working papers

UNIVERSIDAD CARLOS III DE MADRID

PERFORMANCE OF INTEREST RATE RULES UNDER CREDIT MARKET IMPERFECTIONS *

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Abstract

The stabilization effects of Taylor rules are analyzed in a limited participation framework with and without credit market imperfections in capital goods production. Financial frictions substantially amplify the impact of shocks, and also reinforce the stabilizing or destabilizing effects of interest rate rules. However, these effects are reversed relative to New Keynesian models: under limited participation, interest rate rules are stabilizing for technology shocks, but imply an output-inflation tradeoff for demand shocks. Moreover, because financial frictions imply excessive fluctuation, stabilization via an interest rate rule can be a welfare-improving response to technology shocks.

Keywords: financial frictions, Taylor rules, limited participation.

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1   Introduction

How do interest rate rules perform under credit market imperfections? Are their stabilization properties the same as in the frictionless case?

Recent evidence shows that central banks in most industrialized countries use the nominal interest rate as their monetary policy instrument, following a sort of rule to reduce the volatility of inflation and/or output (Clarida, Galí, and Gertler (1998)). The impact of these "Taylor rules" has mainly been modeled under the assumption of perfect credit markets. However, credit markets are far from perfect. Since a credit contract involves the unknown future, there is typically one part of the contract (usually borrowers) with more information about its own performance than the other (lenders). This private information enjoyed by borrowers may be reflected in the interest rate characterizing the contract, to the extent that it may explain the differences in financing between small and large firms (Gertler and Gilchrist (1993), and (1995)).

Figure 1 reports the evolution of the spread between the Bank Prime rate and the three-month commercial paper rate for the period 1971:2-1997:3, together with real GNP for the same period. During this time, the average spread is positive (191 basis points), implying a risk premium paid by borrowers. Also, the chart clearly shows the countercyclical character of this spread, which has a correlation with GNP of -0.33 in the sample. We could interpret this as evidence that financial imperfections diminish in good times and increase in booms. Bernanke, Gertler and Gilchrist (1996) argue that such time-varying imperfections may help amplify the movements in output. If this is the case, then studying the performance of stabilization policy while abstracting from credit frictions might be misleading, and an adequate model for this analysis should reflect the dynamics of the risk premium.

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 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. In this context, I study the effects of shocks to technology and to government spending, comparing the implications of two policy rules: an exogenous constant money growth rule, and a Taylor rule.

The contribution of this paper is threefold. First, by including interest rate rules and credit market imperfections in a limited participation setup I obtain a framework which is well-suited to address the interaction of frictions and monetary policy instruments, but which yields very different implications from new Keynesian models. Second, the model's capability to account for some stylized facts in business cycles dynamics is quantitatively analyzed. And third, comparing Taylor-type rules to the case of constant money growth, this framework is used to analyze the stabilization properties of monetary policy.

The main results can be summarized as follows. Introducing credit market imperfections enables the model to replicate the negative correlation between output and the risk premium, and significantly increases the amplification of shocks. I also find that in a limited participation setup, interest rate rules have the opposite stabilization effects when compared with a sticky price setting. Furthermore, a Taylor rule has stronger effects, either stabilizing or destabilizing, when there are credit market imperfections. Finally, while stabilizing the economy's response to technology shocks is counterproductive if financial markets are frictionless, when there are credit market imperfections I find that using a stabilizing interest rate rule can bring the economy closer to its frictionless optimum.

The following section briefly discusses related literature. Thereafter, Section 2 develops the model, Section 3 defines the equilibrium, and Section 4 specifies parameters. Section 5 studies the model's second moments and impulse responses. The interaction of credit market imperfections and interest rate rules is analyzed in Section 6. Section 7 concludes.

1.1 Related literature

Fuerst (1995) investigates whether the presence of financial frictions alters the effects of technology and monetary shocks. His model economy is also a limited participation setup in which credit market imperfections arise in the production of capital goods, but his analysis differs from mine in some key points. He restricts monetary policy to a constant money growth rule. Also, he does not find significant amplification or propagation from financial frictions, and his model fails to replicate the observed negative correlation between output and the risk premium.

In a comment on Fuerst's paper, Gertler (1995) highlights the crucial role of the elasticity of net worth with respect to output in this type of analysis. Since profits and cash flow and hence

entrepreneurs' net worth show a high positive elasticity with respect to output growth, the need for external financing and the cost of external funds fall substantially during booms. This helps replicate the negative correlation between output and the risk premium observed in the data, and implies a positive feedback on output that can be quantitatively important if net worth is sufficiently elastic. I internalize this fact in my analysis and obtain significant amplification and persistence from credit market imperfections.

Much of the rest of the literature assumes a New Keynesian structure, like Bernanke et al. (2000), who study credit imperfections affecting capital demand in a sticky-price model. These new Keynesian models contrast sharply with mine, because they predict that the use of interest rate rules stabilizes the economy's response to aggregate demand shocks. This follows from the assumption of nominal rigidities and demand-determined output, which imply that distortions arising from the demand side can be neutralized by changing the money supply (that is, by using the interest rate as an instrument). In contrast, given the limited participation setup assumed here, output becomes supply-determined and aggregate demand is left the role of determining the price level. This implies that shocks affecting aggregate supply can be stabilized by manipulating the interest rate, whereas a tradeoff between output and inflation stabilization arises when demand shocks are considered.

2 The model

The model is a cash-in-advance economy with two additional frictions. The first one allows for the nonneutral effects of money by assuming limited participation of households in financial markets. The second one introduces credit market imperfections in the production of capital. The economy is composed of households, firms, financial intermediaries, a monetary authority, a fiscal authority and entrepreneurs.

The households, firms, and financial intermediaries in the economy are assumed to belong to a family. This family splits early in the morning to play separate roles. At the end of the day, they all gather and share all their earnings.

2.1 Households

There is a continuum of infinite-lived households in the interval [0,1]. The representative household chooses contingency plans for consumption (C_t), labor supply (L_t), and deposits[1] ($\bar{D}_t$), taking as given the sequence of prices and quantities $\{\bar{P}_t, \bar{W}_t, \bar{M}_t, R_t, \bar{\Pi}_t^f, \bar{\Pi}_t^{fi}\}_{t=0}^{\infty}$ to solve

$$\max_{C_t, L_t, \bar{D}_t} E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\theta} - 1}{1 - \theta} - \Psi \frac{L_t^{1+\psi}}{1+\psi} \right), \tag{1}$$

$$\text{subject to} \quad \bar{M}_t - \bar{D}_t + \bar{W}_t L_t \geq \bar{P}_t C_t, \tag{2}$$

$$\bar{M}_{t+1} = \bar{M}_t - \bar{D}_t + \bar{W}_t L_t - \bar{P}_t C_t + R_t \bar{D}_t + \bar{\Pi}_t^f + \bar{\Pi}_t^{fi} - \bar{P}_t T_t. \tag{3}$$

Here E_0 denotes expectations conditional on time 0 information, $\beta \in (0, 1)$ is the discount factor, the constant θ denotes the inverse of the intertemporal elasticity of consumption, ψ is the inverse of the elasticity of labor supply with respect to real wages, and Ψ is a scale parameter.

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 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 available for consumption purchases, $\bar{P}_t C_t$, as reflected in the cash-in-advance constraint (2).

The flow of money from period t to period $t+1$ is given by (3), which shows two additional income sources at the end of period t. The household obtains interest plus principal on deposits from the financial intermediary, $R_t \bar{D}_t$, where R_t denotes the gross nominal interest rate; and also dividends $\bar{\Pi}_t^f$ from the firm, and $\bar{\Pi}_t^{fi}$ from the financial intermediary. Finally, he must pay lump-sum taxes, T_t, that finance government spending.

The optimal labor-leisure and deposits decisions are

$$\frac{U_{C,t}}{\bar{P}_t} = -\frac{U_{L,t}}{\bar{W}_t}, \tag{4}$$

$$E_{t-1}\left(\frac{U_{L,t}}{\bar{W}_t} \right) = \beta E_{t-1}\left(\frac{U_{L,t+1} R_t}{\bar{W}_{t+1}} \right), \tag{5}$$

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

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

Equation (5) is equivalent to the *Fisher equation* in other monetary models, except that expectations depend on the information set at $t-1$, reflecting households' *limited participation* in financial markets. That is, households make their portfolio choices before time t shocks are revealed, and cannot adjust their deposits again until the next period. This rigidity induces the *liquidity effect* of a money supply shock on the nominal interest rate observed in the data, because firms are the only agents able to absorb the excess liquidity in the economy after a monetary injection. The central bank achieves money market clearing by reducing the interest rate so that firms are willing to borrow the excess amount of funds (see Lucas (1990), Christiano (1991), Fuerst (1992), and Christiano, Eichenbaum, and Evans (1997)).

2.2 Firms

Firms produce a homogeneous good in a competitive framework. They 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

$$Y_t = F(A_t, K_t, H_t) = A_t K_t^{\alpha_k} H_t^{\alpha_h}, \tag{6}$$

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

$$A_{t+1} = \exp(\varepsilon_{a,t+1}) A_t^{\rho_a}, \tag{7}$$

with $0 < \rho_a < 1$, and $\varepsilon_{a,t+1}$ is an i.i.d. normal shock with zero mean and standard deviation σ_a^ε.

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

$$\bar{B}_t^d \geq \bar{W}_t H_t + \bar{P}_t Q_t Z_t^d, \tag{8}$$

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

Firms buy additional units of investment goods, Z_t^d, in competitive markets that open at the end of the period and involve firms buying capital from entrepreneurs, described below. Firms accumulate capital according to the following law of motion:

$$Z_t^d = K_{t+1} - (1-\delta)K_t, \tag{9}$$

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

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

Firms maximize their shareholders' utility. Since profits are distributed at the end of the period, a firm values one more dollar in dividends at time t, by how much consumption marginal utility households obtain at time $t+1$, by refusing this time t dollar. Thus firms maximize

$$E_0 \sum_{t=0}^{\infty} \Theta_{t+1} \bar{\Pi}_t^f, \tag{10}$$

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

$$\Theta_{t+1} = -\frac{\beta^{t+1} U_{L,t+1}}{\bar{W}_{t+1}}. \tag{11}$$

Maximizing (10) subject to equation (8), the optimal input demands made by firms are obtained. The representative firm demands labor and capital, respectively, according to

$$\frac{\bar{W}_t}{\bar{P}_t} = \frac{\alpha_h Y_t}{H_t R_t}, \tag{12}$$

$$R_t E_t (\Theta_{t+1}) = \beta E_t \left\{ \Theta_{t+2} \frac{\bar{P}_{t+1}}{\bar{P}_t} \frac{Q_{t+1}}{Q_t} \left[R_{t+1}(1-\delta) + \frac{\alpha_k Y_{t+1}}{K_{t+1} Q_{t+1}} \right] \right\}. \tag{13}$$

Note that all decisions made by firms, unlike households' deposit choice, are based on the complete information set at t. Labor demand (12) is affected by the interest rate since it is paid in advance. Capital demand (13) depends on expected inflation, on the price of capital, Q_t, and on the nominal interest rate, everything discounted by the marginal disutility of labor (11). The left-hand side of equation (13) 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 is equated to the value of the extra dividend at time $t+1$, which can be spent at time $t+2$.

2.3 The financial intermediary

Banks in this economy act as financial intermediaries between households and firms. The representative bank collects deposits from households, $\bar{D}_t$, plus any injection of new cash from the central bank, $\bar{X}_t$, and uses these funds to make loans $\bar{B}_t^d$ to firms. At the end of the period, the financial intermediary receives principal plus interest from the loans, $R_t \bar{B}_t^d$, and it pays back principal plus interest due on households' deposits, $R_t \bar{D}_t$. Implicitly, the fact that the interest rate paid to depositors is the same as that paid by borrowers means that banks act in a competitive market for state-contingent loans (that is, R_t is contingent on time t information). Profits of the financial intermediary are thus

$$\bar{\Pi}_t^{fi} = R_t \bar{X}_t. \tag{14}$$

These profits are distributed to households at the end of the period, as seen in (3).

2.4 Entrepreneurs

Capital is produced by entrepreneurs. Entrepreneurs are risk-neutral, live only one period, and can each carry out one project that requires one unit of consumption goods. The entrepreneur operates a technology that transforms this unit of consumption goods into $\widetilde{\omega}_t$ units of capital goods. The variable $\widetilde{\omega}_t$ is an idiosyncratic shock uniformly distributed in the non-negative interval $[1 - \omega, 1 + \omega]$, with density $\phi(\widetilde{\omega}_t)$ and distribution function $\Phi(\widetilde{\omega}_t)$.

Every period, after production takes place, part of the output Y_t is transferred lump-sum to entrepreneurs; this constitutes their net worth NW_t. According to the data, NW_t is positively related with output, and more volatile than output; the elasticity of net worth with respect to output will be called ξ.[2] Net worth will also be affected by a shock $\mathcal{Z}_t$ which captures other factors (e.g. changes in taxes or in market power) affecting firms' cash positions, so I assume $NW_t = \mathcal{Z}_t Y_t^\xi$.

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[2]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, but this difficult extension is left for future research.

To generate financial frictions, it is assumed that this net worth is insufficient for the entrepreneur's project. Moreover, since entrepreneurs live for only one period they cannot accumulate wealth.[3] Therefore, they need to borrow the difference between their required investment and their endowment, $1 - NW_t$. Firms are assumed to lend to entrepreneurs in a competitive market, and to be able to deal with a sufficient number of entrepreneurs in order to pool their idiosyncratic risk. In other words, firms can set up a "mutual fund" to lend to entrepreneurs.

The relationship between entrepreneurs and the mutual fund is affected by asymmetric information. When they sign their contract, neither the lender nor entrepreneurs can observe the idiosyncratic shock. Afterwards, $\widetilde{\omega}_t$ is revealed to the entrepreneurs, but the lender cannot observe this outcome unless he monitors. Monitoring costs are a fixed proportion $\mu_c > 0$ of the capital produced. Thus capital production involves a *costly state verification* problem, which is optimally solved by a *standard debt contract,* according to Townsend (1979), and Gale and Hellwig (1985). In this debt contract, an entrepreneur who borrows $(1 - NW_t)$ consumption goods agrees to repay $R_t^k(1 - NW_t)$ units of capital, if the realization of $\widetilde{\omega}_t$ is good. If the realization of $\widetilde{\omega}_t$ is bad, then the entrepreneur prefers to default. Thus the default decision is determined by a threshold value $\bar{\omega}_t$ which satisfies

$$\bar{\omega}_t \equiv R_t^k(1 - NW_t). \tag{15}$$

In the optimal contract, the lender monitors in case of default, and confiscates all the entrepreneur's production, but nothing more. That is, entrepreneurs have *limited liability.*

To ensure that this debt contract is efficient and incentive compatible, the participation of lenders must be guaranteed. The mutual fund will find it profitable to lend the entrepreneurs as long as the expected return net of monitoring costs (at least) equals the amount lent:

$$1 - NW_t = Q_t \left\{ \int_{1-\omega}^{\bar{\omega}_t} \widetilde{\omega}_t \Phi(d\widetilde{\omega}_t) - \Phi(\bar{\omega}_t)\mu_c + [1 - \Phi(\bar{\omega}_t)]\bar{\omega}_t \right\} \equiv Q_t g(\bar{\omega}_t). \tag{16}$$

Here the left hand side denotes the amount borrowed by entrepreneurs, and the right hand side reflects the expected return on this loan, net of monitoring costs.[4]

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[3]The transfer they receive is taxed away when entrepreneurs die, i.e. at the end of the period, and then returned lump sum to consumers.

[4]Credit rationing issues are avoided 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 Bernanke et al. (2000).

Also, participation of the entrepreneur in the contract must be assured. This means that his expected payoff must (at least) equal the net worth he invests in the project:

$$Q_t \left\{ \int_{\bar{\omega}_t}^{1+\omega} \widetilde{\omega}_t \Phi(d\widetilde{\omega}_t) - [1 - \Phi(\bar{\omega}_t)]\bar{\omega}_t \right\} \equiv Q_t f(\bar{\omega}_t) = NW_t, \qquad (17)$$

where the left hand side denotes the entrepreneur's expected payoff. This expected value includes expected production of capital, minus what must be paid back on the loan, both conditional on not defaulting.

This costly state verification problem is solved taking as given the sequence of variables $\{NW_t, Q_t, R_t^k\}_{t=0}^\infty$. From equations (16) and (17) above, it follows that

$$Q_t = \frac{1}{[E\tilde{\omega}_t - \Phi(\bar{\omega}_t)\mu_c]} = \frac{1}{[1 - \Phi(\bar{\omega}_t)\mu_c]}. \qquad (18)$$

Additionally, note that

$$f(\bar{\omega}_t) + g(\bar{\omega}_t) = 1 - \Phi(\bar{\omega}_t)\mu_c,$$

that is, if monitoring costs are positive, $\mu_c > 0$, part of the output is destroyed by these costs, $\Phi(\bar{\omega}_t)\mu_c$, while the rest is divided between the entrepreneur, $f(\bar{\omega}_t)$, and the lender, $g(\bar{\omega}_t)$. The number of projects undertaken, i_t, net of monitoring costs, constitutes the supply of capital:

$$Z_t^s = i_t[1 - \Phi(\bar{\omega}_t)\mu_c].$$

2.5 The fiscal authority

There is a government in this economy which consumes an amount G_t. This government spending is financed by lump sum taxes levied from households, T_t. In this economy government spending is random and fluctuates according to

$$G_{t+1} = \exp(\varepsilon_{g,t+1})G_t^{\rho_g}, \qquad (19)$$

with $0 < \rho_g < 1$, and $\varepsilon_{g,t+1}$ is an i.i.d. normal shock with zero mean and standard deviation σ_g^ε.

It is assumed that the fiscal authority maintains a balanced budget every period, that is,

$$G_t = T_t, \quad \text{for} \quad \forall t.$$

2.6 The monetary authority

In this model, the central bank is in charge of monetary policy. I will study the stabilization properties of two alternative monetary regimes. First, I take a constant money growth rule as the benchmark. In this case, money supply is perfectly inelastic, and it is the nominal interest rate that must adjust after any shock. Second, I will consider the effects of using a Taylor rule, in which the nominal interest rate depends on its lagged value, and on deviations of GDP from its trend and of inflation from its target level. In this case, the central bank tunes the money supply to achieve the desired nominal interest rate. Thus the nominal interest rate will be

$$r_t = \gamma + \gamma_r r_{t-1} + (1 - \gamma_r)(\tilde{\gamma}_\pi \pi_t + \tilde{\gamma}_y y_t) \equiv \gamma + \gamma_r r_{t-1} + \gamma_\pi \pi_t + \gamma_y y_t, \tag{20}$$

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; $\pi_t \equiv \log P_t - \log P_{t-1}$ is the inflation rate; and y_t denotes the deviation of output from steady state. Thus, the central bank cares about smoothing interest rates ($\gamma_r > 0$), and both inflation and output stabilization ($\gamma_\pi, \gamma_y > 0$).

In his original study, Taylor (1993) estimated the following coefficients: $\gamma_r = 0$, $\tilde{\gamma}_\pi = 1.5$, and $\tilde{\gamma}_y = 1$. However, this parameterization results in indeterminacy in a limited participation model (Christiano and Gust (1999)), as is also the case here after allowing for financial frictions. Therefore, in the simulations below, a *stable* (determinate) version of this rule is employed.

3 Equilibrium

To analyze the general equilibrium, I detrend all nominal variables by dividing by beginning-of-period monetary holdings, $\bar{M}_t^s$. I define equilibrium in recursive form, omitting time subscripts and using primes to denote the next period's variables.

The timing can be summarized as follows:

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At the beginning of time t individuals take as given the current stocks of money and capital, and know the past history of shocks. Given this information, they decide how much money to put in the bank. After having chosen deposits, the current shocks are revealed. At this point, the state of the economy is (S, s) with $S = (M, K)$, and $s = (a, \mathfrak{z}, g)$. All other variables are chosen conditional on this state.

The model is solved by assuming the family structure explained in section 2, which allows one to think of a *representative agent* for the whole economy. This representative agent has m units of money balances, and k units of capital, let $S_i = (m, k)$ for the individual's variables. The individual state is thus given by the vector (S_i, S, s). The Bellman equation of this representative agent's program is

$$V(S_i, S, s) = \max_{D \in [0, M]} \left\{ E_{t-1} \left[\max_{C, L, K', H, B^d} U(C, L) + \beta V(S_i', S', s') \right] \right\} \tag{21}$$

subject to

$$M - D + WL \geq PC,$$
$$B^d \geq WH + PQZ^d,$$
$$M'(1 + \mu) = M - D + WL - PC + RD + \Pi^f + \Pi^{fi} - PT,$$
$$\Pi^f = PY - (WH + PQZ^d) - (R - 1)B^d,$$
$$\Pi^{fi} = RX,$$
$$Y = AK^{\alpha_k} H^{\alpha_h},$$
$$Z^d = K' - (1 - \delta)K,$$
$$i[1 - \Phi(\bar{\omega})\mu_c] = Z^s,$$
$$Q = \frac{1}{[1 - \Phi(\bar{\omega})\mu_c]},$$
$$\bar{\omega} \equiv R^k(1 - NW),$$
$$NW = \mathcal{Z}Y^{\xi}.$$

Definition 1 *A stationary recursive competitive equilibrium in this economy consists of a set of functions (V, C, L, D, H, K', B^d, M', P, R, Q, i, $\bar{\omega}$, NW, W, Π^f, Π^{fi}) such that:*

i) *the value function $V(S_i, S, s)$ solves the representative agent's Bellman equation (21), and*
   $C(S_i, S, s), L(S_i, S, s), D(S_i, S, s_{-1}), K'(S_i, S, s), B^d(S_i, S, s), H(S_i, S, s), M'(S_i, S, s), \Pi^f(S_i, S, s),$
   and $\Pi^{fi}(S_i, S, s)$ are the associated optimal policy functions, taking as given the appropriate information structure,

ii) *the functions i, and $\bar{\omega}$ solve the entrepreneur's problem given R^k, Q, and $NW = \mathcal{Z}Y^{\xi}$,*

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

$$r = \gamma + \gamma_r r_{-1} + \gamma_\pi \pi + \gamma_y y,$$

iv) and consumption goods, money, loan, labor, and capital goods markets clear, that is $C + i + G = Y$, $M = 1$, $D + X = B^d$, $H = L$, $G = T$, $k = K$, $m = M$, and $Z^d = Z^s$.

Under certain restrictions, including sufficiently tightly bounded shock processes, there will exist an equilibrium in which both cash-in-advance constraints (2) and (8) will bind for each state of the world. In such equilibria, the nominal interest rate will be positive, and there will be a positive level of deposits. In the analysis below, I will focus on this type of equilibrium. I solve the model using Campbell's (1994) undetermined coefficients method.

4 Parameter values

The parameters of the model are β, θ, ψ, Ψ, δ, α_k, α_h, ω, μ_c, ξ, as well as the parameters of the stochastic processes for the shocks (ρ_a, ρ_g, ρ_μ, σ_a^ε, σ_ν^ε, σ_μ^ε, and σ_3^ε). I take some of these parameters from previous business cycle literature and calibrate others to match some moments of US data.

Given an average quarterly money growth rate of $\bar{X} = 1.2\%$, the discount factor β is 0.9926. This implies an annual nominal interest rate equal to 7.8% at the non-stochastic steady state, consistent with US data. The relative risk aversion parameter is set equal to $\theta = 2$. The parameter ψ takes the value 0.7, that is, the elasticity of labor supply with respect to real wages is close to 1.5. This value lies within the range usually employed in macroeconomic studies. The coefficient Ψ is normalized so that labor in the non-stochastic steady state equals one.

The depreciation rate, δ, is taken to be 2.4% per quarter. The capital share on aggregate income, in the frictionless model is taken to be 0.36; this implies an α_k equal to 0.3598 in the model with credit frictions. This value takes 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 returns to scale in the production function imply $\alpha_h = 0.6402$. The ratio of government spending over output is taken from US data and equal to 0.21.

Gertler (1995) assigns ξ a value of 4.45. I obtain an elasticity of profits (net worth) with respect to output[5] equal to 3.84. I calibrate R^k to match a risk premium of 191 basis points measured by the spread between the bank prime rate and the three-month commercial paper rate on average terms. The bound ω on the support of the uniform distribution of $\tilde{\omega}_t$ is chosen to match an annual bankruptcy rate, $\Phi(\bar{\omega}_t)$, of 10% for US data from 1980-2001.[6] The proportion of internal project financing, NW, is set equal to 0.15 as in Gertler (1995). The value of monitoring costs, μ_c, is set equal 20% as in Fuerst (1995). This calibration implies a threshold value, $\bar{\omega}$ of 0.8619.

Both technology shocks and government spending are found in the data to be highly persistent (King and Rebelo (2000), Ireland (2001), McGrattan (1994)). Therefore, I set both ρ_a and ρ_g equal to 0.95. Money supply shocks are assumed to have a correlation ρ_μ equal to 0.3 (Fuerst (1995)). Shocks to net worth are considered to be nonautocorrelated, that is, $\rho_{\mathfrak{z}}$ is 0. The standard deviations for the shocks are simultaneously calibrated to match the nine second moments in the data showed in Table 1. The standard deviations of government spending shocks and net worth shocks are tightly restricted by the moments σ_g/σ_y and $\rho(y, rp)$, and the other two parameters are identified jointly by the remaining seven moments. The resulting values are $\sigma_a^\varepsilon = 0.0005$, $\sigma_g^\varepsilon = 0.0032$, $\sigma_\mu^\varepsilon = 0.0009$, and $\sigma_{\mathfrak{z}}^\varepsilon = 0.0011$.

When the Taylor rule is at work, I consider a version with the following coefficients: $\gamma_r = 0.56$, $\tilde{\gamma}_\pi = 1.61$, and $\tilde{\gamma}_y = 0.36$. This rule is denoted as *stable* in the terminology of Christiano and Gust (1999) when applied to a limited participation model, in the sense that it determines a stable unique equilibrium.[7] These weights are close to those in Christiano and Gust (1999), but have been adjusted so that they come close to achieving an optimal response to technology shocks. As usual, I follow the general consensus in giving a higher weight to inflation smoothing rather than to output stabilization.

Below, I will denote the model without frictions the *symmetric information model*, $\mu_c = 0$, and the case with frictions the *asymmetric information model*, $\mu_c > 0$ (SI and AI, respectively).

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[5] Taking data on corporate profits after tax and US GDP for the period 1947:1-2002:1.

[6] US Business Bankruptcy Filings over Total Filings 1980-2001. Source: ABI World. This value is similar to the ones provided by Gertler (1995) and Fisher (1999).

[7] As usual when dealing with interest rate rules, issues regarding indeterminacy of equilibrium arise. I find regions of determinacy and indeterminacy for this model similar to those obtained by Christiano and Gust (1999). The Taylor coefficients considered here lie in the area of unique equilibrium.

Notice that when monitoring costs are zero, the model collapses to a standard limited participation framework.

5 Effects of credit market imperfections

In this section, I study the behavior of the model with credit market imperfections, comparing it to the standard frictionless model. First, I establish that both models (SI and AI) are capable of addressing some of the standard stylized facts considered in the business cycle literature. Next, I analyze the reactions of the two economies to technology and demand shocks.

5.1 Second moments properties

Table 1 presents some key moment relationships implied by the SI and AI models, and compares them with US data. 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*, *Real Government Consumption Expenditures & Gross Investment*, and *Nonfarm Payroll Employment*, from 1970:1 to 2000:4, in logarithms and detrended using the Hodrick-Prescott filter. The risk premium is measured as the spread between the *Bank Prime rate* and the *Three-month commercial paper rate.*

Table 1 reports nine moments matched by choosing the four standard deviations of the shocks. It is observed that consumption is roughly as volatile as output in the two models, and investment is much more volatile than output in both settings, while the relative standard deviation of labor with respect to output is somewhat higher than what is observed in the data. Both models match the standard deviation of government spending, and report correlations among output, labor and investment moderately lower than those in the data. The AI model is, by construction, able to account for the negative correlation between the growth rate of output and the risk premium. Finally, the correlation of prices and interest rates is closer to the data in the AI than in the SI model.

In summary, the models analyzed in this paper display reasonable second moment properties which are quite similar to each other, except that the AI version helps understand the movements in the risk premium, a fact missing in the SI case.

5.2 Impulse response functions

Next, I ask what credit market imperfections add to the dynamics of the model. To isolate the effects of credit market imperfections, I assume the central bank follows a constant money growth rule, leaving the analysis of interest rate rules for later. Results are stated in percentage deviations from their steady states values.

5.2.1 Credit market imperfections and shocks to technology

Figure 2 reports the impulse response functions of the models with (dashed line) and without (solid line) credit market imperfections to a 1% technology shock at time one, $\varepsilon_{a,1} = 0.01$, assuming that monetary policy follows a constant money growth rule.

In the benchmark case (SI), a positive technology shock makes inputs more productive. Output and investment increase and prices fall, enhancing demand for cash inputs. Since monitoring costs are zero in this framework, capital goods are elastically supplied at the price $Q_t = 1$.

With 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; it rises about 30% more than in the benchmark case. Higher productivity increases entrepreneurs' net worth through the increase in output. Since entrepreneurs become richer, they need to borrow less, which lightens the monitoring cost problem, reflected in the fall of the risk premium and of the price of capital,[8] an effect absent in the SI setting. This positive feedback in output and investment makes output increase more and prices fall more than in the SI model. Meanwhile, consumption goods are substituted by investment goods as they become relatively less expensive. This explains the weaker initial reaction of consumption in the AI model, though consumption eventually rises more than in the SI case as capital grows.

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[8]The overall effect on the price of capital is in general ambiguous: in addition to the increased investment supply, the positive technology shock also favors the demand for capital. In this model the price of capital falls, reducing marginal costs of firms.

5.2.2 Credit market imperfections and shocks to demand

Figure 3 displays the response of the economy with and without financial imperfections to a 1% government spending shock at time one, $\varepsilon_{g,1} = 0.01$, when the monetary authority follows a constant money growth rule.

In the standard limited participation model (SI), the rise in government spending induces a rise in output, labor and in prices, while consumption and investment fall. Higher expected taxes imply a negative wealth effect that diminishes consumption and motivates greater labor supply. Regarding the fall in investment, there is no clear theoretical consensus on the effects of changes in government spending: the overall reaction of investment depends both on the persistence of the shock and the elasticity of labor supply.[9] In this model, persistence of $\rho_g = 0.95$ is not high enough to make investment rise.

In the AI model, financial frictions induce a larger increase in output through the rise in entrepreneurs' net worth. This effect, together with the fall in the price of capital, alleviates the fall in investment, while aggravating the reduction of consumption. But notice that in contrast to the case of technology shocks, output and prices now go in the same direction. Thus, positive feedback in output in the AI model reduces the increase in prices after a government spending shock, whereas the decrease in prices was reinforced in response to a technology shock. This difference in transmission of shocks to output and prices helps explain the stabilization effects of monetary policy analyzed in the next section.

6 Stabilization properties of the Taylor rule

The next step is to study the stabilization properties of an interest rate rule, as compared with a constant money growth rule, with and without credit market imperfections.

6.1 A shock to technology

Figure 4 reports impulse response functions under a constant money growth rule (solid line), compared with the responses under a stable version (20) of the traditional Taylor rule (dash-dotted line), for the SI model; Figure 5 shows the same impulse responses for the AI model. In both cases, I implement a one percent technology shock at time $t = 1$.

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[9]See Baxter and King (1993), and Fatás and Mihov (2001).

A Taylor rule reduces the response of output to the shock in both cases, with a stronger effect when there are credit market imperfections. Inflation is very substantially stabilized by the interest rate rule, and the presence of credit market imperfections is irrelevant regarding inflation stabilization.

The stabilization of output and inflation by the interest rate rule occurs because the monetary authority reacts to the rise in output and the fall in prices by increasing the interest rate. Both productive inputs are cash goods, which means that higher interest rates act like a tax on input demands, raising marginal costs and partially offsetting the expansion induced by the shock. This cost effect is strengthened in the model with imperfections. There, stabilizing output by raising interest rates is translated into a lower growth of entrepreneurial net worth, further braking output growth, so the stabilizing effect of the Taylor rule is reinforced by financial frictions. Thus, under flexible prices, and in contrast with a sticky price setup, an interest rate rule reduces both inflation and output variability after technology disturbances. This result is novel in this type of analysis. As mentioned in the introduction, the conventional wisdom associated with sticky price models is that interest rate rules stabilize the economy facing demand shocks, whereas for supply shocks, a tradeoff between output and inflation stabilization arises.

6.2 A shock to demand

The demand shock is a 1% rise in government spending at time $t = 1$. The dynamics of the traditional Taylor rule versus the constant money growth rule for the SI and AI models are displayed in Figures 6 and 7, respectively.

Under the Taylor rule, the initial rise in output is strongly damped by the reaction of the interest rate to rising inflation. Thereafter, output rises but less than under a constant money growth rule. Thus, as before, output is stabilized under the rule and the effects are stronger in the AI model. However, prices are now destabilized in both SI and AI models. In other words, in response to a demand shock the use of interest rate rules involves a tradeoff between output and inflation stabilization.

This confirms the fact that a Taylor rule has the opposite stabilizing effects in a flexible price setting compared to a sticky price model. Using an interest rate rule in response to a demand shock stabilizes output but at the cost of destabilizing inflation.

6.3 Some welfare implications

While this paper focuses primarily on the stabilization properties of interest rate rules, it is obviously also important to ask whether stabilization is desirable. Although computing the optimal rule is beyond the scope of this paper, this impulse response analysis allows for some simple but interesting conclusions about welfare.

Some intuition can be obtained by comparing the two models in this paper with a standard real business cycle model. The RBC model calculated here uses the same technology and preferences as this limited participation model, but eliminates all frictions, including the cash-in-advance constraint. Thus we can measure deviations from optimality on the real side by comparing the responses to a 1% technology and government spending shocks in this RBC model to those in the SI and AI models under the two policy regimes.

Figure 8 plots the results for output. I find that a constant money growth rule keeps the SI model close to the "frictionless" case, whereas the use of a "stabilizing" interest rate rule stabilizes too much, driving output further away from the "frictionless" model. However, with financial frictions the same interest rate rule brings output close to that of the RBC model, reducing the excessive fluctuation caused by the credit market imperfections. Similar calculations for consumption and labor supply confirm that there is a welfare improvement on the real side from following an interest rate rule in the AI case but not in the SI case.

This shows that there may be room for interest rate rules to smooth the excessive fluctuation caused by failures in credit markets. While the RBC comparison only reveals losses on the real side of the model, I have shown that a Taylor rule which stabilizes output after a technology shock also stabilizes inflation. On the other hand, whether it is good to use a Taylor rule in response to a demand shock is ambiguous due to the tradeoff between output and inflation stabilization.

7 Conclusions and further research

This paper analyzes the performance of interest rate rules in the presence of credit market imperfections. In this limited participation economy, a stable version of the Taylor rule similar to the one employed by Christiano and Gust (1999) stabilizes both output and inflation after

a technology shock, whereas an output-inflation tradeoff arises for a demand shock. Both the stabilizing and destabilizing effects of the rule are amplified by the presence of financial frictions.

Contrary to the common intuition that technology-driven fluctuations are optimal, I find that under credit market imperfections the stabilization of technology shocks by means of a Taylor rule can improve welfare. However, whether or not a Taylor rule is optimal overall will depend on whether supply or demand shocks are the dominant source of fluctuations in the economy.

This analysis could be extended to derive the optimal monetary policy rule in a scenario of financial frictions. Rotemberg and Woodford (1999) show how this can be done in a sticky price model without financial frictions. It seems interesting to see how Rotemberg and Woodford's results would change in a limited participation model with financial frictions. Finally, considering the model studied here, it seems that monetary policy performance might be improved if some indicator of credit market imperfections, like the risk premium or the bankruptcy rate, were included in the interest rate rule. These issues are left for future research.

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Tables and Figures

Table 1: Summary statistics

A.- Relative standard deviations with respect to output			
	Sample Data (1970:1-2000:4)	SI Model	AI Model
Consumption	0.83	1.09	1.20
Investment	4.55	4.55	4.94
Labor	0.96	1.48	1.52
Government spending	0.41	0.41	0.41

B.- Correlations			
corr(output,labor)	0.85	0.70	0.66
corr(output,investment)	0.91	0.69	0.65
corr(investment,labor)	0.74	0.63	0.60
corr(output,risk premium)	-0.33	0	-0.33
corr(prices,int. rate)	0.22	0.10	0.26
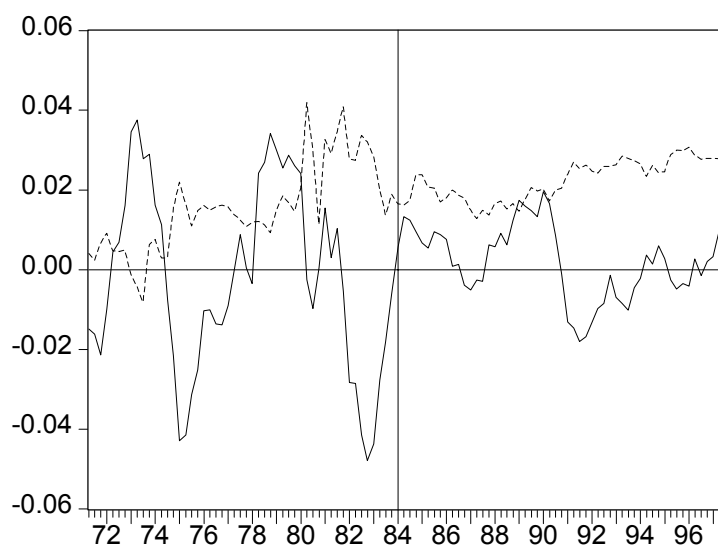
Figure 1: Real US GNP versus the spread between the Bank Prime rate and the Three-month commercial paper rate.

In the figure, the solid line denotes the real GNP, whereas the dashed line refers to the spread between the Bank Prime rate and the Three-month commercial paper rate. *Source: Board of Governors of the Federal Reserve System.*

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Figure 2: **Technology shock under constant money growth rule.**
− Symmetric information
−− Asymmetric information
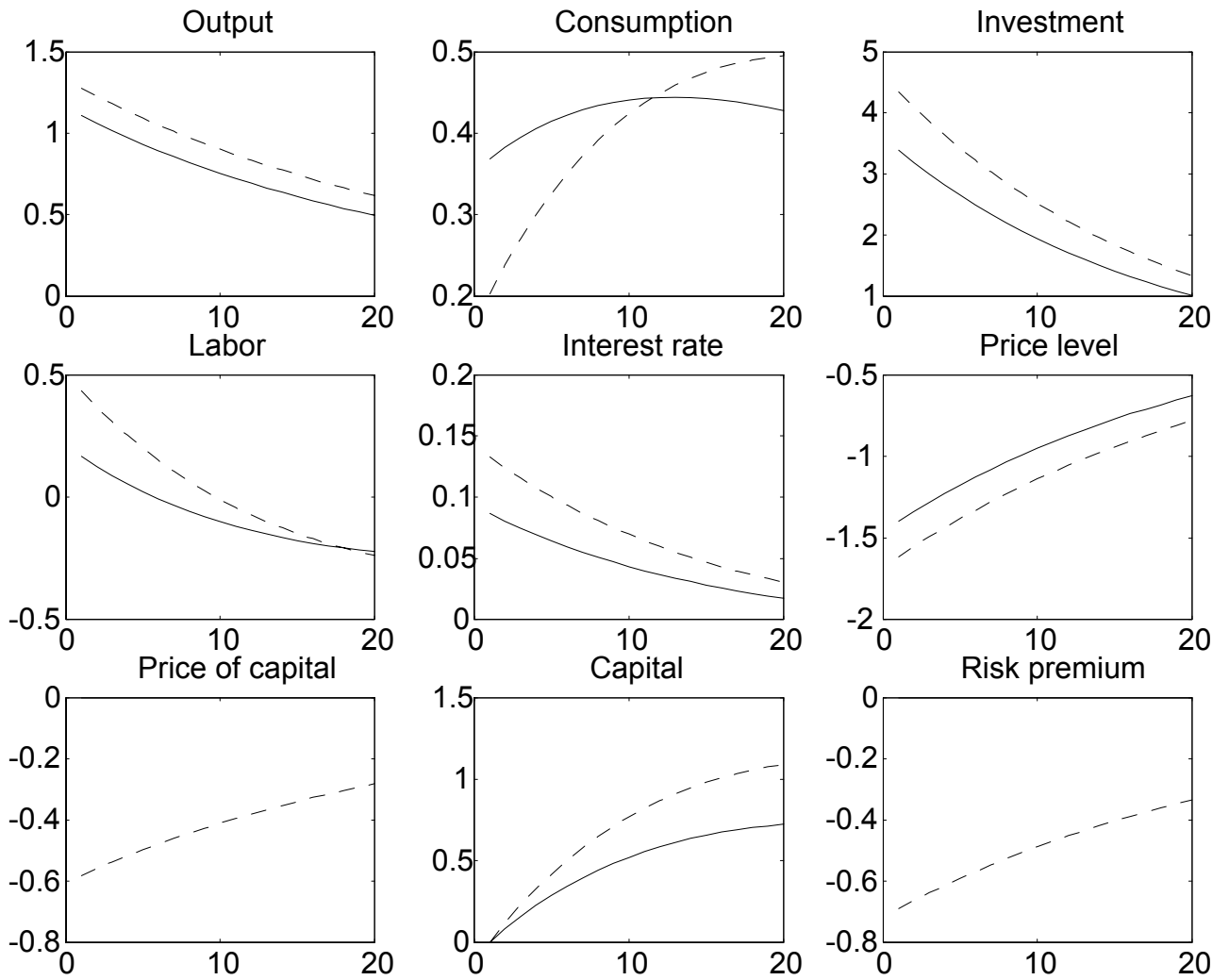
Figure 3: **Government spending shock under constant money growth rule.**
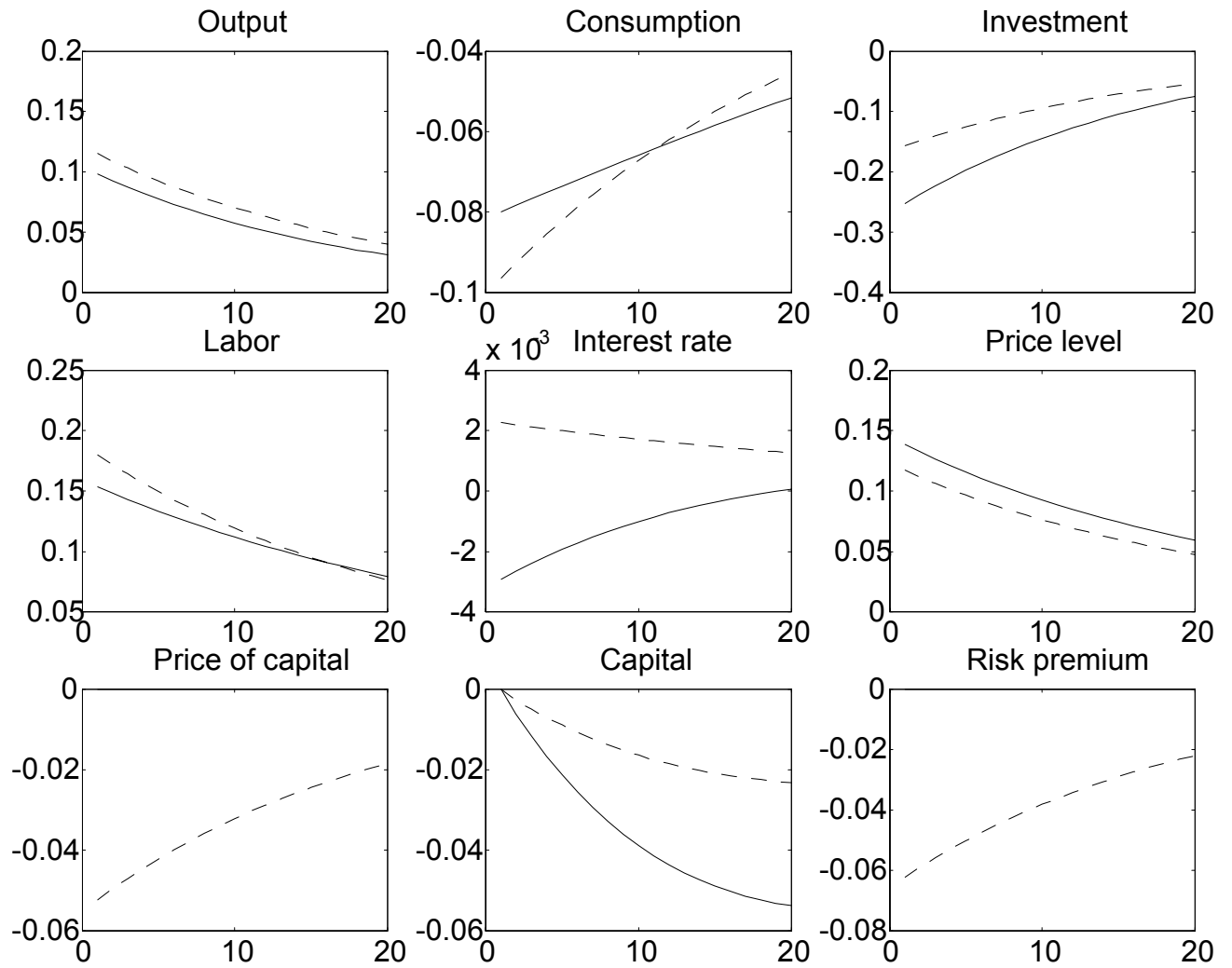− Symmetric information
−− Asymmetric information

Figure 4: **Technology shock in the symmetric information model.**
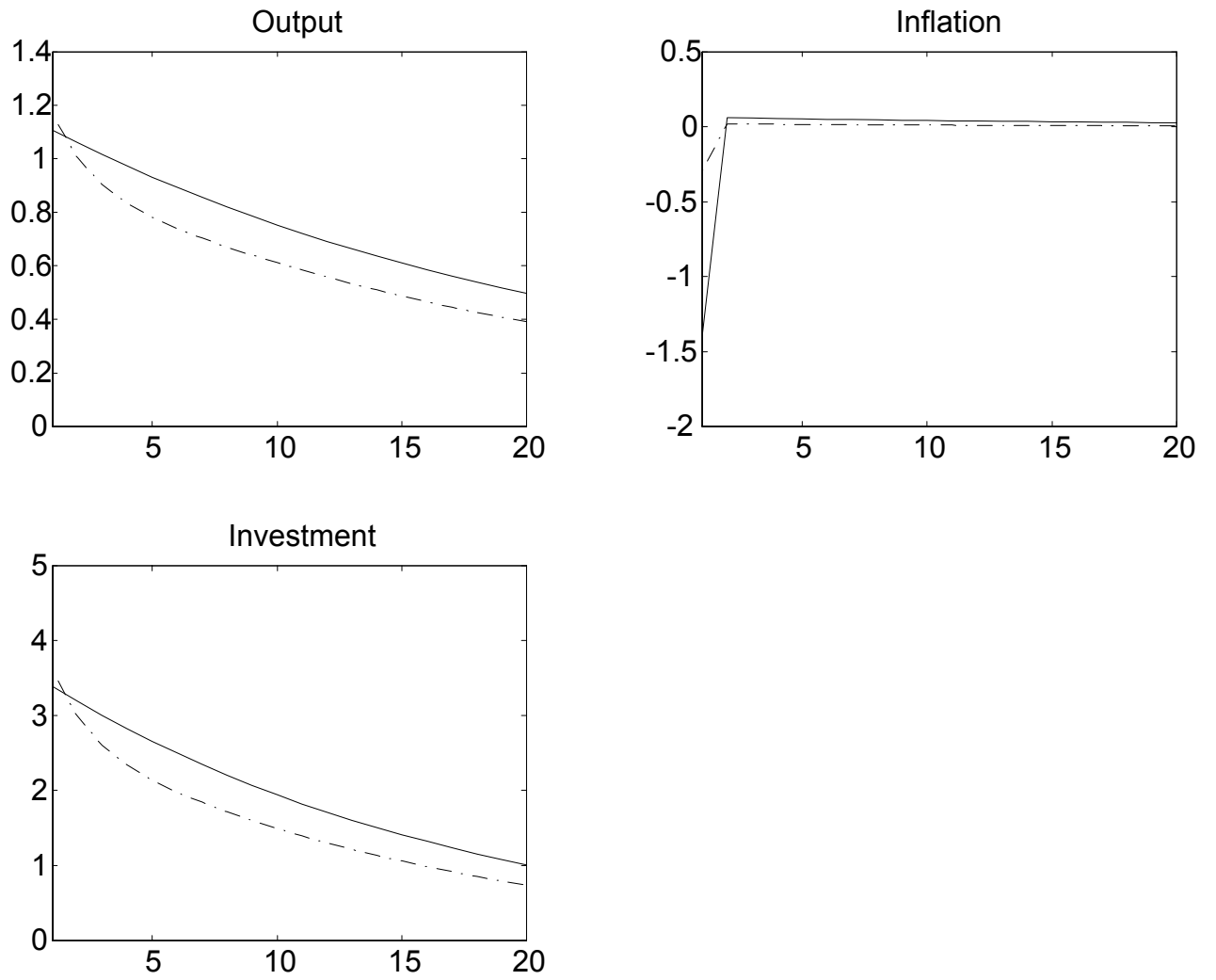— Constant money growth
—· Interest rate rule

Figure 5: **Technology shock in the asymmetric information model.**
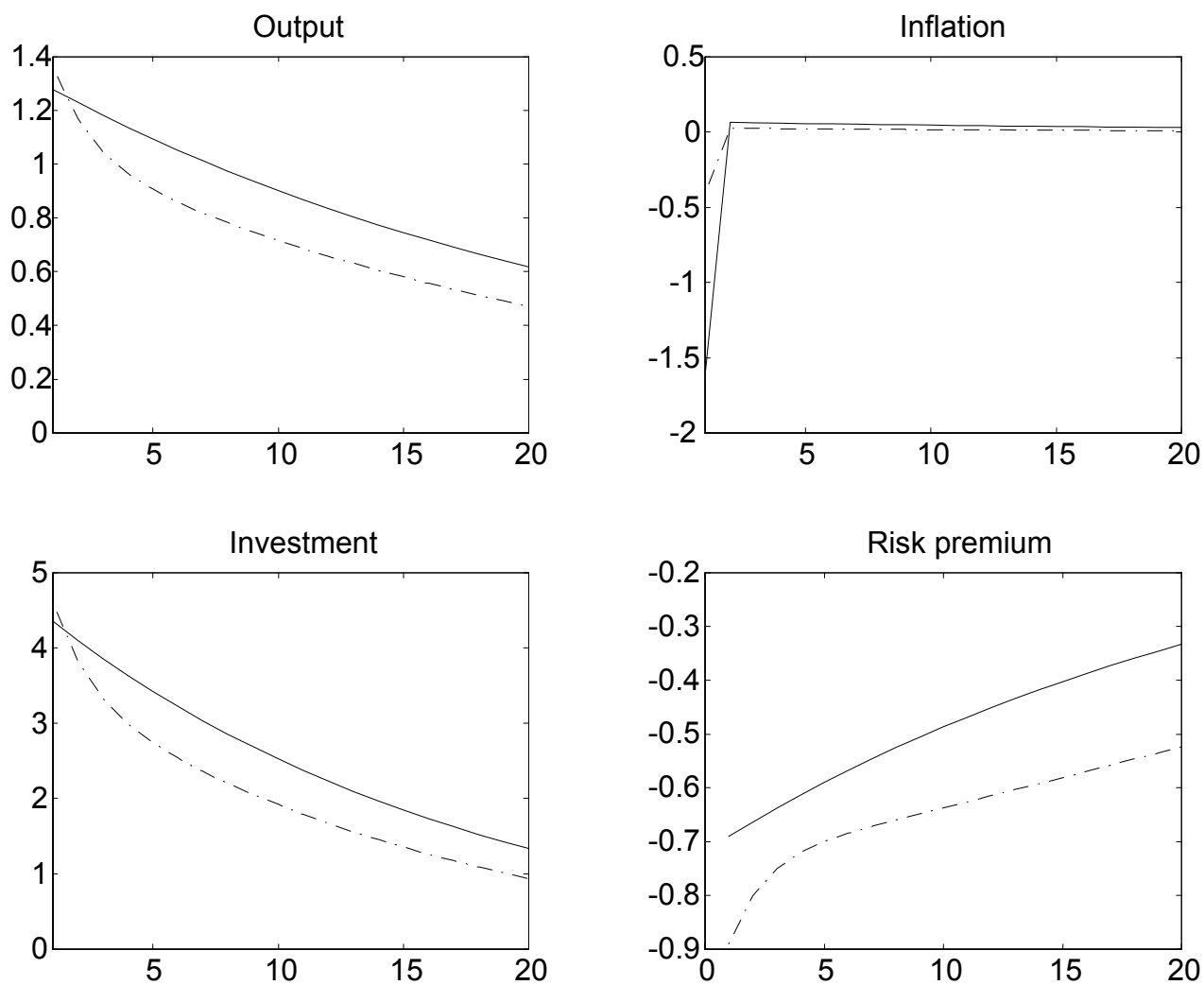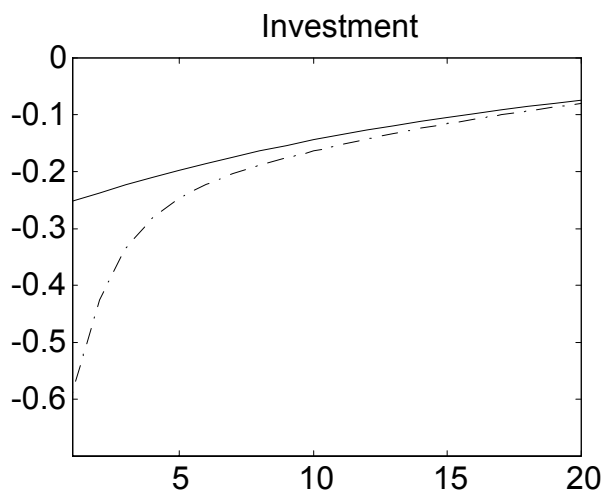— Constant money growth
—· Interest rate rule

Figure 6: **Government spending shock in the symmetric information model.**
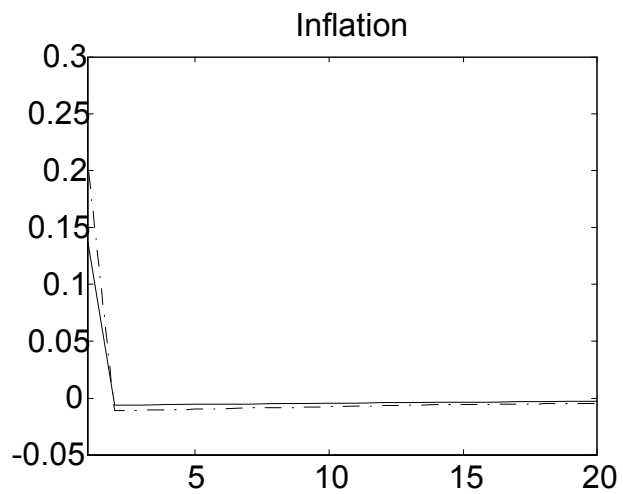— Constant money growth
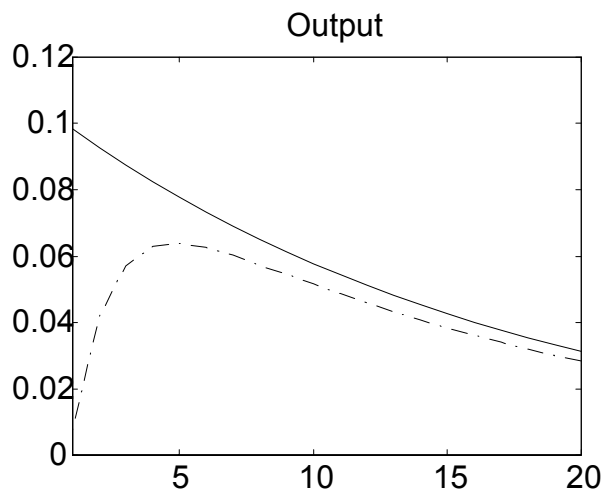—· Interest rate rule

Figure 7: **Government spending shock in the asymmetric information model.**
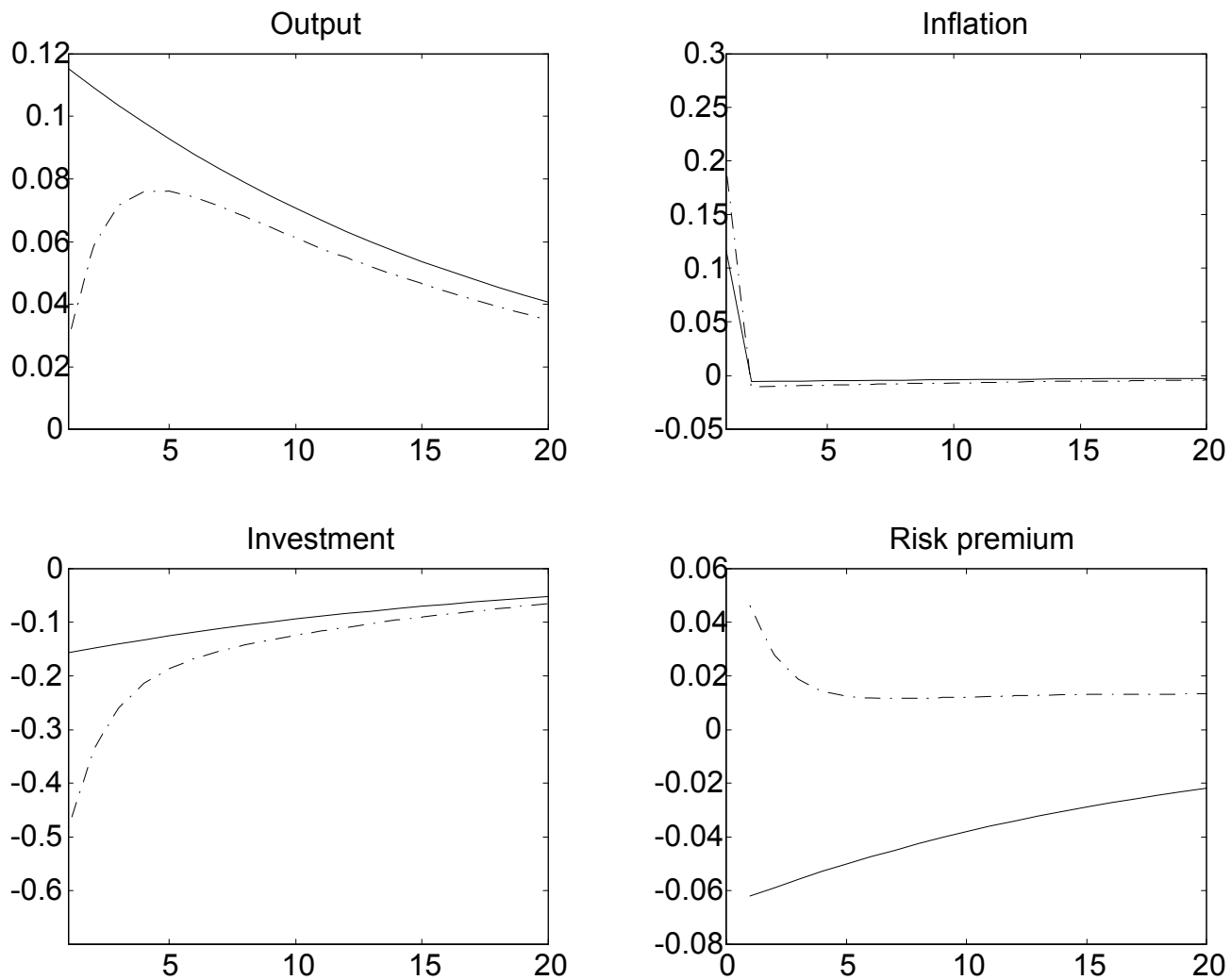— Constant money growth
—· Interest rate rule

Figure 8: **Stabilization properties of the interest rate rule under technology and government spending shocks.**
− Constant money growth
−· Interest rate rule
−∗ RBC model

Output-Symmetric information

Output-Asymmetric information

Output-Symmetric information

Output-Asymmetric information