Essays on Monetary and Fiscal Policy

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A mi familia

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Introduction

This dissertation focuses on the analysis of monetary and …scal policy issues in macroeconomies with …nancial market imperfections.

Macroeconomic research is based on models that aggregate the decisions of many rational agents interacting in a completely speci…ed environment. Keeping track of these interactions is di¢cult, so most in‡uential macroeconomic models are based on strong simplifying assumptions. More recently, mainly due to the advance in computational methods, some of these unrealistic assumptions can be relaxed, opening the door to much deeper analysis of the mechanisms that move the economy. This dissertation's study of imperfect …nancial markets is one example of the recent trend to greater realism in macroeconomics.

The now widespread use of dynamic stochastic general equilibrium models for the analysis of the macroeconomy has been one of the main steps forward. As the name suggests, these models are …rst dynamic, capturing the intertemporal character of economic decisions. Second, they allow for some degree of uncertainty by assuming the stochastic evolution of certain variables that a¤ect the agents' decisions. And …nally, the analysis is developed in a general equilibrium framework. This means that …rst the individual behavior of each agent in the economy is modeled based on microeconomic foundations, and then put together with the behavior of other agents in a logically coherent way. All these elements, that constitute the core of modern macroeconomic analysis, are employed in this thesis.

In addition, some of the traditional assumptions are relaxed, mainly the fact that …nancial markets are perfect. When imperfect credit markets are considered, the role of macroeconomic policy is ampli…ed, because imperfections introduce new mechanisms for the transmission of the policy decisions.

This dissertation is composed of three chapters and is structured in two parts. The …rst part is focused on monetary policy issues, and consists of two chapters. Chapter 1 deals with the e¤ects of monetary policy in an economy with credit market imperfections where the central bank's monetary policy instrument is the interest rate. Chapter 2 analyzes the role of these credit market imperfections in the reduction of output and in‡ation volatility experienced in the US since the 1980s. The second part is devoted to the analysis of …scal policy issues. Chapter 3 studies the e¤ects on growth and welfare of imposing limits to the issue of public debt.

The …rst part of this thesis studies the performance of monetary policy rules in economies with and without credit market imperfections. Theoretical attempts to explain the way economic conditions in‡uence policy makers' decisions, and how these choices are transmitted to the rest of the economy have been developed mainly under the assumption of perfect credit markets. However, there is little doubt that credit markets are far from perfect. In any contractual relationship involving a future outcome, like the one between borrowers and lenders, there is one part of the contract (usually borrowers) with more information about his own performance than the other (lenders). This private information enjoyed by borrowers is often re‡ected in the interest rate characterizing the contract. Transparent, well-known …rms will obtain funds from very diversi…ed sources. However, small, new …rms will …nd it more di¢cult to raise funds and may often depend on a unique source of …nance. According to recent empirical work (Bernanke, Gertler and Gilchrist [2], and Gertler and Gilchrist [5]), the existence of …nancial frictions such as these may amplify and propagate the movements in output. If this is the case, analyzing the e¤ects of central banks' decisions abstracting from …nancial frictions might be misleading, in particular if central bankers are concerned with macroeconomic stabilization issues, and use interest rates as instruments to conduct monetary policy.

In Chapter 1, the e¤ects of endogenously driven monetary policy versus an exogenous constant money growth rule are investigated in a limited participation framework. Following the empirical literature (e.g. Clarida, Galí and Gertler [3]), I will assume that the central bank conducts monetary policy through an interest rate rule and is concerned with both in‡ation and output stabilization. The imperfections arise due to asymmetric information emerging in the production of capital, which introduces a kind of …nancial accelerator in the economy.

The main results of this chapter can be summarized as follows. I obtain that the model economy …ts US data reasonably well. In particular, the setup with credit market imperfections is able to account for some stylized facts of the business cycle absent in the standard frictionless case. This makes it a good candidate to analyze the e¤ects of monetary policy. Regarding the stabilization of shocks, the use of interest rate rules in a limited participation setup has the opposite e¤ects compared with new Keynesian models. More concretely, in a limited participation model, the use of interest rate rules helps stabilize both output and in‡ation in the face of technology shocks, whereas there is a trade-o¤ between stabilizing output or in‡ation if the shock is to money demand. Finally, the e¤ects of a Taylor rule are stronger –either more strongly stabilizing or more strongly destabilizing, depending on the type of shock– when there are …nancial frictions in the economy.

This research can be extended in three complementary ways. One direction is the calibration of the coe¢cients of the rule under credit market imperfections. This could provide a better representation of real data in order to investigate the e¤ects of di¤erent monetary policy rules. Another line of research would lead to the derivation of the optimal monetary policy rule in a scenario of …nancial frictions. Rotemberg and Woodford [8] develop this topic in a sticky price model without …nancial frictions. They conclude in favor of backward-looking rules whenever private agents are forward-looking. It seems interesting to test the robustness of Rotemberg and Woodford's results in a limited participation setup allowing for …nancial frictions. Finally, given the importance of variables such as the risk premium, which a¤ect the cost of borrowing, on the implications of …nancial frictions, research could also focus on how monetary policy performance would change if some indicator of the credit market imperfections is included in the rule. Possible candidates for this purpose are, for example, the bankruptcy rate and the risk premium.

Chapter 2 analyzes whether frictions in credit market or changes in the shock processes may have contributed to the reduction in macroeconomic volatility observed in the US since the 1980s. This reduced volatility has been mostly attributed to the way monetary policy has been conducted before and after Paul Volcker being the Chairman of the US Federal Reserve. In particular, most empirical research identi…es two di¤erent policy rules for the Pre- and Post-Volcker eras (e.g. Clarida, Galí and Gertler [4], and Judd and Rudebusch [6]). These estimated rules re‡ect a central bank less concerned with output and in‡ation stabilization in the Pre-Volcker than in the Post-Volcker period.

The focus of this chapter di¤ers from previous literature in the fact that …nancial frictions are considered when estimating the reaction function of the central bank. Doing this is important for three reasons. First, because of the evidence presented in the first chapter, and elsewhere in the literature, about the amplification and propagation effects of shocks induced by the existence of financial frictions. Second, because the effects of monetary policy can also be altered by the presence of these frictions. And third, because due to the development of financial markets, the degree of financial frictions themselves may have changed.

There are several conclusions worth pointing out from this chapter. First, the analysis of the US data from 1959:4 to 2000:3, including a measure of risk premium, indicates a structural break at 1981:2. This point, close to the usual 1979:3, can be explained by two events. First, the existence of some lags in the implementation of monetary policy after Paul Volcker. But secondly, this breakpoint is obtained once a series of risk premium is considered. This may reflect other policy measures such as the implementation of the Economic Recovery Tax Act in March 1981 that implied a general reduction in corporate and individual income-tax rates affecting the financing resources of firms.

Once a breakpoint has been identified, the limited participation model with credit market imperfections that was developed in Chapter 1 is used to calibrate an interest rate rule for each subsample. In this framework, I also analyze whether other factors, such as financial frictions or changes in the shock processes, may have contributed to the stabilization of the economy, together with the monetary policy rule followed by the central bank. In the absence of financial frictions, the results confirm the widely recognized change in the conduct of monetary policy by reporting substantially different interest rate rules before and after 1981:2. However, in contrast with the empirical literature, the calibration fails to assign more weight to inflation stabilization in the second subsample. This failure is resolved when a positive level of monitoring costs is introduced. Interestingly, in this case the procedure yields two calibrated rules that are much closer to each other than those found in the absence of frictions. That is, there is not such a big change in the monetary policy rule once monitoring costs are included. This may suggest a key role for credit market imperfections in the stabilization of monetary policy. When the rule, monitoring costs, and shocks are allowed to change across time, the calibration reports two interest rate rules re‡ecting a central bank more concerned with stabilizing in‡ation than output after 1981:2. The degree of …nancial frictions is reduced by 10% after 1981:2. Regarding shocks, money demand processes vary between samples, whereas technology innovations remain relatively stable across time, which is consistent with standard literature.

Although doubtless there are other ways to improve the realism of this model of the US Fed, the analysis developed in this chapter is one step forward towards the understanding of the behavior of central banks and their e¤ects on the whole economy. After this, the next step would be a welfare analysis of the performance of the US Fed, that is, how far the rules identi…ed by the calibration in this chapter are from the optimal ones.

The second part of the dissertation turns to …scal policy issues and investigates the consequences on growth and welfare when the government …nancial options are restricted by the imposition of a limit to debt issue. The e¤ects of public debt in growth models has usually been analyzed by imposing no limit on the behavior of debt except a no-Ponzi game condition. Little attention has been paid to tighter constraints on public borrowing. This is the focus of Chapter 3. This topic has gained growing interest in the last years, mainly because of the criteria imposed on EMU countries by the Maastricht Treaty and later reinforced by the Stability Pact. These criteria led many countries to undertake strong …scal policy measures in order to reduce de…cits and debt. The existing literature analyzing limits on public debt is not very large. Moreover, growth issues are not the focus in most of those papers. On the other hand, research on growth has not explored debt ceiling issues. The study undertaken in this chapter tries to fill in the gap by analyzing the effects on growth and welfare of imposing limits to government debt.

In Chapter 3, the model economy displays endogenous growth and allows government spending to have two different roles, either as a productive input (as in Barro [1]) or as services in the utility function, in which case it is private capital that drives growth (as in Romer [7]). Government spending can be financed through taxes on labor and issuing debt. In this framework, I study the efects of different fiscal policies (changes in labor tax rates and the ratio of government spending to output) with and without debt limits in the balanced growth path. In the long run, if there is no debt limit, the growth effects of raising labor income taxes are negative, regardless of the role of government spending. However, which role public spending plays in the economy is crucial for the growth effects of changes in the ratio of public expenditures to output. In the presence of a limit to debt, higher labor tax rates have a positive effect on growth if government spending is productive. However, when private capital drives growth, raising taxes on labor only serves to reduce the incentives to work, with a negative effect on the growth rate.

I also investigate the dynamic effects of imposing a more restrictive fiscal policy in order to attain a debt limit with a lower debt to output ratio, compared with an economy without limits which stays at its balanced growth path. This analysis is done for the case in which government spending is a productive input. I find that raising taxes to lower debt leads the economy to a new balanced growth path with higher growth and lower taxes, because of the productive role of government spending in this model. By the same reason, a fiscal policy consisting of reducing government spending over output has the opposite effects, reducing growth and output. Regarding welfare, raising labor income taxes imply a lower welfare cost of reducing debt than does cutting government spending.

A useful extension to this research would be to set up the second best problem. The idea is to allow the government to optimally design …scal policy taking into account …rst order conditions from individuals' optimization. Here, the Ramsey problem may allow the government to choose just the optimal tax structure, taking as given government spending or deciding on both …scal variables. Additionally, new insights will be drawn from the introduction of debt limits into the government's decision.

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Part I

Monetary Policy

Chapter 1

Interest Rate Rules Performance under Credit Market Imperfections

1.1 Introduction

How do interest rate rules perform under credit market imperfections? Do they have the same stabilization properties in such an environment as compared with the frictionless case?

Theoretical attempts to explain the way economic conditions influence policy makers' decisions, and how these choices are transmitted to the rest of the economy have been developed mainly under the assumption of perfect credit markets. However, there is little doubt that credit markets are far from perfect.

In any contractual relationship involving a future outcome, like the one between borrowers and lenders, there is one part of the contract (usually borrowers) with more information about his own performance than the other (lenders). This private information enjoyed by borrowers is often reflected in the interest rate characterizing the contract. Transparent, well-known firms will obtain funds from very diversified sources. However, small, new firms will find it more difficult to raise funds and may usually depend on a unique source of finance. Gertler and Gilchrist [19], and [20] provide evidence that this is the case for US manufacturing firms.

How and when can these imperfections be observed? In the face of uncertainty about a future repayment on their loans, lenders will charge higher interest rates to the riskier borrowers. Figure 1.1 confirms this intuition. It reports the evolution of the spread between the Bank Prime rate and the Six-month Treasury-bill rate for the period 1970:1-2000:2, as well as the real GNP for the same period.[1] There are two things worth pointing out here. First, during the whole period, the average spread is positive (250 basis points), implying a risk premium paid by firms issuing this type of bonds. Second, the chart clearly shows the countercyclical character of this spread with respect to GNP, with a correlation of -0.15 for the whole sample.[2] This suggests that in good times, when GNP is high, the financial imperfections diminish. The opposite is true in a recession. According to some empirical analysis (for example, Bernanke, Gertler and Gilchrist [3]) the presence of such time-varying imperfections may help amplify the movements in output. If this is the case, analyzing the performance of monetary policy rules abstracting from credit frictions might be misleading, in particular if central bankers are concerned with macroeconomic stabilization issues.

In this paper I investigate the performance of monetary policy governed by interest rate rules in economies with and without credit market imperfections. Money will have real effects

[1] The figure shows a reduction in the variability of both series around 1984:1. McConnell and Pérez-Quirós [26] document this change in US output as a structural break, mainly driven by durable goods. Although not analyzed by these authors, in this figure it is observed that the risk premium mimics this change experienced by output.

[2] This correlation is -0.17 for the sample period 1970:1-1983:4, and -0.33 for the sample period 1984:1-2000:2.

in the model, because I assume limited participation of households in financial markets. Credit market frictions are introduced through asymmetric information in the production of capital. The way monetary policy rules behave in such a framework is analyzed by studying the effects of shocks to technology and money demand. Empirical work shows that most central bankers appear to be following interest rate rules in the conduct of monetary policy (Clarida, Galí, and Gertler [11]); therefore it seems appropriate to focus on interest rate rules, as opposed to money growth rules, in studying the effects of monetary policy. However, in order to get more insight into the mechanisms at work, I will compare two policy rules: an exogenous constant money growth rule, and a traditional Taylor rule.

The main contribution of this paper is threefold. First, several features of monetary models (mainly, interest rate rules and credit market imperfections) are introduced together in a limited participation setup to get a framework in which monetary policy issues can be easily addressed. Second, the model's capability to account for some stylized facts in business cycles dynamics is quantitatively analyzed. And third, focusing on Taylor type rules, this framework is used to analyze the stabilization properties of monetary policy.

The main results of the paper can be summarized as follows. The model with financial frictions turns out to be a useful scenario to analyze some stylized facts in business cycle dynamics absent in standard monetary models. Some of these facts are the negative correlation between output growth and risk premium, the effects of capital prices on output, and the high volatility of investment observed in the data. It turns out that in a limited participation setup the use of interest rate rules to conduct monetary policy has the opposite stabilization effects when compared with a sticky price setting. Finally, it is observed that a Taylor rule has stronger effects, either stabilizing or destabilizing, when there are credit market imperfections in the economy. This confirms the hypothesis that monetary policy may be affected by the presence of credit market imperfections.

The innovations of this analysis in relation with the existing literature on credit market imperfections and monetary policy issues is analyzed in detail in the next section. Section 1.3 develops the model, introducing the role and features of each agent in this economy. Section 1.4 defines the equilibrium. In sections 1.5 and 1.6, the solution method, and parameter values employed are specified, respectively. Section 1.7 quantifies the properties of the model and compares them with real data. The model dynamics are analyzed in Section 1.8. Finally, Section 1.9 closes the paper.

1.2 Related literature

This work is closely related to three other papers that investigate the effects of financial frictions in the business cycle. The papers that originally motivated this analysis are by Fuerst [15] and Gertler [18]. The third one is the work by Bernanke, Gertler and Gilchrist [4].

Fuerst addressed the question of whether the presence of financial frictions distort the impulse and propagation of technology and monetary shocks. His model economy is also a limited participation setup in which imperfections in credit markets arise in the production of capital goods. Unlike the current study emphasis on interest rate rules, the framework chosen by Fuerst is such that the monetary authority employs money supply as the policy instrument. However, Fuerst's analysis differs in some key points. First, he does not find significant differences in the dynamics of the model after allowing for financial frictions. Therefore, in his model financial frictions do not have much role for impulse and propagation. Second, his model is not able to replicate the negative correlation between output and risk premium observed in the data.

In a comment to Fuerst's paper, Gertler [18] highlights the crucial role of the elasticity of net worth with respect to output in this type of analysis. The argument goes as follows. According to the data, net worth (for example, entrepreneurs' profits) shows a high elasticity with respect to output growth. In times of high output, net worth will be high too. This will reduce the need for external financing and at the same time, will diminish the cost of external funds. This helps replicate the negative correlation between output and risk premia observed in the data. I internalize this fact in my analysis.

In contrast to the two papers above, I consider a central bank concerned on both output and inflation stabilization, and with the nominal interest rate as its instrument. With these ingredients I analyze how credit market imperfections may alter the monetary transmission mechanism. The following is obtained. First, I find amplifying and persistent effects of credit market imperfections because net worth responds strongly to output. This amplification is visible in spite of the stabilizing effects of the rule. I go on to do a quantitative assessment of the interaction between output, investment, labor, and the risk premium, which were not spelled out in Gertler's suggestions.

As I show below, this economy implies that technology shocks are stabilized, and money demand shocks destabilize prices with slightly output stabilization, in clear contrast with new Keynesian models of the business cycle. New Keynesian models predict that the use of interest rate rules would stabilize the economy in the event of shocks to money demand. This follows from the assumption of some nominal rigidity (in prices, wages or both), which makes output be demand-determined. In such a setting, any distortion arising from the demand side (and therefore affecting output) can be neutralized by changing the money supply (that is, using the interest rate as an instrument). Why does the opposite occur in this paper? Here, with the limited participation setup, output becomes supply-determined and aggregate demand is left the role of determining the price level. Thus shocks a¤ecting aggregate supply can be neutralized by monetary policy if the interest rate is the instrument, whereas the opposite is true when money demand shocks are considered. This is because unlike new Keynesian models, in a limited participation setup changes in money supply will a¤ect both …rms and households decisions, inducing movements in both the aggregate supply and aggregate demand curves.

Finally, this paper shows that the rule appears to have stronger e¤ects (either stabilizing or destabilizing) in the presence of credit market imperfections. As will be explained in Section 1.8, the supply side e¤ects of shocks in this model are emphasized in the presence of …nancial frictions. This is because of the upward sloped supply of investment goods. In this case, the …rms' borrowing needs are hit by the additional e¤ect of the higher cost of capital a¤ecting their labor and investment decisions. Furthermore, changes in the interest rate also have an e¤ect on such decisions, like an in‡ation tax on investment.

In a similar vein, Bernanke, Gertler and Gilchrist [4] analyze the role of credit imperfections arising in the demand for capital in a sticky price model. Although their setup di¤ers from mine in many ways, there are several common points. Their analysis focuses on the ampli…cation and propagation issues of …nancial frictions (what they call the …nancial accelerator). In their model the central bank also follows an interest rate rule, reacting only to lagged in‡ation and interest rate, without any weight on output stabilization. Unlike here, in their paper they do not consider stabilization issues of monetary policy. This is important because as my analysis makes clear the way monetary policy is implemented may o¤set the amplifying e¤ects of …nancial frictions just by including some output stabilization into the objectives of the monetary authority.

Summing up, in this paper it is shown that a model that …ts relatively well data is able to account for the effects of financial frictions and yet tell us something about the transmission of monetary policy when the interest rate is the instrument. Indeed, the interest rate rule becomes more effective in the presence of credit market imperfections, if the economy is affected by a technology shock, and induces more variability on prices and output when the economy is affected by money demand shocks.

1.3 The model

The model economy is a cash-in-advance environment with two additional frictions. The first one allows for the non-neutral effects of money by assuming limited participation of households in financial markets. The second one introduces credit market imperfections in the production of capital.

Households in this economy supply labor to firms and obtain wage payments in return. In addition to this, they also receive dividends from firms and financial intermediaries which they own. Households choose between depositing money with the bank and keeping cash balances to purchase consumption. This portfolio decision is restricted to be made before the current state of the economy is fully known, reflecting the first of the two frictions mentioned above.[3]

There are firms producing a homogeneous good. In order to do so, they need to hire workers, and purchase investment. Since they have no initial wealth, they need to borrow from the financial intermediary. There are also entrepreneurs devoted to the production of capital inputs. They are affected by idiosyncratic shocks to their technology. It is assumed that it is costly for other agents to verify the entrepreneurs individual uncertainty. This generates a monitoring cost problem that is solved by standard debt contracts. Finally, the central bank conducts monetary

[3] See also Christiano [7], Christiano and Eichenbaum [8], Fuerst [14], and Lucas [25].

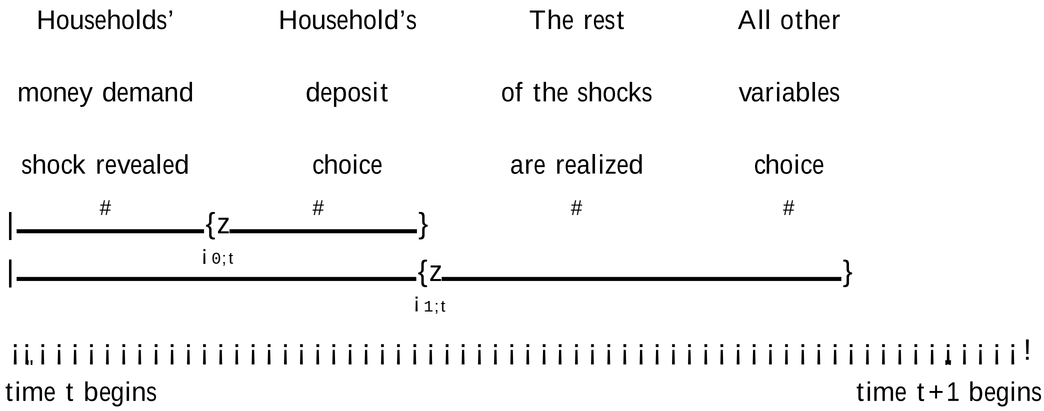
policy through an interest rate rule.

The restrained participation of households in financial markets induces the liquidity effect of a money supply shock on the nominal interest rate observed in the data. The mechanism is the following. After a money injection, there is an excess liquidity in the economy that needs to be absorbed to reestablish equilibrium. Households cannot change their portfolio choice until the following period, therefore firms are the only agents able to clear the money market. The central bank achieves money market clearing by reducing the interest rate so that firms are willing to borrow the excess amount of funds.

At this point, it is important to define the two information sets that govern variables choice in this model. In particular, $\Gamma_{0,t}$ includes endogenous state variables (the stock of money carried from the previous period, $\bar{M}_t$; and the stock of capital determined at time $t-1$; K_t), as well as exogenous time t money demand shock to households, and the technology shocks to firms at time $t-1$; $\Gamma_{1,t}$ includes $\Gamma_{0,t}$ plus time t technology shocks.

To avoid analyzing redistributional issues, which is not the focus of this paper, all the agents in the economy are assumed to belong to a family. This family splits early in the morning. They become then households, firms, entrepreneurs and financial intermediaries. At the end of the day, they all gather and share all their outputs.

The general equilibrium timing can be summarized as follows:



At the beginning of time t individuals take as given the state variables of the model (last period's money and capital stocks), the current money demand shock as well as the past history of shocks. Afterwards, these agents decide how much money to put in the bank. After having chosen deposits, the technology shock is revealed. Next, all other variables are chosen.

1.3.1 Households

There is a continuum of infinite-lived households in the interval [0,1]. The representative household chooses consumption (C_t), labor supply (L_t); and deposits ($\bar{D}_t$), to maximize the expected value of discounted future utilities given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \tag{1.1}$$

where E_0 denotes the expectation operator conditional on the time 0 information set, and $\beta \in (0, 1)$ is the household's subjective discount factor. The utility function is

$$U(C_t, L_t) = \begin{cases} \dfrac{C_t^{1-\theta} - 1}{1-\theta} - \Psi \dfrac{L_t^{1+\psi}}{1+\psi} & \text{if} \quad \theta \neq 1 \\ \log(C_t) - \Psi \dfrac{L_t^{1+\psi}}{1+\psi} & \text{if} \quad \theta = 1; \end{cases} \tag{1.2}$$

where θ denotes the inverse of the constant intertemporal elasticity of consumption, and ψ is the inverse of the labor supply elasticity with respect to real wages, which is assumed to be constant. The representative household begins time t with money holdings from the previous period,[4] $\bar{M}_t$. A fraction of these money holdings is allocated to deposits in the bank, $\bar{D}_t$: Additionally, he supplies elastically labor to firms and receives in return wage payments, $\bar{W}_t L_t$, that can be spent within the same period.[5] This wage income plus money holdings minus deposits is devoted to consumption purchases, $\bar{P}_t C_t$. This is reflected in the following cash-in-advance constraint:

$$\bar{M}_t - \bar{D}_t + \bar{W}_t L_t \geq \bar{P}_t C_t N_t: \tag{1.3}$$

The variable N_t can be understood as a shock to money velocity, and is assumed to follow a first order Markov process given by

$$N_{t+1} = N \exp(\varepsilon_{\nu;t+1}) N_{t+1}^{\rho_\nu}: \tag{1.4}$$

Below, I will use ν_t to denote $\log(N_t)$. In this process, N is the value of the shock in the steady state, the autocorrelation coefficient is $0 < \rho_\nu < 1$; and $\varepsilon_{\nu;t+1}$ is an i.i.d. normally distributed shock with zero mean and standard deviation σ_ν^{ε}:

The representative household receives two additional income flows at the end of the period. On the one hand, he obtains interests plus principal on deposits from the financial intermediary, $R_t \bar{D}_t$; where R_t denotes the gross nominal interest rate; and, on the other hand, he receives dividends from the firm and from the financial intermediary, that he owns, $\bar{\Pi}_t^f$; and $\bar{\Pi}_t^{fi}$, respectively. Thus the flow of money from period t to period t + 1 per household can be expressed as

[4] Henceforth, upper bar letters will denote nominal variables not normalized. Plain upper case letters will denote nominal variables once normalized. Finally, lower case letters will refer to the growth rates of variables.

[5] By allowing households to spend their wage earnings within the same period the impact of inflation on employment is eliminated. For more details on this, see Christiano and Eichenbaum [8].

follows:

$$\bar{M}_{t+1} = \bar{M}_t - \bar{D}_t + \bar{W}_t L_t - \bar{P}_t C_t N_t + R_t \bar{D}_t + \Pi^f_t + \Pi^{fi}_t. \tag{1.5}$$

The household's optimizing problem consists of maximizing (1.1) subject to (1.3) and (1.5), by choosing contingency plans for quantities $\{C_t; L_t; \bar{D}_t\}_{t=0}^{\infty}$ taking as given the sequence of variables $\{\bar{P}_t; \bar{W}_t; \bar{M}_t; R_t; \Pi^f_t; \Pi^{fi}_t\}_{t=0}^{\infty}$ together with the assumed information structure.

From the optimization of the household's problem, the optimal choices for consumption and labor supply are

$$-\frac{U_L(C_t; L_t) N_t}{U_C(C_t; L_t)} = \frac{\bar{W}_t}{\bar{P}_t}; \tag{1.6}$$

and for deposits

$$E\left[\frac{U_C(C_t; L_t)}{N_t \bar{P}_t} \,\Big|\, \Gamma_{0;t}\right] = E\left[\beta R_t \frac{U_C(C_{t+1}; L_{t+1})}{N_{t+1} \bar{P}_{t+1}} \,\Big|\, \Gamma_{0;t}\right]; \tag{1.7}$$

where U_C and U_L denote the marginal utility of consumption and disutility of labor, respectively.

The fact that equation (1.7) depends on the information set $\Gamma_{0;t}$ reflects the limited participation character of the model. This equation is equivalent to the Fisher equation in the usual monetary models, except for the fact that now expectations are taken before agents realize whole period shocks. In particular, it means that households' portfolio choices are made before the complete state of the economy at time t is revealed. This disables households from responding to a current shock by changing deposits within the same period. This nominal rigidity induces the liquidity effect already mentioned above.[6]

[6] The liquidity effect is usually defined as the difference between the Lagrange multipliers corresponding to the two cash-in-advance constraints in the model (equations (1.3), and (1.10) further below), measuring the difference in liquidity between the goods and the financial markets. For a formal explanation see Fuerst [14].

1.3.2 Firms

Firms produce a homogeneous good in a competitive framework. They need to hire labor from households, and purchase capital, as inputs for production. Firms own no initial funds, so they must borrow, at the beginning of every period, to pay the wage bill and current capital purchases. The production function takes the form

$$Y_t = F(A_t; K_t; H_t) = A_t K_t^{\alpha_k} H_t^{\alpha_h}; \tag{1.8}$$

where H_t denotes the demand for household's labor, and K_t is capital needed for production. I assume that $\alpha_k + \alpha_h = 1$, reflecting constant returns to scale in technology. The variable A_t is an aggregate technological shock, modeled by a first order Markov process

$$A_{t+1} = A \exp(\varepsilon_{a;t+1}) A_{t+1}^{\rho_a}; \tag{1.9}$$

where A is the nonstochastic steady state value for the shock, $0 < \rho_a < 1$; and $\varepsilon_{a;t+1}$ is an i.i.d. normally distributed shock with zero mean and standard deviation σ_a^{ε}: Proceeding the same way as before, I denote $\log(A_t)$ as a_t:

As mentioned above, the representative firm must borrow from the financial intermediary each period to pay both wage and capital bills. This decision is subject to the following cash-in-advance constraint:

$$\bar{B}_t^d \geq \bar{W}_t H_t + \bar{P}_t Q_t Z_t; \tag{1.10}$$

where $\bar{B}_t^d$ denotes the demand for loans from the bank; $\bar{W}_t$ is households' wages; Q_t is the capital good price in consumption good units, and Z_t denotes the new investment purchased each period.

Firms buy additional units of investment goods, Z_t; in competitive markets,[7] and accumulate capital according to the following law of motion:

$$Z_t = K_{t+1} - (1 - \delta)K_t; \tag{1.11}$$

where δ is the depreciation rate of capital, and the subscript $t + 1$ denotes the time when capital will be used. The dividends firms distribute to their owners (households) are given by

$$\Pi^f_t = \bar{P}_t Y_t - (\bar{W}_t H_t + \bar{P}_t Q_t Z_t) - (R_t - 1)\bar{B}^d_t:$$

Because of its competitive behavior, the firm's objective is to maximize its market value. In doing this, firms have to take into account their owners' interests. Since profits are distributed at the end of the period, a firm will value one more dollar in dividends at time t; by how much consumption marginal utility households will obtain at time $t + 1$; by refusing this time t dollar. Thus firms maximize the following flow of dividends:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{t+1} \Pi^f_t; \tag{1.12}$$

where Λ_{s+1} denotes the relative marginal utility the household obtains from an additional unity of consumption at time $s + 1$,

$$\Lambda_{s+1} = \frac{\beta^{s+1} U_C(C_{s+1}; L_{s+1})}{N_{s+1}\bar{P}_{s+1}}: \tag{1.13}$$

Maximizing (1.12) subject to equation (1.10), the optimal input demands made by firms are obtained. The representative firm demands households' labor according to

$$\frac{\bar{W}_t}{\bar{P}_t} = \frac{\alpha_h Y_t}{H_t R_t}; \tag{1.14}$$

[7] Competitive capital markets open at the end of the period and involve firms buying capital from other firms, or entrepreneurs.

and investment

$$R_t \bar{P}_t Q_t E[\lambda_{t+1} \mid \Omega_{-1,t}] = \beta E\left\{ \lambda_{t+2} \bar{P}_{t+1} Q_{t+1} \left[R_{t+1}(1-\delta) + \frac{\alpha_k Y_{t+1}}{K_{t+1}Q_{t+1}} \right] \Bigg| \, \Omega_{-1,t} \right\}. \tag{1.15}$$

Note that all decisions made by firms are based on the information set $\Omega_{-1,t}$; that is, once the complete state of the economy at time t has been revealed. Labor demand is affected by the interest rate since it is paid in advance. Finally, capital demand will depend on expected inflation, the price of capital, Q_t, and the nominal interest rate, everything discounted by the marginal utility of consumption. The left-hand side of equation (1.15) is the loss in utility a household bears at time $t+1$ if dividends are reduced by one unit at time t to buy more capital. This equals the value of one unit of extra dividend at time $t+1$, reflected in utility gains at time $t+2$, when the returns on dividends at time $t+1$ can be spent. The inclusion of the nominal interest rate in this equation is due to the intratemporal distortion induced by the cash-in-advance constraint on investment purchases.

1.3.3 Financial intermediaries

Banks in this economy are given the role of taking funds from those who have resources to lend, and give them to agents in need of funding. In this case, the representative bank will collect deposits from households, $\bar{D}_t$, and together with the monetary injection, $\bar{X}_t$, will transform these funds into loans to firms every period, $\bar{B}^d_t$. At the end of the period, the financial intermediary receives principal plus interests from the loans to firms, $R_t\bar{B}^d_t$; additionally, it has to pay back principal plus interests due on households' deposits, $R_t\bar{D}_t$. The financial intermediary can be seen as a profit maximizing agent in a competitive environment whose profits are given by

$$\Pi^{fi}_t = R_t \bar{X}_t, \tag{1.16}$$

where $\bar{X}_t$ denotes the monetary injection from the central bank. These profits are also distributed to households, who own the banks, at the end of the period, as is seen from equation (1.5).

1.3.4 Entrepreneurs

There are also entrepreneurs who live for only one period, and are risk-neutral. Entrepreneurs are devoted to the production of capital goods. Each entrepreneur can carry on one project that requires one unit of consumption goods. To this end, they have access to a technology that transforms this unit of consumption goods into $\tilde{\omega}_t$ units of capital goods, where $\tilde{\omega}_t$ is an idiosyncratic shock. The random variable $\tilde{\omega}_t$ is assumed to vary uniformly in the non-negative interval $[1 - \omega; 1 + \omega]$; with density function $\phi(\tilde{\omega}_t)$: Let $\Phi(\tilde{\omega}_t)$ denote the associated distribution function.

I will assume that each period, after production takes place, part of the output is transferred to entrepreneurs,[8] which amounts to a lump sum transfer when the entrepreneurs are born. This transfer, in consumption goods units, will constitute their net worth, NW_t; and is a function of time t production. That is, entrepreneurs' net worth is $NW_t = NW(Y_t)$. In accordance with the data, it is assumed that NW_t is positively related with output, and more volatile than output. Let ξ denote the elasticity of net worth with respect to output. This assumption is a reduced form way to deal with the fact that in good times investors end up with more cash available than in bad times.[9] However, this net worth is not enough to carry on the project. Moreover,

[8] Following Gertler [18], I assume that this transfer is taxed away when entrepreneurs die, i.e., at the end of the period, and then returned lump sum to consumers.

[9] This assumption is a reduced form way to deal with the fact that in good times investors end up with more cash available than in bad times. This could also be done through a dynamic problem for entrepreneurs, where net worth would be another state variable of the system, possibly different among entrepreneurs, complicating

entrepreneurs live for only one period, so that they cannot accumulate wealth. Therefore, they need to borrow the difference between their required investment and their endowment, $1 - NW_t$.

Entrepreneurs go to a competitive market to borrow the consumption units they need to start production. The lender will be the pool of firms, denoted mutual fund, that gather to share the risk of the borrowers.

The contractual relationship between entrepreneurs and the mutual fund is affected by informational asymmetries. In particular, the lender cannot observe the final outcome of the entrepreneur unless he monitors. Monitoring costs are a fixed proportion of capital produced,[10] μ_c, where $\mu_c > 0$. This asymmetry of information generates a costly state verification problem. The structure of this contract implies that it is optimally solved by a standard debt contract, according to Townsend [30], and Gale and Hellwig [16]. This debt contract is characterized by the following repayment rule: an entrepreneur that borrows $(1 - NW_t)$ consumption goods agrees to repay $(1 + R_t^k)(1 - NW_t)$ if the realization of ω_t is good. The variable R_t^k is the interest rate characterizing the debt contract.[11] If the realization of ω_t is bad, then the entrepreneur defaults, and the lender gets all the production of the defaulting entrepreneur. The lender will only monitor in case of default, and this decision is determined by a threshold value for ω_t

$$\bar{\omega}_t \equiv (1 + R_t^k)(1 - NW_t). \tag{1.17}$$

To assure that the standard debt contract is efficient incentive compatible, the following needs to hold. Participation of the lender must be guaranteed. The mutual fund will find it

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the solution due to heterogeneity.

[10] This monitoring costs structure is convenient for the results below. Allowing for a more complex structure would eliminate aggregation properties.

[11] Note that these contracts are intraperiod, therefore the nominal interest rate does not enter into the structure of the contractual relationship.

profitable to lend the entrepreneurs as long as the amount lent equals the expected return net of monitoring costs, that is,

$$1 - NW_t = Q_t \left\{ \int_{-\infty}^{\bar{\omega}_t} \omega_t \Phi(d\omega_t) - \Phi(\bar{\omega}_t)\mu_c + [1 - \Phi(\bar{\omega}_t)]\bar{\omega}_t \right\} \equiv Q_t g(\bar{\omega}_t); \tag{1.18}$$

where the left hand side of this equation denotes the amount borrowed by entrepreneurs, whereas the right hand side reflects the expected return on this loan, including monitoring costs.[12]

The entrepreneur will invest all his net worth in the project, this means that his expected outcome from investing must exceed his net worth, that is,

$$Q_t \left\{ \int_{\bar{\omega}_t}^{+\infty} \omega_t \Phi(d\omega_t) - [1 - \Phi(\bar{\omega}_t)](1 + R_t^k)(1 - NW_t) \right\} =$$

$$Q_t \left\{ \int_{\bar{\omega}_t}^{+\infty} \omega_t \Phi(d\omega_t) - [1 - \Phi(\bar{\omega}_t)]\bar{\omega}_t \right\} \equiv Q_t f(\bar{\omega}_t) \geq NW_t; \tag{1.19}$$

where the left hand side denotes the expected outcome for the entrepreneur after investing. Here I have used equation (1.17) to eliminate $(1 + R_t^k)(1 - NW_t)$.

According to equation (1.19), an entrepreneur's expected output is composed of expected production of capital, if he does not default, minus what he has to pay back on the loan in case of success. Recall that in the event of bankruptcy, entrepreneurs have limited liability, that is, in case of default, an entrepreneur loses all his outcome but does not have to pay back the debt.

This costly state verification problem is solved taking as given the sequence of $\{NW_t; Q_t; R_t^k\}_{t=0}^{\infty}$. From the combination of the equations above, it follows that

$$Q_t = \frac{1}{[1 - \Phi(\bar{\omega}_t)\mu_c]}. \tag{1.20}$$

[12] Credit rationing issues are omitted in this setup since expected returns going to the mutual fund are increasing in the threshold value $\bar{\omega}_t$. For more details on this see BGG [4].

Additionally, note that

$$f(\omega_t) + g(\omega_t) = 1 - \Phi(\omega_t)\mu_c;$$

that is, on average if monitoring costs are positive, $\mu_c > 0$; part of the output is destroyed by these costs, $\Phi(\omega_t)\mu_c$, while the rest is divided between the entrepreneur, $f(\omega_t)$, and the lender, $g(\omega_t)$. In the non-monitoring costs case, $\mu_c = 0$; all of the outcome is shared between entrepreneur and lender.

Once the general equilibrium is solved, the number of projects undertaken, i_t; is determined. This amount, net of monitoring costs, will constitute the supply of capital goods: $i_t[1 - \Phi(\omega_t)\mu_c]$:

1.3.5 The monetary authority

In this model, the central bank is in charge of conducting monetary policy. Following recent literature, the monetary authority will be assumed to employ an interest rate rule in performing this task.

In his 1993 paper, Taylor [29] inaugurated a line of research concerned on monetary authorities' behavior. More concretely, he estimated a reaction function for the US Federal Reserve Bank, in which the nominal interest rate (in particular, the US federal funds rate) reacted to deviations of both GDP from its trend, and inflation over its target level. Taylor found that for the federal funds rate during the 1987-1992 period "[...] this rule fits the actual policy performance [...] remarkably well". The developments upon Taylor's rule are numerous. In this paper, I will assume the monetary authority employs two possible different rules. First, I will consider a constant money growth rule as a benchmark. In this case, money supply will be perfectly inelastic at a given level, and it will be the nominal interest rate the adjusting variable after any shock. Then, I will consider the effects of using the traditional Taylor rule. In this case, the central bank tunes money supply to keep the nominal interest rate at the level implied by the rule. The nominal interest rate will evolve according to

$$r_t = \gamma + \gamma_r r_{t-1} + \gamma_\pi \pi_t + \gamma_y y_t;$$

where r_t denotes the annualized quarterly interest rate, $4(R_t - 1)$; γ is the long run value for r_t under no disturbances; π_t is the inflation rate, that is $\log P_t - \log P_{t-1}$; and y_t denotes the deviation of output from steady state. That is, in conducting monetary policy the central bank cares about smoothing interest rates, as well as about both inflation and output stabilization.

In the original version, Taylor estimated the following coefficients, $\gamma_r = 0$; $\gamma_\pi = 1.5$; and $\gamma_y = 1.$ However, as already mentioned by Christiano and Gust [10] this parameterization results in indeterminacy in a limited participation model, as is also the case here after allowing for financial frictions. Therefore, in the simulations below, a stable version of this rule is employed.

1.4 Equilibrium

To analyze the general equilibrium I need to express the dynamics in stationary terms. Therefore I divide all nominal variables by monetary holdings at the beginning of period t, $\bar{M}^s_t.$ For convenience, I will omit time subscripts, and primes and -1-subindices will denote next and last period's variables, respectively.[13] Let $M = \bar{M}/\bar{M}^s$; $D = \bar{D}/\bar{M}^s$; $P = \bar{P}/\bar{M}^s$; $X = \bar{X}/\bar{M}^s$; $W = \bar{W}/\bar{M}^s$; $B^d = \bar{B}^d/\bar{M}^s$; $\Pi^f = \bar{\Pi}^f/\bar{M}^s$; and $\Pi^{fi} = \bar{\Pi}^{fi}/\bar{M}^s$.

The model can be easily solved by assuming the family structure explained in section 1.3. According to this assumption, one can think of a representative agent of the whole economy. Therefore the Bellman equation of this representative agent's program is

[13] For notation recall footnote 4.

$$V(M;K;a_{-1};\nu) =$$

$$= \max_{D\in[0;M]} \int \left\{ \int \max_{C;L;K';H;B^d} [U(C;L) + \beta V(M';K';a;\nu')]\, \Delta_1(\epsilon_0'|\epsilon_1)d\epsilon_0' \right\} \Delta_0(\epsilon_1|\epsilon_0)d\epsilon_1 \quad (1.21)$$

$$\text{subject to } M - D + WL \geq PCN \quad (1.22)$$

$$B^d \geq WH + PQZ; \quad (1.23)$$

$$M'(1+\mu) = M - D + WL - PCN + RD + \Pi^f + \Pi^{fi}; \quad (1.24)$$

$$\Pi^f = PY - (WH + PQZ) - (R-1)B^d; \quad (1.25)$$

$$\Pi^{fi} = RX; \quad (1.26)$$

$$Y = AK^{\alpha_k}H^{\alpha_h}; \quad (1.27)$$

$$K' - (1-\delta)K = i[1 - \Phi(\omega)\mu_c]; \quad (1.28)$$

$$\omega = (1+R^k)(1-NW); \quad (1.29)$$

$$NW = Y^{\xi}; \quad (1.30)$$

where Δ_0 and Δ_1 denote the distribution functions for ϵ_0 and ϵ_1; respectively.

Definition 1 A stationary competitive equilibrium consists of a value function V; a set of policy functions C_t; L_t; D_t; H_t; K_{t+1}; B_t^d; i_t; ω_t; a decision rule determining next period's money balances, M_{t+1}; pricing functions P_t; R_t; Q_t; and W_t; and profit and net worth functions Π_t^i, Π_t^f; and NW_t; such that:

i) the value function V solves the representative agent's Bellman equation (1.21), where C_t; L_t; D_t; K_{t+1}; B_t^d; and H_t are the associated policy functions together with the decision rule M_{t+1}; taking as given the appropriate information structure; the pricing functions P_t; Q_t; W_t; and R_t; and the profit functions Π_t^f and Π_t^i;

ii) entrepreneurs solve their maximization problem given R_t^k; Q_t; and NW_t (determined by equation (1.30)); with the solution being i_t; and $\bar{\omega}_t$;

iii) the central bank sets interest rates according to the following rule:

$$r_t = \gamma + \gamma_r r_{t-1} + \gamma_\pi \pi_t + \gamma_y y_t;$$

iv) finally, consumption goods, money, loan, labor, and capital goods markets clear, that is,

$$C_t + i_t = Y_t;$$

$$M = 1;$$

$$D_t + X_t = B_t^d;$$

and

$$H_t = L_t:$$

Under certain restrictions, there will exist equilibria in which both cash-in-advance constraints (1.3) and (1.10) will bind for each state of the world. That is, whenever the Lagrange multipliers corresponding to these constraints and the nominal interest rate will be positive. These restrictions must imply a positive level of deposits, and stationarity of shocks to assure that cash-in-advance constraints will hold with equality in every state. In the analysis below, I will focus on this type of equilibria.

1.5 Solution method

I follow Campbell [5] in the solution method. The main idea is to linearize the equilibrium conditions arising from the household's, firm's and entrepreneurs' problems respectively. These conditions are given in the Appendix. At this point Campbell's method of undetermined coefficients is applied. The mechanism is to guess that the rates of growth of variables can be expressed as functions of capital predetermined in period $t-1$, K_t; and the shocks (technology and money demand ones). The whole system can be reduced to three equations, one for the demand for capital, one for the interest rate rule, and the last one for the Euler equation for consumption. Once all the variables are substituted, I only need to solve for the undetermined coefficients to obtain the solution paths for the variables.

1.6 Parameter values

The model parameterization seeks to match empirical observations of postwar US data. Some parameters are calibrated, whereas others are taken from the standard literature. Results are reported in Tables 1.1 and 1.2. The time period considered is one quarter.

The parameters or the model are β; θ; ψ; Υ; δ; α_k, α_h, ω; μ_c; ξ; as well as those parameters defining the stochastic processes of the shocks (ρ_a; ρ_ν; $\sigma_{\epsilon a}$; and $\sigma_{\epsilon\nu}$): I will take θ; δ; ξ; ρ_a; and ρ_ν from previous estimates in the literature on business cycle models for the US postwar data. The remaining parameters, that is, β; ψ; Υ; α_k, α_h, ω; μ_c, $\sigma_{\epsilon a}$; and $\sigma_{\epsilon\nu}$ are calibrated to match US data.

Regarding preference parameters, the discount factor is chosen to match an annual nominal interest rate equal to 7.8% at the non-stochastic steady state, given an average mean money growth, $\bar{X}$; equal to 1:2%; …gures which are consistent with US data. This implies a ¯ equal to 0:9926: To make it easier to get intuition about the dynamics of the model, I will choose preferences so that income and substitution e¤ects cancel out, that is, the relative risk aversion parameter[14] is µ = 1. The inverse of the labor supply elasticity with respect to real wages, Ã; is more controversial.[15] I give this parameter the value 0:7; that is, the elasticity of labor supply with respect to real wages will be close to 1:5. This elasticity helps the model replicate the empirically observed relative standard deviations reported in Table 1:3; mainly the correlation between output and labor. The coe¢cient ª has been calibrated so that labor in the non-stochastic steady state equals one. This means that all variables are measured in per capita terms:

For technology parameters, I take the depreciation rate, ±; to be 2% per quarter, which is consistent with estimates for the US postwar period. The capital share on aggregate income, in the model without credit market imperfections is taken to be 0:36; this implies an $®_k$ equal to 0:3598 in the model with credit frictions. This is computed taking into account that aggregate output, Y^A; equals output plus added value from the capital sector, Y + i[Q ¡ 1]: Notice that in the case without monitoring costs, the price of capital is one, Q = 1; and therefore, Y^A = Y: By assuming constant returns to scale in the production function, $®_h$ is obtained, where $®_h$ = 1 ¡ $®_k$.

Next, I calibrate parameters related to credit market imperfections. These are the bound on the support of the uniform distribution of $\tilde{!}_t$; that is, !; and the monitoring costs, $¹_c$: Following Gertler [18], I keep the elasticity of net worth with respect to output, »; equal to 4:45; which is consistent with US estimates. The bound ! and the monitoring costs $¹_c$ are calibrated to match

[14] Although I am not analyzing growth, I prefer to use preferences which are consistent with balanced growth, as is the case speci…ed here.

[15] See for example the paper by Christiano, Eichenbaum and Evans [9].

an annual value for the bankruptcy rate, $\Phi(\bar{\omega}_t)$, of 10%, and an annual risk premium of 157 basis points, measured by the spread between the commercial bank lending rate and the commercial paper rate on average terms[16] reported by Fuerst [15]. The resulting values are $\omega = 0.1573$, and $\mu_c = 0.1283$.

It remains to specify the stochastic processes of the shock variables. The steady states of all the shocks are normalized to 1. Following traditional literature estimates, the autocorrelation coefficient for the technology shock, ρ_a, is assumed to be 0.95, consistent with the high persistence of these perturbations observed in the data (King and Rebelo [24], Ireland [23]). For the shock to money demand, estimates for US data show large and highly persistent money demand shocks (Ireland [22]). Thus, I follow Christiano and Gust [10], and set ρ_υ equal to 0.95 also. Given these values, the standard deviations for the shocks are simultaneously calibrated to match several second moments in the data reported in Table $1.3.$ More concretely, I focus on the correlation of output with investment and the correlation between investment and labor. These correlations have been chosen because they summarize the key mechanism of the models investigated. Mainly, the effects induced by credit market imperfections in the production of investment goods are translated to output through changes in labor. The resulting values are $\sigma_{\varepsilon_a} = 0.0071$, and $\sigma_{\varepsilon_\upsilon} = 0.0118$.

Finally, when the Taylor rule is at work, I will consider a version of the rule with the following coefficients: $\gamma_r = 0.66$, $\gamma_\pi = 0.61$, and $\gamma_y = 0.16$. This rule is denoted as stable by Christiano and Gust [10] when applied to a limited participation model, in the sense that it determines a stable unique equilibrium.[17] This is also the case here. The general consensus in giving a higher

[16] There is a wide discrepancy for the values regarding monitoring costs and bankruptcy rates. The reader can find discussion about them in Carlstrom and Fuerst [6], Fisher [13], and Bernanke, Gertler, and Gilchrist [4].

[17] As usual when dealing with interest rate rules, issues regarding indeterminacy of equilibrium arise. In prin-

weight to inflation smoothing rather than to output stabilization is also followed.

Table 1.2 summarizes the steady state values for the two setups considered. In the remainder of the paper I will denote the model without frictions the symmetric information model, $\mu_c = 0$, and refer to the case with frictions as the asymmetric information model, $\mu_c > 0$ (SI and AI, respectively). Recall that when monitoring costs are zero, the model collapses to a standard limited participation framework. Note also that steady state values for some variables differ between models. However, both start at the same level of $1 + \bar{X}$; which means that policies differ only in terms of their cyclical characteristics.

1.7 Quantitative properties of the models

In this section, I analyze the ability of the two models presented above to account for some stylized facts suggested by the literature on business cycles. Table 1:3 presents some key moment relationships implied by the SI and AI models, and compares them with real US data. For actual US data, the sample selected goes from 1970:1 to 2000:4. The series have been taken from the FRED Database (Federal Reserve Bank of St. Louis) and correspond to Real GNP, Real Personal Consumption Expenditure, Real Gross Private Domestic Investment, and Nonfarm Payroll Employment, in logarithms and detrended using the Hodrick-Prescott filter. The risk premium is measured as the spread between the Bank Prime Rate and the Six-month Treasury-bill Rate.

Part A of Table 1.3 presents the relative standard deviations of some variables with respect

ciple, there is no reason to assume that the regions characterizing uniqueness, indeterminacy and explosiveness in this model are the same as those obtained by Christiano and Gust [10] for a limited participation framework. Thus, I analyzed indeterminacy for the models in this paper given the rule. The coefficients reported here lie in the area of unique equilibrium.

to output, which is taken as a reference point. The second line shows that consumption is less volatile than output for both the SI and AI settings. Moreover, it is somewhat lower than the one in the data, especially in the asymmetric information case. For investment, on the other hand, the standard deviation is much higher than that of output, as observed in the data.

The disparity between the responses of the consumption and investment volatilities to the introduction of credit market imperfections can be explained by the structure of the model. In the SI case, it is still observed the higher volatility of investment relative to consumption, as in the sample data. However, the introduction of credit market frictions, in the way it is done here, amplifies the sensitivity of investment with respect to output, and damps the sensitivity of consumption with respect to the SI case.

Finally, both models report a relative standard deviation of labor with respect to output close to one, which is consistent with the data.

Part B of the table focuses on some correlations derived from the two models considered, and compares them with real correlations obtained in the data. Basically, the conclusions from Part A about the changes in relative volatilities once credit market imperfections are considered also appear here. In addition, it is observed that the model with credit frictions is able to account for the negative correlation between the growth rate of output and the risk premium, whereas this fact is absent in the model without frictions. As already mentioned, in good times credit facilities for borrowers are eased, that is high output growth is related to low cost of credits, mainly reflected in low risk premia. In the model with credit market imperfections this is clearly the case, with a correlation of -0.997.

In summary, the model analyzed in this paper displays quantitative properties quite similar to those stylized facts presented in Hansen [21] and Cooley and Hansen [12] for business cycle models. In addition, the AI version helps understand the movements in the risk premium, a fact missing in the SI case. In this sense, the asymmetric information framework seems to be a good toolbox to analyze the consequences of monetary policy in a framework with credit market imperfections.

1.8 Dynamic properties of the models

In this section I analyze the differences introduced by the monitoring costs model ($\mu_c > 0$) with respect to the frictionless setup, ($\mu_c = 0$); and highlight the stabilization properties of interest rate rules relative to technology shocks and money demand shocks.

1.8.1 Effects of credit market imperfections

According to Section 1.7, the introduction of credit market imperfections into a standard limited participation model helps explain some key features of real economic data lacking in standard business cycle models. But, what do these imperfections add to the dynamics of the model?

Recall that the model in the absence of monitoring costs collapses to the standard limited participation setup. Once credit market imperfections are introduced, a new variable becomes important, the elasticity of entrepreneurs' net worth to changes in output, ξ. According to Gertler [18], a proxy variable for net worth is profits. In the data, profits are much more volatile than output, therefore this elasticity is considerably higher than one (the estimate given by Gertler [18] is $\xi = 4.45$).

An illustration of these differences appears in Figure 1.2. The figure reports the impulse response functions of the models with and without credit market imperfections to a 1% technology shock at time one, when monetary policy follows a constant money growth rule.

Consider first the benchmark case, the model without frictions. The shock to technology makes inputs more productive. Output increases and prices fall, enhancing demand for cash inputs. Given that monitoring costs are zero in this framework, capital goods will be elastically supplied at the same price, $Q_t = 1$: The result is an increase in output and a decrease in prices.

In the presence of credit market imperfections, the initial response of output and investment to the same shock is not only amplified but also more persistent than in the frictionless case. The amplification of investment is especially strong: about 40% larger than the benchmark case without imperfections. This is because in the event of an innovation to productivity, higher output increases entrepreneurs' net worth. Given the negative relationship between entrepreneurs' net worth and monitoring costs, an increase in the proportion of internal funds provided by entrepreneurs will diminish the monitoring cost problem. This is reflected in a fall in the risk premium. The final effect on the price of capital is in general ambiguous. In this model, given the high elasticity of net worth with respect to output, consistent with the data, the price of capital falls. These changes will reduce the marginal costs of firms, increasing both labor and investment demands. That is, changes in the price of capital induced by variations in net worth will eventually affect the allocation of labor in the opposite direction. These additional interactions will drive the dynamics of the model under credit market imperfections, whereas they are absent in the SI setting.

The high autocorrelation of the shock assures high productivity of capital for a long time. This high autocorrelation of the shock together with the persistence induced by financial frictions will extend the effects of the shock overtime. This explains the smaller response of consumption at the beginning and the larger persistence of this variable in the asymmetric information case. The small response in consumption on impact, plus the reduction of the marginal costs of …rms (larger in the AI case), imply a large response of labor re‡ected in the behavior of output. This response is not that large in the SI case.

Thus, the introduction of credit market imperfections helps the model explain the volatility exhibited by output, investment and labor in real data, that cannot be attributed purely to shocks, as well as the countercyclical and persistent movement of the risk premium, providing a suitable and tractable framework for the study of credit market imperfections on generating cyclical ‡uctuations.

1.8.2 Dynamics under the Taylor rule

To analyze the stabilization properties of interest rate rules, I compare the performance of the policy rule described in Section 1.3.5, as well as the constant money growth rate rule which will be considered as a benchmark under both settings, with and without credit market imperfections.

As already mentioned in the model's setup, the economy is a¤ected by two sort of perturbations. First of all, there are shocks to technology in the production function. And second, households are a¤ected by money demand disturbances to their cash-purchases. Non-stochastic steady state values di¤er between the models, so I present the results in percentage deviations from their steady states for all variables, except for the risk premium.

A shock to technology

Investigating how this model economy reacts to technology shocks is necessary given the large literature on the contribution of these disturbances to the explanation of business cycle ‡uctuations. In the …gures, the solid line represents the SI case, while the dashed line stands for the AI model. In both cases, I implemented a one percent technology shock at time $t = 1$; that is, $\varepsilon_{a,1} = 0.01$. Although the increase is temporary, this perturbation will show some persistence since the autocorrelation coe¢cient considered for the technology shock, $½_a$; is 0:95:

Figures 1.3 and 1.4 report the impulse response functions under a constant money growth rule, compared with the responses under a stable version of the traditional Taylor rule, for both cases considered (SI and AI). From the charts it becomes clear that a Taylor rule reduces the response of output to the shock in both cases, but with a stronger e¤ect when there are credit market imperfections. This reduction is even clearer in investment. Note that in‡ation is almost completely stabilized, and that the presence of credit market imperfections is not relevant with respect to in‡ation stabilization. It is worth noticing that with credit market imperfections the risk premium is reduced after a positive technology shock (consistent with its countercyclical ‡uctuations in the data), whereas it remains unchanged in the SI setting.

The stabilizing e¤ects of the rule after a productivity shock are displayed in Figure 1.5. This …gure reports the di¤erence of impulse response functions under a constant money growth rule and the Taylor rule. From the previous …gures it could be seen that the rule stabilized output in both models. However, Figure 1.5 shows that the stabilization is higher when there are …nancial frictions in the economy. The intuition can be found in the supply side e¤ects[18] of monetary policy in this model. On one hand, the increased productivity reduces marginal costs of …rms, leading to a higher demand for capital and labor. On the other hand, as output rises, the rule implies that the interest rate rises which acts like a tax on inputs demands. This raises …rms' marginal costs, since …rms must borrow in order to purchase investment and hire labor. This cost increase diminishes both demands, damping the rise in output.

[18] Supply or cost-side e¤ects have already been analyzed empirically by Barth and Ramey [2]; and theoretically by Christiano and Eichenbaum [8], and Christiano, Eichenbaum and Evans [9] among others. The intuition goes through the imposition of a cash-in-advance constraint on the …rms' inputs bill together with the use of interest rate rules to conduct monetary policy.

These cost effects are strengthened in the model with imperfections. There, restraining output growth by raising interest rates means entrepreneurial net worth rises less than it otherwise would, preventing a larger fall of the price of capital. Thus labor and investment demands rise but much less than in the SI model, and this is reflected in output. This is why the rule has more stabilization effects on output in a scenario with financial frictions.

Thus the damping effects of a central bank concerned on inflation and output stabilization reduces the response of variables in the face of a technology shock. This result is novel in this analysis. As mentioned in the introduction, the conventional wisdom associated with sticky price models is that interest rate rules prove useful in stabilizing the economy facing money demand shocks, while for supply shocks, a trade-off between output and inflation stabilization arises. More recently, BGG [4] analyze the amplifying effects of credit market imperfections in response to several perturbations, among them shocks to productivity. These authors introduce financial frictions in the demand for capital, and their monetary policy is implemented through an interest rate rule, but unlike this paper, they work in a framework of sticky prices. They obtain that the financial accelerator theory applies in such a framework. That is, financial frictions amplify the economy-wide response to shocks. Their results arise with a central bank setting the nominal interest rate reacting to lagged deviations of inflation and interest rate, but not to output. As is shown here, giving a slightly positive weight to output stabilization in the rule would reduce the effects of financial frictions, and eventually would offset them. These issues are important when trying to account for the quantitative effects of financial frictions.

The results here show that under flexible prices, an interest rate rule helps reducing both inflation and output variability after technology disturbances. Furthermore, the rule is more effective if there are credit market imperfections in the economy.

A shock to money demand

Most theoretical work, starting with Poole [27] has established that both output and prices could be insulated in the face of money demand shocks whenever the monetary authority employed interest rates as its instrument, rather than managing money supply. This has proven to be the case for certain types of business cycle models, mainly sticky prices ones, so it seems reasonable to extend the analysis to a limited participation framework. As before, the rule at work in this subsection is the traditional Taylor rule versus the constant money growth rule.

In this economy money demand shocks affect households. As before, the shock is one percent money demand shock at time $t = 1$; i.e. $\varepsilon_{\gamma,1} = 0.01$. Figures 1.6 and 1.7 display the dynamics, for the SI and AI models, respectively. The stabilization properties of the rule can be found in Figure 1.8.

Let us concentrate on the SI model. The positive money demand disturbance has two main effects on households' choices. First, the money demand shock makes consumption more expensive in terms of labor, as we can see from the linearized labor supply equation

$$\theta c_t + \psi h_t = w_t - p_t - \gamma_t.$$

Recall that in this equation θ denotes the inverse of the constant intertemporal elasticity of consumption, and ψ is the inverse of the labor supply elasticity with respect to real wages. Lower case letters denote the log-deviations from steady state of variables, in this case, c_t for consumption, h_t for households' labor supply, w_t for nominal wages, p_t for consumption prices, and finally γ_t is the log of the money demand shock.

That is, the shock resembles a cost-push shock as analyzed in the literature on the relationship between marginal costs and the output gap (Galí and Gertler [17]). Thus a positive shock to money demand means that individuals demand less consumption and therefore reduce their labor supply. This falling aggregate demand makes …rms cut their demand for inputs, in particular labor. This a¤ects production that shrinks at the time of the shock, as is shown in Figure 1.6. Meanwhile the decreasing prices and demand of consumption goods induce a substitution e¤ect towards investment.

Second, since individuals have greater needs for funds, they reduce their deposits at the …nancial intermediary. Recall that this shock is observed before the household's portfolio choice is made, therefore individuals are able to react to it by changing the amount of money they deposit at the bank. The fall in deposits reduces the amount of funds available to …rms. This generates an excess of demand for liquidity that depresses the economy.

What is di¤erent in the AI model? On one hand, the higher investment demand a¤ects positively the price of capital, motivating investment supply. On the other side, the falling output is a¤ecting negatively the entrepreneurs' net worth reducing the amount of capital goods supplied to the economy. In this model, the net worth e¤ect dominates. The net e¤ect in this shock is an increase in investment, but at a higher price. Note that the rise in Q_t and the fall in NW_t; both aggravate the information problem, an e¤ect that was absent in the benchmark model as shows the rising risk premium in Figure 1.7. This ampli…es the fall in output, and reduces the increase in investment with respect to the SI case.

When the Taylor rule is considered, the falling output and prices at the time of the shock imply a low interest rate on impact. In this rational expectations model, individuals know that the central bank will react by increasing interest rates in the following periods. This is anticipated by agents who reduce even more their aggregate demand. Prices are even lower, and so are marginal costs of …rms, compared with the constant money growth case. As a result, prices are destabilized and the volatility of output is slightly reduced. When financial frictions are added, the effects of the rule are amplified with respect to the frictionless case, due to the additional factors mentioned above. This is observed in Figure 1.8.

1.9 Conclusions and further research

The purpose of this paper is to analyze the performance of interest rate rules in the presence of credit market imperfections. In the economy with credit imperfections, a stable version of the Taylor rule like the one employed by Christiano and Gust [10] achieves both output and inflation stabilization after a technology shock, and results in a trade-off between output and inflation stabilization when money demand shocks are considered. Additionally, both the destabilization effects of the rule with respect to money demand shocks, and the stabilization effects of the rule with respect to technology shocks are amplified in the presence of credit market imperfections.

The fact that financial frictions affect the performance of monetary policy conducted by interest rate rules opens a wide range of questions. Basically, this research can be extended in two complementary ways. One possible direction would be the calibration of the coefficients of the rule under credit market imperfections. This analysis would provide a better representation of real data in order to investigate the effects of different monetary policy rules.

The other line of research would lead to the derivation of the optimal monetary policy rule in a scenario of financial frictions. Rotemberg and Woodford [28] develop this topic in a sticky price model without financial frictions. These authors evaluate different extensions of the Taylor rule in terms of the variability induced to output and prices and compare them with the optimal rule. They conclude in favor of backward-looking rules whenever private agents are forward-looking. After having analyzed the different effects of interest rate rules in sticky versus limited participation models, it seems interesting to test the robustness of Rotemberg and Woodford's results in a limited participation and allowing for financial frictions.

Given the importance of variables such as the risk premium, which affect the cost of borrowing, on the implications of financial frictions, research could also focus on how monetary policy performance would change if some indicator of the credit market imperfections is included in the rule. Possible candidates for this purpose are, for example, the bankruptcy rate and the risk premium.

Appendix: Equilibrium conditions

To analyze the competitive equilibrium, it is useful to collect the model's equations into several groups, as follows. Equations referring the symmetric information model are given first, then the variations corresponding to the monitoring costs case are reported.

Aggregate demand

$$\text{Resource Constraint} \rightarrow C_t + Z_t = Y_t,$$

$$\text{Consumption Euler equation} \rightarrow E\left[\frac{U_C(C_t, L_t)}{N_t \bar{P}_t}\bigg| \Gamma_{0,t}\right] = E\left[\beta R_t \frac{U_C(C_{t+1}, L_{t+1})}{N_{t+1}\bar{P}_{t+1}}\bigg| \Gamma_{0,t}\right].$$

Aggregate Supply

$$\text{Production Function} \rightarrow Y_t = A_t K_t^{\alpha_k} H_t^{\alpha_h},$$

$$\text{Labor market Equilibrium} \rightarrow -\frac{U_L(C_t, L_t)N_t}{U_C(C_t, L_t)} = \frac{\bar{W}_t}{\bar{P}_t} = \frac{\alpha_h Y_t}{H_t R_t}.$$

Evolution of State Variables

$$\text{Capital stock} \rightarrow K_{t+1} = Z_t + (1 - \delta)K_t,$$

$$\text{Money stock} \rightarrow \bar{M}_{t+1} = \bar{M}_t - \bar{D}_t + \bar{W}_t L_t - \bar{P}_t C_t N_t + R_t(\bar{D}_t + \bar{X}_t) + $$
$$+\bar{P}_t Y_t - (\bar{W}_t L_t + \bar{P}_t Z_t) - (R_t - 1)\bar{B}_t^d.$$

Monetary Policy for the Taylor rule

$$r_t = \gamma + \gamma_r r_{t-1} + \gamma_\pi \pi_t + \gamma_y y_t.$$

Shock Processes

$$\text{Technology shock} \rightarrow a_{t+1} = \rho_a a_t + \varepsilon_{a,t+1};$$

$$\text{Money demand shock to households} \rightarrow \nu_{t+1} = \rho_\nu \nu_t + \varepsilon_{\nu,t+1}.$$

When credit market imperfections are considered, there are changes in the following equilibrium equations: in the aggregate demand,

$$\text{Resource Constraint} \rightarrow C_t + i_t = Y_t.$$

In the aggregate supply, capital goods production

$$\text{Project size} \rightarrow 1\text{unit per entrepreneur};$$

$$\text{Capital goods price} \rightarrow Q_t = \frac{1}{1 - \Phi(\bar{\omega}_t)\mu c};$$

$$\text{Monitoring cutoff value} \rightarrow \bar{\omega}_t = (1 + R^k_t)(1 - NW_t);$$

$$\text{Capital supply} \rightarrow Z_t = i_t[1 - \Phi(\bar{\omega}_t)\mu c].$$

Evolution of State Variables

$$\text{Money stock} \rightarrow \bar{M}_{t+1} = \bar{M}_t - \bar{D}_t + \bar{W}_t L_t - \bar{P}_t C_t N_t + R_t(\bar{D}_t + \bar{X}_t) + \\ + \bar{P}_t Y_t - (\bar{W}_t L_t + \bar{P}_t Q_t Z_t) - (R_t - 1)\bar{B}^d_t.$$

The rest of the equations remain the same.

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Table 1.1: Parameter values

A.- Calibrated parameters

Parameter description	Values	Facts to match
Discount factor (β)	0.9926	Annual Nominal Interest Rate (7.8%)
Coefficient on disutility of labor (Ψ)	0.8457	Variables are in per capita terms
Capital share of output (α_k)	0.3598	Capital share of output (0.36)
Labor share of output (α_h)	0.6402	
Bound of idiosyncratic shock support (ω)	0.1573	Annual average risk premium (157 bp)
Monitoring costs (μ_c)	0.1283	Annual bankruptcy rate (10%)
Inverse of elasticity of labor supply - wages (ψ)	0.7	corr(output, labor) of 0.85(*)
Std. dev. technology shock (σ_a^{ε})	0.0071	corr(output, investment) of 0.92(*)
Std. dev. money demand shock (σ_o^{ε})	0.0118	corr(investment, labor) of 0.74(*)

B.- Other parameteres

Coefficient of relative risk aversion (θ)	1
Depreciation rate of capital (δ)	0.02
Elasticity of net worth - output (ξ)	4.45
Autocorrelation technology shock (ρ_a)	0.95
Autocorrelation money demand shock (ρ_o)	0.95

Note: Time period is a quarter.

(*) These values correspond to the correlations of output with respect to labor and investment, as well as the correlation of investment and labor obtained from the data reported in Table 1.3.

Table 1.2: Nonstochastic Steady State Values

	Symmetric Information Model	Asymmetric Information Model
$\frac{C_{ss}}{Y_{ss}}$	0.7426	0.7426
R_{ss}	1.0195	1.0195
$\frac{K_{ss}}{Y_{ss}}$	12.8718	12.8305
Q_{ss}	1	1.0032
D_{ss}	0.45	0.45
L_{ss}	1	1
$1+X_{ss}$	1.012	1.012
$1+R^{k}$	1	1.0007

Table 1.3: Summary statistics

A.- Relative standard deviations with respect to output			
	Sample Data (1970:1-2000:4)	SI Model	AI Model
Output	1	1	1
Consumption	0.83	0.66	0.55
Investment	4.55	3.48	3.99
Labor	0.96	1.02	0.99
B.- Correlations with respect to output			
corr(output, labor)	0.85	0.81	0.85(*)
corr(output, consumption)	0.86	0.45	0.31
corr(output, investment)	0.91	0.87	0.92(*)
corr(investment, labor)	0.74	0.69	0.74(*)
corr(output, risk premium)	-0.15	0	-0.99

The sample selected goes from 1970:1 to 2000:4. The series have been taken from the FRED Database (Federal Reserve Bank of St. Louis) and correspond to Real GNP, Real Personal Consumption Expenditure, Real Gross Private Domestic Investment, and Nonfarm Payroll Employment, in logarithms and detrended using the Hodrick-Prescott …lter. The risk premium is measured as the spread between the Bank Prime Rate and the Six-month Treasury-bill Rate. The other two columns correspond to the values computed from the models considered in the paper, SI and AI frameworks.

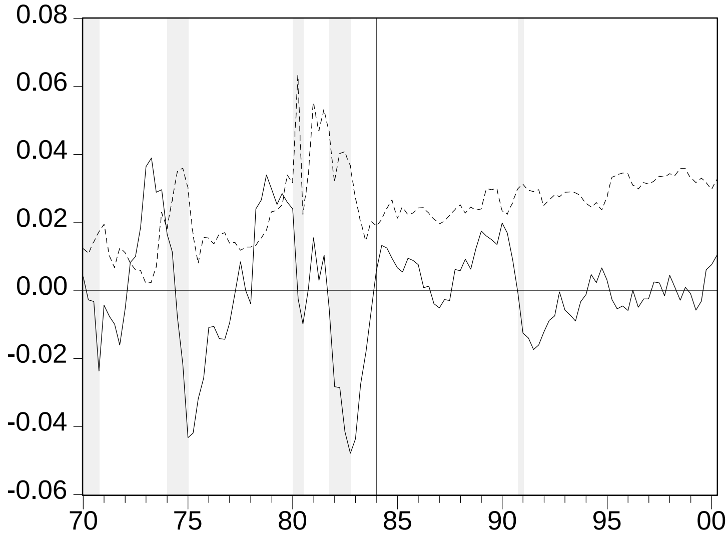


Figure 1.1: Real US GNP versus the spread between the Bank Prime rate and the Six-month Treasury-bill rate.

In the ...gure, the solid line denotes the real GNP, whereas the dashed line refers to the spread between the Bank Prime rate and the Six-month Treasury-bill rate. Source: Board of Governors of the Federal Reserve System.

Period	Corr(GNP, Spread)
1970:1-2000:2	-0.15
1970:1-1983:4	-0.17
1984:1-2000:2	-0.34

Figure 1.2: Impulse response functions to a technology shock under the constant money growth rule. The solid line denotes the symmetric information case, and the dashed line refers to the asymmetric information case. Time period is in the x-axis.

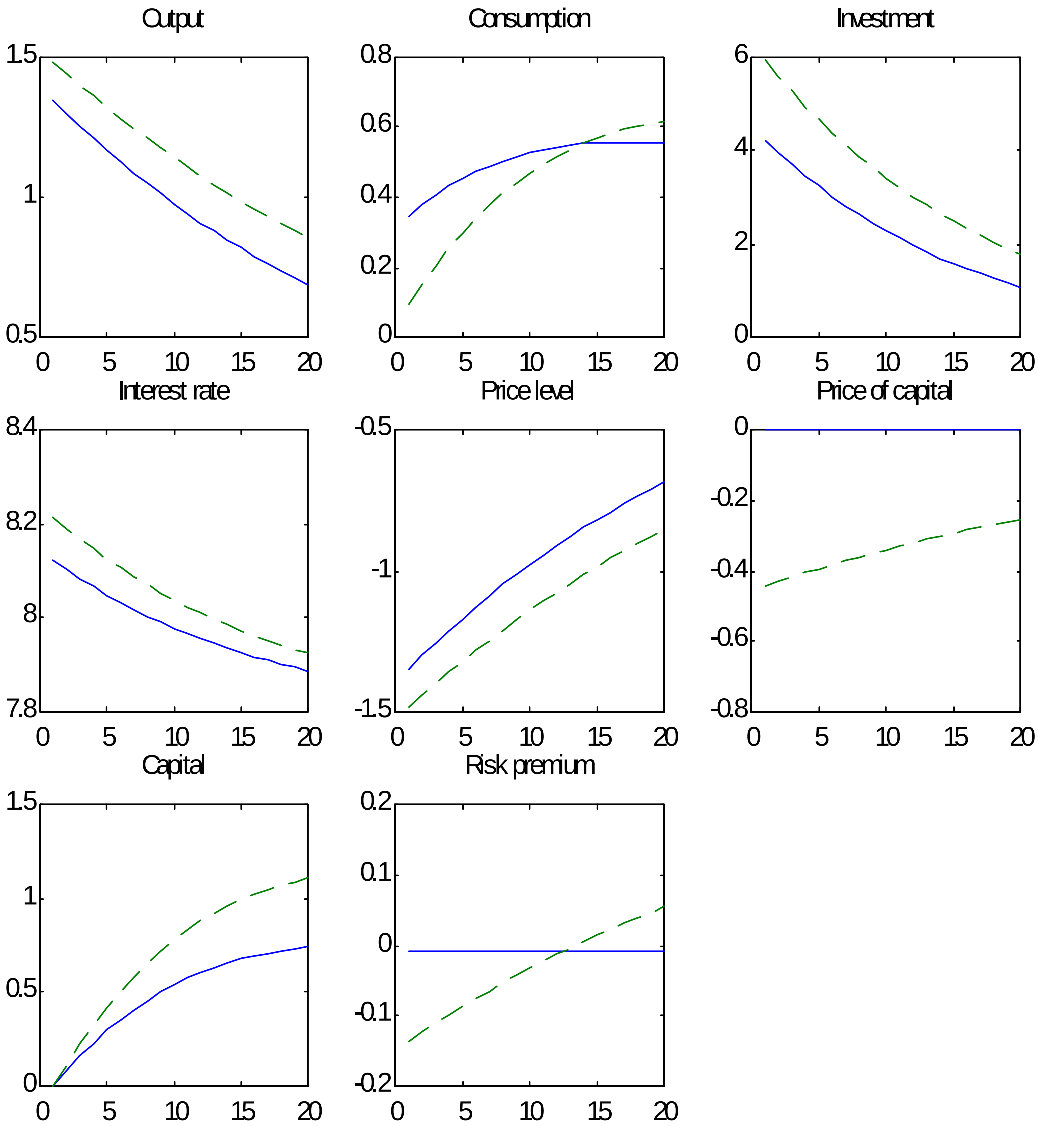


Figure 1.3: Impulse response functions to a technology shock in the Symmetric information case. The solid line refers to the constant money growth rule, whereas the dashed line refers to the Taylor rule. (APR denotes Annual Percentage Rate)

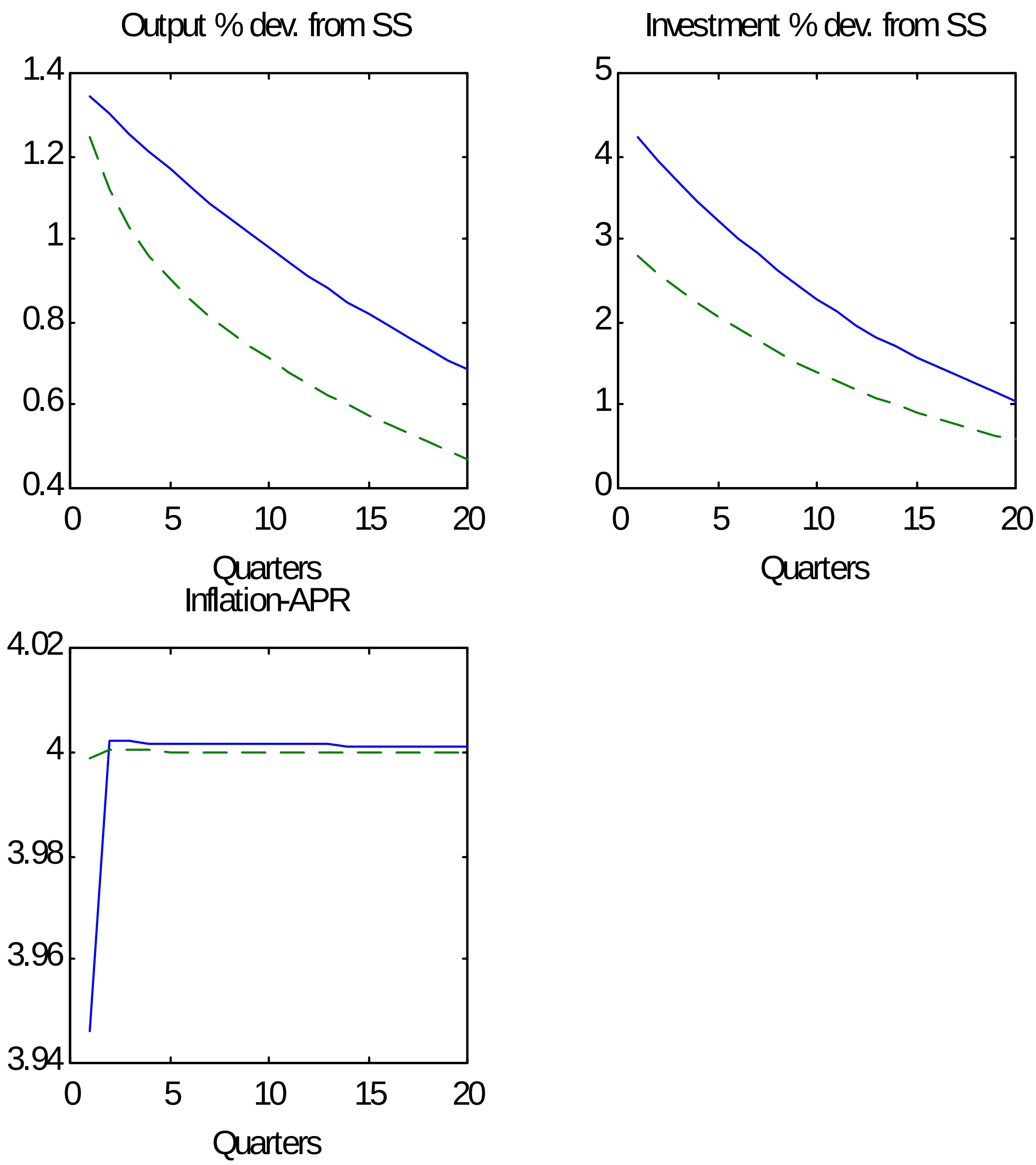


Figure 1.4: Impulse response functions to a technology shock in the Asymmetric information case. The solid line refers to the constant money growth rule, whereas the dashed line refers to the Taylor rule. (APR denotes Annual Percentage Rate)

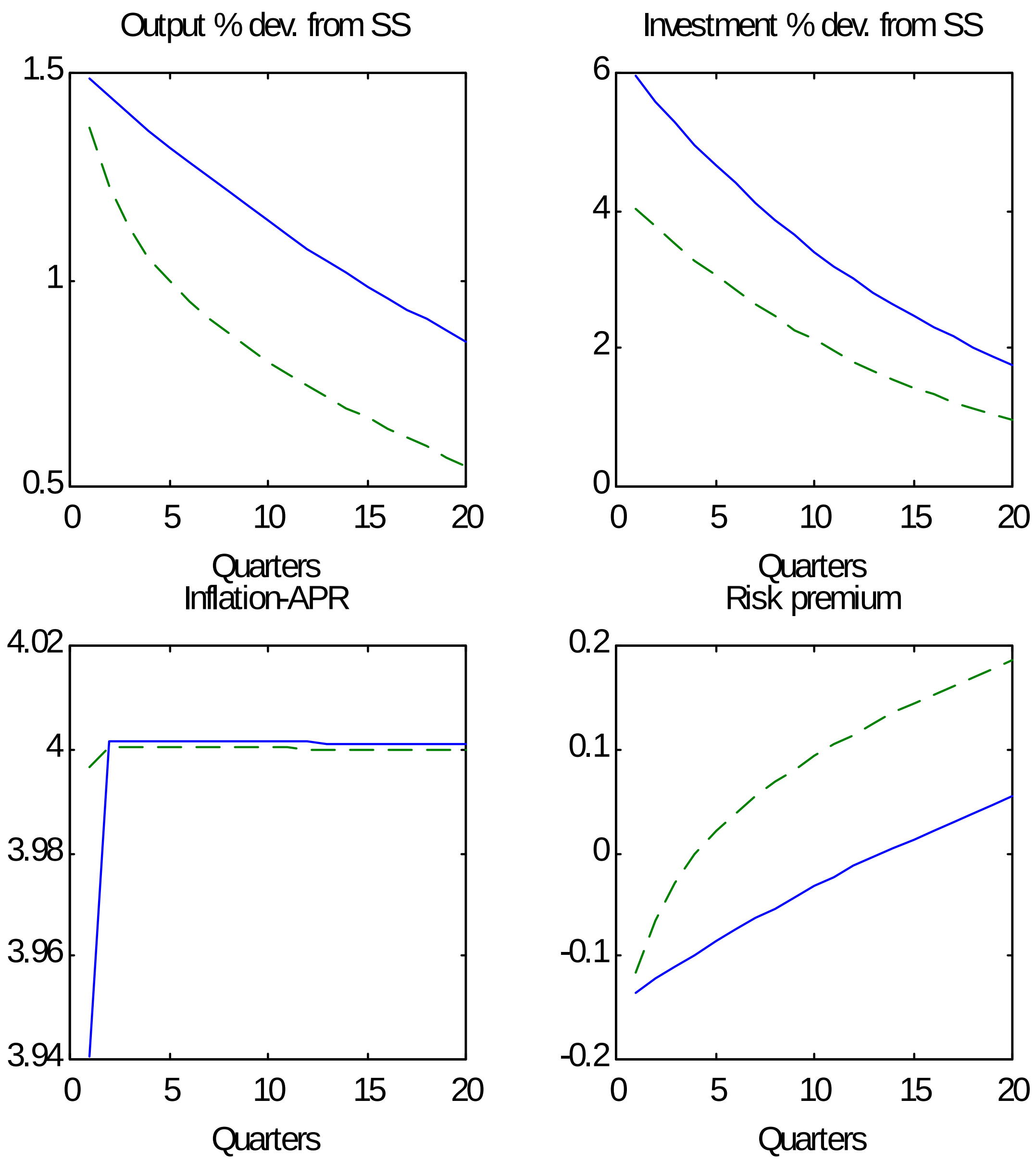


Figure 1.5: Differences in impulse response functions to a technology shock. The solid line refers to the SI model, whereas the dashed line to the AI. In charts, it is plotted $x_{CMG-RULE} - x_{IR-RULE}$.

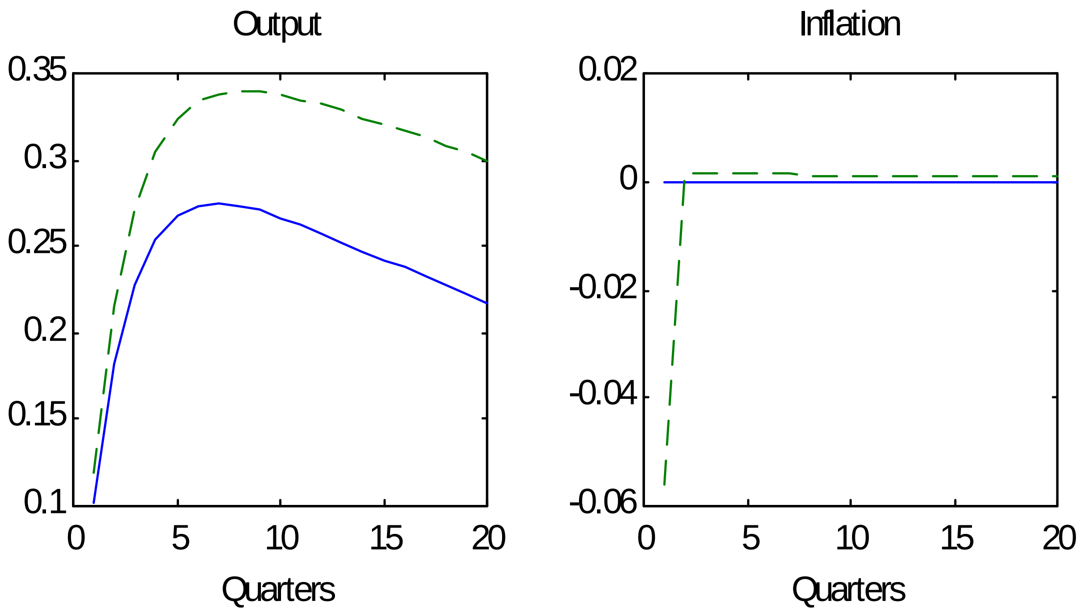


Figure 1.6: Impulse response functions to a money demand shock in the Symmetric information case. The solid line refers to the constant money growth rule, whereas the dashed line refers to the Taylor rule. (APR denotes Annual Percentage Rate)

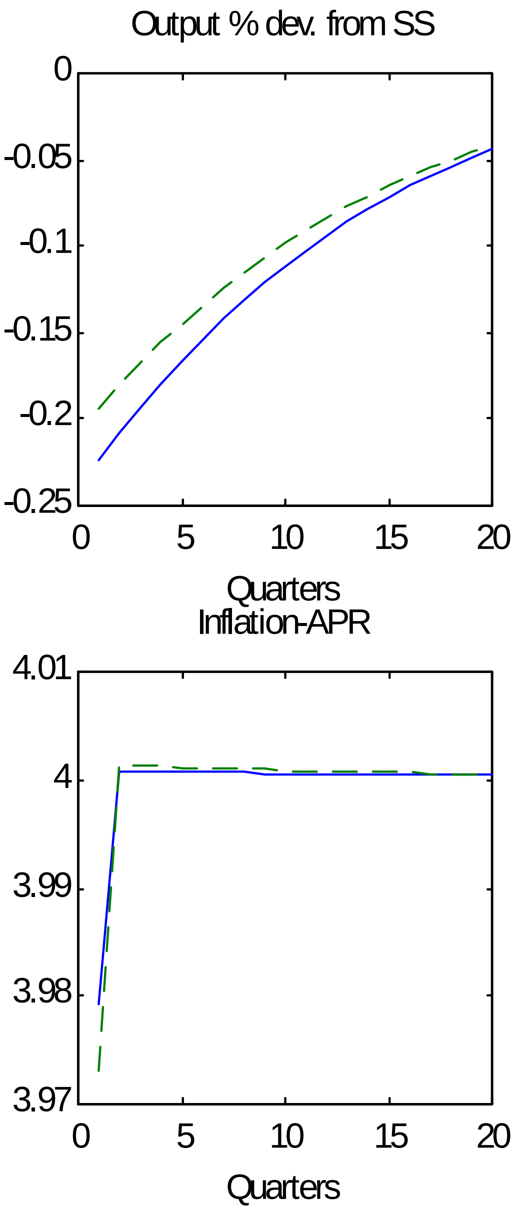


Figure 1.7: Impulse response functions to a money demand shock in the Asymmetric information case. The solid line refers to the constant money growth rule, whereas the dashed line refers to the Taylor rule. (APR denotes Annual Percentage Rate)

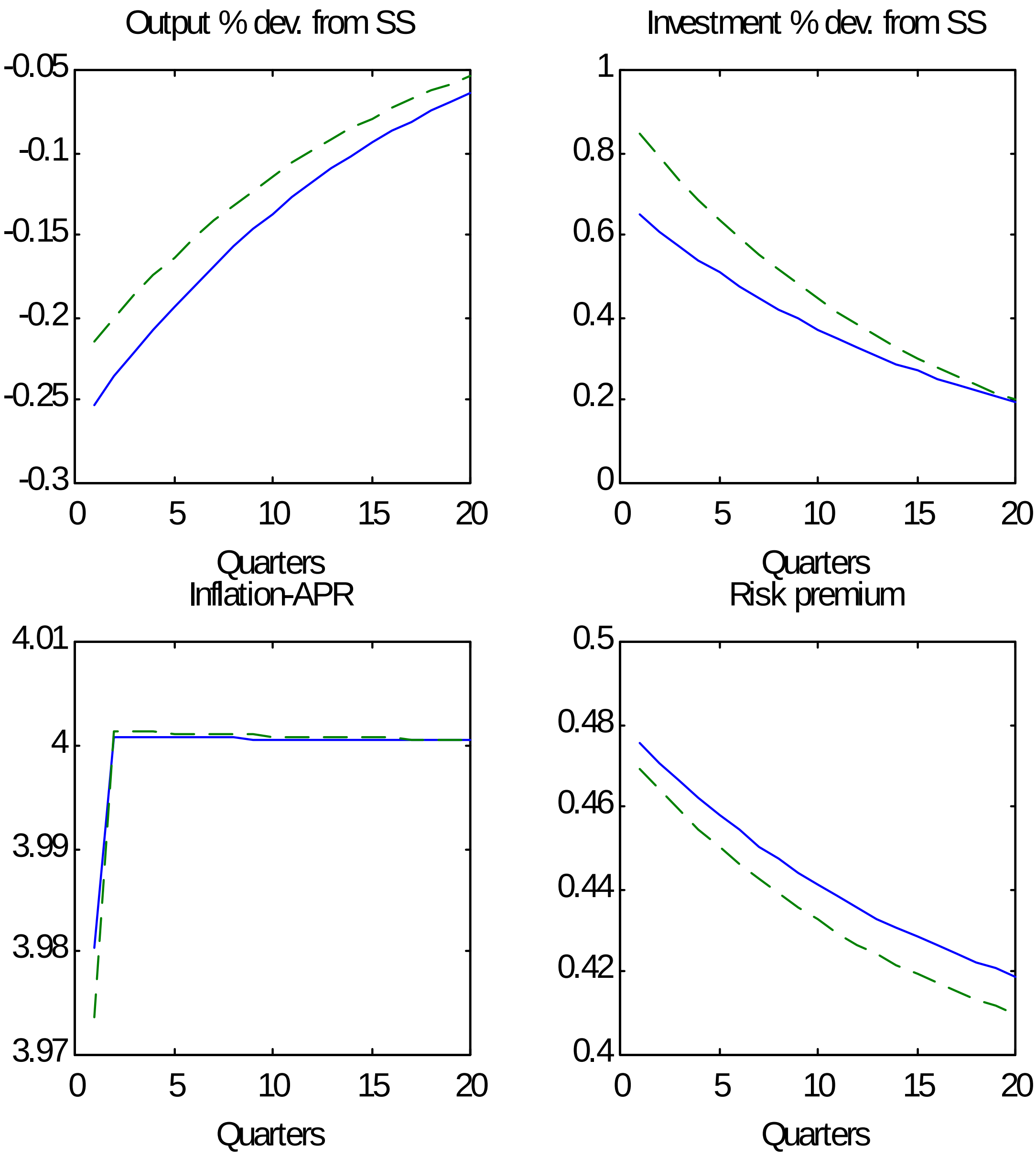
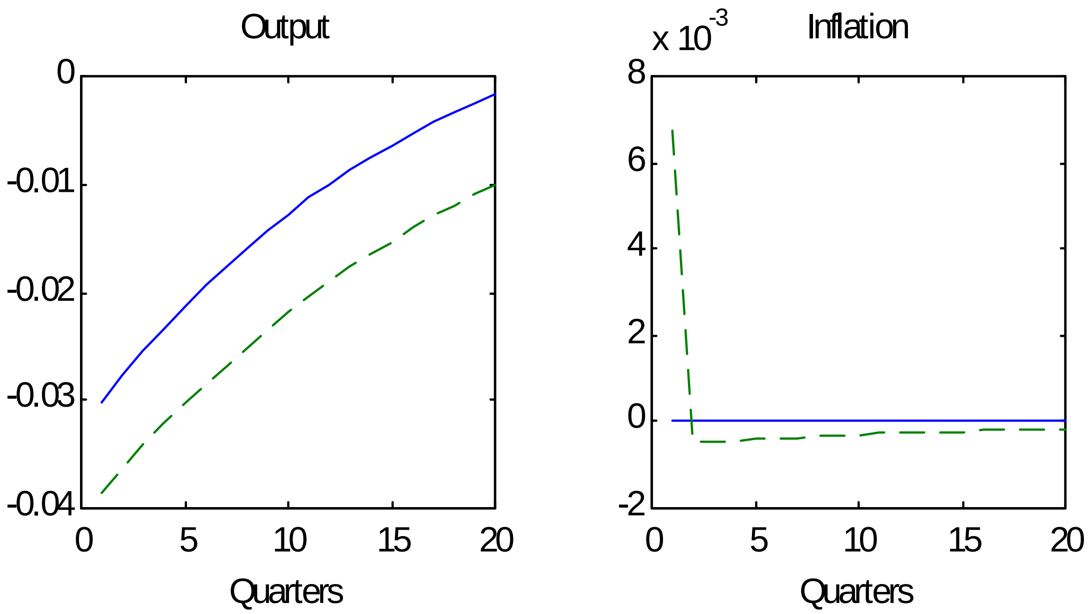


Figure 1.8: Differences in impulse response functions to a money demand shock. The solid line refers to the SI model, whereas the dashed line to the AI. In charts, it is plotted $x_{CMG-RULE} - x_{IR-RULE}$.



Chapter 2

Can Financial Frictions Help Explain the Performance of the US Fed?

2.1 Introduction

This paper investigates whether the presence of financial frictions, which are known to distort the effects of monetary policy conducted by interest rate rules, can help explain the differences in the variability of output and inflation observed in the US data since the 1980s. To this end, I study the interest rate rule followed by the Federal Reserve Bank in the last 40 years considering the presence of credit market imperfections and the possibility that the monetary policy rule, the degree of financial imperfections and shock processes may have changed.

Looking at postwar US data, there are two clear periods in monetary policy, before and after 1980. One of the facts that characterizes these two periods is the reduction in volatility of variables such as output and inflation in the latter period with respect to the former. This reduction in volatility has been mostly attributed to the way monetary policy has been conducted before and after the arrival of Paul Volcker at the Fed. In particular, most empirical research identi…es a di¤erent policy rule in each period (e.g. Clarida, Galí and Gertler [8], Judd and Rudebusch [17] among others). These estimated rules re‡ect a central bank less concerned with output and in‡ation stabilization in the former subsample than in the latter.

The present work di¤ers from previous literature in the fact that …nancial frictions are taken into account when estimating the reaction function of the central bank. Doing this is important for several reasons. First, there is a wide literature which shows that …nancial frictions may amplify and propagate the e¤ects of shocks on variables such as output.[1] Second, the e¤ects of monetary policy can be altered by the presence of these frictions.[2] Thus, this paper asks whether monetary policy alone, as usually modeled, su¢ ces to explain the Post-Volcker stabilization of the economy, or whether other factors, in particular credit market imperfections, also play a role in this stabilization. Third, because of the development of …nancial markets, the degree of …nancial frictions themselves may have changed.

There are three main blocks in this paper. First, postwar US data are analyzed to detect whether there is a clear breakpoint in the series considered. The breakpoint has usually been identi…ed with the di¤erences in the conduct of monetary policy introduced by Paul Volcker. Since there may be many other possible explanations for this breakpoint,[3] here I undertake a noninformed approach and perform stability tests on the moments of the series to detect a statistically signi…cant breakpoint. This is done in Section 2.2.

Once a breakpoint has been identi…ed, I setup a monetary model of the business cycle to

[1] See Bernanke, Gertler and Gilchrist [3], Carlstrom and Fuerst [4], and de-Blas-Pérez [10].

[2] See de-Blas-Pérez [10].

[3] See for example McConnell and Pérez-Quirós [19] for a nonmonetary point of view.

replicate the behavior of the data. This model constitutes the second block. Thus, in Section 2.3 I consider a monetary economy in which some agents cannot immediately access financial markets in response to shocks, but have to wait until the following period. This setup generates a limited participation model, which allows money to have real effects. In addition, credit market imperfections are added to the setup by assuming that the agents who produce capital goods face an agency cost problem. This introduces a kind of financial accelerator in the economy. There is also a central bank in charge of conducting monetary policy, which is assumed to follow an interest rate rule in an attempt to stabilize both inflation and output. Section 2.4 solves and defines the competitive equilibrium in this model.

Finally, the third block covers the calibration of the interest rate rules. Parameter values are described in Section 2.5. In Section 2.6, I estimate the coefficients of the interest rate rule for each of the two subsamples. There are three outcomes worth pointing out. In the absence of financial frictions, the results confirm the widely recognized change in the conduct of monetary policy by reporting substantially different interest rate rules before and after 1981:2, but fail to assign more weight to inflation stabilization in the second subsample. Interestingly, with positive monitoring costs the two calibrated rules are much less different, that is, a far smaller change in policy suffices for stabilization when imperfect credit markets are considered. This may suggest a key role for credit market imperfections in the stabilization of monetary policy. When the rule, shocks and monitoring costs are allowed to adjust between subsamples, the calibration reports interest rate rules that assign more weight to inflation and less to output stabilization after 1981:2. The degree of financial frictions is reduced by 10% after 1981:2. This can be explained by a development of financial markets since the 1980s (Fender [11]) and other policy measures conducing to the reduction of …nancing costs. Regarding shocks, money demand processes vary between subsamples, whereas technology innovations remain relatively stable across time, which is consistent with standard literature. The paper concludes with some guidelines for further research.

2.2 Data and sample selection

The focus of this paper is to consider the e¤ects of …nancial frictions in estimating interest rate rules in the US monetary policy for the period 1959:4 to 2000:3. But before undertaking the estimation, the …rst question to answer is which point should be the appropriate to split the sample.

Most research chooses as breakpoint 1979:3, when Paul Volcker assumed leadership of the Federal Reserve. That could be the approach in this paper; however, I follow Collard, Fève and Langot [9], and identify the potential breakpoint by using a test for parameter instability and structural change with unknown breakpoint.[4] With this procedure, it is the moments in the data that identify a breakpoint in the series, abstracting from any other consideration. This identi…cation is based on Wald, Likelihood ratio and Lagrange multiplier tests.

The variables considered are output, in‡ation, interest rate, and a risk premium measure, re‡ecting the di¤erence in the cost of external versus internal …nancing of …rms, as an indication of …nancial frictions. The data are obtained from the FRED database at the FRB of St. Louis, and correspond to real GNP for output, GNP de‡ator index for in‡ation, the federal funds rate as the nominal interest rate, and the di¤erence between the bank prime rate and the three

[4] See Andrews [2].

month Treasury bill rate as the risk premium. Data are quarterly and are …rst logged and then detrended using the Hodrick-Prescott …lter.

Tables 2.1a and 2.1b report the results for the test statistics computed together with the estimated breakpoint. When only the series of real GNP, GNP de‡ator in‡ation and the federal funds rate are considered for the test, the statistics report noncoincident results. Moreover, only the Wald test is signi…cant. This statistic suggests a breakpoint at 1980:4, just one year after the traditional Pre- and Post-Volcker sample division.

When the series of a measure of risk premium is considered together with those of output, in‡ation and interest rates, results change as shown by Table 2.1b. The Wald test yields again a change point at 1980:4. However, both the LM and the LR tests coincide in signaling 1981:2 as the change point in the sample. This is the same point obtained in Collard, Fève and Langot [9]. I will take as the breakpoint the one indicated by the LM and LR tests and disregard the Wald test, because it usually tends to overreject the null hypothesis. This point remains close enough to the arrival of Paul Volcker in 1979:3 to be consistent with the claim that it results from Volcker's changes in monetary policy. But it is also worth pointing out that there were other important policy changes around this time, such as the Economic Recovery Tax Act (also known as ERTA), implemented in 1981 by the Reagan administration, which lowered corporate and individual income-tax rates and liberalized the depreciation of assets. This tax reform may have a¤ected the …nancing of …rms, and eventually risk premia in …nancial markets inducing the data considered here to exhibit a structural break in 1981:2.

Using this breakpoint, Table 2.2 reports the estimated standard deviations and correlations for the series on each of the two subsamples with the inclusion of the risk premium. It shows that all the variables selected experience a reduction in their volatilities in the second subsample. This is the case especially for output and in‡ation, whose variability is reduced by around 20 and 40%, respectively. Figure 2.1 plots the data re‡ecting the reduction in volatilities reported in Table 2.2. In addition, the correlation between output and interest rates changes after 1981:2, shifting towards a positive correlation in which output leads the interest rate.

The table also shows a negative correlation between output and the risk premium. This negative correlation can be interpreted as re‡ecting …nancial frictions: in good times, when output is high, it is easier for borrowers to obtain external …nancing at a lower cost, and vice versa.

Are these results very di¤erent from the ones I would have obtained by splitting the sample according to the Pre- and Post-Volcker periods? Table 2.3 shows the moments when the breakpoint is 1979:3. It is worth noticing that the estimated moments for the …rst subsample (1959:4-1979:2) are almost exactly the same as those when the breakpoint is 1981:2. The di¤erences appear in the second subsample. However, the reduction in the volatility of output and in‡ation still appears using this alternative split. Also, the estimations again show the negative relationship between output and the risk premium.

Summing up, estimated moments from the data for the period 1959:4-2000:3 show that there is a breakpoint in the sample around 1981:2. This breakpoint is associated with a reduction in the volatility of the variables considered in the second subsample with respect to the …rst one. Given these results, the next step is to analyze whether the reduced volatility of output, in‡ation and interest rates is due only to a change in the monetary policy rule employed by the central bank, or whether other factors such as …nancial frictions or shocks, that alter the e¤ects of monetary policy, have contributed to this stabilization of the economy.

2.3 A monetary economy

I employ a model of a monetary economy to analyze the questions above. The model considered here builds on a limited participation framework with credit market imperfections.[5] In brief, the economy is a cash-in-advance environment with two additional frictions. The first friction is the assumption that households have limited participation in financial markets,[6] which allows for nonneutral effects of money. The second friction is the introduction of credit market imperfections in the production of capital.

The economy is composed of households, firms, entrepreneurs and financial intermediaries that belong to the same family. This family splits early in the morning and, at the end of the day, gather and share all their outputs. There is also a central bank in charge of the conduct of monetary policy.

2.3.1 Households

There is a continuum of infinite-lived households in the interval [0,1]. The representative household chooses consumption (C_t), labor supply (L_t); and deposits ($\bar{D}_t$), to maximize the expected value of discounted future utilities given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t; L_t); \tag{2.1}$$

where E_0 denotes the expectation operator conditional on the time 0 information set, and $\beta \in (0; 1)$ is the household's subjective discount factor. Throughout the paper, I will assume

[5] A model similar to this one has been previously developed by de-Blas-Pérez [10].

[6] See also Christiano [5], Christiano and Eichenbaum [6], Fuerst [12], and Lucas [18].

that the utility function is given by

$$U(C_t; L_t) = \begin{cases} \dfrac{C_t^{1-\theta} - 1}{1-\theta} - \Psi \dfrac{L_t^{1+\psi}}{1+\psi} & \text{if} \quad \theta \neq 1 \\ \log(C_t) - \Psi \dfrac{L_t^{1+\psi}}{1+\psi} & \text{if} \quad \theta = 1; \end{cases} \tag{2.2}$$

where θ denotes the inverse of the constant intertemporal elasticity of consumption, and ψ is the inverse of the labor supply elasticity with respect to real wages, assumed to be constant. The representative household begins time t with money holdings from the previous period, $\bar{M}_t$. A fraction of these money holdings is allocated to deposits in the bank, $\bar{D}_t$: Additionally, he supplies elastically labor to firms and receives in return wage payments, $\bar{W}_t L_t$, that can be spent within the same period. This wage income plus money holdings minus deposits is devoted to consumption purchases, $\bar{P}_t C_t$, subject to the following cash-in-advance constraint:

$$\bar{M}_t - \bar{D}_t + \bar{W}_t L_t \geq \bar{P}_t C_t N_t: \tag{2.3}$$

Note that consumption purchases are affected by N_t; a shock to money demand, assumed to follow a first order Markov process given by

$$\nu_{t+1} = \rho_\nu \nu_t + \varepsilon_{\nu;t+1}; \tag{2.4}$$

where ν_t denotes $\log N_t$, with autocorrelation coefficient $\rho_\nu \in (0; 1)$; and $\varepsilon_{\nu;t+1}$ an i.i.d. normally distributed shock with zero mean and standard deviation $\sigma_{\nu\varepsilon}$:

At the end of the period, the household obtains interests plus principal on deposits from the financial intermediary, $R_t \bar{D}_t$; together with dividends from the firm, $\bar{\Pi}_t^f$; and from the financial intermediary, $\bar{\Pi}_t^{fi}$; that he owns. Thus the flow of money from period t to period t + 1 per household can be expressed as follows:

$$\bar{M}_{t+1} = \bar{M}_t - \bar{D}_t + \bar{W}_t L_t - \bar{P}_t C_t N_t + R_t \bar{D}_t + \Pi^f_t + \Pi^{fi}_t, \tag{2.5}$$

where R_t denotes the gross nominal interest rate.

The household's problem consists of maximizing (2.1) subject to (2.3) and (2.5), by choosing contingency plans for $\{C_t, L_t, \bar{D}_t\}_{t=0}^{\infty}$, taking as given the sequence of $\{\bar{P}_t, \bar{W}_t, \bar{M}_t, R_t, \Pi^f_t, \Pi^{fi}_t\}_{t=0}^{\infty}$. The optimal choices for consumption and labor supply are

$$-\frac{U_L(C_t, L_t) N_t}{U_C(C_t, L_t)} = \frac{\bar{W}_t}{\bar{P}_t}, \tag{2.6}$$

and for deposits

$$E\left[\left.\frac{U_C(C_t, L_t)}{N_t \bar{P}_t}\right| \Omega_{0,t}\right] = E\left[\left.\beta R_t \frac{U_C(C_{t+1}, L_{t+1})}{N_{t+1}\bar{P}_{t+1}}\right| \Omega_{0,t}\right], \tag{2.7}$$

where U_C and U_L denote the marginal utility of consumption and disutility of labor, respectively.

The fact that equation (2.7) depends on the information set $\Omega_{0,t}$ reflects the limited participation character of the model. The information set $\Omega_{0,t}$ includes endogenous state variables (the stock of money carried from the previous period, $\bar{M}_t$, and the stock of capital determined at time $t-1$, K_t), as well as exogenous time t money demand shock to households, and the technology shocks to firms at time $t-1$. This equation is equivalent to the Fisher equation in the usual monetary models, except for the fact that now expectations are taken before agents realize the whole period shocks. This means that households' portfolio choices are made before the complete state of the economy at time t is revealed. This disables households from responding to a current shock by changing deposits within the same period.

This nominal rigidity induces the liquidity effect of a money supply shock on the nominal interest rate observed in the data. The mechanism is the following. At the beginning of the period, households choose between depositing money with the bank and keeping cash balances to purchase consumption. This portfolio decision is restricted to be made before the current state of the economy is fully known. Then after a money injection, for example, there is an excess liquidity in the economy that needs to be absorbed to reestablish equilibrium. Households cannot change their portfolio choice until the following period, therefore firms are the only agents able to clear the money market. The central bank achieves money market clearing by reducing the interest rate so that firms are willing to borrow the excess amount of funds.

2.3.2 Firms

There are firms producing a homogeneous good in a competitive framework. In order to do so, they need to hire workers, and purchase investment. Since they have no initial funds, they must borrow to pay the wage bill and current capital purchases, at the beginning of every period. They are affected by aggregate technological shocks. The production function takes the form

$$Y_t = F(A_t; K_t; H_t) = A_t K_t^{\alpha_k} H_t^{\alpha_h}; \tag{2.8}$$

where H_t denotes the demand for household's labor, and K_t is capital needed for production. I assume that $\alpha_k + \alpha_h = 1$, reflecting constant returns to scale in technology. The variable A_t is the technological shock, modeled by a first order Markov process

$$A_{t+1} = A \exp(\varepsilon_{a;t+1}) A_{t+1}^{\rho_a}; \tag{2.9}$$

where A is the nonstochastic steady state value for the shock, $0 < \rho_a < 1$; and $\varepsilon_{a;t+1}$ is an i.i.d. normally distributed shock with zero mean and standard deviation σ_a^{ε}: Proceeding the same way as before, I denote $\log(A_t)$ as a_t:

The borrowing decision of the representative firm is subject to the following cash-in-advance constraint:

$$\bar{B}_t^d \geq \bar{W}_t H_t + \bar{P}_t Q_t Z_t; \tag{2.10}$$

where $\bar{B}_t^d$ denotes the demand for loans from the financial intermediary; $\bar{W}_t$ is households' wages; Q_t is the capital good price in consumption good units, and Z_t denotes the new investment purchased each period.

Firms buy additional units of investment goods, Z_t; in competitive markets, and accumulate capital according to the following law of motion:

$$Z_t = K_{t+1} - (1 - \delta)K_t; \tag{2.11}$$

where δ is the depreciation rate of capital, and the subscript $t + 1$ denotes the time when capital will be used. The dividends firms distribute to their owners (households) are given by

$$\bar{\Pi}_t^f = \bar{P}_t Y_t - (\bar{W}_t H_t + \bar{P}_t Q_t Z_t) - (R_t - 1)\bar{B}_t^d: \tag{2.12}$$

Firms maximize their market value taking into account their owners' interests. Since profits are distributed at the end of the period, a firm will value one more dollar in dividends at time t; by how much consumption marginal utility households will obtain at time $t + 1$; by refusing this time t dollar. Thus firms maximize the following flow of dividends:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{t+1} \bar{\Pi}_t^f; \tag{2.13}$$

where Λ_{s+1} denotes the relative marginal utility the household obtains from an additional unit of consumption at time $s + 1$,

$$\Lambda_{s+1} = \frac{\beta^{s+1} U_C(C_{s+1}; L_{s+1})}{N_{s+1}\bar{P}_{s+1}}: \tag{2.14}$$

Maximizing (2.13) subject to equations (2.10) and (2.12), the optimal input demands made by firms are obtained. The representative firm demands households' labor and investment according to the following first order conditions:

$$\frac{\bar{W}_t}{\bar{P}_t} = \frac{\alpha_h Y_t}{H_t R_t}; \tag{2.15}$$

and

$$R_t \bar{P}_t Q_t E[\lambda_{t+1} | \Omega_{1,t}] = \beta E \left\{ \lambda_{t+2} \bar{P}_{t+1} Q_{t+1} \left[R_{t+1}(1-\delta) + \frac{\alpha_k Y_{t+1}}{K_{t+1} Q_{t+1}} \right] \Big| \Omega_{1,t} \right\}. \tag{2.16}$$

Equation (2.15) denotes firms' demand for household's labor, while equation (2.16) reflects their capital demand. Note that all decisions made by firms are based on the information set $\Omega_{1,t}$; that is, they are taken once the complete state of the economy at time t has been revealed.[7]

2.3.3 Financial intermediaries

The representative bank in this economy collects deposits from households, $\bar{D}_t$; and together with the monetary injection, $\bar{X}_t$; transforms these funds into loans to firms every period, $\bar{B}_t^d$. At the end of the period, the financial intermediary receives principal plus interests from the loans to firms, $R_t \bar{B}_t^d$; additionally, it has to pay back principal plus interests due on households' deposits, $R_t \bar{D}_t$. The financial intermediary can be seen as a profit maximizing agent in a competitive environment whose profits are given by

$$\bar{\Pi}_t^{fi} = R_t \bar{X}_t; \tag{2.17}$$

where $\bar{X}_t$ denotes the monetary injection from the central bank. These profits are also distributed to households, who own the banks, at the end of the period, as is seen from equation (2.5).

[7] The information set $\Omega_{1,t}$ includes $\Omega_{0,t}$ plus time t technology shocks.

2.3.4 Entrepreneurs

There are entrepreneurs who live for only one period, have risk-neutral preferences over consumption, and are devoted to the production of capital goods. Each entrepreneur can carry on one project that requires one unit of consumption goods through a technology that transforms this consumption goods into $\tilde{\omega}_t$ units of capital goods. In the technology $\tilde{\omega}_t$ is an idiosyncratic shock assumed to vary uniformly in the non-negative interval $[1 - \omega; 1 + \omega]$; with density function $\phi(\tilde{\omega}_t)$: Let $\Phi(\tilde{\omega}_t)$ denote the associated distribution function.

Each period, after production takes place, part of the output is transferred to entrepreneurs,[8] which amounts to a lump sum transfer when the entrepreneurs are born. This transfer is in consumption goods units and constitutes their net worth, NW_t: Note that NW_t is a function of time t production, that is, $NW_t = NW(Y_t)$. In accordance with the data, it is assumed that NW_t is positively related with output, and more volatile than output, with ξ denoting the elasticity of net worth with respect to output. This assumption is a reduced form way to deal with the fact that in good times investors end up with more cash available than in bad times.[9] However, this net worth is not enough to carry on the project. Moreover, entrepreneurs live for only one period, so that they cannot accumulate wealth. Therefore, they need to borrow the difference between their required investment and their endowment, $1 - NW_t$: Entrepreneurs go to a competitive market formed by the pool of firms, denoted mutual fund, from which they borrow the consumption units they need to start production.

[8] Following Gertler [15], I assume that this transfer is taxed away when entrepreneurs die, i.e., at the end of the period, and then returned lump sum to consumers.

[9] This could also be done through a dynamic problem for entrepreneurs, where net worth would be another state variable of the system, possibly different among entrepreneurs, complicating the solution due to heterogeneity.

The contractual relationship between entrepreneurs and the mutual fund is affected by informational asymmetries. In particular, the lender cannot observe the final outcome of the entrepreneur unless he monitors. Monitoring costs are a fixed proportion of capital produced: μ_c, where $\mu_c > 0$. This asymmetry of information generates a costly state verification problem. The structure of this contract implies that it is optimally solved by a standard debt contract, according to Townsend [21], and Gale and Hellwig [13], characterized by the following repayment rule: an entrepreneur that borrows $(1 - NW_t)$ consumption goods agrees to repay $(1 + R_t^k)(1 - NW_t)$ if the realization of $\tilde{\omega}_t$ is good. The variable R_t^k is the interest rate characterizing the debt contract. If the realization of $\tilde{\omega}_t$ is bad, then the entrepreneur defaults, and the lender gets all the production of the defaulting entrepreneur.[10] The lender will only monitor in case of default. The monitoring decision is determined by a threshold value, that is defined as

$$\bar{\omega}_t \equiv (1 + R_t^k)(1 - NW_t). \tag{2.18}$$

In order for the contract to be efficient incentive compatible the following must happen. The mutual fund will find it profitable to lend the entrepreneurs as long as the amount lent equals the expected return net of monitoring costs, that is,

$$1 - NW_t = Q_t \left\{ \int_{1-\omega}^{\bar{\omega}_t} \tilde{\omega}_t \Phi(d\tilde{\omega}_t) - \Phi(\bar{\omega}_t)\mu_c + [1 - \Phi(\bar{\omega}_t)]\bar{\omega}_t \right\} \equiv Q_t g(\bar{\omega}_t); \tag{2.19}$$

where the left hand side of this equation denotes the amount borrowed by entrepreneurs, and the right hand side reflects the expected return on this loan, including monitoring costs.

The entrepreneur will invest all his net worth in the project, this means that his expected

[10] That is, entrepreneurs have limited liability in case of default.

outcome from investing must exceed his net worth, that is,

$$Q_t\left\{\int_{\bar{\omega}_t}^{+\infty} \omega_t \Phi(d\omega_t) - [1-\Phi(\bar{\omega}_t)](1+R_t^k)(1-NW_t)\right\} =$$

$$Q_t\left\{\int_{\bar{\omega}_t}^{+\infty} \omega_t \Phi(d\omega_t) - [1-\Phi(\bar{\omega}_t)]\bar{\omega}_t\right\} \equiv Q_t f(\bar{\omega}_t) \geq NW_t; \tag{2.20}$$

where the left hand side denotes the expected outcome for the entrepreneur after investing.

This costly state verification problem is solved taking as given the sequence of $\{NW_t; Q_t; R_t^k\}_{t=0}^{\infty}$. From the combination of the equations above, it follows that

$$Q_t = \frac{1}{[1-\Phi(\bar{\omega}_t)\mu_c]}. \tag{2.21}$$

Once the general equilibrium is solved, the number of projects undertaken, i_t, is determined. This amount, net of monitoring costs, will constitute the supply of capital goods: $i_t[1-\Phi(\bar{\omega}_t)\mu_c]$.

2.3.5 Monetary policy

In this model, the central bank is in charge of conducting monetary policy. Without entering into normative issues, I will assume that the central bank's objective is to minimize deviations of output and inflation from their steady states. In order to reduce the volatility of these variables, that is, to stabilize output and inflation, the central bank adjusts the nominal interest rate.

Following recent literature, the monetary authority will be assumed to employ a lagged Taylor rule[11] in performing this task. The central bank will set the interest rate as follows:

$$r_t = \gamma + \gamma_r r_{t-1} + \gamma_\pi \pi_{t-1} + \gamma_y y_{t-1};$$

where r_t denotes the annualized quarterly interest rate, $4(R_t - 1)$; γ is the long run value for r_t under no disturbances; π_t is the inflation rate, that is $\log P_t - \log P_{t-1}$; and y_t denotes the

[11] See Taylor [20].

deviation of output from steady state. That is, in conducting monetary policy the central bank cares about smoothing interest rates, as well as about both inflation and output stabilization.

The analysis has also been done for other types of rules, mainly forward-looking and current or traditional Taylor rules. However, the model yields better results for the data with the lagged Taylor rule. Besides, the introduction of interest rate rules allows for the existence of indeterminacy and multiple equilibria depending on the coefficients assigned to the rule. In this case, the use of a lagged Taylor rule increases the uniqueness area making the analysis easier. Finally, there is a practical justification for the use of this rule that is the availability of data at the time of setting the interest rate.

2.4 Equilibrium

In order to express the dynamics in stationary terms, I normalize all nominal variables by monetary holdings at the beginning of period t, $\bar{M}_t^s$. For convenience, I will omit time subscripts. Let $M = \bar{M}/\bar{M}^s$; $D = \bar{D}/\bar{M}^s$; $P = \bar{P}/\bar{M}^s$; $X = \bar{X}/\bar{M}^s$; $W = \bar{W}/\bar{M}^s$; $B^d = \bar{B}^d/\bar{M}^s$; $\Pi^f = \bar{\Pi}^f/\bar{M}^s$; and $\Pi^{fi} = \bar{\Pi}^{fi}/\bar{M}^s$.

The model can be easily solved by assuming the family structure explained in section 2.3. According to this assumption, one can think of a representative agent of the whole economy. Therefore the Bellman equation of this representative agent's program is

$$V(M;K;a_{-1};\nu) =$$

$$= \max_{D\in[0;M]} \int \left\{ \int \max_{C;L;K';H;B^d} [U(C;L) + \beta V(M';K';a;\nu')]\,\Phi_1(\epsilon_0'|\epsilon_{-1})\,d\epsilon_0' \right\} \Phi_0(\epsilon_{-1}|\epsilon_0)\,d\epsilon_{-1} \quad (2.22)$$

$$\text{subject to } M - D + WL \geq PCN \quad (2.23)$$

$$B^d \geq WH + PQZ; \tag{2.24}$$

$$M'(1+\mu) = M - D + WL - PCN + RD + \Pi^f + \Pi^{fi}; \tag{2.25}$$

$$\Pi^f = PY - (WH + PQZ) - (R-1)B^d; \tag{2.26}$$

$$\Pi^{fi} = RX; \tag{2.27}$$

$$Y = AK^{\alpha_k}H^{\alpha_h}; \tag{2.28}$$

$$K' - (1-\delta)K = i[1 - \Phi(\omega)\mu_c]; \tag{2.29}$$

$$\omega = (1+R^k)(1-NW); \tag{2.30}$$

$$NW = Y^{\xi}; \tag{2.31}$$

where Δ_0 and Δ_1 denote the distribution functions for Γ_0 and Γ_1; respectively. Primes and -1-subindices denote next and last period's variables, respectively.

Definition 2 A stationary competitive equilibrium consists of a value function V; a set of policy functions C_t; L_t; D_t; H_t; K_{t+1}; B^d_t; i_t; ω_t; a decision rule determining next period's money balances, M_{t+1}; pricing functions P_t; R_t; Q_t; and W_t; and profit and net worth functions Π^i_t, Π^f_t; and NW_t; such that:

i) the value function V solves the representative agent's Bellman equation (2.22), where C_t; L_t; D_t; K_{t+1}; B^d_t; and H_t are the associated policy functions together with the decision rule M_{t+1} taking as given the appropriate information structure; the pricing functions P_t; Q_t; W_t; and R_t; and the profit functions Π^f_t and Π^i_t;

ii) entrepreneurs solve their maximization problem given R_t^k; Q_t; and NW_t (determined by equation (2.31)); with the solution being i_t; and $\bar{\omega}_t$;

iii) the central bank sets interest rates according to the following rule:

$$r_t = \gamma + \gamma_r r_{t-1} + \gamma_\pi \pi_{t-1} + \gamma_y y_{t-1};$$

iv) and finally, consumption goods, money, loan, labor, and capital goods markets clear, that is,

$$C_t + i_t = Y_t;$$

$$M = 1;$$

$$D_t + X_t = B_t^d;$$

and

$$H_t = L_t:$$

As usual when dealing with interest rate rules, issues regarding indeterminacy of equilibrium arise. In principle, there is no reason to assume that the regions characterizing uniqueness, indeterminacy and explosiveness in this model are the same as those obtained by Christiano and Gust [7] for a limited participation framework. Thus, I analyzed indeterminacy for the model in this paper given the rule. The coefficients for the interest rate rule employed in this work lie in the area of unique equilibrium.

2.5 Parameters of the model

In this section I report the results of the calibrated interest rate rules for the two sample periods determined above. This is a way to check whether the model explained in Section 2.3, which allows for the analysis of financial frictions, can help explain the differences in the volatility of some variables observed in the two subsamples, or whether it is only due to a monetary policy rule effect.

The parameters of the model are β; θ; ψ; Ψ; for preferences; parameters regarding technology α_k; α_h; δ; parameters describing credit market imperfections ω; μ_c; ξ; parameters for the stochastic processes of the shocks ρ_a; ρ_ν; σ_{ε_a}; σ_{ε_ν}; and coefficients of the interest rate rule γ_r; γ_π, γ_y: Given the large number of parameters to consider, 17 parameters, only those for the interest rate rule, shocks and monitoring costs will be allowed to change across subsamples. The rest of the parameters will be assigned constant values.

Regarding preference parameters, the discount factor is chosen to match an annual nominal interest rate equal to $7{:}8\%$ at the non-stochastic steady state, given an average mean money growth, $\bar{X}$; equal to $1{:}2\%$; figures which are consistent with US data. This implies a β equal to $0{:}9926$: To make it easier to get intuition about the dynamics of the model, I will choose preferences so that income and substitution effects cancel out, that is, the relative risk aversion parameter is $\theta = 1$.[12] The inverse of the labor supply elasticity with respect to real wages, ψ; is given the value $0{:}7$; that is, the elasticity of labor supply with respect to real wages will be close to $1{:}5$. The coefficient Ψ has been calibrated so that labor in the non-stochastic steady

[12] Although I am not analyzing growth, I prefer to use preferences which are consistent with balanced growth, as is the case specified here.

state equals one, by doing so all variables are measured in per capita terms:

For technology parameters, I take the depreciation rate, $\delta,$ to be 2% per quarter, which is consistent with estimates for the US postwar period. The capital share on aggregate income, in the model without credit market imperfections is taken to be 0.36; this implies an α_k equal to 0.3598 in the model with credit frictions.[13] By assuming constant returns to scale in the production function, I obtain $\alpha_h = 1 - \alpha_k$.

Regarding credit market imperfections, I follow Gertler [15], and keep the elasticity of net worth with respect to output, $\xi,$ equal to $4.45,$ according to US estimates. Next, I calibrate $\omega,$ the bound on the support of the uniform distribution of the idiosyncratic shock $\tilde{\omega}_t,$ to match an annual value for the bankruptcy rate, $\Phi(\bar{\omega}_t),$ of 10%. The resulting value is $\omega = 0.1573.$

The parameters above have been calibrated to match first order moments. Next, the model is log-linearized around the nonstochastic steady state, and solved. To assess the dynamic properties of the data, the vector of remaining parameters, $S,$ is calibrated to match second order moments where

$$S = (\gamma_r, \gamma_\pi, \gamma_y, \rho_a, \rho_\omega, \sigma_a^{\varepsilon}, \sigma_\omega^{\varepsilon}, \mu_c). \tag{2.32}$$

2.6 Calibration results

I will employ a method of moments for the calibration of the remaining parameters, those of the interest rate rule, shock processes and monitoring costs, keeping the other structural parameters

[13] This is computed taking into account that aggregate output, $Y^A,$ equals output plus value added from the capital sector, $Y + i[Q - 1].$ Notice that in the case without monitoring costs, the price of capital is one, $Q = 1,$ and therefore, $Y^A = Y.$

constant. I will choose the parameters of the model so that they minimize the relative deviations between the vector of empirical moments obtained in the data, M; and those generated by the model, using the calibrated parameters in S, $M(S)$: That is, I will minimize the following loss function:

$$L(S) = \left(\frac{M(S) - M}{M}\right)' \left(\frac{M(S) - M}{M}\right):$$

There is a wide set of moments to choose among in order to calibrate the parameters. I will employ those moments related to the interest rate rule and the volatility of the main variables of interest, in particular, I will consider the standard deviation of output, inflation and interest rates together with the autocorrelation of interest rates, and current plus lead correlations of interest rates with output and inflation. This means

$$M(S) - M = \begin{bmatrix} \sigma_y(S) - \sigma_y \\ \sigma_\pi(S) - \sigma_\pi \\ \sigma_R(S) - \sigma_R \\ \rho[(R_t; \pi_{t+j}); S] - \rho(R_t; \pi_{t+j}) \\ \rho[(R_t; y_{t+j}); S] - \rho(R_t; y_{t+j}) \\ \rho[(R_t; R_{t-1}); S] - \rho(R_t; R_{t-1}) \end{bmatrix}; \qquad (2.33)$$

for $j = \{0; 1\}$; eight moments in total. Each of the moments is computed from data generated by the model using the parameters in S; and detrended by the Hodrick-Prescott filter. This is done for each of the two subsamples.

In order to analyze whether other factors apart from monetary policy may have contributed to the change in the volatilities of variables after 1981:2, several experiments are performed. First, the interest rate rule and shock processes are calibrated abstracting from credit market imperfections ($\mu_c = 0$). Then, monitoring costs are introduced taking a given fixed value ($\mu_c = 0.4727$). In these experiments the vector of calibrated parameters becomes $\mathcal{S} = (\gamma_r; \gamma_\pi; \gamma_y; \rho_a; \rho_o; \sigma^{\varepsilon}_a; \sigma^{\varepsilon}_o)$. Third, I also allow monitoring costs to change between samples.

First, in a standard limited participation model abstracting from credit market imperfections ($\mu_c = 0$), the best match is given for the following coefficients:

Period	$\gamma_r = 0.7522$, $\gamma_\pi = 0.9610$; $\gamma_y = 0.0671$
1959:4-1981:2	
$\mu_c = 0$	$\rho_a = 0.8593$, $\sigma^{\varepsilon}_a = 0.0047$, $\rho_o = 0.2995$, $\sigma^{\varepsilon}_o = 0.0281$

Period	$\gamma_r = 0.4772$; $\gamma_\pi = 0.8238$; $\gamma_y = 0.0185$
1981:3-2000:3	
$\mu_c = 0$	$\rho_a = 0.4863$, $\sigma^{\varepsilon}_a = 0.0062$, $\rho_o = 0.1726$, $\sigma^{\varepsilon}_o = 0.0216$.

Second, positive monitoring costs are considered. The value for μ_c is obtained from the calibration of the parameters in S for the whole sample (1959:4-2000:3). The calibration results are

Period	$\gamma_r = 0.9649$, $\gamma_\pi = 0.2668$; $\gamma_y = 0.0172$
1959:4-1981:2	
$\mu_c = 0.4727$	$\rho_a = 0.9673$, $\sigma^{\varepsilon}_a = 0.0033$, $\rho_o = 0.8706$, $\sigma^{\varepsilon}_o = 0.0246$

Period	$\gamma_r = 0.9645$; $\gamma_\pi = 0.2809$; $\gamma_y = 0.0151$
1981:3-2000:3	
$\mu_c = 0.4727$	$\rho_a = 0.9683$, $\sigma^{\varepsilon}_a = 0.0033$, $\rho_o = 0.8983$, $\sigma^{\varepsilon}_o = 0.0165$.

When μ_c is positive the results show a high degree of interest rate smoothing. Notice that with the introduction of financial frictions, the model also replicates two important results in the empirical literature on interest rate rules. In particular, the calibrated rules give a stronger weight to inflation stabilization and less to output stabilization after 1981:2. This is not the case when monitoring costs are zero. Moreover, the introduction of credit market imperfections provides estimates for the autocorrelation of the technology shocks that are more consistent with values usually found in the literature.

Note also that when monitoring costs are zero, the difference between the two interest rate rules for each subsample is considerable, mainly regarding the coefficients on inflation and output stabilization. When monitoring costs are considered, these differences are reduced. This may suggest that the presence of credit market imperfections, in the way it is done here, requires less difference in the monetary policy rules undertaken before and after 1981:2, because in fact there are other factors that contributed to stabilize the economy. This finding makes sense since it can be shown that the effects of interest rate rules are magnified in the presence of credit market imperfections in the sense that if the rule induces stabilization, the stabilization is stronger with credit market imperfections. And if the rule destabilizes, it destabilizes more under credit market imperfections. That is, when financial frictions are included in the analysis of monetary policy, the results show a smaller change in the rule. This suggests that the existence of financial frictions contributed to the stabilization effects of monetary policy after 1981:2.

Tables 2.4 and 2.5 report the moments implied by the rules calibrated above. The tables show both the moments estimated directly from the data, with standard deviations in parenthesis, and those moments generated by the model. Notice that only the moments in (2.33) are calibrated, the rest are given as an illustration of how the model behaves. It can be observed that the model can account for the reduction in the volatility of variables during 1981:3-2000:3. Unfortunately, the model gets the wrong sign for the autocorrelation of inflation and the lagged correlation of the interest rate with inflation. Both representations also underpredict the autocorrelation for output and the interest rate. However, it can be observed that the introduction of credit market imperfections as monitoring costs in an exogenous way[14] improves the fit of the model along both of these dimensions in both subsamples.

The next step is to allow monitoring costs also to change between periods. When monitoring costs are included in the vector of parameters to be calibrated, $S = (\gamma_r; \gamma_\pi; \gamma_y; \rho_a; \rho_o; \sigma^{\varepsilon}_a; \sigma^{\varepsilon}_o; \mu_c)$; the results are

Period		$\gamma_r = 0.9728$, $\gamma_\pi = 0.1362$; $\gamma_y = 0.0193$
1959:4-1981:2	μ_c =0.4947	ρ_a =0.9691, σ^{ε}_a =0.0021, ρ_o =0.7770, σ^{ε}_o =0.0413
Period		$\gamma_r = 0.9911$; $\gamma_\pi = 0.3092$; $\gamma_y = 0.0053$
1981:3-2000:3	μ_c =0.4453	ρ_a =0.9902, σ^{ε}_a =0.0025, ρ_o =0.9912, σ^{ε}_o =0.0172.

Again, the calibration shows a high degree of interest rate smoothing in the two subsamples. The rules also report a stronger reaction to inflation and less to output stabilization after 1981:2. Regarding monitoring costs, these are reduced after 1981:2. These results are analyzed more in detail in Subsection 2.6.1.

I observe in Table 2.6 that the addition of this extra parameter to be calibrated allows a better match of all the eight objective moments. When the other moments are checked, the model matches the autocorrelation of inflation, but still fails to match lagged correlations of inflation

[14] Recall that in this step, monitoring costs are not still calibrated, but are given a fixed positive value.

and output with the interest rate. These facts are common to both subsamples. Regarding the stabilization of the policy rules, the model can account for the reduction in volatility in all the three variables considered (output, inflation and nominal interest rate). The stabilization of output in the second subsample can be explained by the combination of several factors: the use of a more aggressive rule in that period, a lower degree of credit market imperfections, together with relatively less money demand shocks.

2.6.1 Discussion

From this calibration, some results can be derived. First, these calibrated coefficients of the interest rate rule confirm the common result about US monetary policy, also reported in Clarida, Galí and Gertler [8], and Judd and Rudebusch [17]. These authors estimate two interest rate rules for US monetary policy in 1960:1-1979:2 and 1979:3-1996:4. They obtain two different policy rules. The first one corresponding to the Pre-Volcker period has the nominal interest rate reacting slightly to inflation stabilization, whereas the second rule (Volcker-Greenspan period) shows a central bank reacting more aggressively to inflation and output stabilization. A similar pattern can also be observed here. In spite of the different subsample periods considered, and the use of a lagged versus a forward-looking interest rate rule, the calibration here suggests that the US Fed reacted more strongly to inflation and less to output after 1981:3, consistent with previous papers. This change in the policy rule employed undoubtedly contributed to the stabilization of the economy since 1981:3, as can be observed from the implied moments in Table 2.6. However, the resulting policy rule for the second subsample is not so aggressive as in Clarida, Galí and Gertler [8]. This outcome points to other factors contributing as well to the stabilization of the economy.

Second, regarding a measure of credit market imperfections, in this case monitoring costs, the exercise reports a higher measure of financial frictions in the first subsample compared with the second, in which they are reduced by around 10%. This reduction in the degree of financial frictions is consistent with more efficient financial markets, in the sense that asymmetric information problems would be less important since the 1980s. These results are in line with Fender's [11] in that the wider access of small firms to financial markets since the 1980s may have reduced the differences in firm financing reported by Gertler and Gilchrist [16]. Basically, according to Fender's paper, small firms would protect themselves from risks by investing in secondary markets that became operative at the beginning of the 1980s, and therefore the effects of a financial accelerator in this period would be smaller.

Finally, these two subsamples are characterized by different patterns of stochastic processes: money demand shocks dominating in first period, whereas technology shocks remain more or less stable between subsamples, which is consistent with standard literature. It is worth analyzing this point more in detail.

In a previous paper,[15] I show that the effects of interest rate rules are emphasized when credit market imperfections are considered. That is, if the interest rate rule stabilizes, it stabilizes even more if there are credit market imperfections, and vice versa. Furthermore, the paper pointed out that the stabilization effects of interest rate rules in a limited participation model are the opposite to those in a sticky price model. More concretely, controlling the interest rate in a limited participation framework stabilizes both output and inflation in the face of a technology

[15] See de-Blas-Pérez [10].

shock, whereas if the shock is to money demand there is a trade-off between stabilizing output and inflation. Note that in the calibration results, money demand shocks dominated in the first subsample, precisely when monitoring costs are higher. This may have emphasized the destabilization effects of the rule in this scenario. However, in the second subsample, two things happen: monitoring costs are reduced and so is the standard deviation of money demand shocks helping monetary policy reduce aggregate volatility. This together with a relatively more important presence of technology shocks may have emphasized the stabilization effects of the interest rate rule in this period.

These calibrated values also confirm the intuition in Galí, López-Salido and Vallés [14], that the higher volatility in the Pre-Volcker era was because the Fed gave a bigger weight to output stabilization before 1979:3. The explanation they provide is that such a rule destabilized the economy in response to technology shocks. This is because the framework they use is a sticky price model in which the use of interest rate rules helps stabilize the economy in the presence of money demand shocks, not technology shocks. In the present setup it is still true that the rule before 1981:2 induced economic destabilization, but the intuition goes in a different way. Here, given limited participation, the rule became more stabilizing after 1981:3 not only because the central bank reacted less to output, but because there was a relatively lower presence of money demand shocks in the economy, compared with the previous subsample. This emphasized the stabilizing properties of the rule.

2.6.2 Interest rate rules, monitoring costs, and shocks

To conclude this section, it would be interesting to investigate which of the factors analyzed above (interest rate rule, monitoring costs and shocks) that affected the volatilities of variables before and after 1981:3 is more relevant.

To this end, I have divided the vector of parameters S in three parts. On one hand, I will calibrate the coefficients of the rule plus monitoring costs keeping shock processes constant at the whole sample level, S_1. Then I will calibrate the shocks and monitoring costs keeping the parameters of the rule constant, S_2. Finally, I will fix monitoring costs and calibrate the rule and shocks, S_3. In order to compare the explicative power of each group of parameters, I report the implied value of the function to minimize, $L(S)$: The higher the value of $L(S)$; the more important is the parameter which has been kept constant, and vice versa. The following is obtained

L(S)

Parameter(s) kept constant	1959:4-1981:2	1981:3-2000:3
Shock processes (S_1)	0.5666	1.7582
Monetary policy rule (S_2)	0.5764	6.2654
Monitoring costs (S_3)	0.5733	1.7413

The results are quite clarifying. The greatest loss in both subsamples appears when the rule is fixed (S_2). This confirms the role of monetary policy in explaining the dynamics of the data across time. It is remarkable that monitoring costs provide more explanatory power than shocks in the first subsample. This is reflected in that the loss derived from fixing monitoring costs (S_3) is larger than the loss attained from fixing the shock process (S_1). The opposite is observed in the second subsample. The role of monitoring costs is reduced and shocks become more important in explaining the dynamics of the data.

Although the number of parameters kept fixed in each experiment differs, this result is interesting because, it provides evidence of the relevance of financial frictions before 1981:2. This confirms the thesis in this paper that credit market imperfections may have contributed to the reduction in volatility of the macroeconomy together with the change in monetary policy. It seems monitoring costs were quite relevant for the dynamics in the first subsample. However, after 1981:2 their importance is reduced in favor of shocks. This may be explained by the development of financial markets since the 1980s (Fender [11]) and other policy measures (e.g. tax reductions) conducing to the reduction of financing costs.

After these results it becomes even more evident that it was the change in the rule the driving mechanism that reduced the volatility of the main macroeconomic variables since the 1980s. In addition, the results confirm the key role of financial frictions in this stabilization, dominating the effects of shock processes.

2.7 Conclusions

This paper investigates whether the presence of financial frictions, which are known to affect the results of monetary policy conducted by interest rate rules, can help explain the differences in the variability of output and inflation observed in postwar US data. To this end, I study the interest rate rule followed by the central bank in the last 40 years, in the presence of financial frictions.

The results can be summarized as follows. First, according to postwar US data on output, in‡ation, interest rate, and a measure of the risk premium, there is a structural break in the second quarter of 1981. This point is close enough to the arrival of Paul Volcker in 1979:3 to be consistent with the claim that it results from Volcker's changes in monetary policy. But there were also other important policy changes around this time, that may have a¤ected the …nancing of …rms, and eventually risk premia in …nancial markets inducing the data considered here to exhibit a structural break in 1981:2.

In the absence of …nancial frictions, the results con…rm the widely recognized change in the conduct of monetary policy by reporting substantially di¤erent interest rate rules before and after 1981:2. However, the model does not report a higher weight on in‡ation stabilization in the second subsample with respect to the …rst one, in contrast with empirical results. Interestingly, with positive monitoring costs the two calibrated rules are much more alike. This may suggest a key role for credit market imperfections in the stabilization of monetary policy.

When the monetary policy rule, shock processes and monitoring costs are allowed to adjust between subsamples, the calibration reports two interest rate rules that assign more weight to in‡ation and less to output stabilization after 1981:2. The degree of monitoring costs is reduced by 10% after 1981:2, which may re‡ect a development of …nancial markets mainly since the 1980s. Regarding shock processes, the results show slight di¤erences for money demand shocks, whereas technology innovations remain relatively stable between subsamples, which is consistent with the standard literature. If each of these factors is analyzed separately, the mechanism driving the stabilization of the economy is the change in the monetary policy rule employed by the Fed, followed by the degree of …nancial frictions, and …nally the shock processes governing in each period.

The analysis carried on in this paper opens the door to other factors apart from monetary policy in assessing the performance of the US Fed in the last 40 years. Of course, there are many other variables to take into account, but this study is one step forward towards the understanding of the behavior of central banks and their e¤ects on the economy.

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Table 2.1a: Instability tests (without risk premium)

Test	Statistic value	Breakpoint
Sup(LM)	19:4585	1976 : 1
Sup(LR)	14:6027	1976 : 1
Sup(Wald)	50:2388	1980 : 4

Note: The critical values for the test are 21.27, 23.65,

28.50 for a signi…cance level of 10%, 5%, and 1%.

respectively. The number of parameters is p=9 and ¼0 = 30%:

Table 2.1b: Instability tests (including risk premium)

Test	Statistic value	Breakpoint
Sup(LM)	91:8293	1981 : 2
Sup(LR)	67:0669	1981 : 2
Sup(Wald)	107:431	1980 : 4

Note: The critical values for the test are 27.64, 30.48,

35.85 for a signi…cance level of 10%, 5%, and 1%.

respectively. The number of parameters is p=13 and ¼0 = 25%:

Table 2.2: Estimated moments (Data)

	1959:4-1981:2	1981:3-2000:3
	Value	Value
σ_y	1.5929 (0.2519)	1.2141 (0.2027)
σ_π	0.2867 (0.0522)	0.1677 (0.0118)
σ_R	0.3821 (0.0578)	0.3003 (0.0296)
σ_{rp}	-0.1395 (0.0298)	-0.1314 (0.0328)
$\rho(R_t, \pi_{t-1})$	0.4123 (0.1005)	0.3820 (0.0656)
$\rho(R_t, \pi_t)$	0.3171 (0.0775)	0.1786 (0.0850)
$\rho(R_t, \pi_{t+1})$	0.2314 (0.0914)	0.0925 (0.1220)
$\rho(R_t, y_{t-1})$	0.1087 (0.0759)	0.5535 (0.0810)
$\rho(R_t, y_t)$	-0.1791 (0.0996)	0.2510 (0.1163)
$\rho(R_t, y_{t+1})$	-0.3741 (0.1106)	0.0003 (0.1362)
$\rho(y_t, rp_{t-1})$	-0.5092 (0.0531)	-0.2480 (0.1058)
$\rho(y_t, rp_t)$	-0.2950 (0.0572)	-0.3160 (0.1141)
$\rho(y_t, rp_{t+1})$	-0.0393 (0.0810)	-0.2902 (0.0968)
$\rho(y_t, y_{t-1})$	0.8650 (0.0247)	0.8990 (0.0243)
$\rho(\pi_t, \pi_{t-1})$	0.5005 (0.1052)	0.3109 (0.0712)
$\rho(R_t, R_{t-1})$	0.8151 (0.0405)	0.8088 (0.0586)

Standard errors between parenthesis.

Table 2.3: Estimated moments

(Pre- and Post-Volcker)

	1959:4-1979:2	1979:3-2000:3
	Value	Value
σ_y	1.5929 (0.2422)	1.3341 (0.3280)
σ_π	0.2867 (0.0491)	0.1987 (0.0279)
σ_R	0.3821 (0.0555)	0.3739 (0.0571)
σ_{rp}	-0.1395 (0.0284)	-0.1331 (0.0303)
$\rho(R_t, \pi_{t-1})$	0.4125 (0.1008)	0.1837 (0.1098)
$\rho(R_t, \pi_t)$	0.3171 (0.0783)	0.1444 (0.0930)
$\rho(R_t, \pi_{t+1})$	0.2314 (0.0960)	0.0093 (0.1130)
$\rho(R_t, y_{t-1})$	0.1087 (0.0812)	0.1678 (0.0912)
$\rho(R_t, y_t)$	-0.1792 (0.1053)	-0.1366 (0.1103)
$\rho(R_t, y_{t+1})$	-0.3741 (0.1169)	-0.2802 (0.1283)
$\rho(y_t, rp_{t-1})$	-0.5092 (0.0600)	-0.1113 (0.1023)
$\rho(y_t, rp_t)$	-0.2951 (0.0616)	-0.0520 (0.0770)
$\rho(y_t, rp_{t+1})$	-0.0394 (0.0828)	0.0268 (0.0669)
$\rho(y_t, y_{t-1})$	0.8650 (0.0247)	0.8624 (0.0531)
$\rho(\pi_t, \pi_{t-1})$	0.5005 (0.1052)	0.4076 (0.0929)
$\rho(R_t, R_{t-1})$	0.8151 (0.0389)	0.7610 (0.0901)

Standard errors between parenthesis.

Table 2.4: Estimated moments ($\mu_c = 0$)

	1959:4-1981:2		1981:3-2000:3	
	Data	Model	Data	Model
σ_y	1.5929 (0.2519)	1.6010^{**}	1.2141 (0.2027)	1.4158^{**}
σ_π	0.2867 (0.0522)	0.1735	0.1677 (0.0118)	0.0671
σ_R	0.3821 (0.0578)	0.4634^{*}	0.3003 (0.0296)	0.4202
$\rho(R_t, \pi_{t-1})$	0.4123 (0.1005)	-0.4239	0.3820 (0.0656)	-0.3163
$\rho(R_t, \pi_t)$	0.3171 (0.0775)	0.1627^{*}	0.1786 (0.0850)	0.0941^{**}
$\rho(R_t, \pi_{t+1})$	0.2314 (0.0914)	0.3142^{**}	0.0925 (0.1220)	0.1354^{**}
$\rho(R_t, y_{t-1})$	0.1087 (0.0759)	0.2145^{*}	0.5535 (0.0810)	0.1987
$\rho(R_t, y_t)$	-0.1791 (0.0996)	-0.2082^{**}	0.2510 (0.1163)	0.1434^{**}
$\rho(R_t, y_{t+1})$	-0.3741 (0.1106)	-0.1887^{*}	0.0003 (0.1362)	0.0012^{**}
$\rho(y_t, y_{t-1})$	0.8650 (0.0247)	0.1304	0.8990 (0.0243)	0.0881
$\rho(\pi_t, \pi_{t-1})$	0.5005 (0.1052)	-0.3524	0.3109 (0.0712)	-0.3946
$\rho(R_t, R_{t-1})$	0.8151 (0.0405)	0.6141	0.8088 (0.0586)	0.3808

Standard errors between parenthesis.

**Denotes significancy at 1 S.E. *Denotes significancy at 2 S.E.

Table 2.5: Estimated moments ($\mu_c = 0.4727$)

	1959:4-1981:2		1981:3-2000:3	
	Data	Model	Data	Model
σ_y	1.5929 (0.2519)	1.5151**	1.2141 (0.2027)	1.1492**
σ_π	0.2867 (0.0522)	0.2554**	0.1677 (0.0118)	0.1346
σ_R	0.3821 (0.0578)	0.4276**	0.3003 (0.0296)	0.3600
$\rho(R_t, \pi_{t-1})$	0.4123 (0.1005)	-0.2690	0.3820 (0.0656)	-0.0209
$\rho(R_t, \pi_t)$	0.3171 (0.0775)	0.1812*	0.1786 (0.0850)	0.0526*
$\rho(R_t, \pi_{t+1})$	0.2314 (0.0914)	0.2927**	0.0925 (0.1220)	0.1319**
$\rho(R_t, y_{t-1})$	0.1087 (0.0759)	-0.1524	0.5535 (0.0810)	0.0175
$\rho(R_t, y_t)$	-0.1791 (0.0996)	-0.2227**	0.2510 (0.1163)	0.0362*
$\rho(R_t, y_{t+1})$	-0.3741 (0.1106)	-0.1940*	0.0003 (0.1362)	0.0007**
$\rho(y_t, y_{t-1})$	0.8650 (0.0247)	0.6691	0.8990 (0.0243)	0.6893
$\rho(\pi_t, \pi_{t-1})$	0.5005 (0.1052)	-0.0922	0.3109 (0.0712)	-0.0829
$\rho(R_t, R_{t-1})$	0.8151 (0.0405)	0.7669*	0.8088 (0.0586)	0.7237*

Standard errors between parenthesis.

**Denotes significancy at 1 S.E. *Denotes significancy at 2 S.E.

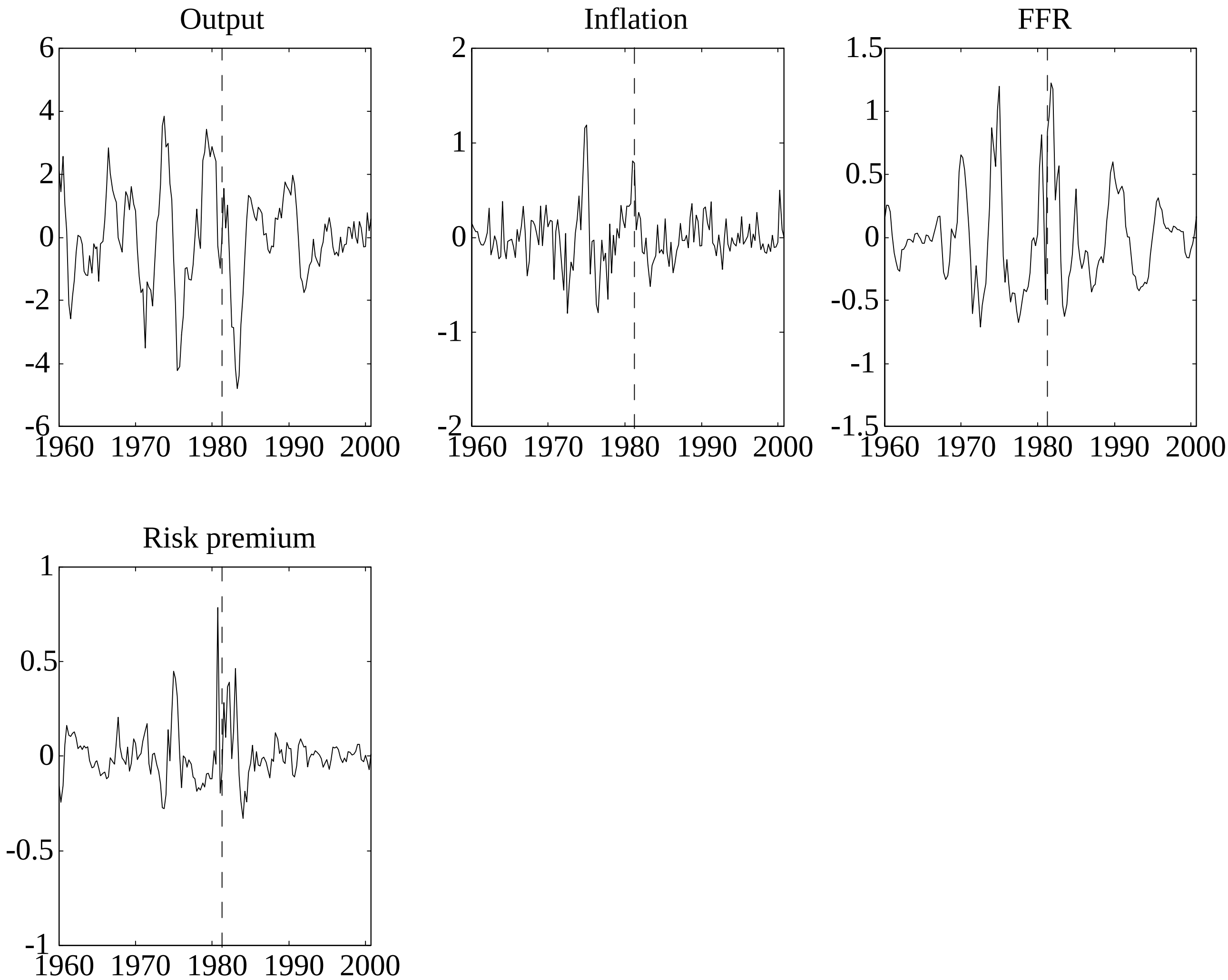
Table 2.6: Estimated moments

	1959:4-1981:2		1981:3-2000:3	
	Data	Model	Data	Model
σ_y	1.5929 (0.2519)	1.7742^{**}	1.2141 (0.2027)	1.2119^{**}
σ_π	0.2867 (0.0522)	0.2175^{*}	0.1677 (0.0118)	0.1663^{**}
σ_R	0.3821 (0.0578)	0.4034^{**}	0.3003 (0.0296)	0.3031^{**}
$\rho(R_t, \pi_{t-1})$	0.4123 (0.1005)	-0.2116	0.3820 (0.0656)	-0.2517
$\rho(R_t, \pi_t)$	0.3171 (0.0775)	0.2799^{*}	0.1786 (0.0850)	0.1780^{**}
$\rho(R_t, \pi_{t+1})$	0.2314 (0.0914)	0.3344^{*}	0.0925 (0.1220)	0.3099^{*}
$\rho(R_t, y_{t-1})$	0.1087 (0.0759)	-0.1343	0.5535 (0.0810)	0.0936
$\rho(R_t, y_t)$	-0.1791 (0.0996)	-0.1645^{**}	0.2510 (0.1163)	0.2514^{**}
$\rho(R_t, y_{t+1})$	-0.3741 (0.1106)	-0.0193	0.0003 (0.1362)	0.3501
$\rho(y_t, y_{t-1})$	0.8650 (0.0247)	0.5989	0.8990 (0.0243)	0.7230
$\rho(\pi_t, \pi_{t-1})$	0.5005 (0.1052)	0.4537^{**}	0.3109 (0.0712)	0.3105^{**}
$\rho(R_t, R_{t-1})$	0.8151 (0.0405)	0.7580^{*}	0.8088 (0.0586)	0.8286^{**}

Standard errors between parenthesis.

**Denotes significancy at 1 S.E. *Denotes significancy at 2 S.E.

Figure 2.1: The evolution of output, in‡ation, federal funds rate and a measure of risk premium in the US during 1959:4-2000:3



Part II

Fiscal Policy

Chapter 3

Debt Limits and Endogenous Growth

3.1 Introduction

This paper analyzes the growth and welfare e¤ects of imposing limits to public borrowing. Macroeconomists have long debated the e¤ects of government spending on economic growth. In addition to the way government spending is employed in the economy, research has also focused on the instruments to …nance this expenditure, such as taxes and debt issue.

The e¤ects of public debt in growth models has usually been analyzed by imposing only a no-Ponzi game condition on the limiting behavior of debt. Little attention has been paid to tighter constraints on public borrowing. Recently, however, this topic has gained growing interest because of the criteria imposed on the EMU countries by the Maastricht Treaty and later reinforced by the Stability Pact. These criteria required, among other things, the ratios of public debt and de…cits over GDP not to be above 60% and 3%, respectively. Furthermore, it is widely recognized that high ratios of debt to GDP are not desirable for the economy. This has led many countries to reduce government de…cits and control the rate of growth of public debt.

In this paper I analyze the e¤ects of …scal policy on growth and welfare when there are limits to public debt. In the model economy, government spending may play two di¤erent roles, either acting as an input to the production function, or providing services directly in the utility function. In these setups I study the e¤ects of …scal policy (changes in taxes and the ratio of government spending to output) with and without debt limits both in the balanced growth path and during the transitional dynamics.

The literature on the imposition of limits on public borrowing can be structured in two main branches. The …rst one investigates the consequences of the credit market discipline hypothesis.[1] This line of research states that individuals' behavior in credit markets may constrain government borrowing. In particular, private agents may ask for risk premia that would be increasing in the amount of outstanding public debt. The government's ability to pay for these premia will determine its access to borrowing from the private sector. It is in this way that credit market conditions limit government borrowing.

The second branch focuses on the e¤ects of exogenously imposed limits to debt, for example in the way it is done by the Maastricht Treaty. In this context, Uctum and Wickens [13] examine from the econometric viewpoint, the e¤ects of imposing debt ceilings on the government intertemporal budget constraint. Their analysis is applied to US and EU data since 1970. They …nd that current …scal policy is not sustainable for most industrialized countries over an in…nite horizon, but it is sustainable in the medium term in the absence of ceilings. Chari and Kehoe

[1] See for example Bayoumi, Goldstein and Woglom [4].

[5] analyze the need for fiscal constraints in the implementation of monetary unions, specially in the case of the European Monetary Union. In a standard economic model with benevolent policy makers, they find that it is desirable to impose fiscal constraints whenever the monetary authority cannot commit to future policies. Finally, Woodford [14] analyzes the role of limits on the rate of growth of public debt in order to maintain price stability.

None of these papers focuses on the effects on growth. However, if government spending affects the equilibrium of the economy, and is partially financed by issuing debt, it is important to analyze the consequences of limiting this source of financing. There is a vast literature on the growth effects of fiscal policies in endogenous growth models. Most papers like Barro [3], Glomm and Ravikumar [6], and Baier and Glomm [2] focus on the growth effects of distortionary taxes when government spending affects private returns of the agents. However, most of them abstract from public debt. In contrast, the present work introduces government debt in a framework in which growth issues can be easily addressed.

The model developed here nests Barro's [3] and Romer's [11] models of growth. In the first case, productive government spending is introduced in the production function enhancing both capital and labor productivity, and permitting endogenous growth. In the second case, public spending enters the household's utility function and endogenous growth is generated by an externality involving learning by doing.

The analysis focuses on both the balanced growth path and the transitional dynamics. Due to the introduction of labor-leisure choice, no closed form analytical solution is available, so I recur to numerical solutions for the competitive equilibrium. Several simulations are carried out to study the effects of changes in fiscal variables (taxes on labor income, and the ratio public expenditures over output). I study how the outcome di¤ers, depending on the role given to government spending in each economy and whether there is a debt limit or not. The analysis of the dynamics explains not only how growth rates are a¤ected, but also shed some light on individuals' welfare.

I …nd that in the long run raising tax rates on labor has positive e¤ects on growth when there are limits to debt and government spending is productive. However, when learning by doing drives growth, rising taxes on labor only serves to reduce the incentives to work, with a negative e¤ect on the growth rate. A reduction in government spending has negative e¤ects on growth if public spending is productive, but has negligible e¤ects if public spending only a¤ects utility, in both cases regardless of the presence of a debt limit.

These results are supplemented by a study of the dynamic e¤ects of tightening …scal policy to reduce public debt in order to attain a lower debt to output ratio in the case of productive government spending. Compared with the initial balanced growth path, raising taxes to lower debt leads the economy to a new balanced growth path with higher growth and lower taxes because of the role of government spending in this model. By the same reason, a …scal policy consisting of reducing government spending over output has the opposite e¤ects, reducing growth and output. Regarding welfare, if the government must achieve a lower debt limit, higher labor income taxes imply a lower welfare cost than reducing government spending.

The rest of the paper is organized as follows. Section 3.2 describes the model economy. Sections 3.3 and 3.4 characterize the competitive equilibrium and the balanced growth path, respectively. Section 3.5 covers the parameterization of the model. In Section 3.6, I report the results for the long run analysis. Section 3.7 deals with the dynamics of the model in response to changes in taxes and or in the government spending to output ratio, and Section 3.8 contains the welfare analysis. Finally, conclusions and extensions close the paper.

3.2 The model

In this section, I present an endogenous growth model in a general equilibrium framework. I consider an economy composed by three types of agents: households, competitive …rms and a government. The population size is normalized to one, so that variables are in per capita terms. In this economy private agents take as given …scal policies when making their decisions.

As mentioned above, the model extends to two di¤erent cases, each one displaying di¤erent externalities. First, externalities arise because of public productive spending in the production function à-la-Barro [3]; in the second case, externalities appear due to the existence of learning-by-doing and knowledge spillovers in the productive process à-la-Romer [11]. In this last setup, government spending only supplies public services and enters additively into the households' utility function.

3.2.1 Households

The economy consists of a large number of identical in…nitely-lived individuals. Agents are endowed with one unit of time to be divided between leisure, $x(t)$, and labor, $l(t)$. Households consume a homogeneous good whose price is taken as numeraire and normalized to one. Individuals derive utility from leisure, and from consuming private goods. When government spending enters the utility function, individuals will also get some utility from public services. In general, the utility function $U[c(t); x(t); g(t)]$; takes the appropriate functional form according to the following CES utility function

$$U[c(t), x(t), g(t)] = \begin{cases} \dfrac{[c(t)^{\theta}x(t)^{1-\theta}]^{1-\sigma} + \eta[g(t)^{\psi}]^{1-\sigma}}{1-\sigma} & \text{if} \quad \sigma \neq 1 \\ \theta \ln c(t) + (1-\theta)\ln x(t) + \eta\psi \ln g(t) & \text{if} \quad \sigma = 1, \end{cases} \tag{3.1}$$

where $c(t)$ is consumption per capita; $x(t)$ is the proportion of time devoted to leisure; $g(t)$ is government spending; $\sigma > 0$ refers to the intertemporal elasticity of substitution, which is constant; $\theta \in [0, 1]$ reflects the household's preference between consumption and leisure, and $\psi > 0$ is a parameter measuring the impact of $g(t)$ on the welfare of the household. The parameter ψ is assumed to be positive (so that public consumption yields a positive marginal utility) and the following expressions must hold $-1 < 1 - \sigma < \dfrac{1}{1+\psi}$, and $\psi(1-\sigma) < 1$, to have a bounded utility.[2] This Cobb-Douglas specification of the utility function together with the constant returns to scale of the production function will allow for the existence of endogenous growth.[3] Finally, the parameter η has been introduced in order to study the effects of government spending entering or not the utility function, thus $\eta = \{0, 1\}$.

Households hold assets, $d(t)$, which return some interest payments. This interest plus labor income minus the amount spent in consumption, is devoted to the acquisition of new assets, as reflected in the following budget constraint:

$$\dot{d}(t) = r(t)d(t) + \omega(t)l(t) - c(t), \tag{3.2}$$

[2] For the isoelastic utility function, ψ can also be interpreted as the marginal rate of substitution between public and private goods and leisure. For the learning-by-doing model if preferences for government spending are separable (or if the agent obtains no utility from government spending) then the wealth and substitution effects cancel and leisure remains unchanged, a condition required for the balanced growth in this model.

[3] For a more detailed discussion, see King, Plosser and Rebelo [7].

where d(t) denotes the household's wealth, composed of the stock of capital and government bonds; and r(t) and $\omega(t)$ refer to the interest rate and the after tax wage in terms of time t consumption.

The representative discounts at a rate $\rho > 0$: His decision problem is given by

$$\underset{\{c(t);x(t);d(t)\}}{Max} \int_0^{+\infty} U[c(t); x(t); g(t)]e^{-\rho t}dt$$

$$\text{subject to } \dot{d}(t) = r(t)d(t) + \omega(t)l(t) - c(t)$$

$$x(t) + l(t) = 1;$$

$$c(t) \geq 0 \text{ for all } t;$$

$$d(0) = d_0 \text{ taken as given;}$$

and the no-Ponzi game condition on assets

$$\lim_{t \to \infty} d(t) \exp\left\{-\int_0^t r(\nu)d\nu\right\} \geq 0; \tag{3.3}$$

The Hamiltonian for the household's problem is

$$H[c(t); l(t); d(t); \lambda(t)] = e^{-\rho t}\{U[c(t); l(t)] + \lambda(t)[r(t)d(t) + \omega(t)l(t) - c(t)]\}; \tag{3.4}$$

where $\lambda(t) = \mu(t)e^{\rho t}$ is the shadow price associated to the household's budget constraint.

The first order conditions (FOC) for an interior solution to this problem are given by

$$\theta c(t)^{\theta(1-\sigma)-1}x(t)^{(1-\theta)(1-\sigma)} = \lambda(t); \tag{3.5}$$

$$(1-\theta)c(t)^{\theta(1-\sigma)}x(t)^{(1-\theta)(1-\sigma)-1} = \lambda(t)\omega(t); \tag{3.6}$$

$$\dot{\lambda}(t) = \lambda(t)[\rho - r(t)]; \tag{3.7}$$

together with the transversality condition

$$\lim_{t\to\infty} e^{-\rho t}\lambda(t)d(t) = 0. \tag{3.8}$$

Equations (3.5)-(3.6) embody the two basic margins in this problem. First, the choice between $c(0)$ and $c(t)$, given by equation (3.5), evaluated at times 0 and t, and second, the choice between $c(t)$ and $x(t)$ that equating the marginal rate of substitution to the real wage.

3.2.2 Firms and technology

There is a large number of identical firms. Markets are competitive. The inputs are capital stock, labor and government expenditure. The representative firm produces a final good according to a Cobb-Douglas constant returns to scale production function. The production function is given by

$$y(t) = Ak(t)^{\alpha}[l(t)\bar{k}(t)^{\phi}g(t)^{1-\phi}]^{1-\alpha}, \tag{3.9}$$

where $\alpha \in [0,1]$, $y(t)$ is output, $A > 0$ is the scale parameter, $k(t)$ is private capital, $l(t)$ is labor, $\bar{k}(t)$ denotes the aggregate level of capital, and $g(t)$ is government expenditure. The parameter $\phi = \{0,1\}$ measures the relative weight of $\bar{k}(t)$ and $g(t)$ in the production function, giving two possible sources of endogenous growth.

Under the assumptions of competitive input markets and constant returns to scale in production technology, factors are paid their marginal products. For capital this means

$$R_k(t) = \alpha A k(t)^{\alpha - 1}[l(t)\bar{k}(t)^{\phi} g(t)^{1-\phi}]^{1-\alpha}; \tag{3.10}$$

and for labor

$$W(t) = (1 - \alpha) A k(t)^{\alpha}[\bar{k}(t)^{\phi} g(t)^{1-\phi}]^{1-\alpha} l(t)^{-\alpha}. \tag{3.11}$$

As a result of this, the interest rate equals the marginal productivity of capital after depreciation

$$r(t) = R_k(t) - \delta; \tag{3.12}$$

while for the after-tax wage rate it is

$$\omega(t) = (1 - \tau_w) W(t); \tag{3.13}$$

where τ_w denotes the tax rate on labor income.

3.2.3 Government

In this model, the government has a path for public expenditure, $g(t)$, that is financed through taxes and debt, the government needs not run a balanced budget at every moment of time. Thus, the path for government spending is financed by taxation but also by debt. Tax revenues come from flat-tax rates on labor income, and debt is issued as government bonds held by the households. The flow of government consumption is an exogenous constant fraction of total production denoted by γ; that is,

$$\frac{g(t)}{y(t)} = \gamma \quad \text{and} \quad \gamma \in [0, 1]. \tag{3.14}$$

With these assumptions the government budget constraint is the following:

$$\dot{b}(t) = R_b(t)b(t) + g(t) - \tau_w W(t)l(t); \tag{3.15}$$

where $R_b(t)b(t)$ denotes public debt expenses, $g(t)$ is the flow of public expenditure, and the remaining term in the equation refers to the revenues from flat-tax rates on labor income, τ_w; that are constant. To completely describe the government's setup, there is the no-Ponzi game condition on public debt

$$\lim_{t \to \infty} b(t) \exp\left\{ -\int_0^t R_b(\upsilon)d\upsilon \right\} \leq 0: \tag{3.16}$$

Definition 3 In the absence of a debt limit, a fiscal policy is a pair $\{\zeta; \tau_w\}$ constant over time which implies a path for government debt that satisfies the no-Ponzi game condition (3.16).

The debt limit

Two possible scenarios are considered. In one case, the government will never be constrained in issuing debt except for the no-Ponzi game condition (the standard setup in the literature), whereas in the other case, there will be a limit imposed at some time T to the amount of debt over output in the economy. Let $\chi(t)$ denote the debt-to-output ratio, that is, $\frac{b(t)}{y(t)}$. Using this notation, the government budget constraint (3.15) can be expressed as follows

$$\dot{\chi}(t) = [R_b(t) - \gamma_y(t)]\chi(t) + \zeta - \tau_w(1 - \alpha): \tag{3.17}$$

where $\gamma_y(t)$ is the growth rate of output, that is, $\gamma_y(t) = \frac{\dot{y}(t)}{y(y)}$. This second case is captured by the following chart:

$$
\underset{\text{time } t}{\text{for } t \le T \to \chi(t) \text{ evolves as } (3.17)} \quad \underset{\text{time } T}{\cdots} \quad \underset{\text{time } t'}{\text{for } t' \ge T \to \chi(t') \le \bar{\chi}} \to \tag{3.18}
$$

From $t \le T$ the path for $\chi(t)$ is given by equation (3.17). At a certain time, T, the debt ceiling is enforced, and the government debt-to-output ratio cannot exceed the limit $\bar{\chi}$. For simplicity in the analysis, I will assume that once the limit is imposed, the government fixes the ratio debt over output at the debt limit. Therefore, $\chi(t) = \bar{\chi}$, and $\dot{\chi}(t) = 0$. This means that from $t' \ge T$ on, the government budget constraint (3.17) becomes

$$
[r(t') - \gamma_y(t')]\bar{\chi} + [1 - \tau_w(t)](1 - \alpha) + \zeta - 1 = 0. \tag{3.19}
$$

Intuitively, constraining the issue of public debt will have important effects on the way government spending is financed. In the absence of limits, the public sector has two instruments available to pay back its expenditure. These instruments are debt and revenues from taxes. When one of these tools is restricted (for example debt), the other (in this case taxes) will have to adjust to keep the government budget constraint holding. Different models will react in a different way to changes in taxes, and consequently will display different paths for growth.

Therefore, fiscal policy in this scenario differs.

Definition 4 If there is a limit to debt, a fiscal policy consists initially of a pair $\{\zeta, \tau_w\}$ constant over time with public debt determined by equation (3.15). Then when the limit is imposed, fiscal policy is a constant ζ, and a path for $\tau_w(t)$ that satisfy equation (3.19).

3.3 Competitive equilibrium

As usual, given fiscal policy, conditions from utility maximization are combined with those of profit maximization, together with the balanced budget for the government and market clearing conditions to characterize the competitive equilibrium of this economy.

Notice that when $\eta = 0$; and $\phi = 0$ the model collapses to a setup à-la-Barro, in which government spending enters the production function enhancing both capital and labor productivity. However, if $\eta = 1$; and $\phi = 1$ it becomes a model in which government spending enters additively the utility function, and the production side exhibits learning-by-doing and knowledge spillovers à-la-Romer. More concretely, I will refer to the first case ($\eta = 0$; and $\phi = 0$) as the Government in the Production Function (GPF) model, and to the second case ($\eta = 1$; and $\phi = 1$) as the Government in the Utility Function (GUF) model.

In equilibrium, assuming symmetry among firms, aggregate and individual stocks of capital are the same, $\bar{k}(t) = k(t)$. Then using equation (3.14), output becomes

$$y(t) = [Ak(t)^{\alpha+\phi(1-\alpha)} l(t)^{1-\alpha} \zeta^{(1-\alpha)(1-\phi)}]^{\varphi};$$

and the marginal products for capital and labor are, respectively,

$$R_k(t) = \alpha k(t)^{\alpha\varphi+\phi\varphi(1-\alpha)-1}[Al(t)^{1-\alpha}\zeta^{(1-\alpha)(1-\phi)}]^{\varphi}; \tag{3.20}$$

and

$$W(t) = (1-\alpha)l(t)^{(1-\alpha)\varphi-1}[Ak(t)^{\alpha+\phi(1-\alpha)}\zeta^{(1-\alpha)(1-\phi)}]^{\varphi}; \tag{3.21}$$

where

$$\varphi = \frac{1}{1-(1-\phi)(1-\alpha)}.$$

In a competitive equilibrium, markets clear. Financial markets clearing implies

$$d(t) = k(t) + b(t); \tag{3.22}$$

that is, assets demanded by the household, $d(t)$, must equal total supply: private assets, $k(t)$; and public assets, $b(t)$.

It remains to state the clearing condition in the goods market

$$\dot{k}(t) = y(t) - c(t) - g(t) - \delta k(t). \tag{3.23}$$

Additionally, due to arbitrage conditions the following must hold:

$$r(t) = R_b(t) = R_k(t) - \delta.$$

Definition 5 Taking as given the initial state, $k(0)$ and $b(0)$; and a fiscal policy, a competitive equilibrium path for the economy described above consists of sequences for quantities $\{c(t); l(t); k(t); b(t)\}_{t=0}^{\infty}$; and prices $\{r(t); \omega(t)\}_{t=0}^{\infty}$, such that:

(i) the triplet $\{c(t); x(t); \dot{k}(t)\}_{t=0}^{\infty}$ solves the representative household's problem;

(ii) the pair $\{l(t); k(t)\}_{t=0}^{\infty}$ solves the representative firm's problem;

(iii) the labor market clears,

$$x(t) + l(t) = 1;$$

the market for goods clears,

$$\dot{k}(t) = y(t) - c(t) - g(t) - \delta k(t);$$

and capital markets clear,

$$d(t) = k(t) + b(t);$$

(iv) the government's budget constraint (3.15) holds,

$$\dot{b}(t) = R_b(t)b(t) + g(t) - \tau_w(t)W(t)l(t);$$

(v) and by no arbitrage, capital and public debt earn the same interest rate,

$$r(t) = R_b(t) = R_k(t) - \delta.$$

The first order conditions characterizing the competitive equilibrium are reported in the Appendix.

3.4 Balanced growth path

In this section the analysis concentrates on the balanced growth path,[4] to account for the long run effects of fiscal policies. Time between parenthesis is removed to denote steady-state variables.

Definition 6 *A balanced growth path is defined as a competitive equilibrium path in which consumption, government spending, output, debt and capital grow at the same rate, γ; and in which the time allocation (leisure, labor), interest and wage rates and the fiscal variables τ_w; and ζ are constant over time.*

[4] To ensure that the balanced growth path exists for this model, it is necessary to assume that the utility function has the CES form, as it is the case here, where $\sigma > 0$. See Lucas [9] and Rebelo [10].

On the balanced growth path all positive growth rates are the same rate, γ; which satisfies

$$\gamma = \frac{1}{1-\theta(1-\sigma)}(R_k - \delta - \rho);$$

where the following needs to hold

$$R_k > \rho + \delta > \theta(1-\sigma)\gamma + \delta;$$

to ensure both endogenous growth and bounded utility, respectively. I will analyze all growing variables in ratios of capital, $k(t)$:

The balanced growth path (hereafter, BGP) in this economy is described by the set of values of the variables $\{\gamma; l; \frac{c}{k}; \frac{y}{k}; \frac{b}{k}\}$ if there is no limit. If there is a limit to debt, the BGP is described either by $\{\gamma; l; \frac{c}{k}; \frac{y}{k}; \tau_w\}$ or by $\{\gamma; l; \frac{c}{k}; \frac{y}{k}; \zeta\}$; depending on which variable adjusts to satisfy the debt limit. These variables must solve the following system of equations:

$$\theta(1-l)(1-\tau_w)(1-\alpha)\frac{y}{kl} = (1-\theta)\frac{c}{k}; \tag{3.24}$$

$$\gamma = \frac{1}{1-\theta(1-\sigma)}\left[\alpha\frac{y}{k} - \delta - \rho\right]; \tag{3.25}$$

$$\frac{y}{k} = A\left[l\left(\zeta\frac{y}{k}\right)^{(1-\phi)}\right]^{1-\alpha}; \tag{3.26}$$

$$\gamma = \frac{y}{k} - \zeta\frac{y}{k} - \frac{c}{k} - \delta; \tag{3.27}$$

and if there is no limit to debt

$$\zeta\frac{y}{k} + \left(\alpha\frac{y}{k} - \delta - \gamma\right)\frac{b}{k} - \tau_w(1-\alpha)\frac{y}{k} = 0; \tag{3.28}$$

or if there is a limit χ;

$$\zeta + \left(\alpha\frac{y}{k} - \delta - \gamma\right)\chi - \tau_w(1-\alpha) = 0: \tag{3.29}$$

Equation (3.24) represents the labor supply decision by households that depends on the after tax wage rate and on consumption. Equation (3.25) is the growth rate of consumption that results from the individual's optimization problem. Equation (3.26) is the production function in terms of the output to capital ratio and labor. Equation (3.27) is the resource constraint. Finally, the next two equations, (3.28) and (3.29), represent the government budget constraint without and with limits, respectively.

In the presence of a debt limit, $\hat{\chi}$; then $\frac{b}{k}$ is determined by $\frac{y}{k}$; since the imposition of a limit implies that $\frac{b}{k} = \hat{\chi}\frac{y}{k}$, and $\hat{\chi}$ is fixed. This means that any change in fiscal policy engineered through taxes, τ_w; make ζ endogenous whereas changes in the ratio of government spending over output, ζ; will make labor tax rates endogenous.

3.5 Parameter values

In general, it is not possible to solve this model analytically. Actually, a closed form analytic solution can be obtained for certain versions of model, but not when the labor-leisure choice is made endogenous, as is the case here. To learn about the consequences of imposing limits to public debt with respect to the standard case, I perform dynamic simulations using parameter values which are conventional in public finance and macroeconomics literature.

The parameters of the model are σ; θ; ψ; α; δ; τ_w; ρ; A; and ζ: I assign values for σ; α; δ; and ζ according to standard literature on endogenous growth. The rest of parameters, θ; ρ; A; τ_w; are calibrated. Tables 3.1, and 3.2 summarize the results.

I set the intertemporal elasticity of substitution, σ; equal to 2. The elasticity of substitution between consumption and leisure, θ; is calibrated to match a proportion of leisure to labor around 0.4; as US data suggest. The discount parameter, ρ; is calibrated to get an annual real interest rate of 4%. The elasticity of substitution between public and private goods in the utility function, ψ; has no effect on the balanced growth path since $g(t)$ is not a choice variable for the household. Therefore, it need not be assigned any value.

As in Stokey and Rebelo [12], I compare economies that are observationally equivalent: they are compared around an identical balanced growth path, but respond differently to any parameter change. To have the two models in the same steady-state, the adjustment is made through the technological parameter, A. The annual depreciation rate, δ; equals 10%, and has been taken from previous estimates in the literature for US data. Finally, the capital share of output, α; is assigned a value of 1/3.

Regarding fiscal variables, I need to determine the tax rate on labor income, τ_w; and the weight of government spending on output, ζ. The tax rate on labor has been chosen to be $\tau_w = 36.47\%$; which corresponds to a government spending to output ratio, ζ; of 24%. All these values imply a debt to output ratio, χ; equal to 65%. Table 3.2 reports the values for the main variables on the steady state.

3.6 Long run effects of fiscal policy

In principle, if a government wants to control its budget has three possible instruments, debt, taxes and government spending. Having one of them constrained (in this case debt) affects the allocation of the others (taxes and government spending). In order to control public debt (either to reduce the amount of outstanding debt or just to prevent it from increasing without control) the government can increase taxes or reduce government spending.

In this section, I analyze the long run e¤ects of …scal policy (changes in the labor tax rate, ¿$_w$, in the government spending to output ratio, ³) in the two models considered (GPF and GUF), and highlight the di¤erences induced by the imposition of debt limits. This will be done abstracting from transitional dynamics. To understand the characteristics of the steady state in the presence of limits, I compare balanced growth paths for di¤erent labor income taxes and government spending over output ratios around a point at which the debt limit is just binding.

3.6.1 An increase in the labor tax rate (¿$_w$)

The …rst experiment consists of increasing labor tax rates from 36.47% to 41.47%, keeping all the rest of parameters unchanged. Figures 3.1 and 3.2 report the results for the GPF and GUF models, respectively. In the …gures, the solid lines refer to the economy without debt limits, and the dashed lines denote the economy with the debt limit. Figure 3.3 shows the e¤ects on the growth rate and the debt to capital ratio under debt limits for the two models considered, the GPF (solid line) and the GUF (dashed line).

As expected, the long run e¤ects of rising taxes di¤er depending on the role of government spending in the model. In the absence of debt limits for the GPF model a rise in the labor tax rate has two opposite e¤ects on labor supply. On one hand, it diminishes the wages e¤ectively earned by households. This reduces the incentives to work, a¤ecting negatively output, revenues from taxes, and therefore growth. On the other hand, it has a positive direct e¤ect on government spending, and a¤ects positively the productivity of labor, which raises labor supply. In the …gures the …rst e¤ect dominates, inducing a reduction of labor. Figure 3.1 shows that in the economy without debt limits the fall in labor reduces output and therefore the growth rate of the economy. Given that government spending is a constant fraction ^{3} of output (recall equation (3.14)), public consumption is also reduced, what enhances the fall in the growth rate. Private consumption is diminished too.

With limits to debt the two opposite effects of the rise in taxes on labor are still at work. However, government finances behave differently. Given that the ratio of public debt to output cannot change, the rising revenues from labor income are completely devoted to higher government spending. The mechanism can be derived from equation (3.29). In the GPF model, higher public expenditure increases the growth rate of the economy and this positive effect is transmitted to the rest of variables. Therefore, unlike in the model without limits, the final outcome is an increase in output, public spending, and growth.

The same results hold for the GUF model in the absence of limits. It is worth noticing that the effects on the growth rate are larger in the GPF than in the GUF model due to the externalities induced by productive public spending. The reason is that in the latter higher public spending does not affect labor productivity, whereas labor taxes do. As a result, in the GUF model the rise in tax rates reduces both public and private consumption. When there is a limit to debt issue, the rise in taxes allows for higher government spending, which weakens the negative effects of fiscal policy.

After analyzing the effects in each model, what is the main difference between models of introducing debt limits? In the presence of limits to debt, raising tax rates on labor has positive effects on growth when the economy's growth is propelled by public spending and there are limits on the debt-to-output ratio. When private investment drives growth, rising taxes on labor only serves to increase government spending and to reduce the incentives to work, with a negative e¤ect on growth. This shows that the role of government spending has in the economy is crucial in determining the long run growth e¤ects of changes in taxes when there is a limit to debt.

3.6.2 A fall in the government spending to output ratio (³)

Next, I consider the long run e¤ects of changes in the share of government spending on output. I will assume that if there is a limit constraining public debt, the government has to change taxes, to maintain the budget constraint holding. The change in ³ is from 24% to 22%.

Figures 3.4, 3.5 and 3.6 show the results. Figure 3.4 refers to the GPF model, Figure 3.5 shows the GUF model. As before, the solid lines refer to the economy without debt limits, whereas the dashed lines denote the economy with a limit to debt. Figure 3.6 compares both models in terms of the e¤ects on the growth rate and the debt to capital ratio, when there is a limit imposed.

Figure 3.4 shows that in the GPF model, reducing ³ a¤ects negatively all variables. Notice that these reductions are less pronounced (or even positive as in the case of labor) if there is a limit to debt. Recall that now with the debt ceiling, a change in ³ implies a change in taxes to keep the government budget constraint (3.29) balanced. Having debt issue controlled by the limit, the tax rate implied by lower ³ need not be so high as before. This has a positive e¤ect on labor supply, and prevents it from falling.

However, in the GUF model the same fall in ³ only a¤ects individuals' welfare, with no direct e¤ect on growth. Figure 3.5 shows a lower level of public consumption to output ratio induces lower output, and labor. The …nal e¤ect on growth is negative. Keeping taxes constant, the resources from reducing ³ go to increase debt issue. Labor falls and so does output, reducing the growth rate. Notice, however, that in the economy with a debt ceiling the fall in ζ has the opposite effects as a rise in taxes, that is, increases the growth rate.

Summarizing, in the GPF model, reducing ζ affects negatively growth with stronger effects in the absence of limits to debt. The fall in ζ reduces growth both in the GPF and GUF models in the absence of limits, with stronger effects when government spending is productive.

3.7 Transitional dynamics

Although the analysis above has concentrated on the balanced growth path, the two models considered in this paper display transitional dynamics. The analysis of the dynamics focuses only on the GPF model.

To recover the equilibrium path of the variables, the following procedure is employed.

1. The set of optimal conditions for the competitive equilibrium (equations A3.1-A3.10 in the Appendix) has to be expressed in terms of the normalized variables. Therefore, growing variables are expressed in ratios to capital, $k(t)$.

2. The system is reduced to the least number of variables. I denote the vector of unknowns as $z(t) = \{\beta(t), \eta(t), \xi(t), l(t)\}$, where $\beta(t) = \frac{b(t)}{k(t)}$, $\eta(t) = \frac{c(t)}{k(t)}$, and $\xi(t) = \frac{y(t)}{k(t)}$. Notice that when the debt limit is imposed, there is an additional equation (the one imposed by the debt limit), and an additional unknown $\tau_w(t)$. Thus, $z(t)$ becomes $z'(t) = \{\beta(t), \eta(t), \xi(t), l(t), \tau_w(t)\}$.

3. To recover the path of the original series I need to characterize the balanced growth path to which the new variables would converge. Given the nonlinearity of the resulting model,

I linearize it around the new balanced growth path in order to solve it. The linearized systems have the following structure

$$A\dot{\hat{z}}(t) + B\hat{z}(t) = 0; \text{ that is, } \dot{\hat{z}}(t) = P\hat{z}(t);$$

where $P = -A^{-1}B$; and $\hat{z}(t) = z(t) - \bar{z}$; where $\bar{z}$ denotes variables on the new balanced growth path. Once this system is solved, I obtain the path for the vector $\hat{z}(t)$ in terms of Λ; the matrix of stable eigenvalues of matrix P: Stability requires the resulting series not to be explosive, that is, in continuous time the elements in Λ must be negative.

In what follows, I investigate the dynamics of the economy when fiscal policy is tightened in order to reduce the debt to output ratio to a new limit. Fiscal policy in this analysis will take two different forms. Recall that in the absence of debt limits, fiscal policy is defined as a pair $\{\zeta; \tau_w\}$ constant over time that imply a path for government debt consistent with the no-Ponzi game condition (3.16). In the presence of debt limits, fiscal policy consists of a constant ζ and a path for $\tau_w(t)$ that make the ratio of debt over output constant and equal to the limit imposed, χ: For simplicity, I will consider the case in which there is only one period of transition between regimes, that is, $T = 1$ in chart (3.18). This is the simplest way to study the dynamic effects of imposing the limit, since I avoid calculating the branch of the dynamics between the time of the announcement and the moment when the limit becomes active, T:

3.7.1 An increase in the labor tax rate (τ_w)

In this section, I will study the transitional dynamics of an economy that raises taxes in order to achieve a lower ratio of debt to output. As mentioned above, for simplicity the moment in which the debt limit is enforced is $T = 1$: The dynamics of balanced growth paths for an economy that raises taxes to attain a lower debt level are compared with the initial balanced growth path, that is, an economy growing at a constant growth rate without the imposition of any debt limit or any other change in fiscal policy, that will be taken as benchmark.

Figure 3.7 displays the results of a temporary rise in the labor tax rate from 36.47% to 40%, implying a drop in the debt to output ratio from 65% to 60%. In the figures, the solid lines refer to the model without limits to debt, and the dashed lines draw the results for the model with limits. The panels of the figure depict the paths for consumption, output, labor, government spending, the growth rate of capital, the debt to output ratio, and the labor income tax. All variables are expressed as fractions of their initial balanced growth path values.

After the initial exogenous change in taxes, the debt is reduced to hit the ceiling as imposed. What are the effects for the rest of variables? Since $\frac{b}{y}$ is constrained by the limit, taxes become endogenous, and converge to a new balanced growth path with lower labor income taxes. This affects positively labor, which increases. Although it may seem counterintuitive, lower taxes result in high government spending. Given the assumption of a fixed spending ratio, $\gamma = \frac{g}{y}$; and given the productive role of government spending in this economy, lower tax distortions result in more output and more government spending as well as increased consumption and growth.

That is, if the economy raises labor income taxes to reduce debt and maintain it at a fix ratio over output, the economy will converge to a new balanced growth path in which consumption, output, labor, and growth all will be higher, labor income taxes lower and government spending will increase with respect to an economy that stays at its initial balanced growth path.

3.7.2 A reduction in the government spending to output ratio (γ)

Following with the analysis parallel to the balanced growth path, this subsection analyzes a reduction in the ratio of government spending to output, γ; from 24% to 22%, once and for all at time $T = 1$. In this case, the economy uses changes in γ to reduce its debt to output ratio and attain another balanced growth path with the debt limit. As before, two cases are compared, without limits or any other change in fiscal policy (the benchmark), and with limits. Recall that in the case with debt limits, the change in γ makes labor tax rates, τ_w; endogenous.

As in the previous case, the solid lines refer to the model without limits to debt, and the dashed lines draw the results for the model with limits. The analysis will focus on the paths for consumption, output, labor, government spending, the growth rate of capital, the debt to output ratio, and labor income tax rates. As before, all variables are expressed as fractions of their initial steady-state values. Figure 3.8 reports the results.

When government spending is diminished to reduce the amount of debt over output, it affects negatively consumption, output, and the growth rate. Notice that reducing government consumption and debt allows the economy to enjoy lower labor income taxes. The immediate effect is a rise in labor supply. Thus, the reduction of γ to attain a level of debt over output below the initial one, and stick to it, leads the economy to a new balanced growth path with lower consumption, output, growth rate, government spending, and taxes, and higher labor.

The main difference between this fiscal policy and the former relies in the sign of the effects. When taxes are raised to reduce $\frac{b}{y}$; the effects on consumption, output and the growth rate go in the opposite direction than when government spending is reduced. Although both policies are conducted to reduce the amount of outstanding debt, the dynamics off steady states confirm the results previously obtained in the long run analysis: increasing taxes in the presence of limits to debt affects positively the growth rate. Now, the dynamics adds the notion of what happens with consumption and labor. With initially higher taxes on labor income, the representative household enjoys higher consumption and lower taxes in the following periods. When government spending is reduced, consumption is lower and labor higher. What are the final effects on welfare is the focus of the next section.

3.8 Welfare analysis

In the two former sections, I have analyzed the effects on growth of different fiscal policies in economies with limits to debt. Raising labor income taxes had positive growth effects in contrast with reductions in government spending. However, what are the consequences for individuals' welfare? In this section, I study the welfare effects of the changes in fiscal policy analyzed before in the economy with debt limits and for the case in which government spending is a productive input (the GPF model).

The welfare cost of implementing a given fiscal policy comes from the comparison of the levels of welfare at the starting balanced growth path and during the transition off the balanced growth paths. In this economy, welfare on the balanced growth path, W_{BGP}; is given by

$$W_{BGP} = \int_0^{+\infty} U[c_{BGP}; x_{BGP}]e^{-\rho t}dt = \int_0^{+\infty} \left[\frac{(c_{BGP}^{\theta} x_{BGP}^{1-\theta})^{1-\sigma}}{1-\sigma} \right] e^{-\rho t}dt =$$

$$= \int_0^{+\infty} \left[\frac{(c_0^{\theta} e^{\theta \gamma_c t} x_0^{1-\theta})^{1-\sigma}}{1-\sigma} \right] e^{-\rho t}dt;$$

where zero subscripts denote the initial balanced growth path, and where the coefficient of relative risk aversion, σ; has been set equal to 2. Note that at the initial balanced growth path all variables grow at the same rate, γ_0. Recall that $\eta = 0$ because the analysis focuses on the GPF model.

The level of welfare attained during the transitional dynamics, W_{TD}, is given by the following expression:

$$W_{TD} = \int_0^{+\infty} U[c(t), x(t)]e^{-\rho t}dt = \int_0^{+\infty} \left\{ \frac{[c(t)^{\theta} x(t)^{1-\theta}]^{1-\sigma}}{1-\sigma} \right\} e^{-\rho t}dt.$$

Recall from the discussion in previous sections that $c(t) = k(t)\eta(t)$, and $k(t) = k_0 e^{\gamma_k(t)t}$, where $\gamma_k(t)$ denotes the growth rate of capital at time t. Given the endogenous character of labor, I cannot study welfare implications of fiscal policy explicitly. Therefore I simulate the economy.

I follow Lucas [8] and measure the welfare cost of fiscal policies as the proportion of consumption in the initial balanced growth path the agent would be willing to lose in order not to experience the change in consumption after the fiscal policy experiment. This cost will be denoted by ς, and can be computed as follows:

$$W_{BGP} = \int_0^{+\infty} U[c_{BGP}(1-\varsigma), x_{BGP}]e^{-\rho t}dt = W_{TD},$$

that is,

$$\varsigma = 1 - \left(\frac{W_{TD}}{W_{BGP}}\right)^{\frac{1}{\theta(1-\sigma)}},$$

where W_{TD} depends on τ_w and ζ.

Table 3.3 reports the welfare cost, ς, of the two fiscal policies analyzed as percentage of initial BGP consumption in the presence of limits to debt. The welfare cost associated with an increase in labor tax rates is lower than when government spending over output is reduced. In the former case, this is due to the increase in labor and the growth rate, that drive the economy to a new balanced growth path with higher levels of consumption. When government spending is reduced the welfare cost is much higher. The reason is the reduction in consumption and the increase in labor that can be seen in Figure 3.8.

Summarizing, a …scal policy consisting on raising taxes to attain a lower debt to output ratio results in higher growth and less welfare cost than other …scal policy that has government spending over output as its instruments.

3.9 Conclusions and extensions

The aim of this paper is to investigate the growth and welfare consequences of imposing debt limits on the government's budget constraint. The long run e¤ects of increases in taxes on labor, and reductions in the government spending to output ratio are analyzed in two di¤erent endogenous growth models with labor-leisure choice, in an environment with and without limits to debt. The two models considered di¤er in the weight and role government spending is given, either as productive spending (entering in the production function), or as providing public services (in the utility function) being private capital what drives growth in the latter case.

The existence of debt limits is crucial for the growth e¤ects of di¤erent …scal policies. In the long run, if there is no debt limit, the growth e¤ects of raising labor income taxes are negative regardless of the role of government spending, and vice versa. However, which role public spending plays in the economy is determinant for the growth e¤ects of changes in the ratio of public expenditures to output. Interestingly, in the presence of a limit to debt, higher labor tax rates have a positive e¤ect on growth if government spending is productive.

I also investigate the dynamic e¤ects of using …scal policy to reduce public debt in order to attain a debt limit with a lower debt to output ratio, and compare them with an economy without limits which stays at its balanced growth path. This analysis is done for the case in which government spending is a productive input. I …nd that raising taxes to lower debt leads the economy to a new balanced growth path with higher growth and lower taxes. This is due to the role of government spending in this model. By the same reason, a …scal policy consisting of reducing government spending over output has the opposite e¤ects, reducing growth and output. Regarding welfare, in the presence of limits to debt, higher labor income taxes imply a lower welfare cost than reducing government spending. The reason is the higher levels of consumption that the representative household enjoys if taxes are used as the instrument of …scal policy.

The introduction of public debt and the imposition of limits to this borrowing in the way it is done in this paper is novel in the framework of endogenous growth models. Moreover, in contrast with traditional models of growth that focus on the growth e¤ects of distortionary taxes disregarding debt issues, the setup presented here o¤ers a lot of new possibilities to analyze the e¤ects of di¤erent …scal policies.

One interesting experiment would be to study the dynamics of the economy with a longer transitional period. This economy would receive at some time t the announcement of a debt limit becoming enforced at a given time $T > t$. This economy would undertake the appropriate …scal policy measures in order to reduce Â(t) from t to T; and converge smoothly to the debt limit at time T: In this experiment …xing the time T will give us the exact change in …scal policy needed at time t, and vice versa. This experiment will be useful to analyze, for example, the preliminary e¤ects of the criteria imposed by the Maastricht Treaty, and the consequences of the possible …scal policies implemented afterwards.

Furthermore, Barro [3] …nds that the tax rate that maximizes growth is the same that maximizes individuals' welfare. It would be interesting to investigate whether it is also the case here. In this sense, setting up the second best problem would allow the government to optimally design …scal policy taking into account …rst order conditions from individuals' optimization. Here, the Ramsey problem may allow the government to choose just the optimal tax structure, taking as given $g(t)$; or deciding on both …scal variables, when there are limits to public debt and therefore its …nancial options are constrained.

In conclusion, the introduction of limits on public debt in endogenous growth models inaugurates a new step in understanding the performance of …scal policy in this environment, both in the long run and during the transition.

Appendix: First order conditions for the competitive equilibrium

The conditions for competitive equilibrium in the general setup are given by the following set of equations:

$$\frac{\theta(1-\tau_w)W(t)}{(1-\theta)} = \frac{c(t)}{[1-l(t)]}; \tag{A3.1}$$

$$\frac{\dot{\lambda}(t)}{\lambda(t)} = [\rho - r(t)]; \tag{A3.2}$$

$$\frac{\dot{c}(t)}{c(t)} = \frac{1}{\theta(1-\sigma)-1}\left[(1-\theta)(1-\sigma)\frac{\dot{l}(t)}{1-l(t)} + \frac{\dot{\lambda}(t)}{\lambda(t)}\right]; \tag{A3.3}$$

$$r(t) = \alpha\frac{y(t)}{k(t)} - \delta; \tag{A3.4}$$

$$W(t) = (1-\alpha)\frac{y(t)}{l(t)}; \tag{A3.5}$$

$$\dot{k}(t) = y(t) - g(t) - c(t) - \delta k(t); \tag{A3.6}$$

$$\dot{b}(t) = r(t)b(t) + g(t) - \tau_w W(t)l(t); \tag{A3.7}$$

$$g(t) = \zeta y(t); \tag{A3.8}$$

$$y(t) \begin{cases} Ak(t)^{\alpha}[l(t)g(t)]^{1-\alpha}; \\ Ak(t)l(t)^{1-\alpha}; \end{cases} \tag{A3.9}$$

$$\lim_{t\to\infty} e^{-\rho t}\lambda(t)d(t) = 0; \tag{A3.10}$$

where $\lambda(t)$ is the shadow price associated to the household's budget constraint. Equations (A3.1), (A3.2) and (A3.3) describe optimal choices of the household. Conditions (A3.4), and (A3.5) are the optimal input demands by firms. Equations (A3.6) and (A3.7) report the laws of motion of the two state variables of the system. Finally, equation (A3.8) describes fiscal policy, equation (A3.9) specifies the production function depending on the model considered, and equation (A3.10) states the transversality condition.

The system defined above fully describes the competitive equilibrium in the economy together with the constraint on $l(t) \in [0; 1]$:

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Table 3.1: Parameter Values

Technology parameter GUF model	Á = 1; A = 0:1799
Technology parameter GPF model	Á = 0; A = 2:1494
Capital share of output	® = 1=3
Depreciation rate	± = 0:0238
Government spending-to-output ratio	³ = 0:24
Labor tax rate	$¿_w$ = 0:3647
Inverse elasticity of intertemporal substitution	¾ = 2
Discount parameter	½ = 0:0026
Elasticity of substitution between consumption and leisure	µ = 0:4481

Table 3.2: Balanced Growth Path Values¤

Growth rate (°)	0:0050
Nominal interest rate (r)	0:0098
Consumption-to-capital ratio ($\frac{c}{k}$)	0:0479
Government spending-to-capital ratio ($\frac{g}{k}$)	0:0242
Output-to-capital ratio ($\frac{y}{k}$)	0:1009
Public debt-to-capital ratio ($\frac{b}{k}$)	0:0656
Labor (l)	0:4198

¤For the sake of comparison, steady state values are common to the two models (GUF and GPF).

Table 3.3: Welfare effects of fiscal policies

	Welfare cost (&)
An increase in labor tax rates	
with limits	14:62%
A decrease in government spending over output	
with limits	25:71%

*The welfare cost of fiscal policies, &; is expressed as percentage of initial BGP consumption.

Figure 3.1: Changes in the GPF model for different taxes on labor income. The solid line reports the model without debt limits, and the dashed line stands for the model with limits.

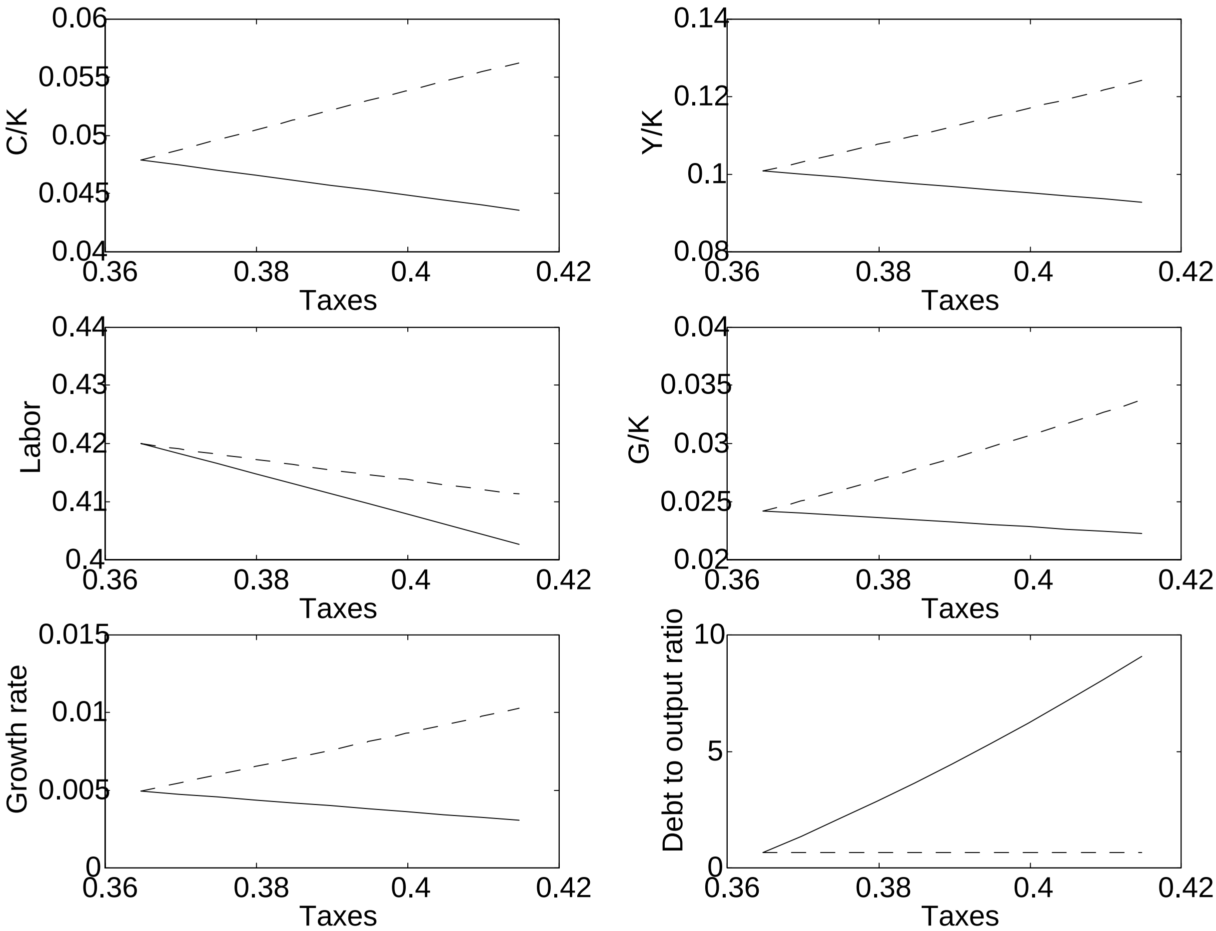

Figure 3.2: Changes in the GUF model for di¤erent taxes on labor income. The solid line reports the model without debt limits, and the dashed line stands for the model with limits.

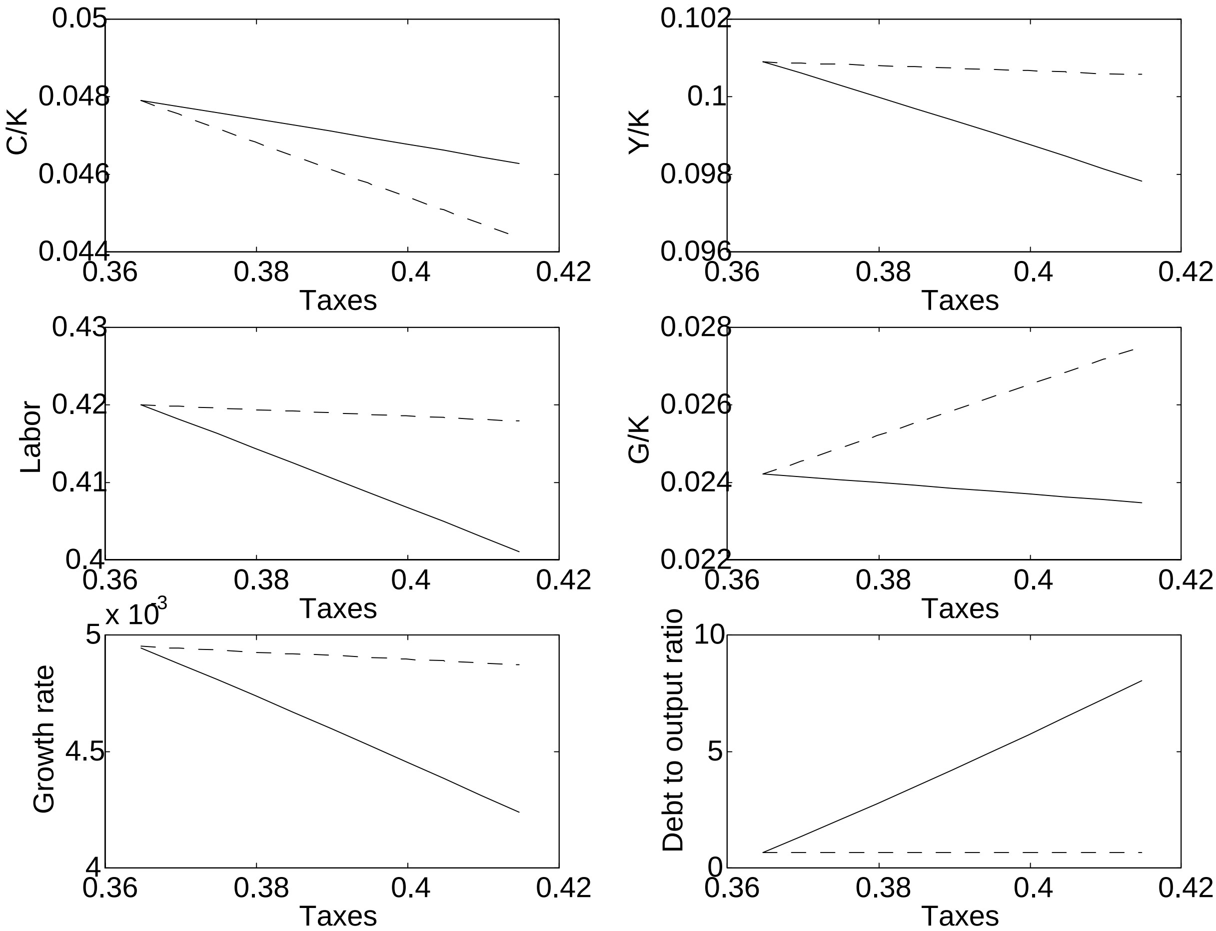

Figure 3.3: Changes in the GPF and GUF models for different tax rates on labor income. The solid line reports the GPF model, and the dashed line the GUF model, both cases in the presence of debt limits.

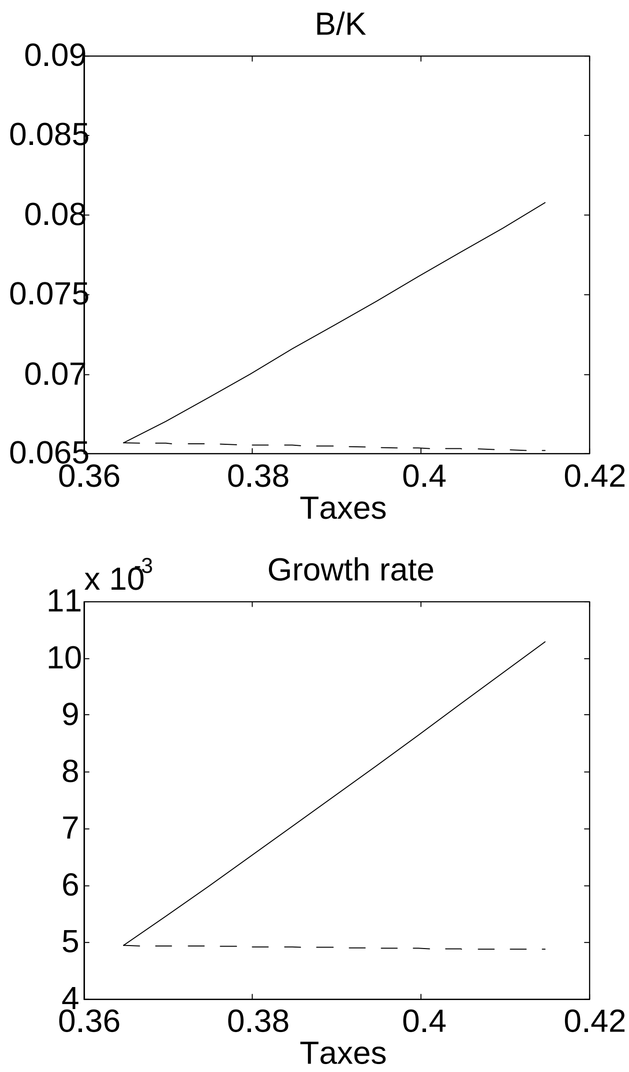

Figure 3.4: Changes in the GPF model for di¤erent ³: The solid line reports the model without debt limits, and the dashed line stands for the model with limits.

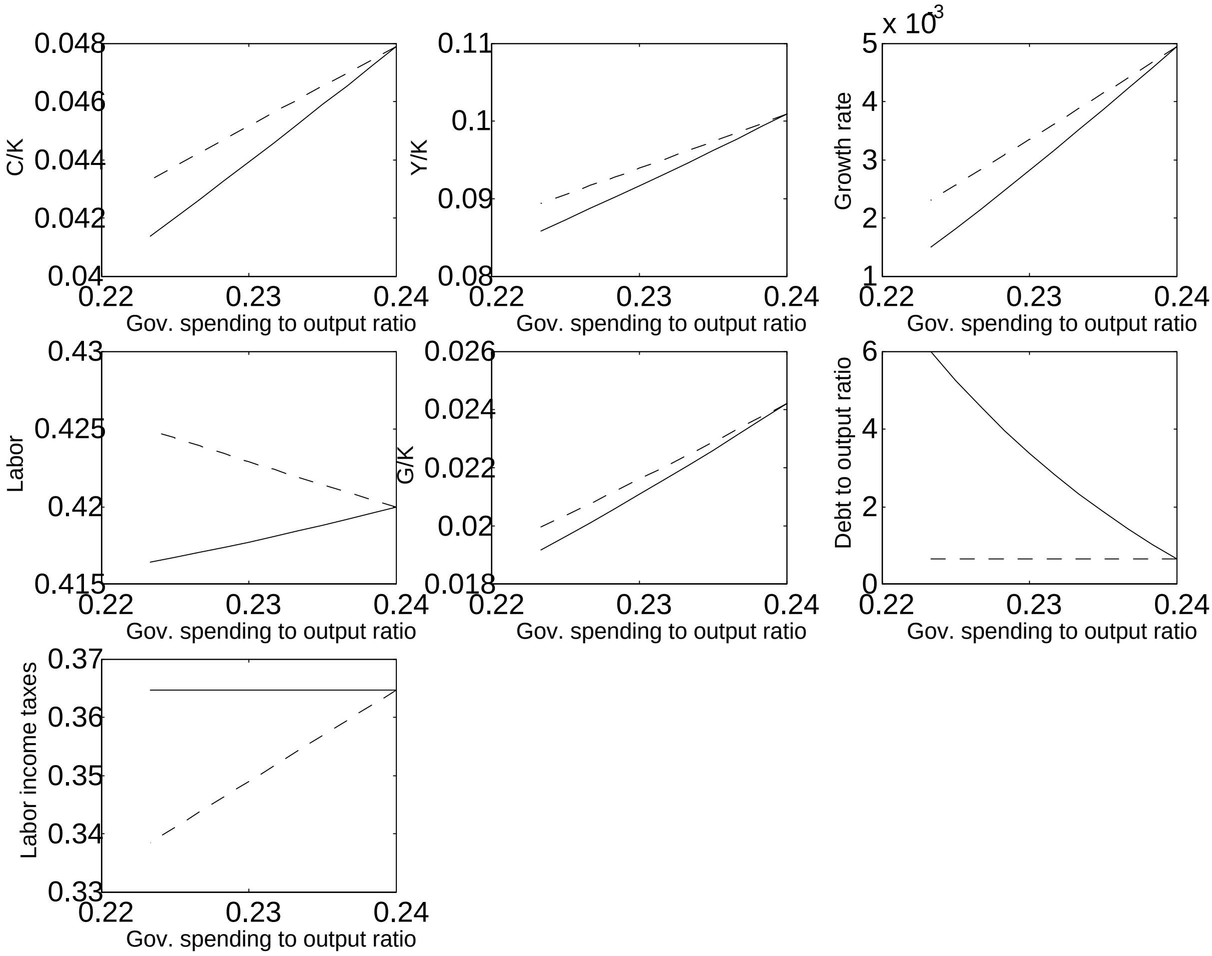

Figure 3.5: Changes in the GUF model for di¤erent ³: The solid line reports the model without debt limits, and the dashed line stands for the model with limits.

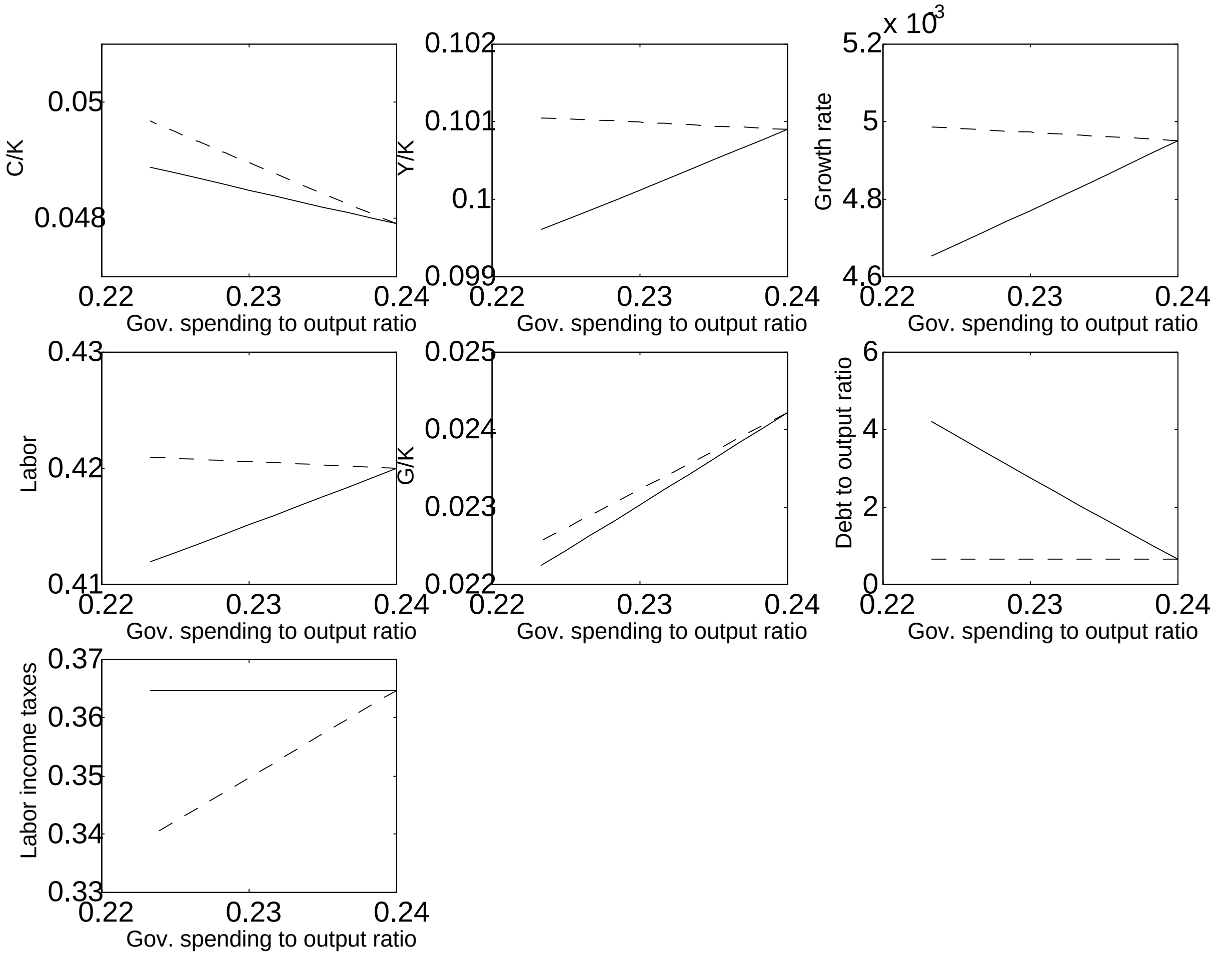

Figure 3.6: Changes in the GPF and GUF models for di¤erent ³: The solid line reports the GPF model, and the dashed line stands for the GUF model, both cases in the presence of debt limits.

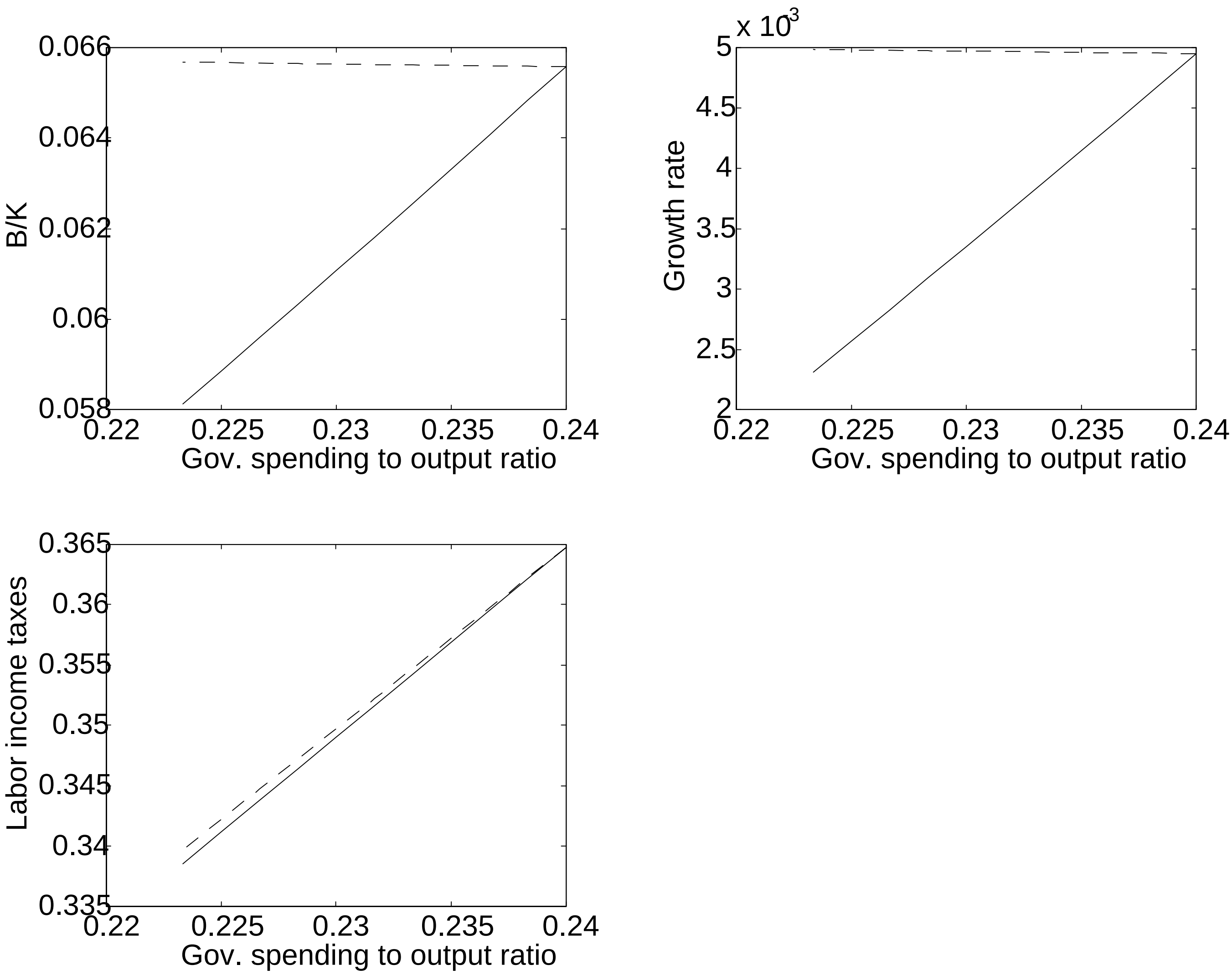

Figure 3.7: The GPF model after a rise in the labor tax rate. The solid line reports the model without limits to debt, and the dashed line stands for the model with debt limits. All variables are expressed as fractions of their initial BGP values.

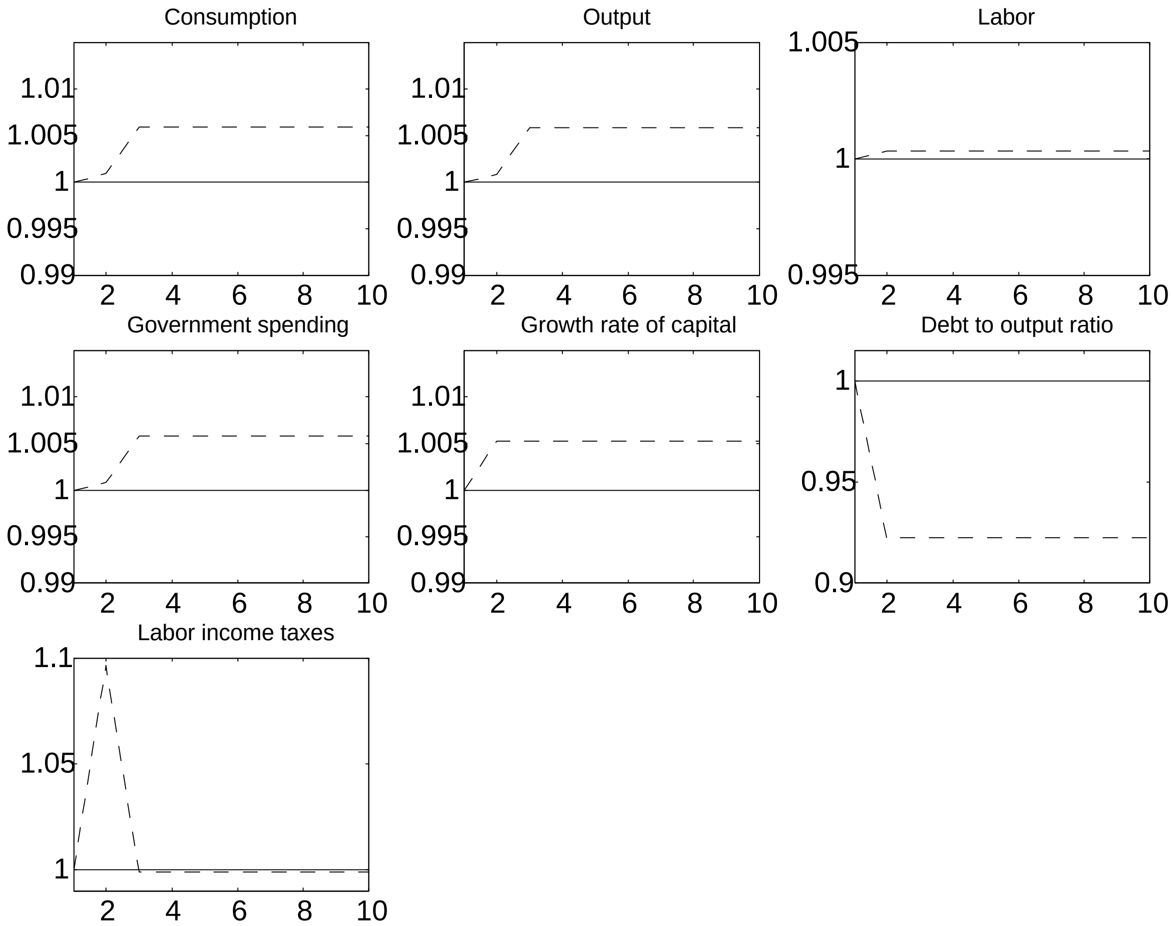

Figure 3.8: The GPF model after a fall in ^{3}. The solid line reports the model without limits to debt, and the dashed line stands for the model with debt limits. All variables are expressed as fractions of their initial BGP values.