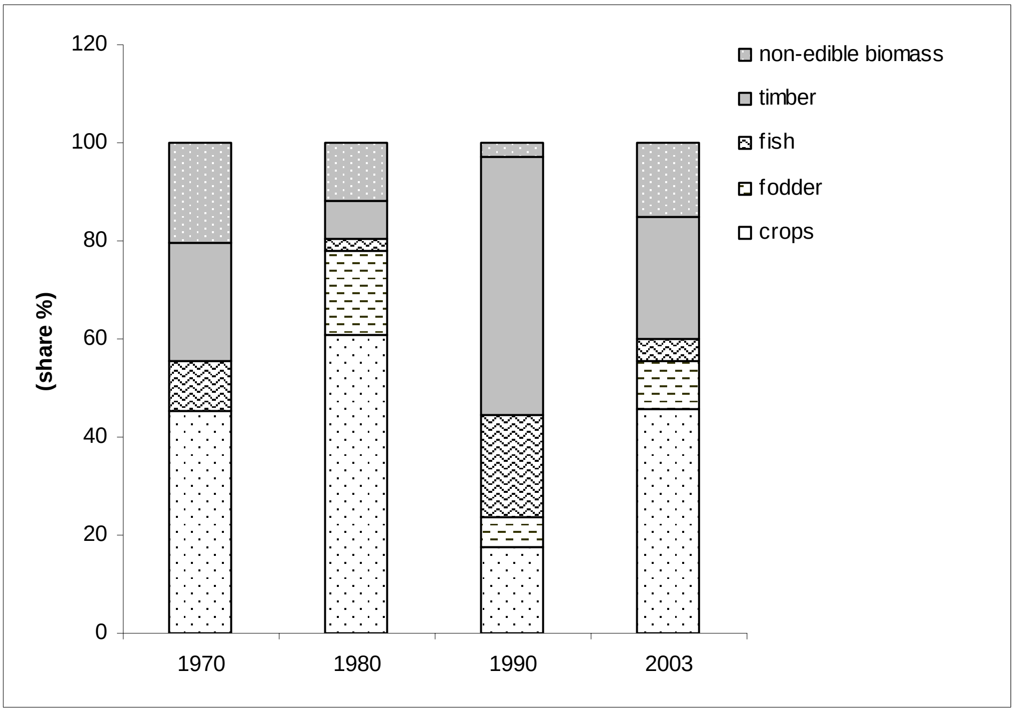
Figure 5.2 Biomass extraction, imports and exports in Mexico 1970-2003 (thousand tonnes)



Note: Exports are depicted in the graph as negative values since it is a material flow that goes out of the economy. Source: Gonzalez-Martinez 2007

As for biomass exports, 70% on average was composed by crops for human consumption (raw materials) followed by non edible biomass which accounted 14% in average during the whole period. In 1970, around 50% of crops exports was composed by raw materials and the other 50% by processed products such as alcoholic beverages and flour. By 2003, crops share in biomass exports increased to 63% while agricultural processed products accounted for 36%. This evidences the fact that in thirty years, added value in agriculture exports did not improve and on the contrary, raw materials increased.

Figure 5.3 Biomass imports composition in Mexico, 1970-2003 (%)

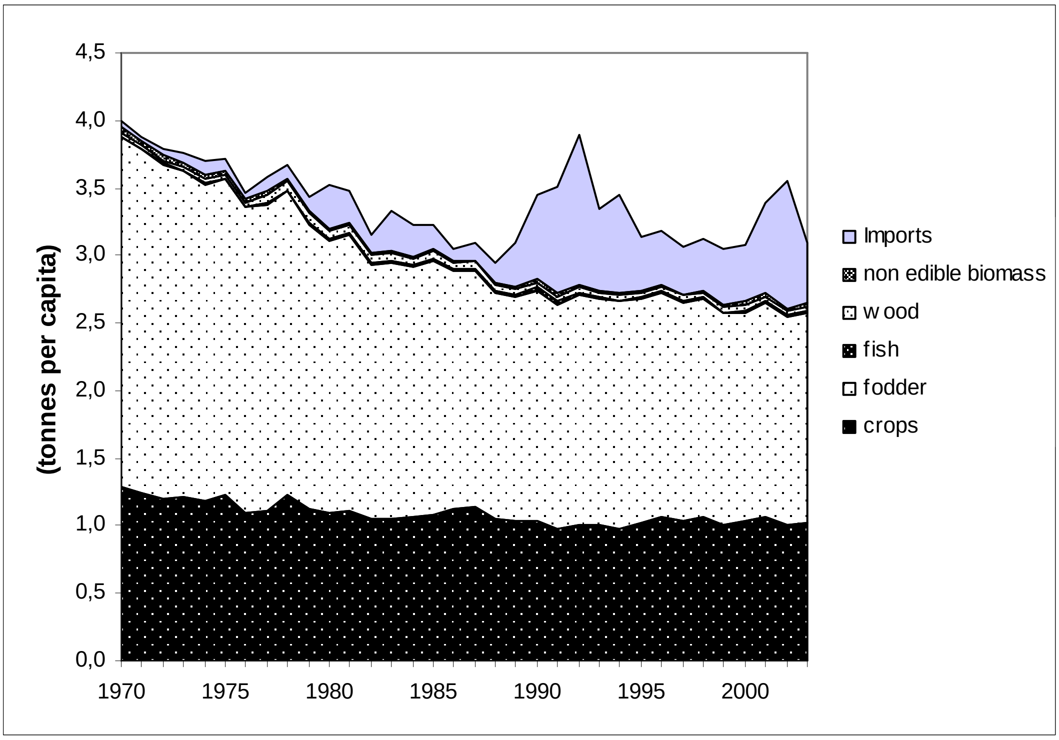


Source: Gonzalez-Martinez 2007

The biomass physical trade balance (the difference between imports and exports measured in tonnes) was predominantly positive in these three decades. Mexico has been a net importer of biomass, with the exception of the first three years of the seventies when a negative balance is observed. Does this evolution makes of Mexico a special case in Latin America? This region has historically specialised as raw materials or primary products exporters (*peripheral* countries) being at the roots of the economic dependency and underdevelopment of the Latin American countries as argued by the “dependency theory” developed by Prebisch (1952). While Mexico is increasing biomass imports, many Latin American countries follow the typical pattern of net biomass exporters. For instance, in Ecuador biomass exports are considerably greater than biomass imports (Vallejo 2006) and after oil, the second most important export flow is constituted by bananas. Colombia falls in the same group of net exporters of biomass. The particularity of this country is that apart from exporting agricultural products like coffee, oil, bananas and flowers, its illegal crops have entered the market with force in the last thirty years (Perez-Rincon 2006). In Chile the same pattern is observed with the difference that this country has been able to diversify its biomass exports towards processed agricultural products (i.e. wine) forestry products (i.e. wood, cellulose and paper products) as well as fishery products (Giljum 2004).

If in absolute terms, biomass extraction and consumption rose in Mexico between 1970 and 2003, in per capita values the tendency is the inverse: biomass extraction decreased from 4 tonnes in 1970 to 2.6 tonnes per capita in 2004 (see Figure 5.4) due to a decrease in fodder extraction per capita and a slight fall in crops. Therefore, population in Mexico grew at a faster pace than biomass production.

Figure 5.4 Biomass extraction and imports evolution in Mexico 1970-2003 (tonnes per capita)



Source: Gonzalez-Martinez 2007

Therefore, domestic biomass input per capita descended from 4 to 3.1 tonnes whereas consumption was reduced from 4.1 to 3.2. To put these numbers in perspective, we provide data for the European Union in 2000 (Eurostat 2002). Biomass extraction per capita was 3.8 tonnes, biomass consumption per capita was 4 tonnes. Mexico´s levels of biomass extraction per capita are then below those pertaining to the industrialised economies. Is it a sign that Mexico is leaving behind the typical pattern of biomass extractive economy?

4. THE IMPORTANCE OF FUELWOOD GATHERING AND THE ENERGY LADDER HYPOTHESIS

Rural households in developing countries strongly rely on the use of natural resources for covering their basic needs (Dovie *et al.* 2003, High and Shackleton 2000). An increasing number of field studies have documented the importance of subsistence activities in the Mexican countryside both in economic and in quantitative terms. These activities concentrate in poli-agricultural fields where maize production with other domesticated species coexist (Toledo *et al.*2003, Ortiz 2005, Escobar 2006), wild plants harvesting (Casas *et al.* 1994, Caballero *et al.* 1998, Camou-Guerrero *et al.* 2004) and fuelwood harvesting (Diaz 2000).

In Mexico, rural households rely heavily on fuelwood to satisfy their energetic needs. According to Masera *et al.* (2005) fuelwood is still the main residential fuel in Mexico accounting for 80% of energy demand in the rural sector and one out of four habitants (25 million people) uses fuelwood for cooking. If this is so and according to the rule that energy use for cooking with fuelwood at least doubles the endosomatic energy intake, we could expect a consumption of wood of about 0.5 ton per capita per year and therefore, 12.5M tons of fuelwood per year.

Fuelwood consumption is determined by a diversity of technical, economic, environmental, social and cultural variables. Analyses conducted in rural Mexico have shown that although the process of inter-fuel substitution has already started in the countryside, fuelwood has still not been entirely replaced, both for cultural and technical reasons (Masera and Navia 1996). For instance, fuel wood is still considered essential for tortilla making. In addition, fuelwood consumption varies importantly from region to region depending on two main factors: availability and income level (Masera and Navia 1996). The diverse consumption levels observed in several field studies conducted in diverse regions of Mexico range from 0.9 and 3.7 kg consumed per capita per day (Diaz 2000).i.e from 338 to 1,350 kg per capita per year.

Two important aspects of fuelwood determine the difficulty to be fully accounted by national statistics. Firstly, it is an energetic resource directly gathered by users. For instance, between 80 and 96% of the firewood consumers gather their own firewood

(FAO 2006). Secondly, fuelwood markets are largely restricted to the local level i.e. village markets.

Recent estimations based on field observations reveal that fuelwood demand is considerably bigger (around four times) than total wood demand for industrial purposes officially reported (Masera *et al.* 2005); whereas according to national statistics, fuelwood represents only 9% of roundwood industry (Presidencia de la República 2005). In the next section, the methodology used to provide an alternative estimation of the quantity of fuelwood gathered in 2002 is described.

4.1 Integrating fuelwood extraction in the material flow accounts

Considering that most of the firewood consumers gather their own firewood, estimates should be primarily based on direct data collection. Field studies have demonstrated that fuelwood demand and supply patterns are very site specific even within areas and regions (Masera *et al.* 2005). From January to March 2003, PRECESAM-COLMEX with the Rural Economies of the Americas and Pacific Rim (REAP)- University of California Davis gathered data in the Mexican rural sector on very local aspects such as economic activities, social indicators and natural resources use. The objective was to obtain representative relevant data on rural communities from 500 to 2,999 habitants. According to the 2000 Population Census nearly 14 million people out of 24.6 million were living in rural communities with such dimensions. The survey and sample were designed in collaboration with the Mexican Institute of Statistics (INEGI) and was conducted in 80 rural communities belonging to 14 States of the Mexican Republic. Communities were chosen by dividing the national territory into 5 different regions (see Annex III). The result was the *Rural Household National Survey* (ENHRUM)[4].

Since this is a nation-wide representative survey, data can be extrapolated to obtain an overall estimation of rural communities (from 500 to 2,999 habitants) by means of the use of expansion factors provided in the survey. For each household surveyed (observation), ENRHUM provides an expansion factor that once applied to the corresponding observation produces a national level estimation. The sum of all expanded

[4] Data, questionnaire, and methodological aspects of the ENHRUM survey are available at http://precesam.colmex.mx/. For the estimations presented in this paper, the updated ENHRUM results (13, July 2006) were used.

observations can be considered a representative nation-wide estimation for rural communities with such characteristics. This can be expressed as follows:

Fuelwood consumption in rural communities in Mexico (*W*) is obtained by summing up all observed household's fuelwood consumption w_x multiplied by their corresponding expansion factor e_x:

$$W = \sum H_x * e_x \qquad (1)$$

Information on fuelwood use is provided in section *Natural Resources* (7) and in section *Other Expenses* (8). In section 7, respondents were asked about the annual monetary value and the annual quantity of natural resources they used in 2002 such as fuelwood, wild animals or other natural resources. Here we focused on the variable expressing the quantity of fuelwood extracted for user's own consumption. In section 8, households were asked about all their expenses. We focused on the variable expressing household´s weekly expenses on fuelwood. We then assume that the total amount of fuelwood used by each household can be obtained by summing up both variables: the bought quantity plus the amount gathered for self-consumption. This can be expressed as follows:

Each household's fuelwood use is composed of two elements: the quantity of fuelwood bought (w_{Bx}) and the quantity of fuelwood gathered for self-consumption (w_{Cx}).

$$H_x = w_{Bx} + w_{Cx} \qquad (2)$$

874 households reported fuelwood gathering out of a 1,766 households surveyed. Most of the respondents provided fuelwood data expressed in dry basis (*leña*) while only nine reported fresh-wood and for this reason they were left out of this calculation. As for fuelwood purchases, data was provided in monetary values. The average price per kilogram of fuelwood was 2.72189 pesos in 2002 (see table 2 in Annex III). Therefore, the quantity of wood bought in the markets was calculated by dividing the monetary value by the average price of fuelwood and multiplying it times 12 as the quantity reported in the questionnaire is per month. Estimates are provided in Table 5.2.

Table 5.2 Fuelwood estimates

Variables	No observations	Quantity extracted* (thousand tonnes)	% total
(1) fuelwood purchases	255	312	8
(2) fuelwood- self consumption	865	3,722	92
TOTAL (1)+ (2)	996	**4,040**	100

Note: *Once the expansion factors were applied to each observation.
Source: Own estimations based on PRECESAM-COLMEX (2006) data

In year 2002, fuelwood consumption in rural communities (from 500 to 2,999 habitants) was more than four million tonnes, more than the whole industrial roundwood production, including fuelwoods v.g. fuelwood and charcoal reported in the national statistics (see Table 5.3), both calculated in dry matter. In our calculation, most of the fuelwood used was directly gathered by users while only 8% was bought.

Considering that 14.3 million inhabitants live in rural communities of 500 to 2,999 in 2000[5] (INEGI 2000b), fuelwood annual consumption per capita was 282 kg and 0,77 kg per day in 2002. Summing industrial production plus our fuelwood estimation, timber consumption in Mexico increased to 7.2 million tonnes in 2002 as shown in Table 5.3

Total fuelwood use in Mexico should be greater than the numbers provided here as our analysis was confined to rural communities of 500 to 2,999 habitants. There is still consumption in communities smaller than 500 habitants where 10 million people live as well as consumption in the longer villages and cities to be accounted for.

[5] Data from the population census in 2000 was used assuming that population did not vary considerably in two years.

Table 5.3 Total wood extraction in Mexico in 2002 (tonnes)

Year 2002	Quantity (thousand tonnes)	% total
Industrial roundwood (a)	3,238	45
Fuelwood direct estimation (b)	4,040	55
Total timber extracted (a+b)	7,278	100

Note: (a) Comprises all industrial uses (wood-based panels, pulpwood, plywood and fibreboard, posts and stakes) plus charcoal and fuelwood reported in Statistics.
Source: Own calculations with data from INEGI (2006) and PRECESAM-COLMEX (2006) data.

4.2 Energy for cooking and the "energy ladder"

There seems to be a 'natural' and universal hierarchy in the use of domestic fuel which was first proposed by Foley (1985). As income increases, dung, wood, charcoal are replaced by kerosene and LPG (in bottles), which are in turn replaced by piped gas or electricity. Pricing policies may accelerate this process or slow it down. Electricity is not a sensible source of energy for cooking when it implies transforming fossil fuels into electricity with a great loss of heat, and then electricity again back into heat. Appropriate pricing policies favoring the distribution of LPG are important in meeting the needs of the poor and the environment. It would be scandalous if a deforestation crisis were to occur in a dry region of an oil exporting country such as Mexico or Nigeria because rural families were too poor to buy LPG. Certainly, deforestation is not always caused by poverty, nor is it always caused by cooking needs. In Brazil today, one main cause of deforestation is the expansion of the soybean frontier. In South-East Asia, rapid deforestation has been caused by exporters of tropical hardwoods. However, in some arid regions of Asia, Africa and Latin America, one reason for deforestation is the use of firewood or charcoal as fuel by the poor. Estimated consumption of firewood may be 750 kg per person per year (Foley 1985: 256). Since roughly speaking, the energy of the firewood consumed per person is twice the energy consumed as food, this may lead to great pressures on resources in densely populated areas.

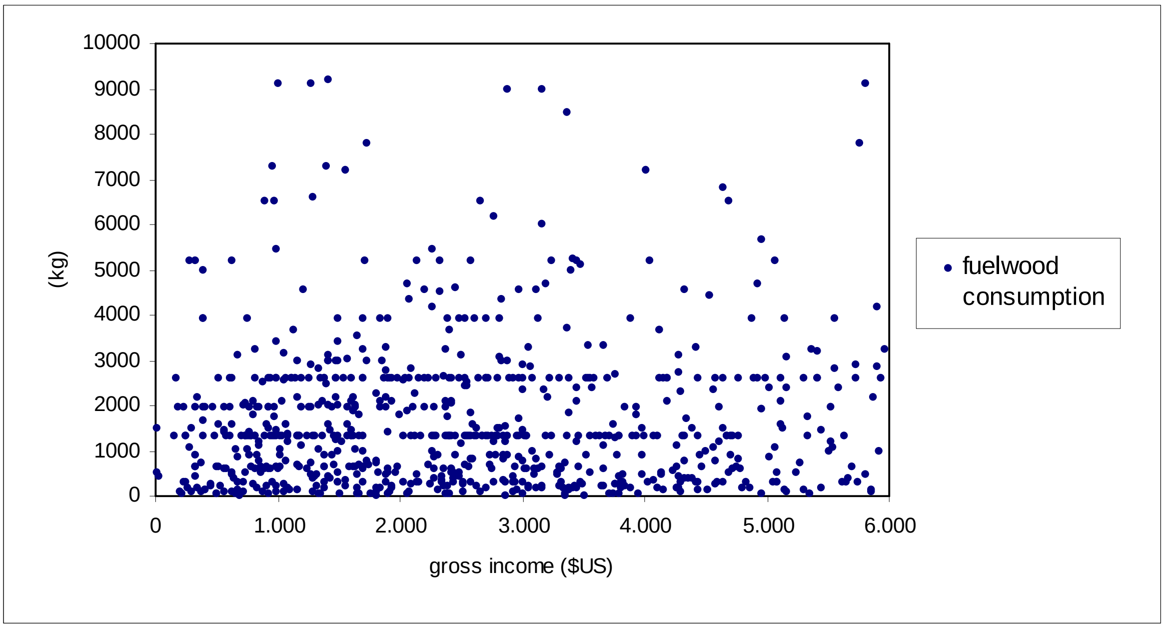
Large quantities of firewood can be replaced by small quantities of fossil fuel. Social preference for LPG as domestic fuel is undeniable, and is due to its cleanliness, the saving in time and effort in collecting wood and in cooking, and the lower amount of indoor pollution caused than by burning firewood, charcoal or dung. Assume that the annual use is about 500 kg of firewood per person, with an energy content equivalent to 0.35 tons of oil per ton of firewood. Taking into account the greater efficiency of stoves that use LPG (compared to modern firewood stoves with an efficiency of 15 percent or less, LPG kitchens have an efficiency of 40 to 50 percent), we conclude that LPG cooking for 3,000 million poor people in the world, would amount to about 200 million tons of oil (4 mbd). This is about one-fifth of U.S. consumption (Martinez-Alier 2005).

Oil or gas are too expensive to be used a domestic fuel by the poor, who cannot ascend in the "energy ladder". In Mexico, however, the concept of "energy ladder" has been challenged by Masera *et al.* (2000). The "energy ladder" model that suggests that with increasing affluence, a progression is expected from traditional biomass fuels to more advanced and less polluting fuels. Masera evaluated the energy ladder model utilizing data from a four-year (1992–96) case study of a village in Mexico and from a large-scale survey from four states of Mexico. He concluded that a "multiple fuel" model of stove and fuel management was more appropriate than the simple progression depicted in the traditional energy ladder scenario. The "multiple fuel" model integrates four factors demonstrated to be essential in household decision making: (a) economics of fuel and stove type and access conditions to fuels, (b) technical characteristics of cookstoves and cooking practices; (c) cultural preferences (as in using fuelwood for *tortillas*); and (d) health impacts.

We give a first try to test the energy ladder hypothesis using data obtained in the ENHRUM survey by correlating household´s gross income and fuelwood consumption. The objective is to measure the strength or degree of linear association between the quantity of fuelwood consumed by household and its corresponding total gross income. Total income was calculated by summing all the sources of monetary income rural families reported in the ENHRUM questionnaire (*section 8*) such as crop and animal sales, salaries as a temporary land-workers as well as transferences from relatives in the US or from other regions in Mexico (i.e. Mexico City).

According to the traditional energy ladder hypothesis, a negative linear relation may be depicted between fuelwood use and income: as income increases, the use of fuelwood decreases. We would then expect a correlation coefficient *r*= -1 or at least close to -1. It was -0,035 and as shown in Figure 5.5, no common pattern is observed between income and fuelwood consumption.

Figure 5.5 Yearly fuelwood consumption and income in rural households in Mexico 2002*



*Note: In rural communities from 500 to 2,999 habitants.. Exchange rate in 2002 was 10.2 pesos per dollar (Presidencia de la Republica 2005). Source: Own calculations based on the ENHRUM survey (COLMEX-PRECESAM 2002)

Is this then enough evidence to accept the alternative "multiple" fuel management model? According to this position, it is unusual for families to make a complete "fuel switch" from one technology to another. It is argued that fuel switching should be considered as a process resulting from the simultaneous interaction of factors pushing households away from biofuels and others pulling them back toward biofuels use (Masera *et al.* 2000: 2094). "Push" factors are more convenience, cleanliness, status while "pull" mechanisms include food flavour, inadequacies of modern devices for traditional cooking practices.

We think that in order to provide evidence for such model, further analysis should be conducted on developing an econometric model where explicative variables contained in the ENHRUM survey such as expenses in gas, expenses in electricity or cultural variables such as maize kept for own consumption should be included. Also, the number of persons per household should be taken into account.

5. CONCLUSIONS

This chapter provides information on biophysical aspects of the Mexican economy. It focuses on biomass flows i.e. food, fodder, animals, timber and other biomass. Information on biomass flows was gathered by applying the standard MFA methodology and therefore results can be compared internationally. By the use of the MFA indicators, we aim at analysing and discussing how the structural changes taking place in the Mexican economy during the period 1970-2003 modified patterns of biomass use. These indicators were also useful to assess the extent this economy depends on international flows, beyond the use of monetary values. Issues such as food security can be discussed through the use of MFA indicators.

In the last thirty years this economy increased its extraction and consumption of biomass in absolute terms which might imply an increasing pressure on its natural endowment. Nevertheless, in the last years material extraction and consumption per capita were reduced evidencing that population increased at a faster pace than biomass production. This reduction of national biomass production was offset by an important growth of biomass imports. During this period, biomass imports in absolute and per capita values grew considerably. Therefore, an increasing dependency on biomass imports was observed particularly on crops for human consumption from 1990 when trade barriers started to be eliminated and the economy was widely opened to international trade.

This growing dependency on international biomass imports in part contradicts the typical pattern of a natural resources exporter economy and imitates the pattern observed in industrial economies but also on some developing countries with low agricultural potential and large populations. As for biomass flows the Mexican economy is a special case in Latin America. Whether this is a sign that Mexico is leaving behind the typical pattern of extractive economy it is difficult to say but it certainly depends less on natural resource exports than 30 years ago. Nevertheless, crude oil exports still represent 50% of total exports in weight (Gonzalez-Martinez and Schandl 2008) and the role of Mexico´s oil exports in the metabolism of the United States has increased very much in the last decades. No provision is being made in Mexico (in terms of constituting a fund for future generations) for the period after oil extraction peak in the next few years.

The ratio DE/DMC for biomass which expresses the degree of self-sufficiency fell from 0.97 to 0.61 from 1970 to 2003, reflecting the fact that food demand rose while the internal capacity to meet food requirements decreased. The greater the external dependency on basic biomass flows, the greater this country's vulnerability in terms of food security. These results are coherent with the new model of development displayed in Mexico from 1980 onwards, which is characterized by an abrupt opening of the economy and the dismantling of rural production.

By using direct information on fuelwood use obtained in the *Rural Households National Survey* (ENHRUM) we estimated this natural resource use in rural communities in 2002. We have demonstrated that the quantity of fuelwood gathered and consumed by households is higher than the quantity officially reported for commercial timber production. Therefore, we find a hybrid pattern of biomass use in Mexico. It shows an increasing dependency on international biomass imports coexisting with a still high reliance on the own natural resources as energetic carriers in the countryside.

According to the *energy ladder* model, as income increases, consumer will switch from traditional biomass fuels to modern fuels. Mexico has reached a certain level of income per capita and it is now considered as a middle income economy (WB 2007). Does it imply less traditional biofuels consumption? Masera et al (2000) propose the "multiple fuel" model of stove and fuel management based on field work in Mexico. It seems that cultural preferences play an important role in fuel options choice. Based on the ENHRUM data on fuelwood use and income in rural communities we tried to test if the energy ladder model is appropriate for Mexico thus tending to confirm Masera *et al*. view. The results do not show any correlation between both variables. Further analysis should be conducted on specifying an econometric model where other explicative variables should be included, apart from income.

The inclusion of material flows resulting from subsistence activities in the national accounts is of great importance for designing effective environmental protection strategies and policies. Further research should be conducted to measure the quantity of wood extracted in illegal timber logging. The quantity arising from this activity should be very significant if we take into account that between 1993 and 2000, 10.3% of the rainforest vegetation was lost and 5% of forests have faded away (Semarnat 2006). Therefore, the methodology of MFA must be improved by using sources based on field information, household sample studies and land use changes, beyond national-level statistics.

CHAPTER 6

CONCLUSIONS

The analysis conducted in this thesis suggests several conclusions that can be divided into four groups: A) current patterns of material use and biophysical profiles, B) evidence of dematerialisation, C) usefulness of the MFA methodology for comparative and historical analyses and D) future research.

A) CURRENT PATTERNS OF MATERIAL USE AND BIOPHYSICAL PROFILES

In our globalised world, countries are becoming more dependent on international trade, and the role each country plays on the international markets (either as a raw material provider or as a technology-based product exporter) strongly determines the pattern and intensity of its material and energy use or biophysical profile. Imports and exports have increased considerably in the last twenty years in all the analysed countries, and their dependency on international trade has grown following different trajectories. On the one hand, we could identify countries such as Spain that have benefited from this process: this country's convergence in income per capita with the older members of the European Union is based on an increasing use of strategic natural resources, such as fossil fuels, coming from other economic systems (Spain is a net importer of natural resources as a typical European country).

One specific Spanish trait is that the main driving force shaping the biophysical profile of this economy has been the construction sector, due to the housing and infrastructure boom, an internal factor. Whether this trend will continue, it is currently very uncertain. In 2008, the financial bubble in mortgages has burst and it is very likely that many debts will not be paid (or will be paid for only in part). The construction sector may then be in crisis and as a consequence, the amount of building materials consumption might decrease and probably go back to the average European levels (7 or 8 tons per person/year) rather than the 2004 level of 12 per person/year.

On the other hand, we could identify those countries that historically relied on the extraction of natural resources, or *extractive economies (*Bunker 1985), such as Chile, Ecuador, Mexico and Peru. The Latin-American region historically played the role of natural resource provider, first to the benefit of the colonial centre (Europe) and later in the form, also, of bulk commodities in the form of “preciosities” to that of industrial centres such as the US. Nevertheless, over the last decade these countries have started to diverge, and we can no longer talk about a uniform pattern of natural resource use or a generalised metabolic profile in the Latin American region. This is in spite of the fact that all of these countries implemented the same neo-liberal economic reforms in the 1990s as a way to get out of the economic crisis affecting the region.

Ecuador remains a typical case of *extractive economy*, as its export-oriented oil extraction and agriculture production are still the predominating economic activities, increasing its oil and biomass outflows and therefore its physical trade deficit. In general, raw materials are exchanged on the international markets at low prices. The case of oil is different, as it has reached peak prices in recent years. However, the resulting drastic rise in revenue has not boosted economic growth in Ecuador; on the contrary, the oil boom has resulted in a deterioration of the productive structure, a phenomenon described in the literature as the *Dutch disease* (Sachs and Warner 1999).

In Chile and Peru, extractive activities were the driving force of material use change mainly minerals, but also fish meal. Nevertheless, a diversification of exports away from bulk commodities towards products with more added value could be observed recently, to a greater extent in Chile and increasingly also in Peru. More importantly, the Chilean economy has grown markedly in the last thirty years, and therefore it can be regarded as a successful example of the staple theory of growth (Innis 1930, 1949) among the Latin American countries under study. Nevertheless, its material intensity has grown still, as we saw in chapter 4.

Mexico is an odd hybrid case. Despite being an important oil exporter, it behaves as an *industrial economy* since construction materials dominate its biophysical structure, as a result of a dynamic population growth and a rise of the export-oriented manufactures. In addition, despite the great potential of biomass extraction in the country, Mexico has undergone a substitution process of national biomass for imported biomass, in particular of basic crops for human consumption. This fact poses problems for food security in the medium and long terms, as was made clear in 2007 by the high prices reached by the tortilla (a basic component of the Mexican diet) caused by the shortage of maize imports from the USA, as a larger share of production was diverted to agrofuels. The role of the maquila industrial economy may be noticed in the MF accounts. Manufactured goods now have a much greater importance in Mexico due to a boom in assembling industries. In this sense, the country shows certain similarities with the Southeast Asian region, which has high a population density and is currently undergoing a specialization process in labour-intensive light industrial production (Eisenmenger *et al.* 2007). Mexico has achieved a diversification of production, moving towards technology-intensive products and a better mix in its export portfolio due to the predominance of the assembling industry. This fact is however a blessing in disguise, since this type of industry is largely based on the availability of cheap labour, does not have a spill-over effect on the rest of the economy, and is exerting a growing pressure on natural resources in those regions where such activities are geographically located. Thus, Mexico’s position in the world economy is determined by the combination of exploitation of natural resources and intensive use of cheap labour.

Furthermore, contrasting the Chilean case, the Mexican economy has only undergone a modest growth, and has been unable to create enough jobs to satisfy the growing supply of labour. Therefore, it is not clear from this analysis whether diversification of exports can be regarded as a successful strategy for economic growth.

Whereas an increasing emphasis on the use of construction materials and fossil fuels was observed in the whole Mexican economy, in the countryside rural households still rely heavily on traditional biomass flows such as fuelwood to satisfy their energetic needs. An interesting finding of this thesis is that the “energy ladder” hypothesis could not be confirmed in rural Mexico. As income increased, traditional biomass fuels were really not replaced by modern fuels in rural households in Mexico.

Finally, the empirical evidence obtained in the countries under study does in part validate the theory of *deterioration terms of trade.* This theory holds for Ecuador whose metabolic profile is dominated by agricultural products like bananas and fossil fuels, mostly for exporting. In Chile, Mexico and Peru, it held in the 1980s when the price per imported tonne was much higher than the price per exported tonne. However, in the year 2000, this pattern changed in these countries, due to a diversification of exports and a subsequent reduction of the difference between the price per tonne of imports and exports. As for Spain, it can be considered a typical *centre* economy as its dependence on raw materials imports has increased. Spain is using more and more natural resources from other economic systems to increase its welfare, thereby displacing environmental loads to other countries, since an important part of its physical imports is composed of fossil fuels and metals. The negative environmental and social impacts associated to oil extraction and metals production are very well documented (see Epstein and Selver 2002, Martinez-Alier 2002, Gately 2007). For instance in Chile, large quantities of ancillary copper ends up as waste in the concentration process, remaining within Chile's borders. Therefore, some of the biophysical information provided in this document also reinforces the hypothesis of *environmental load displacement*.

B) EVIDENCE OF DEMATERIALISATION OF THE ECONOMIES

Thirty-five years after the publication of the Limits of Growth (Meadows *et al.* 1972) when concerns about the effects of material scarcities and wastes widely reached public opinion, and ten years after the factor 10 Club (1997) affirmed that human economy could decouple itself from energy and material inputs by a factor of ten, most of the evidence contradicts the hypothesis of a general dematerialisation process.

In none of the countries analyzed in this document – Chile, Ecuador, Mexico, Peru and Spain – has either an absolute nor a relative dematerialisation process occurred. The case of Spain is remarkable as it is a country that has reached a high income per capita level and is a net importer of natural resources. The relation between material use and GDP clearly shows that Spain has increased its material consumption not only in absolute terms but also per unit of economic output, and no inflection point is foreseen in the short term. Material intensity (DMC/GDP) has strongly increased. This case might be a good example of the *Jevons´ paradox* applied to materials, or *rebound effect*. In a country such as Spain, the availability of technological improvements in material use might have boosted total consumption of those resources, rather than decreased it; i.e.

improved efficiency lowers the cost of using a resource, which in turn increases the demand for it. Thus, improvements in efficiency might have been offset by higher consumption both because of price and income effects.

In the case of the Latin American countries, few small improvements in material efficiency were observed for the case of Mexico in the period under study. On the contrary, countries based on material-intensive mining activities such as Chile and Peru were characterized by a re-materialisation process. Both countries showed an upward trend in their material intensity curves, indicating an undesirable development since less GDP is generated with more materials. In this sense, we can confirm that economic growth has led to a generalised process of materialisation of the economies and that the current general resource use patterns may well present serious social and environmental problems to the medium- and long-term sustainability of those economies, since in general, the higher the material use, the larger the impact on the global environment. This threat is even more serious in countries based on the exploitation of non-renewable resources or where material-intensive activities predominate such as Ecuador, Peru, Mexico and Chile.

On the whole, in our analysis we could not foresee a rosy future for the world societies as regards metabolic flows.

C) USEFULNESS OF THE MFA METHODOLOGY

From the empirical analysis carried out in this research, it can be concluded that national-wide MFA indicators are of great use in order to identify physical aspects of an economy and to do comparative studies of socio-ecological transitions. The indicators obtained by applying this methodology are meaningful and permit a valuable comparison between different socioeconomic systems. In particular, this research provides physical evidence of socioeconomic changes taking place in Latin America, a region where this type of information and studies are still lacking. It is remarkable that MF analysis in Latin America has not been fed by CEPAL or other statistical offices but by academics publishing in journals such as REVIBEC, Journal of Industrial Ecology and Ecological Economics.

MFA can provide:

1) A biophysical profile of an economic system (even though not an exhaustive one).
2) Information on the pressure a socioeconomic system exerts on its surrounding environment. MFA indicators express a potential for environmental impact rather than environmental impact as such. Although there is always an environmental impact associated with the extraction and consumption of materials, the actual impact depends on specific characteristics and also on factors of scale.
3) Information to conduct a historical analysis of resource use in a long time. MFA indicators allow identifying trends on pressures and conflicts on the environment.
4) An alternative picture of the environmental changes taking place in the world. Using economic valuation, importance is attributed to money alone, and anything that cannot be evaluated in monetary terms or whose economic value is low becomes irrelevant. On the other hand, biophysical measures provide different importance weights. For instance, the amount of materials needed to support an inhabitant in the OECD countries is on the average higher than in Latin America, and therefore the impact of the OECD countries on the global environment is higher than those of the Latin American ones; in spite of OECD countries´ higher income and higher willingness to pay for environmental protection. The basic necessities of human societies and their demand for natural resources are more meaningful when they are expressed in physical terms if we need to compare them with the limited resources we have.
5) MFA provides also very useful inputs for the discussion on "ecologically unequal exchange".

Therefore, MFA can provide valuable guidance for economic policy planning as it complements traditional economic analysis. For instance, in 2008 there is a Keynesian demand in Spanish society that the collapse in the demand for private housing should be compensated for by an increase in the building of infrastructures, more motorways, more railroads, more airport lanes, larger harbours. But in physical and ecological terms, the idea of building more physical infrastructures as a Keynesian compensatory expenditure has important consequences. Knowledge of Material Flows allows us to put the question in different terms, in real physical economic terms. Should the building of infrastructures allow the consumption of material flows for building to remain at 12 tons per capita/year? Why? Is this considered to be the historically normal Spanish level forever? Or should the indicator go down at 5,6,7,8 tons per capita/year, as an average European level? Which would be the consequences of this lower level of material flows for the economy of the building industry, its employment level, its profits, and also for the decrease in environmental pressure (including soil sealing)?

D) FUTURE RESEARCH

Metabolic profiles of countries today should be characterised by using diverse methodologies, among which MFA. Therefore, future research will be directed to extend the use of MFA, historically and at the regional level and to provide other useful biophysical indicators to complete the metabolic profiles of the countries analysed here. Energy and land use, HANPP are key aspects of the metabolism of societies that have to be included in future work.

As mentioned throughout the thesis, unused flows were omitted from the analysis in order to allow comparison between countries. This issue definitely limits the scope of our analysis as we provide an incomplete picture of material flows and therefore, of environmental impacts. Therefore, future work should include the calculation of key unused flows. For instance, in Mexico unused flows arising from oil extraction should definitely be calculated.

Another issue that can improve the work presented here has to do with material flows associated to subsistence activities. In the case of Mexico it was shown that the methodology of MFA must be improved by using sources based on field information, household sample studies and land use changes, aside from national-level statistics. The same type of analysis should be carried out in other countries where subsistence activities are still relevant to cover the basic needs of an important share of the population in the countryside.

Finally, regarding the case of fuelwood and the energy ladder hypothesis, future analysis will be focused on specifying an econometric model where explicative variables other than income will be included. Following the “multiple fuel model” proposed by

Masera *et al.* (2000), variables such as expenses in gas and other modern fuels will be considered, as well as cultural factors like maize consumption.

REFERENCES

Adriaanse, A., S. Brigenzu, A. Hammond, Y. Moriguchi, E. Rodenburg, D. Rogich, and H. Schuetz. 1997. *Resource flows: The material basis of industrial economies*. World Resource Institute, Washington DC.

Aguayo, F. and K. Gallagher. 2005. Economic reform, energy and development: the case of Mexican manufacturing. *Energy Policy* 33: 829-837.

Almenar, R., E. Bono, and E. Garcia. 1998. *La sostenibilidad del desarrollo: el caso valenciano*. Fundació Bancaixa, Valencia.

Alonso, F. and L. Bailón. 2003. *Balance y cuentas de flujos de materiales*. Documentos de Trabajo 3/03, INE, Madrid.

Altman, M. 2003. Staple theory and export-led growth: constructing differential growth. *Australian Economic History Review* 43(3):230-255.

Amann, C., W. Bruckner, M. Fischer-Kowalski, and C. M. Grünbühel. 2002. *Material flow accounting in Amazonia. A tool for sustainable development. Amazonia 21*. Social Ecology working paper 63. IFF.

Appendini, K. 1996. *Changing agrarian institutions: interpreting the contradictions*. CERLAC Working Paper Series, No.4-Enero.

Appendini, K. 2001. *De la milpa a los tortibonos: La reestructuración alimentaria en México*. Segunda edición. Instituto de Investigaciones de las Naciones Unidas. El Colegio de México.

Arto, I. 2003. Requerimientos totales de materiales en el País Vasco. *Economía Industrial* 351:115-128.

Ayres, R.U. 1989. Industrial Metabolism. In *Technology and Environment*, edited by J.H. Ausubel and H. E. Sladovich. National Academy Press: 469-477, Washington,D.C.

Banco Central de Chile. 2007. *Statistical database*. www.bcentral.cl/esp/

Banco de Mexico. 2007. *Informacion financiera y economica.* www.banxico.org.mx

BANCOMEXT (Banco Mexicano de Comercio Exterior). 2002. *World Trade Atlas.* Banco de Comercio Exterior, Mexico, DF.

BANCOMEXT(Banco Mexicano de Comercio Exterior). 2004. *World Trade Atlas*. Banco de Comercio Exterior, Mexico, DF.

Behrens, A., S. Giljum, J. Kovanda, and S. Niza. 2007. The material basis of the global economy: worldwide patterns in natural resource extraction and their implications for sustainable resource use policies. *Ecological Economics* 64(2): 444-453.

Boulding, K. 1966. The economics of the coming spaceship earth. In *Environmental Quality in a Growing Economy,* edited by K. Boulding et al. John Hopkins University Press: 3-14, Baltimore, USA.

Bringezu, S. and H. Schütz. 2001. *Total material requirement of the European Union.* Technical Report No55, European Environmental Agency, Copenhagen.

Bringezu, S., H. Schütz, and S. Moll. 2003. Rationale for and interpretation of economy-wide materials flow analysis and derived indicators. *Journal of Industrial Ecology* 7(2): 43-64.

Bringezu, S., M. Fischer-Kowalski, R. Kleijn, and V. Palm. 1997. *Regional and National Material Flow Accounting: from paradigm to practice of sustainability.* ConAccount Workshop 21-23 January. Leiden, The Netherlands

Brown, S. 1997. *Estimating Biomass and Biomass Change of Tropical Forests: a Primer*. FAO- Food and Agriculture Organisation of the United Nations, Rome.

Bunker, S. 1985. *Underdeveloping the Amazon : extraction, unequal exchange, and the failure of the modern state.* Urbana: University of Illinois Press.

Bunker, S. 2007. Natural values and the physical inevitability of uneven development under capitalism. In *Rethinking Environmental History: World-System History and Global Environmental Change*, edited by A. Hornborg, J. McNeill, and J. Martinez-Alier. Altamira Press, USA.

Caballero, J., A. Casas, L. Cortés, and C. Mapes. 1998. Patrones en el conocimiento, uso y manejo de plantas en pueblos indígenas de México. *Estudios Atacameños* 16: 181-196.

Camou-Guerrero, A., E. Pérez–Negrón, and A. Casas. 2004. *Etnobotánica tarahumara: un estudio de caso en el ejido forestal de Cuiteco, Chihuahua, México.* Paper presented at XVII Congreso Mexicano de Botánica, 17-22 October, Oaxaca, México.

COTECOCA. 1987. Memorias de Coeficientes de Agostadero (1972-1986). SARH, México DF.

Cañellas, S., A. C. Gonzalez, I. Puig, D. Russi, C. Sendra, and A. Sojo. 2004. Material flow accounting of spain. *International Journal of Global Environmental Issues* 4: 229-239.

Carpintero, O. 2005. *El metabolismo de la economía española: Recursos naturales y huella ecológica (1955-2000)*. Fundación César Manrique. 2005.

Carrillo, J. and M. De la O. 2003. Las dimensiones del trabajo en la industria maquiladora de exportación en México. In *Situación del Trabajo en México*, edited by E. De la Garza and C. Salas. Plaza y Valdés-IET, Mexico.

Casas, A., J. L. Viveros, and J. Caballero. 1994. *Etnobotánica Mixteca: Sociedad, cultura y recursos naturales en la Montaña de Guerrero*. INI/CONACULTA, México.

Chavez, M. 2006. La quimera neoliberal mexicana. In *Experiencias de crisis y estrategias de desarrollo: Autonomía económica y globalización*, edited by A. Nadal and F. Aguayo. El Colegio de Mexico, Mexico.

Cleveland, C. and M. Ruth. 1999. Indicators of dematerialization and the materials intensity of use. *Journal of Industrial Ecology*, 2(3): 15-50.

COLMEX-PRECESAM. 2002. Encuesta Nacional de Hogares Rurales en México. http://precesam.colmex.mx/.

Conabio (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad). 2007. Sistema Nacional de Información sobre biodiversidad de México. www.conabio.gob.mx/institucion/snib/doctos/acerca.html

Damián, A. and J. Boltvinik. 2003. Evolución y características de la pobreza en México. *Comercio Exterior* 53(6): 519-531.

Dasgupta, S., A. Mody, S. Roy, and D. Wheeler. 1995. Environmental regulation and development: a cross-country empirical analysis. *Policy Research Working Paper* No1448, World Bank, Washington.

De la Garza, E. 2005. La maquila en méxico: Aspectos generales. In *Modelos de Producción en la Maquila de Exportación. La Crisis del Toyotismo Precario*, edited by E. De la Garza. UAM I- Plaza y Valdés, Mexico.

Díaz, R. 2000. Consumo de leña en el sector residencial de México: Evolución histórica y emisiones de CO2. UNAM: Facultad de Ingeniería, México DF.

Díaz, J., J. Saavedra, and M. Torero. 2000. Liberalización de la balanza de pagos: Efectos sobre el crecimiento, la desigualdad y la pobreza, El caso de Perú. In *Liberalización, desigualdad y pobreza. America Latina y el Caribe en los 90.* Edited by E. Ganuza et al. PNUD- Editorial Universitaria de Buenos Aires, Argentina.

Díaz, R. 2000. *Consumo de leña en el sector residencial de México: Evolución histórica y emisiones de* CO_2. UNAM: Facultad de Ingeniería, Mexico.

Doldán X. 2003. Energía, materiales y agua en la industria manufacturera gallega. *Economía Industrial* 352:25-45.

Dovie, D. B. K., E. T. F. Witkowski, and M. Shackleton. 2003. Direct use of smallholder crop production in a semi-arid rural South African village. *Agricultural Systems* 76: 337-357.

Dussel, E. 2002. México en la globalización y la apertura comercial. In *Política económica para el desarrollo sostenido con equidad.* Tomo II, edited by J.L. Calva. Casa Juan Pablos/Universidad Autónoma de Mexico, Mexico.

Dussel, E. 2003. Ser o no ser maquila, ¿Es esa la pregunta? *Comercio Exterior*. 53(4).

Eisenmenger, N., J. Ramos-Martin, and H. Schandl. 2007. Transition in a contemporary context: patterns of development in a globalizing world. In *Socioecological*

Transitions and Global Change. Trajectories of Social Metabolism and Land use, edited by M. Fischer-Kowalski and H. Haberl. Cheltenham: Edward Elgar.

El Serafy, S. 1989. The proper calculation of income from depletable natural resources. In *Environmental Accounting for Sustainable Development,* edited by Y. Ahmad, S. Serafy, and E. Lutz. UNEP- World Bank Symposium, Washington D.C.

Epstein, P. and J. Selver. 2002. *Oil: A life cycle analysis of its health and environmental impacts*. The Center for Health and the Global Environment, Harvard Medical School, Boston.

Erkman, S. 1997. Industrial Ecology: An historical view. *Journal of Cleaner Production* 5(1-2): 1-10.

Escobar, D. 2006. Valoración Campesina de la Diversidad del Maíz: Estudio de caso de dos comunidades indígenas en Oaxaca. PhD Thesis, Universitat Autónoma de Barcelona.

Eurostat.1992*. COMEXT*. http://fd.comext.eurostat.cec.eu.int/xtweb.

Eurostat. 2001. *Economy-wide material flow accounts and derived indicators: A methodological guide.* Luxemburg: Office for Official Publications of the European Communities.

Eurostat. 2002. *Material use in the European Union 1980-2000: Indicators and analysis.* Luxemburg: Office for Official Publication of the European Communities.

Eurostat. 2007a. *Structural Indicators*. www.eurostat.org

Eurostat. 2007b. *COMEXT*. http://fd.comext.eurostat.cec.eu.int/xtweb.

Eurostat. 2008. Economy and Finance. Annual National Accounts. www.eurostat.org

Factor 10 Club. 1997. *Statement to government and business leaders*. Factor 10 Institute, Carnoules, France.

FAO. 2006a. FAOSTAT- Statistical database. http://faostat.fao.org. FAO, Rome

FAO. 2006b. FAOSTAT-Definitions.http://faostat.fao.org/site/396/default.aspx.

FAO. 2006c. *México-Balance Energético Nacional*, FAO, FAO-Forestal, Rome. www.fao.org/docrep/t2363s/t2363s0y.htm.

FAO, 2007. FAOSTAT- Statistical database.1980-2004 http://faostat.fao.org. FAO, Rome.

Farm.net.2005. Liquid densities. http://www.farm.net/~mason/materials/liquid_densities.html

Fischer-Kowalski, M. 1998. Society's Metabolism: The Intellectual History of Material Flow Analysis, Part 1: 1860-1970. *Journal of Industrial Ecology* 2(1): 61-78.

Fischer-Kowalski, M. and C. Amann. 2001. Beyond IPAT and Kuznets Curves: Globalization as a Vital Factor in Analyzing the Environmental Impact of Socio-Economic Metabolism. *Population and Environment* 23(1): 7-47.

Fischer-Kowalski, M. and H. Haberl. 2007. Conceptualizing, observing and comparing socioecological transitions. In *Socioecological Transitions and Global Change. Trajectories of Social Metabolism and Land use,* edited by M. Fischer-Kowalski and H. Haberl. Cheltenham: Edward Elgar.

Fischer-Kowalski, M. and W.Hüttler. 1998. Society's Metabolism. The Intellectual History of Material Flow Analysis, Part II, 1970-1998. *Journal of Industrial Ecology* 2(4): 107-136.

Foley, G. 1985. Fuelwood and conventional fuel in the developing world. *Ambio* 14(4-5): 253-257.

Galeano, E. 1971. *The open veins of Latin America: five centuries of the pillage of a continent.* Latin America Bureau, London.

Garza, G. 1999. Global economy, metropolitan dynamics and urban policies in Mexico. *Cities* 16(3): 149-170.

Gately, M. 2007. The EROI of U.S. offshore energy extraction: A net energy analysis of the Gulf of Mexico. *Ecological Economics* 63:355-364.

Gaz de France.2005 ,Densités. http://www.jeunes.gazdefrance.com.

Georgescu-Roegen, N. 1976. La ley de la entropía y el problema económico. *Ciencia y Desarrollo* 18: 64-70. CONACYT, México. Translation from the original version: The Law of entropy and the economic process. In *Energy and Economic Myths: Institutional and Analytical Economic Essays*. Pergamon Press.

Georgescu-Roegen, N. 1977. What thermodynamics and biology can teach economists. *Atlantic Economic Journal*, 1: 13-21.

Giljum, S. 2004. Trade, material flows and economic development in the South: The example of Chile*. Journal of Industrial Ecology* 8: 241-261.

Giljum, S. and N. Eisenmenger. 2004. North–South trade and the distribution of environmental goods and burdens: a biophysical perspective. *The Journal of Environment and Development*, 13(1): 73–100.

Giljum, S., A. Behrens, D. Jölli, K. Vogt, J Kovanda, and S. Niza. 2005. *MOSUS. material input data for the GINFORS model.* Technical report. Project of the International Human Dimensions Programme (IHDP-IT). Project number: E/2003/01.

Gliessman, S. R. 1998. *Agroecology, ecological processes in sustainable agriculture*. Ann Arbor Press, Chelsea.

González-Martínez A. C., and H. Schandl. 2008. The biophysical perspective of a middle income country: Material Flows in Mexico. *Ecological Economics, d*oi:10.1016/j.ecolecon.2008.03.013

González-Martínez, A.C. 2007. *Material Flow Accounting of Mexico (1970-2003). Sources and Methods*. Working paper 1-2007, Unit of Economic History. Autonomous University of Barcelona, Barcelona.

Grossman, G. M., and A.B. Krueger. 1991. Environmental Impacts of a North American Free Trade Agreement. National Bureau of Economic Research, Working paper No.3914, Cambridge, Mass.

Grünbühel, C. M., S. J. Singh, and M. Fischer-Kowalski. (forthcoming). Contemporary transitions in rural communities of developing countries. In: *Global Change and Socio-Ecological Transitions. Comparing historical and current patterns of social metabolism and land use.* Edited by M. Fischer-Kowalski and H. Haberl, Edward Elgar.

Guillen, H. 2006. El modelo mexicano de desarrollo: balance y alternativas. In *Experiencias de crisis y estrategias de desarrollo. Autonomía económica y globalización,* edited by A. Nadal and F. Aguayo. El Colegio de Mexico, Mexico.

Haberl, H., M. Fischer-Kowalski, F. Krausmann, H. Weisz, and V. Winiwarter. 2004. Progress towards sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer. *Land Use Policy*, 21:199-213.

Haberl, H., N. B. Schulz, C. Plutzar, K. Erb, F. Krausmann, W. Loibl, D. Moser, N. Sauberer, H. Weisz, H. G. Zechmeister, and P. Zulka. 2004. Human Appropriation of Net Primary Production and Species Diversity in Agricultural Landscapes. *Agriculture, Ecosystems and Environment* 102(2): 213-218.

Hercowitz, M. 2003. *Metabolismo social y turístico de Lanzarote*. Cabildo de Lanzarote. Lanzarote.

Hernandez, J. C. 2003. La distribución territorial de la población rural*. La Situación Demográfica de México*, 2003: 63. CONAPO, México.

Herzer, D. and F. Nowak-Lehnmann. 2006. What does export diversification do for growth? An econometric analysis. *Applied Economics* 38(15): 1825-1838.

High, C. and M. Shackleton. 2000. The comparative value of wild and domestic plants in home gardens of a South Africa rural village. *Agroforestry Systems* 48:141-156.

Holdren, J. and P. Ehrlich. 1971. Impact of population growth. *Science* 171: 1212-1217.

Hornborg, A. 1998. Towards an ecology theory of unequal exchange: articulating world system theory and ecological economics. *Ecological Economics*, 23(1): 127-136.

Hornborg, A. 2007. Introduction: environmental history as political ecology. In *Rethinking Environmental History: World System History and Global Environmental Change,* edited by A. Hornborg et al. Lanham, MD: Alta Mira Press.

IEA. 2004. Energy Statistics of OECD Countries, 1960-2002.Organisation for Economic Co-operation and Development (OECD), Paris.

INE. 2005, 2000, 1998, 1988. *Anuario estadístico de España.* www.ine.es/prodyser/pubweb/anuarios_mnu.htm

INE.2007.*Comercio Exterior*. http://www.ine.es/inebase/

INE. 2007b. INEBASE. *Estadísticas de la construcción.* www.ine.es/inebase

INE.2007a. INEBASE. *Estadísticas sobre el medio ambiente*. http://www.ine.es/inebase/cgi/axi

INEGI. 1993. *Anuario estadístico de los Estados Unidos Mexicanos*. Instituto Nacional de Estadística, Geografía e Informática, México DF.

INEGI. 1998. *EHCEM, Estadísticas Históricas del Comercio Exterior de México* (1975-1985).Instituto Nacional de Estadística, Geografía e Informática, Aguascalientes, México.

INEGI. 1999. *Estadísticas Históricas de México.* Vol. I & II. Instituto Nacional de Estadística, Informática y Geografía. México.

INEGI. 2000a. *Anuario estadístico de los Estados Unidos Mexicanos*. Instituto Nacional de Estadística, Geografía e Informática, México.

INEGI. 2000b. *Censo Nacional de Población y Vivienda*. www.inegi.gob.mx.

INEGI. 2006a. Banco de *Información Económica*. Mexico: Gobierno de los Estados Unidos Mexicanos. www.inegi.gob.mx

INEGI. 2006b. Superficie *insular y continental del territorio mexicano.* http://mapserver.inegi.gob.mx/geografia/espanol/datosgeogra/extterri/frontera.cfm?c=154.

INEGI. 2007. Sistema de Cuentas Nacionales de México. Cuentas de bienes y servicios. www.inegi.gob.mx.

INEGI. 2008. Censos de población y vivienda. www.inegi.gob.mx/inegi/default.aspx?s=est&c=10202

Innis, H. A. 1954. *The Cod Fisheries: The History of an International Economy.* 1949. Revised edition. New Haven: Yale University Press.

Innis, H. A. 1956. *The Fur Trade in Canada: An Introduction to Canadian Economic History*. 1930. Revised edition. New Haven: Yale University Press.

Jaramillo, V. 1992. La importancia forrajera del maíz. COTECOCA, SARH, INCA RURAL, México DF.

Jaramillo, V. 1994a. Revegetación y reforestación de las áreas ganaderas en las zonas áridas y semiáridas de México.Comisión Técnico Consultiva de Coeficientes de Agostadero. SARH, México DF.

Jaramillo, V. 1994b. Revegetación y reforestación de las áreas ganaderas en las zonas templadas de México. Comisión Técnico Consultiva de Coeficientes de Agostadero. SARH, México DF.

Jaramillo, V. 1994c. Revegetación y reforestación de las áreas ganaderas en las zonas tropicales de México. Comisión Técnico Consultiva de Coeficientes de Agostadero. SARH, México DF.

Jevons, W. S. 1965. *The Coal Question*. Augustus M. Kelley, New York.

Jímenez, A. ,1989. La Producción de Forrajes en México. Colección FENIX, FIRA, México.

Kapp, K.W., 1976. El carácter de sistema abierto de la economía y sus implicaciones. In *De la Economía Ambiental a la Economía Ecológica*, edited by F. Aguilera and V. Alcántara, 1994, Icaria, Madrid.

Katz, J. 2000. Cambios estructurales y productividad en la industria latinoamericana, 1970-1996. *Revista de la CEPAL* 71: 65-84.

Krausmann, F., K. H. Erb, S. Gingrich, C. Lauk, and H. Haberl. 2007. Global patterns of socioeconomic biomass flows in the year 2000: A comprehensive assessment of supply, consumption and constraints. *Ecological Economics*. Article in press. Doi: 10.1016/j.ecolecon.2007.07.012

Kuramoto, J. and M. Glave. 2002. *Mineria, Minerales y Desarrollo Sustentable en Perú*. Iniciativa de Investigación sobre Politicas Mineras (IIPM), Lima.

Larson, E. D., M. H. Ross, and R. H. Williams. 1986. Beyond the era of materials. *Scientific American* 254: 34-41.

Levin, J. 1960. *The export economies: their pattern of development in historical perspective.* Cambridge: Harvard University Press.

Lutz, W., W. C. Sanderson, and S. Scherbov. 2004. The end of the world population growth. In *The End of World Population growth in the 21st Century*. Edited by W. Lutz, W. C. Sanderson, and S. Scherbov, New Challenges for Human Capital Formation and Sustainable Development, Earthscan, London: 17-83.

Malhi, Y. J., T. Roberts, R. W. Betts, T. J. Killeen, W. Li, and C. A. Nobre. 2008. Climate Change, Deforestation, and the Fate of the Amazon. *Science* 319:169.

Martinez-Alier, J. 2002. *The environmentalism of the poor: A study of ecological conflicts and valuation.* Edward Elgar, Northampton.

Martinez-Alier, J. 2004*. Metabolic Profiles of countries and ecological distribution conflicts.* Working paper 25-2004,Unit of Economic History. Autonomous University of Barcelona, Barcelona, Spain.

Martinez-Alier, J. 2005. Energy, Economy and Poverty. Past and Present of the Debate. In *Transforming Power: Energy, Environment and Society in Conflict Transaction,* edited by J. Byrne et al., New Brunswick and London, pp. 35-60.

Martinez-Alier, J., Schlüpmann, K. 1987. *Ecological Economics*. Basil Blackwell, Oxford.

Masera, O. and J. Navia. 1996. Fuel Switching or multiple cooking fuels? Understanding inter-fuel substitution patterns in rural Mexican households. *Biomass and Bioenergy* 12(5): 347-361.

Masera, O., A. Velázquez, M. Ordoñez, R. Drigo, and M. Trossero. 2005. *Fuel wood "hot spots" in Mexico: A case study using WISDOM -fuelwood integrated supply-demand overview mapping*. First edition, FAO, Rome.

Masera, O., B. Saatkamp, D. Kammen. 2000. From linear fuel switching to multiple cooking strategies: A critique and alternative to the energy ladder model. *World Development* 28(12): 2083-2103.

Matthews, E., C. Amann, S. Brigenzu, M. Fischer-Kowalski, W. Hütler, R. Kleijn, Y. Moriguchi, C. Ottke, E. Rodenburg, H. Schandl, H. Schütz, E. van den Voet, and H. Weisz. 2000. *The weight of nations. Material outflows from industrial economies.* World Resource Institute, Washington DC.

Meadows, D.H., D.L. Meadows, and J. Randers. 1972. *The limits to growth*. Universe Books, New York.

Ministerio de Economía y Finanzas de Peru. 2007. *Estadísticas nacionales*. www.mef.gob.pe. Peru

Ministerio de Agricultura, Pesca y Alimentación.1980-2005. *Anuario de Estadística Agroalimentaria.* Spain

Ministerio de Economía y Hacienda. 1980 - 1985. *Estadística del Comercio Exterior de España*, Volumen I: comercio por países y por productos. Spain

Ministerio de Economía y Hacienda. 1980-1998. *Estadística Minera de España.* Spain

Ministerio de Industria, Comercio y Turismo. 2001. *La Energía en España.* Dirección General de Política Energética y Minas. Secretaria de Estado de Energía, Desarrollo Industrial y de la Pequeña y Mediana Empresa. Spain

Ministerio de Industria, Comercio y Turismo. 2002. *La Energía en España.* Dirección General de Política Energética y Minas. Secretaria de Estado de Energía, Desarrollo Industrial y de la Pequeña y Mediana Empresa. Spain

Ministerio de Industria, Comercio y Turismo.2000. *Estadística Minera de España.* Spain

Ministerio de Industria, Comercio y Turismo.2005. *La Energía en España*. Dirección General de Política Energética y Minas, Secretaria de Estado de Energía, Desarrollo Industrial y de la Pequeña y Mediana Empresa. Spain.

Moreno-Brid, J. C., J. Santamaria, and J.C. Rivas. 2005. Industrialization and economic growth in Mexico after NAFTA: The road traveled. *Development and Change* 36(6): 1095-1119.

Moriguchi, Y. 2007. Material flow indicators to measure progress toward a sound material-cycle society. *Journal of Material Cycles and Waste Management* 9(2): 112-120.

Morley, S. 2000. *La distribución del ingreso en América Latina y el Caribe.* CEPAL-Fondo de Cultura Económica, Santiago de Chile.

Muñoz, P. and K. Hubacek. 2007. Material implications of Chile's economic growth: combining material flow accounting (MFA) and structural decomposition analysis (SDA). *Ecological Economics.* In press.

Muradian, R. and J. Martínez-Alier, 2001. Trade and the environment from a southern perspective. *Ecological Economics* 36: 281–297.

Muradian, R., J. Martinez-Alier, and H. Correa. 2003. International capital versus local population: The environmental conflict of the Tambogrande mining project, Peru. *Society and Natural Resources* 16: 775-792.

Muradian, R., M. O'Connor, and J. Martinez-Alier. 2002. Embodied Pollution in Trade: Estimating the 'Environmental Load Displacement' of Industrialised Countries. *Ecological Economics* 41(1): 41-57.

Nadal, A. 2002. *Corn in NAFTA: Eight years after.* Research report prepared for the North American Commission for Environmental Cooperation. Science, Technology and Development Program, El Colegio de México.

Naredo, J. 2006. *Raíces económicas del deterioro ecológico y social: Más allá de los dogmas*. Siglo XXI, España Editores.

Naredo, J. M. and J. Frias. 1988. *Los flujos de materiales, los flujos de energía y los residuos*. Working paper, Consejería de Economía, Comunidad de Madrid.

Observatorio de la sostenibilidad en España. 2006. *Cambios de ocupación del suelo en España. Implicaciones para la sostenibilidad*. Madrid.

OECD. 2007. *OECD Factbook 2007: Economic, Environmental and Social Statistics*.

OECD-FAO. 2007. Agricultural Outlook 2007-2016. OECD, Paris.

Ortiz, T. 2005. *Análisis de interacciones sociales y económicas de tres sistemas de manejo de recursos naturales. Estudio de caso en el ejido Casas Blancas, Michoacán, México*. Universidad Internacional de Andalucía, Sede Antonio Machado, Baeza, Jaén, España.

Panayotou, T., Ashton, P. 1992. Not by timber alone. Economics and Ecology for sustaining tropical forest. Island Press, Washington D.C.

Pascó-Font, A. 2000. *El impacto del programa de estabilización y las reformas estructurales sobre el desempeño ambiental de la minería de cobre en el Perú 1990-1997.* CEPAL, Santiago de Chile.

Pérez-Rincón, M. 2006. Colombian international trade from a physical perspective. Towards an ecological "Prebisch thesis". *Ecological Economics* 59:519-529.

Penman, J., Gytarsky, M. and Hiraishi, T., et al. ,2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry, Hayama, Kanagawa. IGES-IPCC, Japan.

Prebisch, R. 1952. *Theoretical and practical problems of economic growth.* CEPAL, Mexico.

PRECESAM-COLMEX. 2006. *Encuesta Nacional de Hogares Rurales (ENHRUM)*. http://precesam.colmex.mx/

Presidencia de la República. 2005. *Anexo estadístico del 5o. informe de gobierno*. Gobierno de los Estados Unidos Mexicanos, México.

Quiroga, R. 2005. *Estadísticas del medio ambiente en América Latina y el Caribe : Avances y perspectivas*. CEPAL Series Manuales. United Nations. Economic Commission for Latin America and the Caribbean. Division of Statistics and Quantitative Analysis. Santiago de Chile.

Repetto, R. 1989. *Wasting assets: natural resources in the national income accounts.* World Resources Institute, Washington, D.C.

Ricardo, D. 1817. *On the principles of political economy and taxation*. John Murray, London.

Rothman, D. S. 1998. Environmental Kuznets curves—Real progress or passing the buck? Acase for consumption-based approaches. *Ecological Economics* 25(2): 177-194.

Russi, D., A. C. Gonzalez-Martinez, J. Silva-Macher, S. Giljum, J. Martinez-Alier, and C. Vallejo. 2008. Material flows in Latin America: A comparative analysis of Chile, Ecuador, Mexico and Peru. *Journal of Industrial Ecology*. 12(5), (forthcoming)

Sachs, J. and A. Warner. 2001. The curse of natural resources, *European Economic Review* 4-6(45): 827-838.

Sachs, J. D. and A. M. Warner. 1999. The big push, natural resource booms and growth. *Journal of Development Economics* 59: 43-76.

SAGARPA, 2005. *Sistema de Información Agroalimentaria de Consulta (SIACON).* http://www.siap.sagarpa.gob.mx/ar_comdownload.html.

SAGARPA, 2006a. *Comercialización del frijol en México.* http://www.siap.sagarpa.gob.mx/modelos/Cadenas/frijol/comerci.pdf.

SAGARPA. 2006b. *Sistema de Información Agroalimentaria y Pesquera (SIAP)*. http://www.siap.sagarpa.gob.mx/ar_comdownload.html

Sastre, S. 2007. Material flow accounting of Spain. A regional perspective. Master's thesis. Universitat Autonoma de Barcelona.

Schandl, E. and N. Eisenmenger. 2006. Regional Patterns in Global Resource Extraction. *Journal of Industrial Ecology* 10(4): 133-147.

Schandl, H. and C. M. Grünbühel. 2005. Using land-time budgets to analyse farming systems and poverty alleviation policies in Lao PDR. *International Journal of Global Environmental Issues* 5(3-4): 142-180.

Schandl, H. and F. Krausmann. 2007. The great transformation: a socio-metabolic reading of the industrialization of the United Kingdom. In *Socioecological Transitions and Global Change. Trajectories of Social Metabolism and Land use.* Edited by M. Fischer-Kowalski and H. Haberl. Edward Elgar, Cheltenham.

Schandl, H., H. Weisz, and B. Petrovic. 2000. Materialflussrechnung für Österreich 1960 bis 1997. *Statistische Nachrichten* 55(2): 128–137.

Schmidt-Bleek, F. 1999. *The factor 10*. www.factor10-institute.org/pdf/MIPS.pdf

Semarnat, 2006. *Sistema nacional de información ambiental y de recursos naturales*. http://portal.semarnat.gob.mx/

Sendra, C., X. Gabarrell, and T. Vicent. 2006. Análisis de los flujos de materiales de una región: Cataluña (1996-2000). *Revista Iberoamericana de Economía Ecológica* 4: 43-54.

Sener. 2007. *Sistema de información energética (SIE)*. Mexico. www.sie.energia.gob.mx

SGM. 2004. Anuario Estadístico de la Minería Mexicana. Secretaría de Economía, México DF.

SGM. 2003. Anuario Estadístico de la Minería Mexicana. Secretaría de Economía, México DF.

SGM. 2001. Anuario Estadístico de la Minería Mexicana. Secretaría de Economía, México DF.

SGM. 2000. Anuario Estadístico de la Minería Mexicana. Secretaría de Economía, México DF.

SGM. 1999. Anuario Estadístico de la Minería Mexicana. Secretaría de Economía, México DF.

SGM. 1998. Anuario Estadístico de la Minería Mexicana. Secretaría de Economía, México DF.

Shafik, N. and S. Bandyopadhyay.1992. Economic growth and environmental quality: Times series and Cross-country evidence. Background paper for the World Development Report 1992, The World Bank, Washington D.C.

Silva-Macher, J. C. 2007. El peso de la economía peruana. Contabilidad de flujos de materiales en Perú 1980-2004. Master's thesis. Autonomous University of Barcelona.

SPP. 1971. Anuario Estadístico del Comercio Exterior Mexicano.Secretaria de Industria y Comercio. Dirección General de Estadística, México, DF.

SPP. 1973. Anuario Estadístico del Comercio Exterior Mexicano.Secretaría de Industria y Comercio. Dirección General de Estadística, México, DF.

SPP. 1975. Anuario Estadístico del Comercio Exterior Mexicano.Secretaría de Industria y Comercio. Dirección General de Estadística, México, DF.

Stern, D. I. 2001. Progress on the environmental Kuznets curve? *Environment and Development Economics* 3: 173-196.

Stromberg, P. 2005. La industria maquiladora mexicana y el medio ambiente; una revisión de los problemas. In *El medio ambiente y la maquila en México: un problema ineludible,* edited by J. Carrillo and C. Schatan. Colección Libros de la CEPAL, No.83. México: United Nations.

Suri, V. and D. Chapman. 1998. Economic growth, trade and energy: Implications for the environmental kuznets curve. *Ecological Economics* 25: 195-208.

Székely, M. 2005. Pobreza y desigualdad en México entre 1950 y 2004. *El Trimestre Económico* LXXII(4): 913-931.

Taylor, L. and R. Vos. 2000. *Liberalización de la balanza de pagos en América Latina: Efectos sobre el crecimiento, la distribución y la pobreza*. UNDP, Tegucigalpa.

Ten Kate, A. and F. De Mateo. 1989. Apertura comercial y estructura de la protección en México: Estimaciones cuantitativas de los ochenta. *Comercio Exterior* 39: 312-329.

Toledo, V. M., B. Ortíz-Espejel, L. Cortés, P. Moguel, and M. D. J. Ordóñez. 2003. The multiple use of tropical forests by indigenous peoples in Mexico: A case of adaptive management. *Conservation Ecology* 7: 9-25.

UN (United Nations). 2007. *Comtrade database*. United Nations: Statistical Division. http://comtrade.un.org/db/default.aspx.

UNSTATS. 2006. *Industrial Commodity Statistics Yearbook*. United Nations http://unstats.un.org/unsd/industry/yearbook/default.htm.

USGS. 2003. *Minerals Yearbook.* http://minerals.usgs.gov/minerals/pubs/.

Vallejo, M. C. 2006*. La estructura biofísica de la economía ecuatoriana: el comercio exterior y los flujos ocultos del banano*. FLACSO/Abya-Yala, Quito.

Wallerstein, I. 1974, 1980, 1989. *The modern world-system*. 3 vols. Academia Press, San Diego.

WB (World Bank). 2007. *World Development Indicators*. www.worldbank.org/data.

Weisz H., F. Krausmann, C. Amann, N. Eisenmenger, K. H Erb, K. Hubacek, and M. Fischer-Kowalski. 2006. The physical economy of the European Union: Cross-country comparison and determinants of material consumption. *Ecological Economics* 58: 676– 698.

Weisz, H. 2007. Combining social metabolism and input-output analyses to account for ecologically unequal trade. In *Rethinking Environmental History: World System History and Global Environmental Change,* edited by A. Hornborg et al. Lanham, MD: Alta Mira Press.

Weiszäcker E.U. von., Lovins A.B., Lovins L.H. 1998. *Factor four. Doubling wealth, halving resources use*. Earthscan, London.

Whetten, N.L. 1948. *Rural Mexico*. University of Chicago Press, Chicago.

Whiteman, A., Broadhead, J. and Bahdon, J. 2002. The revision of woodfuel estimates in FAOSTAT. *Unasylva* 53: 41-45.

Wirsenius, S. ,2000. *Human use of Land and Organic Materials. Modeling the turnover of biomass in the global food system.* Chalmers University. Göteborg, Sweden.

ANNEX I

MATERIAL FLOW ACCOUNTING OF MEXICO (1970-2003)

SOURCES AND MFA DATABASE

This technical background paper describes the data sources used in the compilation of the 1980-2003 data set for material flow accounts of the Mexican economy and presents the data set. It is organised in two parts: the first part presents the main material flows of the Mexican economy including biomass, fossil fuels, metal ores, industrial minerals and, construction minerals. The aim of this part is to explain the procedures and methods followed, the data sources used as well as providing a brief evaluation of the quality and reliability of the information used and the accounts established. Finally, some conclusions will be provided.

1. MAIN MATERIAL FLOWS OF THE MEXICAN ECONOMY

The following table provides an overview of the size and relative share of the main material flows in Mexico at the beginning and end of the period under study.

Table AI.1 Main material flow categories for Mexico in 1970 and 2003

	1970		**2003**	
	Magnitude (million t)	**% of total DE**	**Magnitude (million t)**	**% of total DE**
DE biomass	204.2	59	295.6	26
DE fossil fuels	40.7	12	230.4	20
DE minerals	104.1	30	622.1	54
TOTAL DE	**349.1**	**100**	**1148.2**	**100**
TOTAL IMPORTS	**8.5**	**2**	**185.1**	**16**
TOTAL EXPORTS	**14.1**	**4**	**243.7**	**21**

Source: own calculations

Domestic extraction of materials of 349 million tonnes in 1970 is showing an significant increase to 1,148 million in 2003. This implies that DE has tripled within three decades. Also, the composition of DE has undergone an important change between 1970 and 2003. While in 1970, DE of biomass was clearly the dominating fraction with a share of 59% of total DE; in 2003 the dominating fractions of DE are minerals with a share of 54% of total DE. In addition, DE of fossil fuels has gained importance during this period and has passed from a 12% share in 1970 to a 20% share in 2003.

While biomass extraction shows moderate growth, the most pronounced fact is the considerable rise of minerals and fossil fuels domestically extracted since 1970. Both categories have grown nearly six-folded during these three decades. As a consequence, biomass extraction has seen its relative importance drop from 59% to 26%.

Beside these considerable growth dynamics in the use of natural resources also the integration into the world economy expressed by the amount of materials traded is impressive. Trade flows have shown a dramatic rise in terms of weight during the period under study. Imports have passed from 8.5 to 185 million tonnes whilst exports have grown from 14 to 243 million tonnes; registering a yearly growth rate of 2.1% and 1.6% respectively.

As for the relative importance of trade flows, imports in 1970 represented 2% of material input while in 2003 imported materials amounted to 16% of direct material input. Showing the same trend, exports amounted to 14% of DMI in 1970 and 21% of DMI 2003.

1.1 Domestic extraction of biomass

Biomass extraction is composed of the subcategories food, animal fodder, animals, wood and other biomass. In the following table, shares of each component as well as the magnitude for the year 1970 and 2003 are shown.

Table AI.2 Biomass domestic extraction in Mexico in 1970 and 2003

	1970		2003	
	Magnitude (1000 t)	**% of biomass DE**	**Magnitude (1000 t)**	**% of biomass DE**
Food	61,930	30.0	106,405	36.0
Fodder	124,823	61.1	161,559	54.5
Animals	308	0.2	1,565	0.5
Wood	15,645	7.7	23,533	8.0
Other biomass	1,551	0.8	2,606	1.0

Source: own calculations

In Mexico, domestic extraction of biomass has been dominated by fodder over the whole period, despite a slight decrease of its share. In 1970, fodder accounted for 61% of biomass extraction while in 2003 this was 55%. The second largest biomass flow is agricultural production for human consumption (food crops). This flow does not show an important increase over the whole period (2% average growth and with negative growth rates in some years) despite the dynamic population growth (2.5% average growth rate). Food crops passed from 30% share of biomass extraction to 36%. It seems that agricultural production could more or less grow with population growth although a certain amount of human nutrition had to be increasingly supplied by imports.

Timber is the third largest flow but accounts for a small fraction of only 8% and shows little variation over the period under analysis. Finally, *other biomass* such as fibres and non-timber products account only for 1% of biomass extraction whilst *animals* (mainly fish) represents only 0.5%, both figures are for 2003.

1.1.1 Domestic extraction of biomass: food

Domestic extraction of food is based on agriculture production statistics. Primary crops production used as human food include cereals, roots and tubers, pulses, oil crops, vegetables, fruits, tree nuts and other crops.

There are two national data sources, namely the Agriculture Information System called *SIACON* (SAGARPA 2005) which is the main data source for the period 1980-2003. The second source covering the period from 1970-1979 is the printed version of the

Historical Statistics database (*Estadísticas Históricas de México*) (INEGI 1999) where long historical time series on crops production are available.

No inconsistencies or differences in magnitude were found when comparing national databases with FAOSTAT data (FAO 2006a).

Additionally, crops and agricultural production arising from subsistence activities are accounted for in this calculation. According to an expert for agricultural statistics of the Ministry of Agriculture[1], crops production in Mexico is recorded directly from the field plots by applying assumptions for average yield to planted area. In addition, FAOSTAT clarifies with regard to subsistence production on its website as follows: "crop production data refer to the actual harvested production from the field or orchard and gardens, excluding harvesting and threshing losses and that part of crop not harvested for any reason. Production therefore includes the quantities of the commodity sold in the market (marketed production) and the quantities consumed or used by the producers (auto-consumption)" (FAOSTAT 2006b). This is of particular importance since smallholder production is an important mainstay of the rural economy in countries such as Mexico. As it has been shown in several field studies, the biggest part of the maize production in Mexico is carried out for self-consumption purposes in small field plots (Escobar 2006, Ortiz 2005). The same situation occurs with bean crops. According to Government sources, 20% of total production of beans is destined to self-consumption (SAGARPA 2006a).

In Mexico, the share of food biomass in the total DE of biomass was 30% at the beginning and 36% at the end of the investigated period. Compared to total domestic extraction, the share of agricultural biomass dropped from 17% to 9% between 1970 and 2003. Due to the fact that the information used here includes subsistence production, we can be confident about the reliability of our food estimations.

1.1.2 Domestic Extraction of biomass: fodder

Fodder for livestock accounts for the biggest part of biomass extraction in Mexico. It is composed of three subcategories:

[1] Interview by mail with Mr. José Luis Campos Leal, Deputy Director of Agriculture Information and Statistics. Ministry of Agriculture (SAGARPA). In Mexico City on the 5th of October, 2006.

A) primary crops destined entirely to feeding animals,

B) food uptake from permanent pastures (grazing),

C) fodder as by-product of harvest.

A) Primary crops:

In Mexico, several crops are destined to produce forage and silage for livestock feeding the most important of them being alfalfa. In addition, crops like turnips and beets are solely used as fodder. The data source for these crops is FAOSTAT (FAO 2006a), where data is reported as fresh weight (with approximately 80% of water content). For reasons of consistency, the water content of fodder crops have been standardised to 15% water content using the procedure suggested in Eurostat (2001). The standardisation of the water content of livestock fodder is necessary to avoid a wrongful difference between stable feeding and feeding on pastures. In general, for reasons of consistency all grass categories should be included in the material flows accounts with 15% standardised water content (Eurostat 2002:56).

Table AI.3 Agricultural products with 80% water content in primary data

Product name	FAO classification
Maize for forage and silage	-
Sorghum for forage and silage	-
Rye grass for forage and silage	638
Grasses nes for forage and silage	639
Clover for forage and silage	640
Alfalfa for forage and silage	641
Mixed grasses and legumes	645

Source: FAO 2006a

B) Grazing:

In addition to grass harvest, direct grass uptake by ruminants on permanent pastures was included in the MFA account for domestic extraction. Because direct fodder uptake is usually not reported in agricultural statistics, the amount of grazed biomass had to be estimated. As already explained for grass crops', grazing has to be reported in hay weight.

Given the fact that this category can have considerably influence on the amount of biomass extraction, special care has to be taken to narrow down the range of uncertainty. In order to do so, (Eurostat 2002) suggests calculating demand and supply of animal fodder from permanent pastures and use the lower value for the MF account.

For the fodder supply estimation, the standard procedure is to multiply the area destined to grazing with annual yield coefficients. Given the territorial extension of Mexico, 1,964,375 km2 (INEGI 2006b), climate conditions vary considerably in each region. Grazing is carried out in different regions with different climate conditions and therefore, different grass productivities are found from the bush areas to the tropical forest. However, grazing predominates mainly in two areas: permanent pastures (praderas) and bush areas (matorrales) (SEMARNAT 2006). Only grazing in these two areas is considered in this estimate. The extensions were obtained from (SEMARNAT 2006) whose database is built with information provided by COTECOCA. The annual yield coefficients were obtained directly from several COTECOCA publications (COTECOCA 1987, Jaramillo 1994a, 1994b, 1994c).

COTECOCA is the government organisation in charge of grazing and livestock raising activities. In the seventies it calculated “carrying capacity coefficients” for several grazing areas in Mexico. COTECOCA has calculated a minimum and a maximum yield coefficient for each type of predominant vegetation in permanent pastures and bush areas. In order to simplify the analysis, we calculate the average values. The minimum coefficient was applied to each area.

Table AI.4 Pasture Forage Yields for Mexico

Forage Yields Tonnes Dry Matter/ha/year		
Zone	**lowest value**	**highest value**
Permanent pastures	1,17	11,3
Bush area	1,75	18,8

Source: own calculations based on COTECOCA 1987, Jaramillo 1994a, 1994b, 1994c.

The results show, that the total supply of pasture did not rise considerably over the period. In 1970, grass from pasture was around 99 million tonnes of dry matter (DM) while in 2003 it was around 106 million tonnes. The biggest share was obtained from permanent pastures areas (73%).

Fodder demand was calculated by multiplying total stock of ruminants with the unitary demand of fodder per year. The animals included in the fodder demand account are cattle, horses, sheep and goats. Data was taken from the Historical Statistics database (*Estadísticas Históricas de México*) (INEGI 1999) for the period 1970-1979 and from the Agriculture Information System called *SIACON* (SAGARPA 2005) for the period 1980-onwards. The coefficients applied are shown in table 6 in dry matter (DM) and were taken from Eurostat (2002, p.57).

Table AI.5 Fodder demand of ruminants

Coefficients **Kg Dry Matter/ head/ day**	
Species	**Average fodder demand**
Cattle	9
Goats	1
Horses	11
Sheep	1
Source: Eurostat 2002, p. 57.	

Fodder demand has increased more than potential supply from pastures during this period. In 1970, fodder demand was nearly 108 million tonnes whilst in 2003, it was 134 million tonnes. Supply estimations were used in this study as they were the lowest values.

C) By-products of harvest:

The use of by products from harvest as forage is a widely spread practice in Mexico. Residues that would be thrown away in Europe, are generally kept for feeding animals in Mexican agriculture. The use of straw from crops such as sesame, cotton, safflower seed, soybeans, beans for feeding cattle is well documented (Jímenez 1989). Straw from peanuts and strawberry crops are also be used as animal fodder as well as is the case for by-products such as sugar cane bagasse and beer production residues (Jaramillo 1992). In this study, only by-products from the main grain crops are included in the account. This refers to residues from barley, sorghum, wheat, rice and maize, mainly straw of these crops. Maize straw is by far the most important residue in terms of quantity produced.

Culturally and economically speaking, maize is one of the most important crops since the Mexican diet is based on maize being the main staple food. While the grain is used for human consumption, the straw and the rachis are destined for animal feeding. Therefore, 100% of the plant is used. The relation of maize grain production to forage production can vary depending on the region. While in the central semi-humid region this relation between crop and residue is one to one[2] in other regions this relation goes up to 2.25:1 considering the use of both residues, straw and rachis (Jimenez 1989). In the current study, an average relation of 1.9:1 was applied.

Most of the coefficients applied in this study come from Mexican sources and only if such information was absent coefficients from international studies were used. The main international reference with regard to agriculture and livestock rising used in this study was Wirsenius (2000).

Table AI.6 Straw coefficients for Mexico

Crops	Relation
Maize	1.9
Sesame	0,6
Rice	1,3
Sunflower seed	0,8
Barley	1,0
Sorghum	1,1
Soybean	0,6
Wheat	0,7
Beans	0,7
Green peas	1,0
Source: adapted from Jimenez 1989, Gonzalez 2006, Jaramillo 1992	

Table AI.7 International straw coefficients

Crops	Relation
Canary seed	0,5
Millet	0,5
Oats	0,5
Rye	0,5
Triticale	0,5
Source: Wirsenius 2000.	

[2] Interview with Prof. Carlos González Esquivel. CICA, Autonomous University of the State of Mexico (UAEM) in Toluca, State of Mexico on the 15th of March, 2006.

The share of fodder in total DE of biomass was 61% in 1970 and 55% in 2003, respectively. Compared with total domestic extraction (all domestic materials), fodder biomass share dropped considerably, from 33% to 14%.

In general, data quality for fodder estimations is good apart from grazing estimations where the level of uncertainty is considerably higher. Improvements in grazing estimates can be made in future work. Firstly, a more detailed calculation can be carried out by type of vegetation including other grazing areas apart from bush areas and permanent pastures. Secondly, yield coefficients should be updated since the ones available date from the seventies. Also, it is worth noting that biomass and especially, the food and fodder outcomes are highly dependent on climate variations.

1.1.3 Domestic Extraction of biomass: animals

Biomass from hunting and fishing activities are accounted for in this category. However, in this study, only biomass extraction from fishing was estimated since data on hunting was not available. Nevertheless, hunting activities should only account for a very small fraction compared with other biomass flows.

Data for fish catch were obtained from Mexican statistics and compared with FAO data. There are two Mexican sources: for the period 1970-1989 data were collected from the Historical Statistics database (*Estadísticas Históricas de México)* (INEGI 1999). From 1990 onwards, the President annual report (*Anexo Estadístico del 5o. Informe de Gobierno*) (Presidencia de la República 2005) was the source used. Important deviations were found when Mexican data was compared to FAO data. For the period 1970-1990, FAOSTAT time series seem to be overestimated by a range from 2.5% to 28%. From 1993 onwards FAO data is underestimated by approximately 3%.

Since fish catch is provided in annual tonnes, there is no need for any conversion. Fish biomass accounted for the smallest part in the total DE of biomass during the period. In 1970 its share was only 0.2%, showing a very small increase in 2003 to 0.5%. The quality of data, however, can be considered as reliable.

1.1.4 Domestic Extraction of biomass: wood

Wood extraction is composed of two main categories: wood for forestry products and wood fuels. While forestry products time series are rather easy to obtain in main national data sources (INEGI 1999, Presidencia de la República 2005) there is a lack of reliable information on wood fuels extraction at the national level.

The forestry products appraised in this study are: wood-based panels, cellulose pulpwood, plywood and fibreboard, posts and stakes, sleepers and charcoal and fuel wood. All these products are classified in coniferous and non-coniferous. It is worth noting that values for charcoal fuel wood provided in the national statistics only correspond to the amount sold in the markets and therefore, were registered as timber products. These values represent only a very small fraction of the total fuel wood consumption in the country.

The lack of reliable fuel wood estimations is an important bias when accounting for material flows in developing countries. Wood remains the main source of energy of rural households. In the case of Mexico, one out of four inhabitants, around 25 million people, uses wood for cooking (Masera *et al*. 2005); and fuel wood actually covers 80% of the rural household energy supply (Díaz 2000). When accounting for the extraction of this energetic resource, the troublesome fact is that the biggest part is collected directly by the consumers and therefore, not accounted in the national statistics. According to FAO (FAO 2006c) approximately 80 to 96% of the fuel wood consumers in Mexico collect this energy resource directly.

Moreover, fuel wood accounts for the biggest part of total round wood production and it is by far, the most important use of wood. Estimations done with FAOSTAT data (FAO 2006b) reveal that total fuel wood use in Mexico accounts for three times the total commercial timber legally harvested in the country.

Several case studies have been carried out in order to obtain estimates of fuel wood consumption per capita. It has been found that consumption of this natural resource varies considerably depending on availability in a range between 1.48- 2.97 kg per day (Masera *et al*. 2005). Nevertheless, there is a lack of an overall estimation at the national level. In this sense, FAOSTAT is the only database that provides a time series for overall fuel wood consumption estimated through a model. Details on the modelling procedure can be found in (Whiteman *et al*. 2002). Absent better sources of information, in this study fuel wood consumption is based on FAOSTAT (FAO 2006a).

Both, timber products and fuel wood data are presented in cubic meters. To convert forestry data from cubic meters into tonnes, conversion factors for coniferous and non-coniferous wood were applied depending on the region where wood was obtained from. We assumed that pine, beech and other coniferous grow mainly in boreal regions while oak and other foliages are found in temperate regions. Precious and other tropical species such as mahogany and teakwood are assumed to be produced in tropical regions.

Table AI.8 Forestry factors

Transformation factors T per green volume [t dm / m³] Oven dry biomass per cubic metre green volume			
Region	Factor		
		C	**NC**
Tropical	America	0,43	0,60
Temperate	America	0,41	0,58
Boreal	America	0,44	0,45
Source: Adapted from Brown 1997, Penman *et al.* 2003			

The wood density coefficients above, convert the production data from volume to mass dry matter. To allow for international comparability of results we apply the recommendation of Eurostat to report timber extraction at 15% water content.

Although wood is the third most important biomass flow, it accounts only for 8% of the total DE of biomass in Mexico over the whole period. Timber extraction, however, should be bigger given the high rates of deforestation in the country. According to the Ministry of the Environment (SEMARNAT 2006) a great part of timber extraction is carried out under illegal conditions. Following the report, between 1990 and 2000, Mexico had lost nine million ha of forest.

Hence, current estimations are incomplete and should be improved in the future by using geographical information systems (GIS) and cartography. GIS can be a good tool to obtain information on the quantity of illegal wood extraction. Another remaining problem is the need to access direct fuel wood estimations since the ones available are generated through models. Given the huge quantity of fuel wood use and the high rates of deforestation due to illegal logging, current estimations should be taken as a conservative measure of timber extraction.

1.1.5 Extraction of biomass: other biomass

Other biomass is composed by agriculture products such as fibres and non-timber products. Apart from fibres – cotton, sisal, agave, other agriculture products included in this group are gums and natural rubbers. The non-timber products accounted for are resins, fibres, rubbers, waxes, rhizomes and soil.

Data for *other biomass* was taken from the same sources as for *food biomass*: The Agriculture Information System *SIACON* (SAGARPA 2005) and the printed version of the Historical Statistics database (*Estadísticas Históricas de México*) (INEGI 1999). Non-timber products were obtained from the same sources we used for forest products (INEGI 1999, Presidencia de la República 2005). All data was reported in tonnes and no conversion was necessary.

Non-timber products account for a very small part of total biomass, only 1% and have not varied through the whole period. However, it is worth pointing out that non-timber products reported in the national statistics do not comprise products gathered directly by consumers. Here, we face the same problem as explained for fuel wood. According to field studies in indigenous communities, a big number of plant species and other non timber forest products are used as food, medicine, fodder, and building materials. Moreover, these species have a great importance, both culturally and economically speaking (Camou *et al.* 2004, Casas *et al*. 1994, Panayotou and Ashton 1992). Thus, we conclude that the estimates of *other biomass* presented here are incomplete and should be taken as minimum values, making further improvements in future research is necessary.

1.2 Domestic extraction of fossil fuels

In Mexico, the extractive industry of fossil fuels is based mainly on three material categories: crude oil, natural gas and hard coal. As it has been shown in Table AI.2, domestic extraction of fossil fuels is the least important fraction of domestic extraction in terms of magnitude in Mexico despite a rise observed during the period. In 1970, 40 million tonnes of fossil fuels were extracted whilst in 2003 extraction increased up to 230 million tonnes. Fossil fuel extraction nearly six-folded in three decades and should further increase in the future.

Table AI.9 Fossil fuel extraction

	1970		2003	
	Magnitude (1000 t)	**% of fossil fuels DE**	**Magnitude (1000 t)**	**% of fossil fuels DE**
Total	40,741	100	230,456	100
Coal	2,959	7	6,648	3
Crude oil	24,223	59	190,333	83
Natural gas	13,559	33	33,475	15

Source: own calculations

According to Table AI.9, crude oil has been by far the most important fossil fuel in the whole period. Its contribution to total extraction of fossil fuels increased considerably from 59% in 1970 to 83% in 2003. The quantity extracted today is eight times higher than in the 1970s. It increased from 24 to 190 million tonnes. Natural gas is the second most important fossil fuel extracted In Mexico. However, its contribution is small when compared to oil: in 1970 it had a share of 33% but only a share of 15% in 2003. Coal represents a tiny part of fossil fuel extraction: 7% in 1970 and 3% in 2003, respectively.

Data for fossil fuels were gathered from Mexican databases. For reasons of comparison IEA data (IEA 2004) and data from the US Geological Survey- Mineral yearbooks (USGS 2004) were used for the period 1990-2003, when both data sets had information available for Mexico.

Mexican sources used are the Historical Statistics database (*Estadísticas Históricas de México* (INEGI 1999) for the period 1970-1995. From 1996 onwards data were collected from the national yearbooks (INEGI 1993, INEGI 2000a) and the President Report (*Anexo Estadístico del 5o. Informe de Gobierno*) (Presidencia de la República 2005). Comparing Mexican data with IEA data, we found that IEA is showing smaller production at a range of 2% up to 8% in the case of crude oil whereas for natural gas the difference can go up to as much as 25% for some years. USGS- Mineral yearbook data generally coincided with Mexican data.

We carried out some conversions in order to obtain fossil fuels data in tonnes. For instance, hard coal is provided in annual tonnes while crude oil is provided in thousand of barrels per year. The conversion factor used is 1 barrel = 0.15899 cubic meters. A density of Mexican crude oil of $973kg/m^3$ was obtained in a web source (www.farm.net 2005). Natural gas was converted from cubic meters into tonnes using a density of $0,72kg/m^3$ (Gaz de France 2005) the density of natural gas in vaporous state.

Data quality and reliability can be considered very good since fossil fuels production data is permanently collected and supplied to the public due to the economic importance of these natural resources for the Mexican economy.

1.3 Domestic extraction of minerals

Minerals are disaggregated into: metal ores, industrial minerals and construction minerals (Eurostat 2001). Minerals extraction in Mexico is shown in Table AI.10

Table AI.10 Minerals extraction composition

	1970		2003	
	Magnitude (1000 t)	**% of minerals DE**	**Magnitude (1000 t)**	**% of minerals DE**
Total	131,359	100	622,109	100
Mineral Ores	27,239	21	79,610	13
Industrial	3,125	2	20,906	3
Construction	100,994	77	521,591	84

Source: own calculations

Minerals extraction has experienced a dramatic rise in the last three decades, becoming the dominating category of domestic extraction in recent years. In 2003, half of the whole materials extracted in Mexico were minerals whereas in the seventies, minerals represented roughly 30%. Within this category, construction minerals have been the most extracted, showing a considerable rise during this period because of considerable infrastructure up-built. Construction minerals extraction five folded and its contribution to total mineral extraction grew from 77% to 84%. On the contrary, mineral ores have decreased their share from 21% in 1970 to 13% in 2003. As for industrial minerals, even though that their extracted quantity increased six times, their contribution to total mineral extraction only increased from 2 to 3%.

1.3.1. Metal ores and industrial minerals

15 metal ores and 24 industrial minerals were accounted for Mexico. Certain minerals such as aluminium were left out despite that they are reported as national production in the Mexican statistics. This is due to the fact that they are produced with imported raw materials, such as bauxite in the case of aluminium.

In the case of industrial minerals, in addition to the categories listed in the Eurostat guidebook (2001), minerals such as wollastonite and vermiculite were added. Clays and abrasives were also included in the account. The minerals data set built up for Mexico was based mainly on Mexican sources. These are the Mexican Mining Yearbooks (*Informes de la Minería Mexicana)* published by the Geological National Service (*Servicio Geológico Mexicano*) *(*SGM 2003, 2002, 2001, 2000, 1999, 1998, 1993). The second reference used was the Historical Statistics database (*Estadísticas Históricas de México)* (INEGI 1999). For some minor minerals not registered in the national sources such as magnesia, natural abrasives and sodium compounds, the Minerals Yearbooks (USGS 2004) published by the United States Geological Survey were used as data source. These yearbooks provide data only for the period 1989-2003, therefore the industrial minerals taken from this source were included only for this period.

Metal and non-ferrous minerals are reported in the statistics as the net content of the mineral. Following the international MFA convention, the total crude mineral extracted should be accounted instead of the net mineral content. This is the “run of mine” approach. This implies that the data reported in the statistics have to be multiplied by a factor reflecting the concentration of the metal in crude ores. The following table shows the factors used in our estimations and their source.

Through interviews with experts[3], we learnt that there is a risk of double counting when applying factors since crude metal ores in many cases contain several metals. The metals produced in Mexico that frequently occur as by-products of other ores are: arsenic, bismuth, cadmium, selenium. These metals were not multiplied by their respective factor. For the specific case of lead and zinc that may occur in the same crude ore, we may have a problem of double counting since concentration factors were applied to both. Ores and industrial minerals are in general reported in tonnes, thus no particular conversion was needed apart from the respective ores listed in Table AI.11.

[3] Interview with Sergio Rendón Medina, Director of Mining Statistics and Analysis in the Ministry of Economy. In Mexico City on 17th of March, 2006.

Table AI.11 Metals conversion factors

Metals ores or concentrates	Metal contents in crude ores or concentrates as %	Factor (multiplier) to convert metal contents into total crude ore in metric tonnes (t)
Antimony ore	9,0	11,11
Copper ores	0,8	125,00
Gold ores	0,0001	1000000,00
Iron ores	58,0	1,72
Lead ores	8,75	11,43
Manganese ores	30,0	3,33
Mercury concentrates	50,0	2,00
Molybdenum ores	0,2	500,00
Silver ores	0,03	3333,33
Tin ores	0,3604	277,47
Tungsten ores	1,09	91,71
Zinc ores	12,2	8,20

Source: UNSTATS 2001.

Mineral ores data reliability can be considered high since under the *Minerals Law*, annual reporting of data by mines is compulsory. As for the industrial minerals data, we can differentiate two periods: in the period 1975-onwards, information can be considered good while data quality for the first half of the seventies is rather low since there is a lack of data for some industrial minerals such as salt, celestite (strontium sulphate), calcite, bentonite and feldspar.

Further improvements can be made by checking for double counting for ores such as zinc, lead as well as copper. It would be a valuable next activity to improve the reliability of the result.

1.3.2 Domestic Extraction of construction minerals

Construction minerals are raw materials extracted from nature that are used for construction directly or that are used for the production of construction minerals like bricks or tiles (Eurostat 2002). For Mexico, data on domestic extraction of marble, clays, dolomite, limestone are available and were taken from the Mexican Mining Yearbooks (*Informes de la Minería Mexicana)*(SGM 2003, 2002, 2001, 2000, 1999, 1998, 1993).

Nevertheless, there is a gap in sand and gravel statistics, a common problem not only found in developing countries but also in industrialised countries. In general, coverage of construction minerals is unsatisfactory in industrialised countries (Bringezu and Schutz 2001, Eurostat 2002) because of several reasons: prices of these minerals are generally very low and building and cement companies extract these minerals directly, not buying these materials in the market. In the special case of Mexico, another explanation is that in the *Mining Law*, annual reporting of industrial minerals and ores extraction by mines has been compulsory which not the case for construction minerals is. Extraction of construction minerals is not monitored by the government. Therefore, there are no statistics of such minerals but incomplete data collected by the Mexican Geologic Services and only from the year 1981 onwards.

In addition, there is no agreed methodology for calculating indirectly sand & gravel extraction and several methods have been used. For instance, in the MOSUS project, the estimation procedure used was calculating levels of per capita extraction of construction minerals depending on the income level. The assumption behind this procedure is that construction minerals extraction increases, when population grows and the absolute level is determined by GDP/capita levels (Giljum *et al.* 2005).

In this paper, the annual quantity of sand and gravel used in the economy was calculated from the quantity of cement consumed. According to this method, the relation cement to sand and gravel for producing concrete is 1:4, that is, for each tonne of cement domestically consumed, 4 tonnes of sand and gravel are needed. In addition, the relation of sand& gravel for concrete production to the use of sand and gravel as a filling material is estimated to be 1:2.5. Once having calculated the quantity of sand and gravel with this methodology, the estimation obtained was summed up to the rest of construction minerals available as shown in Table AI.12.

Table AI.12 Construction minerals in Mexico

	1970		2003	
	Magnitude (1000 t)	**Const. min / capita tonnes**	**Magnitude (1000 t)**	**Const. min / capita tonnes**
Sand & gravel (estimate)	100,520		448,000	
Other construction minerals	474		73,591	
TOTAL	100,994	2	521,591	5

Source: own calculations

The results are totally consistent with the level of per capita extraction, calculated for a country such as Mexico in other studies. Mexico in the seventies had a per capita construction mineral extraction of 2 tonnes which is within the range observed in developing countries. In 2003, Mexico reached the level of 5 tonnes per capita which corresponds to a middle income country (see the MOSUS project website for further details on levels of extraction per capita based on income. http://www.mosus.net//).

Due to the lack of data on this type of minerals, it is rather unlikely that improvements can be made in the near future using direct information. However, we would recommend trying other indirect methods of estimations and comparisons between national case studies.

1.4 Foreign trade: Imports and Exports

Foreign trade in Mexico has shown a dramatic change during the last two decades. While in the seventies, the Mexican economy was hardly present at international markets in 1986 trade barriers and tariffs were suppressed, making Mexico one of the most economic open countries in the world. This trend has been reflected in both, the incoming and outgoing trade flows during the period under analysis.

Table AI.13 Mexico: Imports and Exports

(1000 t)	1970	2003
Imports	8,516	185,117
Exports	14,180	243,770
Physical trade Balance	-5,654	-58,663

Source: own calculations

Imports in 2003 were nearly 22 times bigger than in 1970. Exports followed the same trend: in 2003 they were 17 times bigger than in 1970. Data on imports and exports for Mexico stem from different national databases. The Physical Trade Balance (PTB) is negative in both years, which means that Mexico has been a net exporter of materials. However, there have been some years when a positive PTB was registered along the period under study. It is of great relevance the fact that in 1994 the North American Free Trade Agreement (NAFTA) was put into action and from then on the PTB has been mainly positive meaning that Mexico has been a net importer of materials in the last decade.

For the period between 1970-1974, data was extracted from the Mexican Foreign Trade Yearbooks published by the Ministry of Industry and Commerce (SPP 1971, 1973, 1975) where data on imports and exports are provided in tonnes, classified in 9 sections: food, beverages and tobacco, raw materials, fuels, lubricants, chemical products, manufactured products, machinery, diverse final products and arms and weapons.

For the period 1975-1993, historical time series of imports and exports were taken from the database *(Estadísticas Históricas del Comercio Exterior de México)* (INEGI 1998). This database is divided into two periods. In the first period up to 1987, commodities were classified using the "old classification", the Brussels Commodity Nomenclature. In Mexico, this classification was used from 1965 until the first semester of 1988. From the second semester of 1988 it was substituted by the HS "harmonized commodity description and Coding System". Therefore, the second period from 1988 up to 1993 is classified following this international convention. The primary sources of this historical database are the Mexican Foreign Trade Yearbooks, quoted in precedent lines. In addition, two important facts concerning this database are that information is disaggregated to 6 digits, and an important quantity of items are provided in several different units of measurement – especially metal final products- are provided either in units (pieces, pairs) while fabrics are provided in squared meters. Therefore, all these items has to be converted into tonnes using coefficients.

Finally, for the last period (1993-2003), the database World Trade Atlas (BANCOMEXT 2002, 2004) was used. This is a modern and easy to access database provided by BANCOMEXT which is the government institution that deals with foreign trade. The primary source of the information compiled in this database is the Ministry of Economy *(SECOFI, Secretaría de Comercio y Fomento Industrial*). As in the previous period, a great quantity of metal items was provided mainly in pieces in this database. Also in this case, coefficients were applied for converting all these items into tonnes.

The *maquila* industry:

Whether the imports and exports flows arising from the maquila industry in Mexico are accounted in this calculation is of great relevance due to the increasing economic importance of these activities in Mexico.

Maquila industry are assembly plants that use imported foreign parts and semi-finished products to produce final products for exports, taking advantage of the big pool of cheap labour in developing countries. In 1966 the first maquila activities started in the northern border region of Mexico (Carrillo and de la O 2003). However, it was not before 1990, when the maquila industry gained economic relevance due to the dramatic growth and increasing contribution both in the economy and employment registered in this decade. In 2000, the maquila industry produced 48% of the total manufactured exports (De la Garza 2005) and according to foreign trade statistics (BANCOMEXT 2004) the maquila exports share was 47,7% of total Mexican exports and 35,3% of total Mexican imports, both in monetary terms.

For the long period between 1970 up to 1992, the maquila foreign trade flows should be accounted for in the Mexican Foreign Trade Yearbooks although these flows are not differentiated from the rest of the flows arising from the national industry. Since we could not find information on whether these flows are accounted, in this paper we assumed that the imports and exports arising from the maquila activities in Mexico were considered in this period's total imports as well as in total exports. We assumed so, due to a footnote found in the Foreign Trade Yearbooks, published by the Ministry of Industry and Commerce (SPP 1971, 1973, 1975), where it was mentioned that the import and export figures reported in these publications are those declared by the importers and exporters in the corresponding customs documents. Importers and exporters are obliged to declare.

From 1993 onwards, all foreign trade databases offer: 1) the maquila figures separately from 2) the national industry *figures* and 3) the total were both concepts are summed up. Hence, the total imports and exports were used in our calculations.

This is the first time that a disaggregated exports and imports times series data is calculated in tonnes for Mexico using national databases. Harmonisation of the diverse databases has implied a great deal of effort. However, further improvements can be made in the conversion step into tonnes, being more precise in the weights applied. For instance, washing machines are available in different sizes and weights. Here in this study we applied an average weight. However, the biggest part of the items needing to be converted account for a very small fraction of total trade flows.

2. CONCLUSIONS

This is the first Material Flow Account for Mexico carried out for a thirty years period and based mainly on national data sources. The results show the important rise of materials domestically extracted in Mexico and particularly, of considerable increases of fossil fuels and construction minerals. Regarding imports and exports, both have shown a dramatic rise in terms of weight during the period under study. Imports have passed from 8.5 to 185 million tonnes whilst exports have grown from 14 to 243 million tonnes; registering an annual average growth rate of 2.1% and 1,6% respectively.

In general, quality and reliability of the information used for estimating the main material flows is good. Our biomass extraction figures comprise most of the materials used in the economy and can be considered a reliable estimate. Fossil fuels estimates and metal ores and industrial minerals can also be considered of good reliability.

However, the calculations presented in this study can be improved in two directions. On the one hand, in the biomass flow by a) calculating an overall figure of fuel wood extraction by means of direct methodologies, b) including wood illegally extracted, c) including estimates of non-timber products collected directly by the consumers.

On the other hand, important improvements can be carried out with regard to mineral flows and particularly, for construction minerals by including data on sand and gravel obtained directly or by investing in more sophisticated modelling of such flows. Nevertheless, it is rather unlikely that improvements can be made in the near future since generating data through direct methods, such as census and surveys, imply a great deal of time and money. However, we would recommend comparing the Mexican results to material flow data for other countries in the region to see communalities and variations.

It is also the first time that a disaggregated physical export and import time-series were calculated in tonnes for Mexico using national databases. Harmonisation of the diverse databases has implied a great deal of effort. Although further improvements in data quality can be made, these will not necessarily change the overall trends considerably.

Annex. Detailed tables

Part I

Mexico

Unit: 1000 tonnes

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
DOMESTIC EXTRACTION	**376.357**	**376.125**	**396.777**	**420.327**	**443.156**	**472.752**	**487.744**	**521.854**	**580.452**	**608.569**
Biomass	**204.257**	**204.724**	**204.212**	**206.654**	**207.311**	**213.860**	**207.504**	**215.987**	**227.185**	**218.069**
Food crops	61.930	61.609	61.168	62.867	63.551	67.062	61.986	63.732	72.363	68.554
Fodder	124.823	125.961	125.292	125.710	125.062	128.242	126.656	131.221	133.331	127.704
Animals	308	286	302	358	390	451	526	562	704	850
Timber	15.645	15.377	15.881	16.049	16.475	16.746	17.049	19.083	19.385	19.819
Non edible biomass	1.551	1.491	1.569	1.671	1.832	1.359	1.286	1.390	1.403	1.142
Minerals	**131.359**	**132.389**	**152.243**	**172.283**	**185.948**	**200.047**	**216.817**	**232.560**	**263.090**	**283.638**
Construction minerals	100.994	103.527	120.917	140.378	152.355	167.663	181.401	190.434	219.853	237.162
Industrial minerals	3.125	3.334	3.396	3.683	4.034	4.020	3.689	8.727	10.170	10.600
Ores	27.239	25.527	27.930	28.221	29.559	28.364	31.728	33.398	33.067	35.876
Fossil fuels	**40.741**	**39.013**	**40.322**	**41.390**	**49.898**	**58.846**	**63.423**	**73.307**	**90.176**	**106.862**
Coal and products	2.959	1.776	1.899	2.082	2.252	2.344	2.344	2.685	2.646	2.654
Crude oil and products	24.223	24.119	24.963	25.511	32.463	40.466	45.344	55.395	68.469	82.503
Natural gas and products	13.559	13.118	13.461	13.798	15.183	16.035	15.736	15.227	19.061	21.704
Products from fossils										
IMPORTS	**8.516**	**9.226**	**10.725**	**15.997**	**13.985**	**15.902**	**11.782**	**12.460**	**16.877**	**17.229**
Biomass	**2.261**	**1.712**	**2.797**	**3.861**	**5.454**	**5.255**	**2.763**	**5.885**	**5.890**	**6.194**
Food crops	1.021	391	1.263	2.236	3.651	3.098	1.450	2.986	3.141	1.987
Fodder	-	-	-	-	-	880	111	731	788	857
Animals	236	262	282	298	374	132	152	168	188	287
Timber	539	420	420	511	550	735	692	734	793	1.029
Non edible biomass	465	639	832	816	879	410	357	1.266	980	2.034
Minerals	**3.151**	**2.874**	**3.115**	**4.258**	**4.516**	**7.303**	**5.882**	**4.840**	**8.328**	**8.812**
Construction minerals						230	196	67	118	246
Industrial minerals	1.648	1.697	1.772	1.925	2.040	3.712	3.417	2.982	4.455	4.274
Ores	1.503	1.177	1.344	2.333	2.477	3.361	2.269	1.792	3.754	4.292
Fossil fuels	**3.104**	**4.640**	**4.813**	**7.879**	**4.014**	**3.344**	**3.137**	**1.735**	**2.659**	**2.223**
Coal and products	-	-	-	-	-	563	190	92	472	435
Crude oil and products	-	-	-	-	-	2.126	2.220	793	1.215	826
Natural gas and products	-	-	-	-	-	1	1	1	0	0
Products from fossils	-	-	-	-	-	654	726	849	972	961
EXPORTS	**14.180**	**14.587**	**15.873**	**13.778**	**16.403**	**17.669**	**19.922**	**27.976**	**38.541**	**45.915**
Biomass	**2.952**	**3.479**	**4.016**	**3.323**	**3.207**	**2.380**	**2.585**	**3.317**	**3.772**	**3.490**
Food crops	2.090	2.673	2.962	2.598	2.493	1.854	1.832	2.279	2.368	2.498
Fodder	-	-	-	-	-	3	4	2	2	2
Animals	260	231	286	213	167	128	213	242	302	177
Timber	62	59	82	68	72	96	211	480	703	404
Non edible biomass	540	516	685	444	474	299	325	314	397	409
Minerals	**7.398**	**8.288**	**9.814**	**8.672**	**10.605**	**9.025**	**10.323**	**12.805**	**14.534**	**13.000**
Construction minerals	6.339	7.062	8.223	7.351	9.042	490	719	1.922	1.708	824
Industrial minerals	214	289	436	443	459	6.633	6.549	6.950	8.704	8.225
Ores	844	938	1.155	877	1.104	1.901	3.055	3.933	4.122	3.951
Fossil fuels	**3.831**	**2.819**	**2.043**	**1.784**	**2.591**	**6.264**	**7.014**	**11.854**	**20.235**	**29.425**
Coal and products	-	-	-	-	-	16	0	0	44	68
Crude oil and products	-	-	-	-	-	6.125	6.822	11.613	19.729	28.894
Natural gas and products	-	-	-	-	-	10	0	52	201	201
Products from fossils	-	-	-	-	-	113	192	188	261	261

Source: Own estimates based on national data sources

Annex. Detailed tables

Part II

Mexico

Unit: 1000 tonnes

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
DOMESTIC EXTRACTION	**688.515**	**751.757**	**790.176**	**756.532**	**775.626**	**816.170**	**787.835**	**834.841**	**834.809**	**851.482**
Biomass	**233.131**	**241.678**	**231.577**	**238.152**	**241.178**	**250.832**	**249.401**	**255.285**	**247.243**	**249.308**
Food crops	74.843	76.932	75.479	76.598	79.412	82.823	87.780	91.155	85.696	86.952
Fodder	136.339	142.387	133.706	138.904	138.626	144.337	138.023	139.589	136.609	137.833
Animals	1.059	1.364	1.160	973	993	1.099	1.177	1.281	1.237	1.336
Timber	19.909	19.965	20.321	20.656	21.154	21.584	21.597	22.228	22.274	22.243
Non edible biomass	982	1.030	910	1.022	994	989	824	1.032	1.428	944
Minerals	**318.906**	**348.070**	**371.140**	**335.890**	**352.240**	**387.556**	**372.147**	**405.822**	**415.482**	**429.439**
Construction minerals	259.418	291.223	311.767	274.880	287.862	321.196	306.316	337.394	344.327	356.729
Industrial minerals	13.795	9.354	12.005	12.738	14.206	15.051	14.421	14.653	15.448	16.420
Ores	45.693	47.493	47.368	48.272	50.173	51.309	51.410	53.775	55.708	56.290
Fossil fuels	**136.478**	**162.008**	**187.458**	**182.490**	**182.207**	**177.782**	**166.287**	**173.734**	**172.083**	**172.735**
Coal and products	408	1.237	786	1.818	2.215	2.440	3.678	4.252	4.211	4.244
Crude oil and products	109.594	130.552	155.071	150.506	151.990	148.524	137.076	143.451	141.919	141.910
Natural gas and products	26.476	30.219	31.601	30.166	28.002	26.817	25.533	26.031	25.953	26.582
Products from fossils										
IMPORTS	**41.493**	**39.017**	**25.545**	**30.588**	**29.543**	**33.604**	**19.354**	**23.911**	**51.382**	**99.468**
Biomass	**22.417**	**16.019**	**9.256**	**21.941**	**17.270**	**13.422**	**7.481**	**10.213**	**12.350**	**27.669**
Food crops	13.668	8.167	3.808	13.490	9.648	6.548	3.813	6.013	3.825	7.073
Fodder	3.812	2.940	2.589	6.340	5.144	3.475	794	789	802	3.114
Animals	513	537	330	336	304	486	375	390	544	843
Timber	1.774	1.779	1.005	1.274	1.302	1.771	1.312	1.726	6.575	14.569
Non edible biomass	2.649	2.596	1.524	502	872	1.141	1.187	1.296	604	2.070
Minerals	**15.281**	**19.520**	**12.334**	**6.580**	**9.393**	**14.374**	**8.010**	**9.269**	**35.916**	**64.429**
Construction minerals	585	889	430	52	76	98	62	72	110	272
Industrial minerals	5.079	8.387	7.948	4.307	6.237	7.504	4.737	4.820	1.925	3.716
Ores	9.617	10.244	3.957	2.221	3.080	6.772	3.212	4.377	33.881	60.442
Fossil fuels	**3.795**	**3.478**	**3.955**	**2.067**	**2.880**	**5.808**	**3.863**	**4.430**	**3.116**	**7.370**
Coal and products	1.620	951	1.253	331	446	1.222	325	112	98	10
Crude oil and products	601	722	1.326	610	1.033	2.317	1.984	2.859	2.167	5.413
Natural gas and products	1	0	0	0	1	1	1	1	1	1
Products from fossils	1.573	1.805	1.376	1.125	1.401	2.267	1.553	1.458	851	1.946
EXPORTS	**77.978**	**94.679**	**112.273**	**125.143**	**135.515**	**128.280**	**108.789**	**130.021**	**104.508**	**132.680**
Biomass	**3.387**	**2.512**	**3.062**	**3.495**	**4.726**	**4.094**	**7.010**	**7.091**	**4.107**	**5.440**
Food crops	2.764	1.901	2.329	1.940	3.180	3.271	3.062	4.143	2.822	4.056
Fodder	5	2	9	2	2	2	3	7	4	44
Animals	161	149	180	269	174	218	357	377	211	559
Timber	154	145	280	1.020	986	314	3.208	2.114	826	549
Non edible biomass	303	316	264	265	384	288	380	450	243	231
Minerals	**23.037**	**24.059**	**21.065**	**31.441**	**36.944**	**34.174**	**25.422**	**43.394**	**24.608**	**47.623**
Construction minerals	805	590	820	2.577	4.782	5.322	4.194	4.812	2.266	4.709
Industrial minerals	18.247	17.462	14.589	16.181	17.322	15.828	9.030	10.188	5.396	11.647
Ores	3.986	6.007	5.657	12.683	14.840	13.025	12.199	28.394	16.946	31.267
Fossil fuels	**51.554**	**68.107**	**88.146**	**90.207**	**93.845**	**90.012**	**76.357**	**79.536**	**75.793**	**79.617**
Coal and products	14	0	35	0	0	164	25	64	143	58
Crude oil and products	48.558	65.468	85.526	87.579	91.377	88.317	74.780	77.898	74.062	77.220
Natural gas and products	2.747	2.390	2.222	1.887	1.454	616	593	517	1.023	971
Products from fossils	234	249	363	741	1.014	915	959	1.056	564	1.367

Source: Own estimates based on national data sources

Annex. Detailed tables

Mexico

Part III

Unit:1000 tonnes

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
DOMESTIC EXTRACTION	**875.920**	**897.633**	**938.303**	**952.513**	**999.204**	**924.228**	**980.748**	**1.030.056**	**1.046.058**	**1.061.465**
Biomass	**259.991**	**255.374**	**265.811**	**266.359**	**269.012**	**275.806**	**283.870**	**281.889**	**287.953**	**281.810**
Food crops	87.939	84.950	89.903	90.499	90.486	95.894	100.944	100.486	104.912	100.333
Fodder	146.354	145.081	150.959	151.371	154.096	154.873	157.508	155.427	156.956	154.754
Animals	1.447	1.453	1.246	1.192	1.260	1.404	1.530	1.571	1.233	1.286
Timber	22.056	21.965	22.128	21.789	21.885	22.320	22.741	23.240	23.590	23.801
Non edible biomass	2.196	1.925	1.575	1.509	1.284	1.313	1.147	1.167	1.261	1.635
Minerals	**440.663**	**459.265**	**489.648**	**502.875**	**545.213**	**465.282**	**494.963**	**535.771**	**541.251**	**571.152**
Construction minerals	365.938	385.918	413.661	424.844	462.666	373.965	398.430	435.876	439.839	472.356
Industrial minerals	16.797	16.042	16.156	15.518	15.963	16.570	18.093	18.233	18.919	18.808
Ores	57.929	57.304	59.831	62.513	66.584	74.747	78.440	81.661	82.493	79.989
Fossil fuels	**175.266**	**182.993**	**182.844**	**183.279**	**184.979**	**183.141**	**201.915**	**212.396**	**216.854**	**208.502**
Coal and products	4.220	4.865	5.060	5.718	6.393	7.391	8.780	8.510	7.832	8.765
Crude oil and products	143.869	151.085	151.040	150.950	151.610	147.776	161.832	170.644	173.369	164.085
Natural gas and products	27.177	27.043	26.744	26.611	26.976	27.973	31.303	33.242	35.653	35.653
Products from fossils										
IMPORTS	**90.953**	**167.544**	**173.966**	**140.407**	**127.688**	**106.083**	**134.758**	**169.826**	**203.372**	**246.742**
Biomass	**53.116**	**68.461**	**98.499**	**54.560**	**67.348**	**36.685**	**38.034**	**33.520**	**37.064**	**40.325**
Food crops	9.231	6.133	7.894	7.181	10.062	8.578	14.799	11.504	15.292	16.919
Fodder	3.312	3.803	5.545	4.330	4.268	2.648	2.491	2.557	3.585	5.222
Animals	11.101	1.023	1.361	1.275	1.343	842	1.114	1.410	1.557	1.659
Timber	27.919	55.482	81.421	39.187	47.912	20.985	12.829	12.867	9.529	10.411
Non edible biomass	1.552	2.021	2.278	2.588	3.764	3.632	6.802	5.183	7.100	6.115
Minerals	**30.012**	**89.390**	**62.290**	**74.405**	**45.252**	**55.192**	**83.303**	**104.945**	**136.516**	**181.050**
Construction minerals	318	393	743	809	961	509	467	900	1.279	1.283
Industrial minerals	4.825	4.479	3.996	3.393	9.631	6.369	7.333	9.756	11.369	11.063
Ores	24.868	84.518	57.551	70.203	34.660	48.314	75.503	94.289	123.868	168.704
Fossil fuels	**7.825**	**9.693**	**13.177**	**11.442**	**15.088**	**14.205**	**13.421**	**31.361**	**29.792**	**25.366**
Coal and products	277	135	614	824	877	1.708	1.979	2.777	2.958	2.808
Crude oil and products	5.554	7.009	9.006	7.932	8.785	8.099	7.403	12.351	15.293	15.554
Natural gas and products	1	1	1	1	1	1	2	2	2	3
Products from fossils	1.993	2.549	3.556	2.685	5.425	4.397	4.036	16.230	11.539	7.001
EXPORTS	**131.456**	**109.364**	**115.752**	**108.617**	**151.858**	**126.914**	**137.647**	**147.598**	**150.205**	**147.142**
Biomass	**4.606**	**5.310**	**5.275**	**5.599**	**6.815**	**10.412**	**9.555**	**10.418**	**12.501**	**14.572**
Food crops	3.288	4.096	3.507	3.804	4.313	6.691	6.674	7.266	9.047	8.402
Fodder	36	41	57	43	34	72	43	61	37	73
Animals	686	565	511	627	524	811	412	479	466	611
Timber	441	422	1.018	675	1.358	1.662	1.283	1.259	1.417	1.496
Non edible biomass	155	187	182	450	586	1.177	1.143	1.352	1.533	3.989
Minerals	**49.037**	**20.520**	**26.648**	**25.756**	**65.513**	**40.806**	**43.646**	**43.531**	**42.394**	**44.132**
Construction minerals	3.196	3.856	6.053	6.358	6.472	10.231	13.213	12.201	10.952	10.562
Industrial minerals	10.562	12.528	11.887	12.148	14.334	16.379	17.156	16.880	15.758	16.231
Ores	35.280	4.137	8.707	7.250	44.707	14.197	13.278	14.450	15.684	17.339
Fossil fuels	**77.812**	**83.533**	**83.829**	**77.262**	**79.530**	**75.696**	**84.446**	**93.650**	**95.310**	**88.438**
Coal and products	10	30	0	5	1	1	15	1	3	70
Crude oil and products	74.127	78.999	79.783	73.474	71.416	71.527	80.475	90.269	91.508	83.619
Natural gas and products	1.603	1.226	636	628	1.038	1.021	1.018	463	392	1.240
Products from fossils	2.072	3.278	3.410	3.155	7.075	3.147	2.938	2.917	3.407	3.509

Source: Own estimates based on national data sources

Annex. Detailed tables

Mexico

Part IV

Unit: 1000 tonnes

	2000	2001	2002	2003
DOMESTIC EXTRACTION	**1.117.592**	**1.118.517**	**1.119.185**	**1.148.232**
Biomass	**288.038**	**297.880**	**289.335**	**295.667**
Food crops	104.698	108.496	103.688	106.405
Fodder	155.054	161.104	159.293	161.559
Animals	1.403	1.521	1.554	1.565
Timber	24.379	23.862	23.295	23.533
Non edible biomass	2.505	2.897	1.505	2.606
Minerals	**616.435**	**603.523**	**611.171**	**622.109**
Construction minerals	512.833	500.955	511.717	521.591
Industrial minerals	19.740	21.379	20.024	20.907
Ores	83.862	81.189	79.430	79.611
Fossil fuels	**213.118**	**217.114**	**218.679**	**230.456**
Coal and products	8.230	6.986	6.371	6.648
Crude oil and products	170.066	176.562	179.390	190.333
Natural gas and products	34.822	33.566	32.918	33.475
Products from fossils				
IMPORTS	**251.063**	**244.297**	**298.021**	**185.117**
Biomass	**41.080**	**67.132**	**97.246**	**46.636**
Food crops	17.284	20.022	20.033	21.327
Fodder	5.693	5.731	5.651	4.604
Animals	1.902	2.043	2.120	2.089
Timber	9.705	11.065	60.925	11.635
Non edible biomass	6.495	28.271	8.517	6.981
Minerals	**178.975**	**147.920**	**167.448**	**119.184**
Construction minerals	1.511	1.167	1.367	1.202
Industrial minerals	23.900	9.491	11.495	10.246
Ores	153.564	137.262	154.587	107.736
Fossil fuels	**31.007**	**29.245**	**33.326**	**19.297**
Coal and products	3.067	3.853	6.294	7.748
Crude oil and products	20.168	17.616	7.246	2.504
Natural gas and products	4	3	3	3
Products from fossils	7.768	7.773	19.783	9.042
EXPORTS	**158.835**	**166.015**	**212.654**	**243.770**
Biomass	**15.539**	**23.805**	**33.935**	**15.309**
Food crops	8.525	8.961	10.194	8.528
Fodder	58	78	60	147
Animals	719	656	586	670
Timber	2.069	1.422	1.709	2.274
Non edible biomass	4.169	12.687	21.386	3.691
Minerals	**46.733**	**44.810**	**72.412**	**106.039**
Construction minerals	11.168	11.663	10.283	11.257
Industrial minerals	14.598	13.072	11.616	11.954
Ores	20.967	20.074	50.513	82.828
Fossil fuels	**96.563**	**97.400**	**106.307**	**122.421**
Coal and products	6	9	4	2
Crude oil and products	92.087	93.107	95.032	106.137
Natural gas and products	363	289	48	9
Products from fossils	4.107	3.995	11.223	16.273

Source: Own estimates based on national data sources

Annex. Detailed tables

Mexico- Material Input Extensive Indicators

Part I

Unit:1000 tonnes

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
DE	**376.357**	**376.125**	**396.777**	**420.327**	**443.156**	**472.752**	**487.744**	**521.854**	**580.452**	**608.569**	**688.515**
Biomass	204.257	204.724	204.212	206.654	207.311	213.860	207.504	215.987	227.185	218.069	233.131
Minerals	131.359	132.389	152.243	172.283	185.948	200.047	216.817	232.560	263.090	283.638	318.906
Fossil fuels	40.741	39.013	40.322	41.390	49.898	58.846	63.423	73.307	90.176	106.862	136.478
DMI	**384.873**	**385.351**	**407.502**	**436.325**	**457.141**	**488.654**	**499.526**	**534.314**	**597.328**	**625.798**	**730.009**
Biomass	206.518	206.436	207.008	210.515	212.764	219.114	210.267	221.872	233.075	224.263	255.549
Minerals	134.509	135.262	155.358	176.540	190.464	207.350	222.699	237.400	271.418	292.450	334.187
Fossil Fuels	43.845	43.653	45.135	49.269	53.912	62.190	66.560	75.042	92.835	109.084	140.273
DMC	**370.693**	**370.764**	**391.629**	**422.546**	**440.738**	**470.985**	**479.604**	**506.337**	**558.788**	**579.883**	**652.030**
Biomass	203.566	202.957	202.993	207.193	209.558	216.734	207.681	218.554	229.303	220.773	252.161
Minerals	127.112	126.974	145.545	167.869	179.859	198.325	212.377	224.595	256.885	279.450	311.149
Fossil Fuels	40.015	40.834	43.092	47.485	51.321	55.926	59.546	63.188	72.600	79.659	88.719
PTB	**-5.664**	**-5.361**	**-5.148**	**2.219**	**-2.418**	**-1.767**	**-8.140**	**-15.517**	**-21.664**	**-28.686**	**-36.485**
Biomass	-691	-1.767	-1.219	538	2.247	2.875	178	2.567	2.118	2.704	19.030
Minerals	-4.247	-5.415	-6.698	-4.414	-6.088	-1.722	-4.440	-7.965	-6.206	-4.188	-7.756
Fossil fuels	-726	1.821	2.769	6.095	1.423	-2.919	-3.877	-10.119	-17.576	-27.203	-47.759

Mexico- Material Input Intensive Indicators

Unit: tonnes per capita

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
DE	**7,4**	**7,2**	**7,4**	**7,6**	**7,7**	**8,0**	**8,0**	**8,3**	**9,0**	**9,2**	**10,2**
Biomass	4,0	3,9	3,8	3,7	3,6	3,6	3,4	3,5	3,5	3,3	3,5
Minerals	2,6	2,5	2,8	3,1	3,2	3,4	3,6	3,7	4,1	4,3	4,7
Fossil fuels	0,8	0,7	0,7	0,7	0,9	1,0	1,0	1,2	1,4	1,6	2,0
DMI	**7,6**	**7,4**	**7,6**	**7,8**	**8,0**	**8,3**	**8,2**	**8,5**	**9,3**	**9,5**	**10,8**
Biomass	4,1	4,0	3,8	3,8	3,7	3,7	3,5	3,5	3,6	3,4	3,8
Minerals	2,7	2,6	2,9	3,2	3,3	3,5	3,7	3,8	4,2	4,4	4,9
Fossil Fuels	0,9	0,8	0,8	0,9	0,9	1,1	1,1	1,2	1,4	1,7	2,1
DMC	**7,3**	**7,1**	**7,3**	**7,6**	**7,7**	**8,0**	**7,9**	**8,1**	**8,7**	**8,8**	**9,6**
Biomass	4,0	3,9	3,8	3,7	3,7	3,7	3,4	3,5	3,6	3,3	3,7
Minerals	2,5	2,4	2,7	3,0	3,1	3,4	3,5	3,6	4,0	4,2	4,6
Fossil Fuels	0,79	0,78	0,80	0,85	0,89	0,95	0,98	1,01	1,13	1,21	1,31

Mexico- Material Input Intensive Indicators

Unit: tonnes per 1000 US $ (constant US$ 2000)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
DE	**2,08**	**2,00**	**1,95**	**1,92**	**1,91**	**1,93**	**1,90**	**1,97**	**2,01**	**1,92**	**1,99**
Biomass	1,13	1,09	1,00	0,94	0,89	0,87	0,81	0,81	0,79	0,69	0,67
Minerals	0,72	0,70	0,75	0,78	0,80	0,81	0,85	0,88	0,91	0,90	0,92
Fossil fuels	0,22	0,21	0,20	0,19	0,21	0,24	0,25	0,28	0,31	0,34	0,39
DMI	**2,1**	**2,0**	**2,0**	**2,0**	**2,0**	**2,0**	**1,9**	**2,0**	**2,1**	**2,0**	**2,1**
Biomass	1,1	1,1	1,0	1,0	0,9	0,9	0,8	0,8	0,8	0,7	0,7
Minerals	0,7	0,7	0,8	0,8	0,8	0,8	0,9	0,9	0,9	0,9	1,0
Fossil Fuels	0,2	0,2	0,2	0,2	0,2	0,3	0,3	0,3	0,3	0,3	0,4
DMC	**2,0**	**2,0**	**1,9**	**1,9**	**1,9**	**1,9**	**1,9**	**1,9**	**1,9**	**1,8**	**1,9**
Biomass	1,1	1,1	1,0	0,9	0,9	0,9	0,8	0,8	0,8	0,7	0,7
Minerals	0,7	0,7	0,7	0,8	0,8	0,8	0,8	0,8	0,9	0,9	0,9
Fossil Fuels	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,3	0,3	0,3

Source: Own estimates based on national data sources. Source for population is Presidencia de la República (2005) and for GDP is WB (2007).

Annex. Detailed tables

Mexico- Material Input Extensive Indicators

Part II

Unit: 1000 tonnes

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
DE	**751.757**	**790.176**	**756.532**	**775.626**	**816.170**	**787.835**	**834.841**	**834.809**	**851.482**	**875.920**	**897.633**
Biomass	241.678	231.577	238.152	241.178	250.832	249.401	255.285	247.243	249.308	259.991	255.374
Minerals	348.070	371.140	335.890	352.240	387.556	372.147	405.822	415.482	429.439	440.663	459.265
Fossil fuels	162.008	187.458	182.490	182.207	177.782	166.287	173.734	172.083	172.735	175.266	182.993
DMI	**790.774**	**815.720**	**787.120**	**805.169**	**849.773**	**807.189**	**858.753**	**886.191**	**950.951**	**966.873**	**1.065.177**
Biomass	257.697	240.833	260.093	258.448	264.254	256.882	265.498	259.593	276.977	313.107	323.836
Minerals	367.590	383.474	342.470	361.634	401.930	380.157	415.091	451.398	493.868	470.675	548.655
Fossil Fuels	165.487	191.413	184.557	185.087	183.590	170.150	178.164	175.200	180.106	183.091	192.686
DMC	**696.095**	**703.447**	**661.977**	**669.654**	**721.494**	**698.400**	**728.732**	**781.684**	**818.271**	**835.418**	**955.814**
Biomass	255.185	237.771	256.598	253.722	260.160	249.873	258.407	255.486	271.537	308.501	318.526
Minerals	343.530	362.409	311.029	324.690	367.756	354.735	371.697	426.791	446.245	421.638	528.135
Fossil Fuels	97.380	103.267	94.350	91.242	93.578	93.793	98.628	99.407	100.489	105.279	109.153
PTB	**-55.662**	**-86.729**	**-94.555**	**-105.972**	**-94.676**	**-89.434**	**-106.109**	**-53.125**	**-33.211**	**-40.503**	**58.181**
Biomass	13.507	6.193	18.446	12.544	9.328	472	3.121	8.243	22.230	48.510	63.151
Minerals	-4.540	-8.731	-24.860	-27.551	-19.800	-17.412	-34.125	11.308	16.806	-19.026	68.870
Fossil fuels	-64.629	-84.191	-88.140	-90.965	-84.204	-72.493	-75.106	-72.677	-72.247	-69.987	-73.840

Mexico- Material Input Intensive Indicators

Unit: tonnes per capita

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
DE	**10,9**	**11,2**	**10,5**	**10,5**	**10,8**	**10,2**	**10,6**	**10,4**	**10,4**	**10,5**	**10,6**
Biomass	3,5	3,3	3,3	3,3	3,3	3,2	3,2	3,1	3,1	3,1	3,0
Minerals	5,0	5,2	4,6	4,8	5,1	4,8	5,2	5,2	5,3	5,3	5,4
Fossil fuels	2,3	2,6	2,5	2,5	2,4	2,2	2,2	2,1	2,1	2,1	2,2
DMI	**11,4**	**11,5**	**10,9**	**10,9**	**11,3**	**10,5**	**10,9**	**11,1**	**11,6**	**11,6**	**12,6**
Biomass	3,7	3,4	3,6	3,5	3,5	3,3	3,4	3,2	3,4	3,8	3,8
Minerals	5,3	5,4	4,7	4,9	5,3	4,9	5,3	5,6	6,0	5,7	6,5
Fossil Fuels	2,4	2,7	2,6	2,5	2,4	2,2	2,3	2,2	2,2	2,2	2,3
DMC	**10,1**	**9,9**	**9,1**	**9,1**	**9,6**	**9,1**	**9,3**	**9,8**	**10,0**	**10,0**	**11,3**
Biomass	3,7	3,4	3,5	3,4	3,4	3,2	3,3	3,2	3,3	3,7	3,8
Minerals	5,0	5,1	4,3	4,4	4,9	4,6	4,7	5,3	5,5	5,1	6,2
Fossil Fuels	1,41	1,46	1,30	1,23	1,24	1,22	1,26	1,24	1,23	1,26	1,29

Mexico- Material Input Intensive Indicators

Unit: tonnes per 1000 US $ (constant US$2000)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
DE	**2,00**	**2,11**	**2,11**	**2,09**	**2,14**	**2,15**	**2,24**	**2,21**	**2,16**	**2,12**	**2,08**
Biomass	0,64	0,62	0,66	0,65	0,66	0,68	0,68	0,65	0,63	0,63	0,59
Minerals	0,92	0,99	0,94	0,95	1,02	1,02	1,09	1,10	1,09	1,06	1,06
Fossil fuels	0,43	0,50	0,51	0,49	0,47	0,45	0,47	0,46	0,44	0,42	0,42
DMI	**2,1**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,3**	**2,3**	**2,4**	**2,3**	**2,5**
Biomass	0,7	0,6	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,8	0,8
Minerals	1,0	1,0	1,0	1,0	1,1	1,0	1,1	1,2	1,3	1,1	1,3
Fossil Fuels	0,4	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,4	0,4
DMC	**1,8**	**1,9**	**1,8**	**1,8**	**1,9**	**1,9**	**2,0**	**2,1**	**2,1**	**2,0**	**2,2**
Biomass	0,7	0,6	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7
Minerals	0,9	1,0	0,9	0,9	1,0	1,0	1,0	1,1	1,1	1,0	1,2
Fossil Fuels	0,3	0,3	0,3	0,2	0,2	0,3	0,3	0,3	0,3	0,3	0,3

Source: Own estimates based on national data sources. Source for population is Presidencia de la República (2005) and for GDP is WB (2007).

Annex. Detailed tables

Mexico- Material Input Extensive Indicators

Part III

Unit: 1000 tonnes

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DE	**938.303**	**952.513**	**999.204**	**924.228**	**980.748**	**1.030.056**	**1.046.058**	**1.061.465**	**1.117.592**	**1.118.517**	**1.119.185**	**1.148.232**
Biomass	265.811	266.359	269.012	275.806	283.870	281.889	287.953	281.810	288.038	297.880	289.335	295.667
Minerals	489.648	502.875	545.213	465.282	494.963	535.771	541.251	571.152	616.435	603.523	611.171	622.109
Fossil fuels	182.844	183.279	184.979	183.141	201.915	212.396	216.854	208.502	213.118	217.114	218.679	230.456
DMI	**1.112.268**	**1.092.921**	**1.126.892**	**1.030.311**	**1.115.506**	**1.199.882**	**1.249.430**	**1.308.206**	**1.368.654**	**1.362.814**	**1.417.206**	**1.333.349**
Biomass	364.310	320.920	336.359	312.491	321.904	315.410	325.017	322.135	329.118	365.011	386.582	342.303
Minerals	551.937	577.280	590.465	520.474	578.266	640.716	677.767	752.203	795.411	751.444	778.619	741.293
Fossil Fuels	196.021	194.721	200.068	197.346	215.336	243.757	246.646	233.868	244.126	246.359	252.005	249.754
DMC	**996.516**	**984.304**	**975.034**	**903.397**	**977.859**	**1.052.284**	**1.099.225**	**1.161.065**	**1.209.819**	**1.196.799**	**1.204.552**	**1.089.579**
Biomass	359.035	315.321	329.544	302.078	312.348	304.992	312.516	307.563	313.579	341.206	352.647	326.993
Minerals	525.289	551.524	524.952	479.668	534.620	597.185	635.373	708.071	748.678	706.634	706.207	635.254
Fossil Fuels	112.192	117.459	120.538	121.650	130.890	150.107	151.336	145.430	147.563	148.960	145.698	127.332
PTB	**58.214**	**31.790**	**-24.170**	**-20.832**	**-2.889**	**22.228**	**53.167**	**99.600**	**92.228**	**78.283**	**85.367**	**-58.653**
Biomass	93.224	48.961	60.532	26.273	28.479	23.102	24.563	25.753	25.541	43.326	63.312	31.326
Minerals	35.642	48.649	-20.261	14.386	39.657	61.414	94.122	136.919	132.242	103.111	95.036	13.145
Fossil fuels	-70.652	-65.820	-64.441	-61.491	-71.025	-62.289	-65.518	-63.072	-65.556	-68.154	-72.980	-103.124

Mexico- Material Input Intensive Indicators

Unit: tonnes per capita

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DE	**10,9**	**10,8**	**11,2**	**10,1**	**10,6**	**11,0**	**11,0**	**11,0**	**11,4**	**11,3**	**11,1**	**11,2**
Biomass	3,1	3,0	3,0	3,0	3,1	3,0	3,0	2,9	2,9	3,0	2,9	2,9
Minerals	5,7	5,7	6,1	5,1	5,3	5,7	5,7	5,9	6,3	6,1	6,1	6,1
Fossil fuels	2,1	2,1	2,1	2,0	2,2	2,3	2,3	2,2	2,2	2,2	2,2	2,3
DMI	**12,9**	**12,4**	**12,6**	**11,3**	**12,1**	**12,8**	**13,1**	**13,5**	**14,0**	**13,7**	**14,1**	**13,0**
Biomass	4,2	3,6	3,8	3,4	3,5	3,4	3,4	3,3	3,4	3,7	3,8	3,3
Minerals	6,4	6,6	6,6	5,7	6,2	6,8	7,1	7,8	8,1	7,6	7,7	7,2
Fossil Fuels	2,3	2,2	2,2	2,2	2,3	2,6	2,6	2,4	2,5	2,5	2,5	2,4
DMC	**11,5**	**11,2**	**10,9**	**9,9**	**10,6**	**11,2**	**11,5**	**12,0**	**12,3**	**12,0**	**11,9**	**10,7**
Biomass	4,2	3,6	3,7	3,3	3,4	3,2	3,3	3,2	3,2	3,4	3,5	3,2
Minerals	6,1	6,3	5,9	5,3	5,8	6,4	6,7	7,3	7,6	7,1	7,0	6,2
Fossil Fuels	1,30	1,34	1,35	1,33	1,41	1,60	1,59	1,51	1,51	1,50	1,45	1,24

Mexico- Material Input Intensive Indicators

Unit: tonnes per 1000 US $(constant US$2000)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DE	**2,10**	**2,09**	**2,10**	**2,07**	**2,09**	**2,06**	**1,99**	**1,95**	**1,92**	**1,93**	**1,91**	**1,94**
Biomass	0,59	0,58	0,57	0,62	0,60	0,56	0,55	0,52	0,50	0,51	0,49	0,50
Minerals	1,10	1,10	1,15	1,04	1,05	1,07	1,03	1,05	1,06	1,04	1,04	1,05
Fossil fuels	0,41	0,40	0,39	0,41	0,43	0,42	0,41	0,38	0,37	0,37	0,37	0,39
DMI	**2,5**	**2,4**	**2,4**	**2,3**	**2,4**	**2,4**	**2,4**	**2,4**	**2,4**	**2,3**	**2,4**	**2,3**
Biomass	0,8	0,7	0,7	0,7	0,7	0,6	0,6	0,6	0,6	0,6	0,7	0,6
Minerals	1,2	1,3	1,2	1,2	1,2	1,3	1,3	1,4	1,4	1,3	1,3	1,3
Fossil Fuels	0,4	0,4	0,4	0,4	0,5	0,5	0,5	0,4	0,4	0,4	0,4	0,4
DMC	**2,2**	**2,2**	**2,0**	**2,0**	**2,1**	**2,1**	**2,1**	**2,1**	**2,1**	**2,1**	**2,1**	**1,8**
Biomass	0,8	0,7	0,7	0,7	0,7	0,6	0,6	0,6	0,5	0,6	0,6	0,6
Minerals	1,2	1,2	1,1	1,1	1,1	1,2	1,2	1,3	1,3	1,2	1,2	1,1
Fossil Fuels	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,2	0,2

Source: Own estimates based on national data sources. Source for population is Presidencia de la República (2005) and for GDP is WB (2007).

ANNEX II

MATERIAL FLOW ACCOUNTING FOR SPAIN (1980-2004)

SOURCES AND MFA DATABASE

This document provides the data sources used in the compilation of the 1980-2004 data set for material flow accounts of the Spanish economy and presents the data tables.

Table AII.1. MFA categories, subcategories and data sources

Material categories	Subcategories	Data sources
Biomass	Food, fodder, animals, timber and other biomass	All data used to calculate biomass flow through Spanish economy has been obtained from FAO (2007). Data was verified and compared with national data from the Spanish Ministry of Agriculture, Fisheries and Food: Ministerio de Agricultura, Pesca y Alimentación (1980-2005).
Fossil fuels	Coal, Oil, Natural gas and other fossils	The source is Spanish Ministry of Industry: Ministerio de Industria, Comercio y Turismo (2001, 2002, 2005)
Minerals	Industrial minerals, metal ores and construction minerals	Data used for the mineral fraction of the MFA were obtained in the Spanish national statistics: 1) Spanish Ministry of Economy: Ministerio de Economía y Hacienda for the period 1980 -1998. 2) Spanish Ministry of Industry: Ministerio de Industria, Comercio y Turismo for the period 1999-2004
Imports and Exports		Data on foreign trade were obtained in three different sources: 1. For the period 1980-1984 the source is the Spanish foreign trade statistics published by the Ministry of Economy: Ministerio de Economía y Hacienda (1985) 2. For the period 1985-1991 the source is Eurostat (1992) and; 3. for the period 1992-2004 the source is Instituto Nacional de Estadística (INE, 2007).

Source: Own elaboration

Annex. Detailed tables

Part I

Spain

Unit: 1000 tons

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
DE	**324.030**	**311.892**	**324.905**	**323.542**	**329.460**	**328.957**	**326.302**	**349.157**	**372.306**	**419.378**	**396.876**	**412.469**
Biomass	110.925	98.731	105.854	104.240	116.580	112.467	108.407	120.018	121.086	118.390	118.576	114.034
Minerals	182.801	176.228	178.181	176.324	170.887	174.422	177.431	192.364	217.191	262.235	240.615	262.894
Fossil Fuels	30.304	36.933	40.870	42.978	41.993	42.068	40.465	36.775	34.029	38.752	37.686	35.541
IMPORTS	**96.780**	**92.849**	**93.849**	**94.506**	**92.588**	**97.902**	**103.968**	**120.862**	**124.850**	**128.994**	**138.561**	**143.777**
Biomass	14.481	13.236	15.198	15.480	12.076	12.503	14.158	18.100	18.686	19.291	22.464	23.472
Minerals	20.186	19.206	20.574	19.381	21.547	23.623	25.216	29.777	31.477	33.275	36.026	38.175
Fossil Fuels	62.113	60.407	58.077	59.645	58.964	61.777	64.594	72.986	74.687	76.428	80.071	82.130
EXPORTS	**37.798**	**40.372**	**45.969**	**50.999**	**55.109**	**55.636**	**54.541**	**49.852**	**52.523**	**55.541**	**52.397**	**54.692**
Biomass	6.797	9.271	8.205	8.924	10.258	10.430	11.366	10.786	11.522	12.307	11.756	12.418
Minerals	26.947	26.732	29.821	32.559	33.447	32.848	26.994	27.570	27.660	27.750	27.977	28.082
Fossil Fuels	4.053	4.369	7.943	9.517	11.404	12.358	16.181	11.495	13.341	15.484	12.663	14.191

Spain - Material Input Extensive Indicators

Unit: 1000 tons

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
DMI	**420.810**	**404.740**	**418.754**	**418.048**	**422.048**	**426.859**	**430.271**	**470.019**	**497.156**	**548.372**	**535.437**	**556.246**
Biomass	110.925	98.731	105.854	104.240	116.580	112.467	108.407	120.018	121.086	118.390	118.576	114.034
Minerals	182.801	176.228	178.181	176.324	170.887	174.422	177.431	192.364	217.191	262.235	240.615	262.894
Fossil Fuels	30.304	36.933	40.870	42.978	41.993	42.068	40.465	36.775	34.029	38.752	37.686	35.541
DMC	**383.012**	**364.368**	**372.785**	**367.048**	**366.939**	**371.223**	**375.730**	**420.168**	**444.633**	**492.830**	**483.040**	**501.554**
Biomass	118.608	102.695	112.847	110.796	118.399	114.539	111.200	127.332	128.250	125.373	129.283	125.087
Minerals	176.039	168.702	168.934	163.147	158.987	165.196	175.653	194.571	221.008	267.760	248.664	272.987
Fossil Fuels	88.364	92.971	91.004	93.106	89.553	91.488	88.877	98.265	95.375	99.697	105.093	103.480
PTB	**58.982**	**52.477**	**47.880**	**43.507**	**37.479**	**42.266**	**49.428**	**71.011**	**72.327**	**73.453**	**86.164**	**89.085**
Biomass	7.684	3.965	6.993	6.556	1.819	2.073	2.793	7.313	7.164	6.983	10.707	11.053
Minerals	-6.761	-7.526	-9.247	-13.178	-11.900	-9.226	-1.777	2.207	3.817	5.525	8.049	10.093
Fossil Fuels	58.060	56.038	50.134	50.128	47.560	49.419	48.412	61.490	61.346	60.945	67.407	67.939

Spain - Material Input Intensive Indicators

Unit: tons per capita

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
DE	**8,70**	**8,29**	**8,59**	**8,51**	**8,62**	**8,58**	**8,48**	**9,05**	**9,63**	**10,82**	**10,22**	**10,61**
Biomass	2,98	2,62	2,80	2,74	3,05	2,93	2,82	3,11	3,13	3,05	3,05	2,93
Minerals	4,91	4,68	4,71	4,64	4,47	4,55	4,61	4,99	5,62	6,77	6,20	6,76
Fossil Fuels	0,81	0,98	1,08	1,13	1,10	1,10	1,05	0,95	0,88	1,00	0,97	0,91
DMI	**11,30**	**10,75**	**11,07**	**10,99**	**11,05**	**11,13**	**11,18**	**12,18**	**12,85**	**14,15**	**13,79**	**14,31**
Biomass	3,37	2,97	3,20	3,15	3,37	3,26	3,18	3,58	3,61	3,55	3,63	3,54
Minerals	5,45	5,19	5,25	5,14	5,04	5,16	5,27	5,76	6,43	7,62	7,13	7,74
Fossil Fuels	2,48	2,59	2,61	2,70	2,64	2,71	2,73	2,84	2,81	2,97	3,03	3,03
DMC	**10,28**	**9,68**	**9,85**	**9,65**	**9,60**	**9,68**	**9,76**	**10,89**	**11,50**	**12,72**	**12,44**	**12,90**
Biomass	3,18	2,73	2,98	2,91	3,10	2,99	2,89	3,30	3,32	3,23	3,33	3,22
Minerals	4,73	4,48	4,46	4,29	4,16	4,31	4,56	5,04	5,71	6,91	6,40	7,02
Fossil Fuels	2,37	2,47	2,40	2,45	2,34	2,39	2,31	2,55	2,47	2,57	2,71	2,66

Spain - Material Input Intensive Indicators

Unit: tons per 1000$(1995)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
DE	**1,04**	**1,01**	**1,03**	**1,01**	**1,01**	**0,99**	**0,95**	**0,96**	**0,98**	**1,05**	**0,96**	**0,97**
Biomass	0,36	0,32	0,34	0,33	0,36	0,34	0,32	0,33	0,32	0,30	0,29	0,27
Minerals	0,59	0,57	0,57	0,55	0,53	0,52	0,52	0,53	0,57	0,66	0,58	0,62
Fossil Fuels	0,10	0,12	0,13	0,13	0,13	0,13	0,12	0,10	0,09	0,10	0,09	0,08
DMI	**1,36**	**1,31**	**1,33**	**1,31**	**1,30**	**1,28**	**1,25**	**1,30**	**1,30**	**1,37**	**1,29**	**1,31**
Biomass	0,40	0,36	0,39	0,37	0,40	0,38	0,36	0,38	0,37	0,34	0,34	0,32
Minerals	0,65	0,63	0,63	0,61	0,59	0,60	0,59	0,61	0,65	0,74	0,67	0,71
Fossil Fuels	0,30	0,31	0,32	0,32	0,31	0,31	0,31	0,30	0,29	0,29	0,28	0,28
DMC	**1,23**	**1,17**	**1,19**	**1,15**	**1,13**	**1,12**	**1,09**	**1,16**	**1,17**	**1,23**	**1,16**	**1,18**
Biomass	0,38	0,33	0,36	0,35	0,36	0,34	0,32	0,35	0,34	0,31	0,31	0,29
Minerals	0,57	0,54	0,54	0,51	0,49	0,50	0,51	0,54	0,58	0,67	0,60	0,64
Fossil Fuels	0,28	0,30	0,29	0,29	0,28	0,27	0,26	0,27	0,25	0,25	0,25	0,24

Source: Own estimates. Source for population and GDP is Eurostat 2008

Annex. Detailed tables

Part II

Spain

Unit: 1000 tons

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
DE	**416.464**	**397.445**	**396.354**	**406.671**	**429.261**	**450.582**	**484.701**	**508.177**	**540.664**	**564.927**	**614.702**	**666.266**	**682.642**
Biomass	108.392	111.394	106.212	96.179	119.749	119.712	121.876	114.114	125.499	115.688	120.567	123.542	127.525
Minerals	272.842	253.141	259.269	280.964	281.308	303.915	336.143	369.411	391.341	425.856	471.428	521.704	534.128
Fossil Fuels	35.230	32.910	30.874	29.527	28.205	26.955	26.682	24.652	23.823	23.383	22.708	21.021	20.988
IMPORTS	**149.895**	**144.140**	**151.934**	**163.956**	**163.791**	**173.189**	**194.646**	**209.324**	**221.968**	**224.004**	**240.930**	**242.828**	**257.735**
Biomass	24.904	24.890	27.613	33.156	29.709	32.436	36.509	38.500	38.807	40.415	44.779	42.731	44.657
Minerals	37.911	34.408	39.409	43.630	46.734	50.783	57.655	63.273	64.875	69.074	70.210	75.736	78.893
Fossil Fuels	87.079	84.843	84.912	87.170	87.348	89.970	100.482	107.551	118.286	114.516	125.941	124.361	134.185
EXPORTS	**57.349**	**60.921**	**67.704**	**71.533**	**80.909**	**86.414**	**92.173**	**89.035**	**94.451**	**94.285**	**96.172**	**103.240**	**108.554**
Biomass	13.085	14.484	17.409	16.967	18.584	22.460	23.060	22.223	23.152	25.163	25.799	27.457	27.708
Minerals	29.181	31.219	36.219	40.439	46.615	46.080	47.957	47.570	49.694	49.780	50.494	52.465	54.939
Fossil Fuels	15.083	15.218	14.076	14.127	15.710	17.873	21.157	19.243	21.605	19.342	19.879	23.318	25.908

Spain - Material Input Extensive Indicators

Unit: 1000 tons

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
DMI	**566.359**	**541.585**	**548.288**	**570.627**	**593.052**	**623.771**	**679.347**	**717.501**	**762.631**	**788.931**	**855.632**	**909.094**	**940.377**
Biomass	108.392	111.394	106.212	96.179	119.749	119.712	121.876	114.114	125.499	115.688	120.567	123.542	127.525
Minerals	272.842	253.141	259.269	280.964	281.308	303.915	336.143	369.411	391.341	425.856	471.428	521.704	534.128
Fossil Fuels	35.230	32.910	30.874	29.527	28.205	26.955	26.682	24.652	23.823	23.383	22.708	21.021	20.988
DMC	**509.010**	**480.664**	**480.585**	**499.094**	**512.143**	**537.357**	**587.174**	**628.467**	**668.180**	**694.646**	**759.461**	**805.854**	**831.823**
Biomass	120.211	121.799	116.416	112.368	130.874	129.688	135.326	130.392	141.154	130.939	139.547	138.816	144.475
Minerals	281.573	256.330	262.459	284.155	281.427	308.617	345.841	385.114	406.523	445.150	491.144	544.975	558.083
Fossil Fuels	107.225	102.535	101.709	102.571	99.843	99.052	106.007	112.961	120.504	118.557	128.770	122.064	129.265
PTB	**92.545**	**83.219**	**84.230**	**92.423**	**82.882**	**86.775**	**102.473**	**120.290**	**127.517**	**129.719**	**144.758**	**139.589**	**149.181**
Biomass	11.819	10.405	10.205	16.188	11.125	9.976	13.450	16.278	15.655	15.251	18.980	15.274	16.949
Minerals	8.730	3.189	3.190	3.191	119	4.703	9.699	15.704	15.181	19.294	19.716	23.272	23.955
Fossil Fuels	71.996	69.624	70.836	73.044	71.638	72.097	79.325	88.309	96.681	95.174	106.062	101.043	108.277

Spain - Material Input Intensive Indicators

Unit: tons per capita

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
DE	**10,68**	**10,16**	**10,10**	**10,34**	**10,89**	**11,40**	**12,23**	**12,77**	**13,50**	**13,96**	**15,01**	**15,99**	**16,12**
Biomass	2,78	2,85	2,71	2,44	3,04	3,03	3,07	2,87	3,13	2,86	2,94	2,97	3,01
Minerals	7,00	6,47	6,61	7,14	7,13	7,69	8,48	9,28	9,77	10,52	11,51	12,52	12,61
Fossil Fuels	0,90	0,84	0,79	0,75	0,72	0,68	0,67	0,62	0,59	0,58	0,55	0,50	0,50
DMI	**14,52**	**13,84**	**13,97**	**14,50**	**15,04**	**15,78**	**17,14**	**18,03**	**19,04**	**19,49**	**20,89**	**21,82**	**22,21**
Biomass	3,42	3,48	3,41	3,29	3,79	3,85	4,00	3,83	4,10	3,86	4,04	3,99	4,07
Minerals	7,97	7,35	7,61	8,25	8,32	8,97	9,93	10,87	11,39	12,23	13,22	14,34	14,48
Fossil Fuels	3,14	3,01	2,95	2,97	2,93	2,96	3,21	3,32	3,55	3,41	3,63	3,49	3,66
DMC	**13,05**	**12,28**	**12,25**	**12,69**	**12,99**	**13,60**	**14,81**	**15,79**	**16,68**	**17,16**	**18,54**	**19,34**	**19,64**
Biomass	3,08	3,11	2,97	2,86	3,32	3,28	3,41	3,28	3,52	3,23	3,41	3,33	3,41
Minerals	7,22	6,55	6,69	7,22	7,14	7,81	8,72	9,68	10,15	11,00	11,99	13,08	13,18
Fossil Fuels	2,75	2,62	2,59	2,61	2,53	2,51	2,67	2,84	3,01	2,93	3,14	2,93	3,05

Spain - Material Input Intensive Indicators

Unit: tons per 1000$(1995)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
DE	**0,97**	**0,94**	**0,91**	**0,89**	**0,92**	**0,93**	**0,96**	**0,96**	**0,97**	**0,98**	**1,03**	**1,09**	**1,08**
Biomass	0,25	0,26	0,24	0,21	0,26	0,25	0,24	0,21	0,22	0,20	0,20	0,20	0,20
Minerals	0,64	0,60	0,60	0,62	0,60	0,63	0,66	0,70	0,70	0,74	0,79	0,85	0,84
Fossil Fuels	0,08	0,08	0,07	0,06	0,06	0,06	0,05	0,05	0,04	0,04	0,04	0,03	0,03
DMI	**1,32**	**1,28**	**1,26**	**1,25**	**1,27**	**1,28**	**1,34**	**1,35**	**1,37**	**1,36**	**1,44**	**1,48**	**1,49**
Biomass	0,31	0,32	0,31	0,28	0,32	0,31	0,31	0,29	0,29	0,27	0,28	0,27	0,27
Minerals	0,72	0,68	0,69	0,71	0,70	0,73	0,78	0,81	0,82	0,86	0,91	0,98	0,97
Fossil Fuels	0,28	0,28	0,27	0,26	0,25	0,24	0,25	0,25	0,25	0,24	0,25	0,24	0,25
DMC	**1,19**	**1,13**	**1,11**	**1,09**	**1,10**	**1,11**	**1,16**	**1,18**	**1,20**	**1,20**	**1,28**	**1,32**	**1,32**
Biomass	0,28	0,29	0,27	0,25	0,28	0,27	0,27	0,25	0,25	0,23	0,23	0,23	0,23
Minerals	0,66	0,60	0,60	0,62	0,60	0,64	0,68	0,72	0,73	0,77	0,83	0,89	0,88
Fossil Fuels	0,25	0,24	0,23	0,22	0,21	0,20	0,21	0,21	0,22	0,20	0,22	0,20	0,20

Source: Own estimates. Source for population and GDP is Eurostat 2008

Annex. Detailed tables

Spain
part I

Domestic Extraction

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Unit: 1000 tonnes												
Biomass	**110.925**	**98.731**	**105.854**	**104.240**	**116.580**	**112.467**	**108.407**	**120.018**	**121.086**	**118.390**	**118.576**	**114.034**
Agriculture	56.939	48.169	53.929	52.771	61.817	59.806	56.587	64.669	63.817	61.861	63.283	59.891
Forage & Silage	22.326	21.716	21.251	20.316	20.988	19.889	20.321	21.370	21.737	20.657	21.853	20.959
Grazing	10.739	10.718	10.704	10.283	10.116	10.296	10.190	10.211	10.210	10.377	10.300	10.282
By-products	9.558	6.298	7.226	7.901	10.871	10.103	8.097	10.157	11.914	9.651	9.332	9.448
Fishing	1.376	1.397	1.465	1.408	1.442	1.490	1.502	1.539	1.599	1.531	1.335	1.304
Forestry	9.987	10.433	11.278	11.560	11.347	10.883	11.710	12.072	11.810	14.313	12.472	12.150
Minerals	**182.801**	**176.228**	**178.181**	**176.324**	**170.887**	**174.422**	**177.431**	**192.364**	**217.191**	**262.235**	**240.615**	**262.894**
Metals	14.612	14.181	13.130	13.344	15.185	14.707	12.005	12.100	13.122	12.374	14.238	13.022
Industrial minerals	14.339	14.798	14.042	13.746	13.695	13.373	14.129	14.360	15.285	14.732	14.581	13.329
Construction minerals	153.850	147.249	151.010	149.234	142.007	146.342	151.297	165.904	188.785	235.129	211.795	236.543
Fossil fuels	**30.304**	**36.933**	**40.870**	**42.978**	**41.993**	**42.068**	**40.465**	**36.775**	**34.029**	**38.752**	**37.686**	**35.541**
Coal	28.687	35.676	39.305	39.953	39.592	39.663	38.323	34.634	31.909	36.577	35.952	33.520
Crude oil	1.593	1.226	1.531	2.976	2.245	2.183	1.861	1.640	1.483	1.086	795	1.067
Natural gas	24	31	34	49	156	222	281	501	637	1.089	939	954

Spain

Domestic Extraction

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Unit: tonnes per capita												
Biomass	**3,0**	**2,6**	**2,8**	**2,7**	**3,1**	**2,9**	**2,8**	**3,1**	**3,1**	**3,1**	**3,1**	**2,9**
Agriculture	1,5	1,3	1,4	1,4	1,6	1,6	1,5	1,7	1,7	1,6	1,6	1,5
Forage & Silage	0,6	0,6	0,6	0,5	0,5	0,5	0,5	0,6	0,6	0,5	0,6	0,5
Grazing	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
By-products	0,3	0,2	0,2	0,2	0,3	0,3	0,2	0,3	0,3	0,2	0,2	0,2
Fishing	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,03	0,03
Forestry	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,4	0,3	0,3
Minerals	**4,9**	**4,7**	**4,7**	**4,6**	**4,5**	**4,5**	**4,6**	**5,0**	**5,6**	**6,8**	**6,2**	**6,8**
Metals	0,4	0,4	0,3	0,4	0,4	0,4	0,3	0,3	0,3	0,3	0,4	0,3
Industrial minerals	0,4	0,4	0,4	0,4	0,4	0,3	0,4	0,4	0,4	0,4	0,4	0,3
Construction minerals	4,1	3,9	4,0	3,9	3,7	3,8	3,9	4,3	4,9	6,1	5,5	6,1
Fossil fuels	**0,8**	**1,0**	**1,1**	**1,1**	**1,1**	**1,1**	**1,1**	**1,0**	**0,9**	**1,0**	**1,0**	**0,9**
Coal	0,77	0,95	1,04	1,05	1,04	1,03	1,00	0,90	0,83	0,94	0,93	0,86
Crude oil	0,04	0,03	0,04	0,08	0,06	0,06	0,05	0,04	0,04	0,03	0,02	0,03
Natural gas	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,02	0,02

Source: Own estimates. Source for population and GDP is Eurostat 2008

Annex. Detailed tables

Spain part II

Domestic Extraction

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Unit: 1000 tonnes													
Biomass	**108.392**	**111.394**	**106.212**	**96.179**	**119.749**	**119.712**	**121.876**	**114.114**	**125.499**	**115.688**	**120.567**	**123.542**	**127.525**
Agriculture	58.209	58.894	54.854	47.892	66.026	66.864	67.330	63.225	71.009	64.228	68.428	70.886	72.486
Forage & Silage	20.144	20.115	19.024	17.062	17.847	18.742	18.756	17.324	18.331	18.575	16.495	17.281	17.946
Grazing	10.332	10.376	10.687	10.966	10.995	11.000	11.442	11.450	11.462	11.476	11.475	11.470	11.470
By-products	7.308	9.769	8.116	5.980	10.955	9.142	10.877	8.759	11.868	7.885	10.282	9.810	11.424
Fishing	1.261	1.226	1.287	1.420	1.421	1.459	1.572	1.508	1.372	1.420	1.216	1.210	1.167
Forestry	11.139	11.014	12.244	12.860	12.505	12.505	11.899	11.848	11.457	12.105	12.671	12.884	13.032
Minerals	**272.842**	**253.141**	**259.269**	**280.964**	**281.308**	**303.915**	**336.143**	**369.411**	**391.341**	**425.856**	**471.428**	**521.704**	**534.128**
Metals	12.486	11.574	10.347	6.645	6.047	4.432	3.705	1.286	907	659	153	30	17
Industrial minerals	12.455	12.516	14.199	14.918	15.593	15.423	14.854	15.587	15.669	14.310	13.540	14.178	15.139
Construction minerals	247.901	229.051	234.723	259.401	259.668	284.060	317.583	352.538	374.765	410.886	457.734	507.495	518.972
Fossil fuels	**35.230**	**32.910**	**30.874**	**29.527**	**28.205**	**26.955**	**26.682**	**24.652**	**23.823**	**23.383**	**22.708**	**21.021**	**20.988**
Coal	33.299	31.566	29.491	28.465	27.370	26.466	26.075	24.258	23.486	22.685	22.035	20.548	20.496
Crude oil	1.073	874	807	652	519	371	532	300	224	338	316	322	255
Natural gas	858	470	576	410	316	118	75	94	113	360	357	151	237

Spain

Domestic Extraction

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Unit: tonnes per capita													
Biomass	**2,8**	**2,8**	**2,7**	**2,4**	**3,0**	**3,0**	**3,1**	**2,9**	**3,1**	**2,9**	**2,9**	**3,0**	**3,0**
Agriculture	1,5	1,5	1,4	1,2	1,7	1,7	1,7	1,6	1,8	1,6	1,7	1,7	1,7
Forage & Silage	0,5	0,5	0,5	0,4	0,5	0,5	0,5	0,4	0,5	0,5	0,4	0,4	0,4
Grazing	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
By-products	0,2	0,2	0,2	0,2	0,3	0,2	0,3	0,2	0,3	0,2	0,3	0,2	0,3
Fishing	0,03	0,03	0,03	0,04	0,04	0,04	0,04	0,04	0,03	0,04	0,03	0,03	0,03
Forestry	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
Minerals	**7,0**	**6,5**	**6,6**	**7,1**	**7,1**	**7,7**	**8,5**	**9,3**	**9,8**	**10,5**	**11,5**	**12,5**	**12,6**
Metals	0,3	0,3	0,3	0,2	0,2	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0
Industrial minerals	0,3	0,3	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,3	0,3	0,4
Construction minerals	6,4	5,9	6,0	6,6	6,6	7,2	8,0	8,9	9,4	10,2	11,2	12,2	12,3
Fossil fuels	**0,9**	**0,8**	**0,8**	**0,8**	**0,7**	**0,7**	**0,7**	**0,6**	**0,6**	**0,6**	**0,6**	**0,5**	**0,5**
Coal	0,85	0,81	0,75	0,72	0,69	0,67	0,66	0,61	0,59	0,56	0,54	0,49	0,48
Crude oil	0,03	0,02	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Natural gas	0,02	0,01	0,01	0,01	0,01	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,01

Source: Own estimates. Source for population and GDP is Eurostat 2008

ANNEX III

THE ENHRUM QUESTIONNAIRE

The following tables contain the relevant parts of the ENHRUM questionnaire used for the calculation of fuelwood use in Mexico rural communities for the year 2002.

In order to obtain the quantity consumed by each household, two variables were summed up: the quantity of fuelwood bought (w_{Bx}) and the quantity of fuelwood gathered for self-consumption (w_{Cx}).

$$H_x = w_{Bx} + w_{Cx} \qquad (2)$$

Column 7.1 in Table 1a provides information on the type of natural resource gathered by households; for instance, fuelwood, wood, minerals, and wild animals. In table 1b, respondents reported the annual quantity of such natural resource reserved to self-consumption, variable (w_{Cx}).

Table AIII.1a. Questionnaire on natural resources use

RECURSOS NATURALES		Mano de obra													
		familiar			asalariados de planta					eventuales				origen	
7.1 En el 2002, ¿qué productos naturales aprovecharon Uds., como productos locales, madera, leña, animales silvestres, minerales u otros?		7.14 En el 2002, ¿quiénes de la familia trabajaron en *actividad*? ¿Cuántos días cada uno?		Si trabajo mensual: ¿Durante cuántos meses?	7.15 r7_15 ¿Contrataron gente de planta para *actividad* en el 2002? ►	r7_15_1 ¿Cuántas personas de planta contrataron? ►	r7_15_2 ¿Cuántos meses? ►		r7_15_3 ¿Cuánto les pagaron? ►	7.16 r7_16 ¿Contrataron trabajadores eventuales para *actividad* en el 2002? ►	r7_16_1 ¿Cuántos días emplearon trabajadores eventuales? ►	Si mensual: ¿Durante cuántos meses? ►	r7_16_2 ¿Cuánto les pagaron? ■	7.17 r7_17_1a ¿Alguna de las personas que emplearon vive fuera de *comunidad*? ¿Dónde?	Si alguno vive fuera: r7_17_1b De cada 10 días que pagaron, ¿cuántos fueron personas *comunidad* y cuántos de fuera?
r7_1 *actividad*	r7_1a *recurso*	r7_14_1 *persona*	r7_14_1a *días*				c/u	total							
recolección de leña	leña		□ /sem □ /mes □ total												
			□ /sem □ /mes □ total		□ s □ n					□ s □ n					
			□ /sem □ /mes □ total						□ c/u □ total				□ c/u □ total		
			□ /sem □ /mes □ total						□ /sem □ /mes		□ /mes □ total		□ /día □ /total		/
			□ /sem □ /mes □ total												
			□ /sem □ /mes □ total		□ s □ n					□ s □ n					
			□ /sem □ /mes □ total						□ c/u □ total				□ c/u □ total		
			□ /sem □ /mes □ total						□ /sem □ /mes		□ /mes □ total		□ /día □ /total		/
			□ /sem □ /mes □ total												
			□ /sem □ /mes □ total		□ s □ n					□ s □ n					
			□ /sem □ /mes □ total						□ c/u □ total				□ c/u □ total		
			□ /sem □ /mes □ total						□ /sem □ /mes		□ /mes □ total		□ /día □ /total		/
			□ /sem □ /mes □ total												
			□ /sem □ /mes □ total		□ s □ n					□ s □ n					
			□ /sem □ /mes □ total						□ c/u □ total				□ c/u □ total		
			□ /sem □ /mes □ total						□ /sem □ /mes		□ /mes □ total		□ /día □ /total		/
1. Productos naturales . Locales 99. Otros (especifique)		50. Otros familiares												2. Otras com. 99. Otro (esp.)	

Source: PRECESAM-COLMEX 2006

Table AIII.1b. Questionnaire on fuel wood gathering for self-consumption

Ventas y autoconsumo												
ventas							transporte		consumo			
7.2						7.3	▫ "NO TRANSP." ► 7.4		7.4			
En el 2002, ¿cuánto vendían de *producto*? - al mes o en total. ►			*Si ventas no totales:* ¿Durante cuántos meses? ►	r7_2_2 ¿Quiénes son sus clientes? Particulares, tiendas, intermediarios o quién? ►	r7_2_3 ¿*Cliente* es de *comunidad* o de dónde? ►	r7_3 ¿ Ustedes transportaron *producto* para la venta? r7_3a ¿Cómo? ►	*Si veh. no propio:* r7_3_1 ¿El dueño del vehículo es de *comunidad* o de donde? ►	r7_3_2 ¿Cuánto gastaron o pagaron Uds. por el transporte de *producto*? ►	↓ En el 2002, del *producto* que aprovecharon ¿cuánto consumieron en casa? – al mes o en total. ►			*Si consumo no total:* ¿Durante cuántos meses? ►
cantidad/unidad	*valor total*	*periodicidad*		*cliente*					*cantidad/unidad*	*valor total*	*periodicidad*	
r7_2cantidad/r7_2a unidad	$r7_2b	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	r7_4/r7_4a	$r7_4b	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
/	$	▫ /sem ▫ /mes ▫ total						▫ /mes ▫ total	/	$	▫ /sem ▫ /mes ▫ total	
1. Unidades				*1. Particular 2. Tienda 3. Intermediario 4. Otros 99. Otros (esp.)*	*1. Comunidad 2. Otras 99. Otros (esp.)*	*1. Vehículo propio 2. Veh. comunit. 3. Transp. público 4. Otros 0. No transportaron 99. Otros (esp.)*	*1. Comunidad 2. Otras 99. Otros (esp.)*					

Source: PRECESAM-COLMEX 2006

The quantity of fuel wood bought (w_{Bx}) was obtained in table 1c. Here respondents were asked about their monthly/weekly expenses such in services such as electricity, water, telephone and some other services as well as in fuels. The money spent in fuel wood was reported per month.

Table AIII.1c. Questionnaire on expenses on fuelwood

Sección: Otros gastos e ingresos
Tabla: 8 GastosMensualesySemanales

Variable	Etiqueta de la variable	Valores	Etiqueta de los valores
NUMHOGAR	Identificador del hogar		
o8_3_1	Gasto bimestral en luz en 2002 (pesos)	-2	No especificado
o8_3_2	Gasto mensual en gas en 2002 (pesos)	-2	No especificado
o8_3_2a	Lugar donde se registró el gasto de gas		Ver Cat Comunidades
o8_3_3	Gasto mensual en leña en 2002 (pesos)	-2	No especificado
→ o8_3_3a	Lugar donde se registró el gasto de leña		Ver Cat Comunidades
o8_3_5	Gasto mensual en agua en 2002 (pesos)	-2	No especificado
o8_3_6	Gasto mensual en teléfono en 2002 (pesos)	-2	No especificado
o8_3_7	Gasto mensual en televisión de paga en 2002 (pesos)	-2	No especificado
o8_3_8	Gasto mensual en transporte en 2002 (pesos)	-2	No especificado
o8_3_9	Gasto mensual en gasolina en 2002 (pesos)	-2	No especificado
o8_3_9a	Lugar donde se registró el gasto de gasolina		Ver Cat Comunidades
R	Región		Ver Hoja Localidades Muestra
EDO	Estado		Ver Hoja Localidades Muestra
MPIO	Municipio		Ver Hoja Localidades Muestra
LOC	Localidad		Ver Hoja Localidades Muestra

Source: PRECESAM-COLMEX 2006

In order to traduce these monetary values into kilograms, the average price of fuel wood in rural markets was calculated (2,72 pesos per kilogram, see table 2) using the information provided on prices put on kg of fuel wood collected for selling. Table 2 provides the main data obtained on quantity, value and prices of fuel wood.

Table AIII.2. Value and prices of fuel wood consumed and sold by households

	Obs	Mean	Std. Dev.	Min	Max
Number of observations (households)	888	2.55E+11	1.28E+11	1.20E+11	5.28E+11
Value of fuelwood sold (pesos)	887	168.1127	1441.154	0	31200
Value of fuelwood consumed (kg)	888	3031.767	7911.838	0	186385.9
Price of fuelwood sold (selling price, pesos/kg)	38	2.72189	6.432484	0.0057143	35
Price of fuelwood consumed (buying price, pesos/kg)	872	3.446478	8.934311	0.015	140

Source: Own calculations with data from PRECESAM-COLMEX 2006

Survey's Geographic Cover

ENHRUM survey was carried out at national level in rural communities of 500 to 2,499 inhabitants grouped in five regions defined in the *National Plan of Development*. Table 3 provides the population living in rural communities of such dimensions, according to the National Population Census.

Table AIII.3. Rural population distribution by region in rural communities from 500 to 2,499 habitants

Region	Population
1	5,534,105
2	3,509,457
3	3,676,140
4	831,651
5	780,537
Total	14,331,890

Source: INEGI 2002

Table AIII.4. Regions, States and number of communities surveyed in ENHRUM

Regions	States	Number of Communities surveyed
1 South-southeast	Oaxaca, Veracruz, Yucatán	16
2 Center	Edo de Mexico, Puebla	16
3Center-west	Guanajuato, Nayarit, Zacatecas	16
4 Northweast	Baja California, Sonora, Sinaloa	16
5 Northeast	Chihuahua, Durango, Tamaulipas	16
TOTAL	*14*	*80*
Source: PRECESAM-COLMEX, 2006		

Basic Statistical data

In the following table, the main statistical parameters are provided for the variables used in the fuelwood calculation.

Table AIII.5. Basic statistical data

	Number of observations	mean	Std. Dev	Min	Max
Yearly quantity of woodfuel bought (kg)	255	187,71	611,50	4,41	13.226,10
Yearly woodfuel gathered for self-consumption (kg)	865	1.570,29	2.311,23	6,25	31.200,00
Total woodfuel used by household per year (kg)	996	1.758,00	2.335,12	4,41	31.477,75
Expanded data Woodfuel used at national level (kg)	-	4.056.581,34	7.726.325,35	2.308,51	125.651.244,59

Source: Own calculation