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CAN FINANCIAL FRICTIONS HELP EXPLAIN THE PERFORMANCE OF THE US FED?*

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Abstract

This paper analyzes the contribution of additional factors, apart from monetary policy, to the stabilization of the economy observed in the US since the 1980s. I estimate a limited participation model with financial frictions, allowing for changes in the interest rate rule, financial frictions, and shock processes. The results confirm the well-known differences in the interest rate rules between subsamples. However, when monitoring costs are considered, these differences are much smaller. A comparison of fit across several specifications finds that a decrease in financial frictions was more important than changed monetary policy or changed shock processes in stabilizing the economy. These results highlight the important differences in the effects of shocks and policies between limited participation and sticky price models.

Keywords: financial frictions, monetary policy rules, limited participation.

JEL Classification: E13, E42, E44, E52, E58.

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1 Introduction

This paper investigates whether the presence of financial frictions can help explain the reduction in the variability of output and inflation observed in the US since the 1980s. In contrast with the traditional view that assigns a dominant role to monetary policy, I allow other factors as well, estimating the interest rate rule followed by the Federal Reserve Bank in the last 40 years allowing for changes in the monetary policy rule, the degree of financial frictions and shock processes.

The reduced volatility of output and inflation has been mostly attributed to the way monetary policy was conducted mainly after the arrival of Paul Volcker at the Fed in 1979:3. In particular, most empirical research identifies a different policy rule for each period (e.g. Clarida et al. (1999), Judd and Rudebusch (1998)), reflecting a central bank more concerned with inflation stabilization after the 1980s. But in addition to the improved policy hypothesis, other authors ascribe this stabilization to more diverse sources such as the management of inventories (McConnell and Pérez-Quirós (2000); Blanchard and Simon (2001)), good luck reflected in reduced volatility of exogenous shocks (Sims (1990); Bernanke and Mihov (1998)), and asymmetric business cycles (Jovanovic (2003)), to mention some of them.

The present work differs from previous literature in the fact that financial 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 financial frictions may amplify and propagate the effects of exogenous shocks.[1] Second, the effects of monetary policy rules can be altered by the presence of these frictions.[2] And third, because of the development of financial markets, the degree of financial frictions themselves may have changed[3], which could alter the effects of exogenous shocks. Thus, this paper asks whether monetary policy alone, as usually modeled, suffices to explain the *Post-Volcker* stabilization of the economy, or whether other factors, in particular credit market imperfections, have also played a role in this stabilization.

[1] See Bernanke et al. (2000), Carlstrom and Fuerst (2000), and de-Blas-Pérez (2003).
[2] See de-Blas-Pérez (2003).
[3] See Fender (2000).

There are three main blocks in this paper. First, in Section 2 postwar US data are analyzed to detect whether there is a clear breakpoint in the series considered. The breakpoint has usually been identified with the differences in the conduct of monetary policy introduced by Paul Volcker. Since there may be many other possible explanations for this breakpoint, here I undertake a non-informed approach and perform stability tests on the moments of the series to detect a statistically significant breakpoint.

Once a breakpoint has been identified, in Section 3 I set up a model of the business cycle to replicate the behavior of the data. This constitutes the second block. I consider a monetary economy in which some agents cannot access financial markets immediately in response to shocks (limited participation), which allows money to have real effects. In addition, credit market imperfections are added by assuming that the agents who produce capital goods face an agency cost problem. This introduces a kind of financial accelerator in the economy. Finally, 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 4 defines and solves for the competitive equilibrium in this model.

The third block of the paper covers the calibration and the results. I calibrate the coefficients of the interest rate rule, shock processes and the degree of financial frictions for each of the two sub-samples, in Section 6. First, I calibrate the rule and shock processes assuming that there are no financial frictions and then taking them as given. Then, I also calibrate the degree of financial frictions and check how this affects the results.

There are four results worth pointing out. First, the breakpoint for the series considered is 1981:2. Second, 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. Third, interestingly, with positive monitoring costs the two calibrated rules are much less different. That is, a smaller change in policy suffices for stabilization when imperfect credit markets are considered, which may suggest a key role for credit market imperfections in modelling the stabilization effects of monetary policy. When the rule, shocks and monitoring costs are allowed to adjust between subsamples, the calibration reports interest rate rules that assign roughly the same weight to inflation and more weight to output stabilization after 1981:3. Also the degree of financial frictions is reduced by 10% after 1981:2., which can be explained by a development of financial markets since 1980s (Fender, 2000), and by policy measures favoring the reduction of financing costs. Fourth, regarding shocks, money demand processes are found to vary between subsamples, whereas the technology process remains relatively stable across time, which is consistent with standard literature. The paper concludes with some guidelines for further research.

2 Data and sample selection

To study the determinants of the changes in the volatility of output and inflation occurred in the US[4] the first question to answer is which point is the appropriate one to split the sample, if any. Most researchers choose as breakpoint 1979:3, when Paul Volcker assumed leadership of the Federal Reserve. That could be the approach in this paper, however there is an important debate over the location and causes of this breakpoint.[5] Therefore, I follow Collard, Fève and Langot (2001), and identify the potential breakpoint by using a test for *parameter instability and structural change with unknown breakpoint*.[6] With this procedure, it is the moments in the data that identify a breakpoint in the series, abstracting from any other consideration. This identification is based on Wald, Likelihood ratio (LR) and Lagrange multiplier (LM) tests.

The variables considered are output, inflation, interest rate, and a risk premium measure, reflecting the difference in the cost of external versus internal financing of firms, as an indication of financial frictions. The period studied is 1959:4-2000:3. Data are obtained from the FRED database at the FRB of St. Louis, and correspond to real GNP for output, GNP deflator index for inflation, the federal funds rate as the nominal interest rate, and the difference between the bank prime rate and the three month Treasury bill rate as the risk premium. Data are quarterly and are first logged and then detrended using the Hodrick-Prescott filter.

[4]This phenomenon is also observed in other countries as reported by Cecchetti and Krause (2001).

[5]For example McConnell and Pérez-Quirós (2000) argue it was due to a change in the volatility of consumption and investment; Sims (1980, 1999) bases the change in luck; finally, Jovanovic (2003) atributes it to asymmetric cycles.

[6]See Andrews (1993).

Tables 1a and 1b report the results for the test statistics computed together with the estimated breakpoint. When only the series of real GNP, GNP deflator inflation and the federal funds rate are considered for the test, the statistics report noncoincident results. Moreover, only the Wald test is significant. This statistic suggests a breakpoint at 1980:4, only 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, inflation and interest rates, results change as shown in Table 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 (2001). I will take as the breakpoint the one indicated by the LM and LR tests and disregard the Wald test, since it often yields very large numbers and tends to overreject the null hypothesis.

Quarter 1981:2 could arise as a breakpoint for several reasons. 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. However, there were also crucial changes in tax policy at that time (McGrattan and Prescott, 2003). The *Economic Recovery Tax Act* (also known as ERTA), implemented in 1981 by the Reagan administration, lowered income tax rates, increased investment tax credits, and liberalized the depreciation of assets. The fact that this breakpoint is found after including the spread betwen the bank prime rate and the three month Treasury-bill rate suggests that changed financial conditions are an important aspect of the breakpoint. But this does not tell us whether spreads were changed more by monetary policy or by tax policy, and does not rule out a role for other factors, such as financial innovation.

Using this breakpoint, Table 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 inflation, whose variability is reduced by around 20 and 40%. Figure 1 plots the data reflecting the reduction in volatilities reported in Table 2.

The table also shows a change in the correlation between output and interest rates after 1981:2, shifting towards a positive correlation in which output leads the interest rate. This may suggest a central bank reacting positively to output and inflation deviations from targets after

1981:2. In addition, there is a negative correlation between output and the risk premium. This negative correlation is interpreted as reflecting financial frictions: in good times, when output is high, it is easier for borrowers to obtain external financing at a lower cost, and vice versa. This is the stylized fact that underlies the mechanism of the financial accelerator that I use in this paper.

Are these results very different from the ones that would be obtained by splitting the sample according to the Pre- and Post-Volcker periods? Table 2 also shows the moments when the breakpoint is 1979:3. It is worth noticing that the estimated moments for the first sub-sample (1959:4-1973:2) are the same as those when the breakpoint is 1981:2. The differences appear in the second sub-sample. However, the reduction in the volatility of output and inflation still appears using this alternative split. Also, the estimates again show the negative relationship between output and the risk premium.

Summing up, estimated moments of the data for the period 1959:4-2000:3 show that there is a breakpoint in the sample at a point near 1981:2. This breakpoint is associated with a reduction in the volatility of the variables considered in the second subsample with respect to the first one. Given these results, the next step is to analyze whether the reduced volatility of output, inflation 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 financial frictions, that alter the effects of monetary policy, have contributed to this stabilization of the economy.

3 A monetary economy

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, 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.

3.1 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[7] ($\bar{D}_t$), 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

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

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

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

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 variable N_t is a shock to money velocity assumed to follow a first order Markov process given by

$$N_{t+1} = N \exp(\varepsilon_{\nu,t+1}) N_t^{\rho_\nu}. \tag{4}$$

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 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.

[7] 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.

The optimal labor-leisure and deposits decisions are

$$\frac{U_{C,t}}{P_t} = -\left\{\frac{U_{L,t}N_t}{W_t} + \beta E\left[\frac{U_{L,t+1}(1-N_t)}{W_{t+1}}\middle|\Gamma_{1,t}\right]\right\}, \tag{5}$$

$$E\left[\frac{U_{L,t}}{W_t}\middle|\Gamma_{0,t}\right] = \beta E\left[\frac{U_{L,t+1}R_t}{W_{t+1}}\middle|\Gamma_{0,t}\right], \tag{6}$$

where U_C and U_L denote the marginal utility of consumption and disutility of labor, respectively. 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 the time t money demand shock to households, and the technology shocks at time $t-1$; $\Gamma_{1,t}$ includes $\Gamma_{0,t}$ plus time t technology shocks.

Equation (6) 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)).

3.2 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

$$Y_t = F(A_t, K_t, H_t) = A_t K_t^{\alpha_k} H_t^{\alpha_h}, \tag{7}$$

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

$$A_{t+1} = \exp(\varepsilon_{a,t+1}) A_t^{\rho_a}, \tag{8}$$

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:

$$\bar{B}_t^d \geq \bar{W}_t H_t + \bar{P}_t Q_t Z_t^d, \tag{9}$$

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:

$$Z_t^d = K_{t+1} - (1-\delta) K_t, \tag{10}$$

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

$$E_0 \sum_{t=0}^{\infty} \Theta_{t+1} \bar{\Pi}_t^f, \tag{11}$$

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

$$\Theta_{t+1} = -\frac{\beta^{t+1} U_{L,t+1}}{\bar{W}_{t+1}}. \tag{12}$$

Maximizing (11) subject to equation (9), the optimal input demands made by firms are obtained. The representative firm demands labor and capital, respectively, according to

$$\frac{\bar{W}_t}{\bar{P}_t} = \frac{\alpha_h Y_t}{H_t R_t}, \tag{13}$$

$$R_t E_t\left(\Theta_{t+1}\right) = E_t\left\{\Theta_{t+2}\frac{\bar{P}_{t+1}}{\bar{P}_t}\frac{Q_{t+1}}{Q_t}\left[R_{t+1}(1-\delta)+\frac{\alpha_k Y_{t+1}}{K_{t+1}Q_{t+1}}\right]\right\}. \tag{14}$$

Note that all decisions made by firms, unlike households' deposit choice, are based on the complete information set at t. Labor demand (13) is affected by the interest rate since it is paid in advance. Capital demand (14) 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 (12). The left-hand side of equation (14) 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 $t+2$.

3.3 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

$$\bar{\Pi}_t^{fi} = R_t\bar{X}_t. \tag{15}$$

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

3.4 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,[8] so I assume $NW_t = Y_t^{\xi}$.

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.[9] 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

$$\bar{\omega}_t \equiv R_t^k(1 - NW_t). \tag{16}$$

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:

$$1 - NW_t = Q_t \left\{ \int_{1-\omega}^{\bar{\omega}_t} \widetilde{\omega}_t \Phi(d\widetilde{\omega}_t) - \Phi(\bar{\omega}_t)\mu_c + [1 - \Phi(\bar{\omega}_t)]\bar{\omega}_t \right\} \equiv Q_t g(\bar{\omega}_t). \tag{17}$$

[8] 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.

[9] 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.

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.[10]

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:

$$Q_t \left\{ \int_{\bar{\omega}_t}^{1+\omega} \widetilde{\omega}_t \Phi(d\widetilde{\omega}_t) - [1 - \Phi(\bar{\omega}_t)]\bar{\omega}_t \right\} \equiv Q_t f(\bar{\omega}_t) = NW_t, \tag{18}$$

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 (17) and (18) above, it follows that

$$Q_t = \frac{1}{[E\tilde{\omega}_t - \Phi(\bar{\omega}_t)\mu_c]} = \frac{1}{[1 - \Phi(\bar{\omega}_t)\mu_c]}. \tag{19}$$

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:

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

3.5 The monetary authority

In this model, the central bank is in charge of 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 some 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 (Taylor, 1993), the monetary authority will be assumed to employ a lagged Taylor rule in performing this task. The central bank will set the interest rate as follows:

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

[10] 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).

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 ($\gamma_\pi, \gamma_y > 0$).

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 simplifying the analysis. 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.

4 Equilibrium

To analyze the general equilibrium I need to express the dynamics in stationary terms. Therefore nominal variables are divided by monetary holdings at the beginning of period t, $\bar{M}_t^s$. For convenience, I will omit time subscripts and primes will denote next period's variables.

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.

The state of the economy is (S, s) with $S = (M, K)$, $\tilde{s} = (a_{-1}, \nu)$, and $s = (a, \nu)$. Notice that households choose deposits before the current state of the economy is revealed, but after observing ν_t. Therefore the deposit choice is made subject to $\tilde{s} = (a_{-1}, \nu)$, whereas the rest of variables take $s = (a, \nu)$.[11] This difference in shock information motivates the introduction of the two information sets, Γ_1 and Γ_0.[12]

The model can be easily solved by assuming the family structure explained in section 3. According to this assumption, one can think of a *representative agent* of the whole economy. The representative agent has m units of money balances, and k units of capital, let $S_i = (m, k)$

[11] Note that $s = (a, \nu)$ includes $\tilde{s} = (a_{-1}, \nu)$.

[12] Recall that Γ_0 and Γ_1 include $(S, \tilde{s})$ and (S, s), respectively as already mentioned in Section 3.1.

for the individual's variables. The state of this individual is then given by the vector (S_i, S, s). Therefore the Bellman equation of this representative agent's program is

$$
\begin{aligned}
&V(S_i, S, s) = \\
&\qquad = \max_{D \in [0,M]} \left\{ E_{\Gamma_1|\Gamma_0} \left[\max_{C,L,K',H,B^d} U(C,L) + \beta E_{\Gamma_0'|\Gamma_1} V(S_i', S', s') \right] \right\} \qquad (21)
\end{aligned}
$$

subject to

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

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 $C(S_i, S, s)$, $L(S_i, S, s)$, $D(S_i, S, \tilde{s})$, $K'(S_i, S, s)$, $B^d(S_i, S, s)$, $H(S_i, S, s)$, $M'(S_i, S, s)$, $\Pi^f(S_i, S, s)$, 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 (determined by equation (4)),

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

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

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

$$
\begin{gathered}
C + i = Y, \\
M = 1, \\
D + X = B^d, \\
H = L, \\
k = K, \\
m = M,
\end{gathered}
$$

and

$$Z^d = Z^s.$$

Under certain restrictions, there will exist equilibria in which both cash-in-advance constraints (2) and (9) 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.

5 Parameters of the model

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_ν, σ_a^ε and σ_ν^ε). I take some of these parameters from previous business cycle literature and calibrate others to match some moments of US data over the period 1980:1-2000:3.

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 is selected somewhat high, but lies within a range which is commonly employed in macroeconomic studies because it helps the model generate sufficient fluctuations. 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.

Taking data on corporate profits after tax and US GDP for the period 1947:1-2002:1 I obtain an elasticity of profits (net worth) with respect to output equal to 3.84. This is similar to the value $\xi = 4.45$ assigned by Gertler (1995). 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.[13] 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, obtained from combining equations (16)-(19) in the steady state.

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 the eight remaining parameters, ϑ, is calibrated to match second order moments where

$$\vartheta = (\gamma_r, \gamma_\pi, \gamma_y, \rho_a, \rho_\nu, \sigma_a^\varepsilon, \sigma_\nu^\varepsilon, \mu_c). \tag{22}$$

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 constant. This method consists of choosing the parameters of the model that help minimize the difference between the vector of empirical moments obtained in the data, $\mathcal{M}$, and those generated by the model, using the calibrated parameters, $\mathcal{M}(\vartheta)$. The criterion is to minimize the following loss function:

$$\mathcal{L}(\vartheta) = [\mathcal{M}(\vartheta) - \mathcal{M}]' \times \mathcal{W}(\mathcal{M}) \times [\mathcal{M}(\vartheta) - \mathcal{M}],$$

where $\mathcal{W}(\mathcal{M})$ is the inverse of the covariance matrix of the moments derived from the actual data.

In the calibration, I omit the period between 1979:3-1981:2 of nonborrowed reserves due to its high volatility. There is a wide set of moments to choose among in order to calibrate the

[13] 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).

parameters. I will employ those moments related with the interest rate rule and the volatility of the main variables of interest. In particular, I will consider the following eight moments:

$$\mathcal{M}(\vartheta) - \mathcal{M} = \begin{bmatrix} \sigma_y(\vartheta) - \sigma_y \\ \sigma_\pi(\vartheta) - \sigma_\pi \\ \sigma_R(\vartheta) - \sigma_R \\ \rho[(R_t, \pi_{t-1}), \vartheta] - \rho(R_t, \pi_{t-1}) \\ \rho[(R_t, y_{t-1}), \vartheta] - \rho(R_t, y_{t-1}) \\ \rho[(y_t, y_{t-1}), \vartheta] - \rho(y_t, y_{t-1}) \\ \rho[(\pi_t, \pi_{t-1}), \vartheta] - \rho(\pi_t, \pi_{t-1}) \\ \rho[(R_t, R_{t-1}), \vartheta] - \rho(R_t, R_{t-1}) \end{bmatrix}. \tag{23}$$

Thus, the parameters are calibrated to match standard deviations of output, inflation and interest rate; the correlations between current nominal interest rate and lagged inflation and output,[14] plus the autocorrelations of output, inflation and interest rate. Each of the moments is computed from data generated by the model using the parameters in ϑ, and detrended by the Hodrick-Prescott filter, for each of the two sub-samples.

I consider first the calibration of $\vartheta' = (\gamma_r, \gamma_\pi, \gamma_y, \rho_a, \rho_\nu, \sigma_a^\varepsilon, \sigma_\nu^\varepsilon)$, assuming that monitoring costs take a fixed value, either zero or positive. The best match is given in Table 3, for monitoring costs equal to zero and 0.2, the value advocated by Fuerst (1995). I report the calibrated values for each parameter with standard errors in parenthesis. The right most column reports the *J-statistic* resulting from the minimization procedure.

Note that when monitoring costs are zero, the difference between the two interest rate rules for each sub-sample is substantial. The degree of interest rate smoothing is much higher after 1981:3 and also the weight on output stabilization. However, unlike most previous studies, the model fails to report an interest rate rule with more weight on inflation stabilization after 1981:2. Regarding shocks, both technological and money demand shocks show a high persistence in both subsamples, with more variance of technology rather than money demand shocks.

When nonzero monitoring costs are considered, the differences between the two subsamples are reduced. The degree of interest rate smoothing differs less between subsamples (and is also smaller overall). The coefficients on inflation and output stabilization vary less, and the direction of change is as expected. Finally, shocks are still persistent in both subsamples but neither

[14] It is natural to choose these lagged correlations since this is the form of the interest rate rule the central bank uses in this model.

the autocorrelation nor the standard deviation of money demand shocks is significant, which may suggest that there is an identification problem with these parameters. Thus, the introduction of a positive level of monitoring costs yields interest rate rules more in line with previous research. It also helps the model match the data since the J-statistics are substantially reduced. Summarizing, introducing Fuerst's value of financial frictions helps the model's performance in two directions. First, with the same set of parameters to be calibrated, the model matches more moments than was the case for the version without financial frictions, and second, the calibrated rules show a central bank more concerned with inflation and output stabilization after 1981:3 as in the literature.[15]

The next step is to allow monitoring costs also to be calibrated simultaneously with the other parameters, that is $\vartheta = (\gamma_r, \gamma_\pi, \gamma_y, \rho_a, \rho_\nu, \sigma_a^\varepsilon, \sigma_\nu^\varepsilon, \mu_c), .$ The resulting coefficients are reported in Table 4. Choosing the best monitoring costs to match the data considerably improves the fit in both subsamples. The degree of interest rate smoothing is higher after 1981:3, and so is the weight on both output and inflation stabilization. In both cases, technology and money demand shocks are highly persistent, with technology shocks being relatively more dominant after 1981:3. Notice that money demand shocks are not significant in the second subsample. Finally, the degree of financial frictions measured in this paper by monitoring costs falls by around 10% in the second subsample with respect to the first, reflecting a reduction of financial imperfections in time. The implied moments are reported in Table 5. The calibration of the two subsamples matches within one standard error the targeted moments. However, the model has difficulty in replicating the correlations between current interest rates and current and future output.

6.1 Robustness analysis

In this section I study the robustness of the results to different specifications of the interest rate rule. I consider a current and a forward-looking version of the rule followed by the central bank.

The current interest rate rule is of the form

$$r_t = \gamma + \gamma_r r_{t-1} + (1 - \gamma_r)\bar{r}_t, \tag{24}$$

[15] See, among others, Clarida, Galí and Gertler (2000).

where

$$\bar{r}_t = \tilde{\gamma}_\pi \pi_t + \tilde{\gamma}_y y_t, \tag{25}$$

that is, the central bank sets today's interest rates as a function of today's deviations of inflation and output from their respective targets.

The forward-looking rule is of the type employed by Clarida, Galí and Gertler (2000)

$$r_t = \gamma + \gamma_r r_{t-1} + (1 - \gamma_r)\bar{r}_t, \tag{26}$$

with

$$\bar{r}_t = \tilde{\gamma}_\pi E_t \pi_{t+1} + \tilde{\gamma}_y E_t y_{t+1}, \tag{27}$$

according to which the central bank reacts to expected deviations of inflation and output from their respective targets.

I estimate the model with these new rules included, and report the results in Table 6. Standard errors are reported in parenthesis. I also report the calibration of the lagged rule as a reference. The coefficients reported in Table 6 are $\tilde{\gamma}_\pi$ and $\tilde{\gamma}_y$, where $\tilde{\gamma}_\pi = \dfrac{\gamma_\pi}{1-\gamma_r}$ and $\tilde{\gamma}_y = \dfrac{\gamma_y}{1-\gamma_r}$, in the notation of Tables 3 and 4. Qualitative results do not change with the specification of the rule. Absent financial frictions, the weight on both inflation and output deviations are higher in the second subsample than in the first one. The degree of interest rate smoothing also increases after 1981:3. With positive and constant monitoring costs, there is no big difference in the weight on inflation stabilization across subsamples. When the degree of financial frictions is also calibrated (which is the case reported in the table) the calibration reports a central bank that assigns more weight on both inflation and output stabilization after 1981:3 as reported in the previous discussion.

7 Discussion of results

This calibration leads to several conclusions. First, the calibrated coefficients of the interest rate rule confirm the common result about US monetary policy, also reported in Clarida, Galí, and Gertler (2000), and Judd and Rudebusch (1998). 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, whereas the second rule (*Volcker-Greenspan* period) shows a central bank reacting more aggressively to both inflation and output. A similar pattern can also be observed here. In spite of the use of a lagged versus a forward-looking interest rate rule, the baseline calibration here suggests that the US Fed reacted more strongly to inflation and 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 5. However, the resulting policy rule for the second subsample is not so aggressive as in Clarida, Galí, and Gertler (2000) in that the reaction to inflation is not so high. This outcome points to other factors contributing as well to the stabilization of the economy. Another difference is that Clarida, Galí and Gertler (2000) do not obtain significant values for the response to output deviations in their estimation. Here the calibrated rules do respond significantly to output, a fact that is specially important in this type of model, as explained below.

Second, the exercise reports higher financial frictions (measured here by monitoring costs) in the first subsample than in the second, where they are reduced by around 10%. This reduction in the degree of financial frictions is consistent with more efficient financial markets, suffering less severe asymmetric information problems, since the 1980s. These results are in line with Fender's (2000) 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 (1993). 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 are found to be dominant in the first period, whereas technology shocks remain more or less stable between subsamples, which is consistent with previous literature. It is worth analyzing this point in more detail.

In a previous paper, I showed that in a limited participation model, the effects of interest rate rules are strengthened by credit market imperfections. That is, if the interest rate rule stabilizes (destabilizes), it stabilizes (destabilizes) even more if there are credit market imperfections.

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, following an interest rate rule that reacts to deviations of both output and inflation stabilizes both variables in a limited participation framework in the face of a technology shocks. However, in response to money demand shocks, there is a trade-off between stabilizing output and inflation.[16] Note that in the calibration results, money demand shocks were relatively more important in the first subsample, precisely when monitoring costs are higher. 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 may have emphasized the stabilization effects of the interest rate rule in this period.

Galí, López-Salido, and Vallés (2003) find that 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 calibration studied here it is still true that the rule before 1981:2 destabilized the economy, 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 more 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.

7.1 Relative importance of 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 most relevant. To this end, I perform three different exercises. First, I calibrate the parameters in ϑ assuming that the coefficients of the rule remain the same across both subsamples, while allowing monitoring costs and shock processes to vary. I will refer to this case as *Model 1.* Then I hold the shock processes constant across subsamples, letting the rest of

[16] The different stabilization properties of interest rate rules in limited participation models versus sticky price ones are analyzed in detail in de-Blas-Pérez (2003).

parameters vary (*Model 2*). And finally, I maintain the same degree of monitoring costs across subsamples, while the coefficients of the rule and shock processes change (*Model 3*). This will give an idea of how much explanatory power is lost by keeping some set of parameters constant across subsamples, and therefore which parameters are most important to explain the dynamics of the data. In order to compare among the three sets of calibrations, I compute the Akaike Information Criterion (AIC) and the Schwartz Information Criterion (BIC) to discriminate across models. The results are presented Table 7 and the corresponding estimated moments appear in Table 8.

According to these criteria, the best model is the one corresponding to the lowest AIC or BIC statistic. Keeping the same shock processes across subsamples implies the lowest statistic in both cases, meaning that this model fits best. In the same line, the worst fit is the one that maintains the same level of monitoring costs before and after 1981:3, suggesting that this is the parameter where a breakpoint is most important. Finally, fixing the coefficients of the rule stays in an intermediate place.

These results do not favor explaining the reduction in the volatility of output and inflation after the 1980s entirely as a monetary effect. In fact, the results suggest that a change in financial frictions was the most important factor in stabilizing the economy. The role of shock processes across subsamples seems not to be so important in explaining the differences in volatility of variables before and after 1981:3, in contrast with the literature that argues that "luck" was the main reason for the change in volatility of output and inflation after the 80s.

8 Conclusions

This paper investigates whether the presence of financial frictions, shown to affect the results of monetary policy conducted by interest rate rules, can help explain the differences in the variability of output and inflation between the *Pre-* and the *Post-Volcker* periods. The data show a breakpoint in 1981:2, stronger when a measure of risk premium is introduced. In the absence of financial frictions, the calibrated rules for each subsample 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. With positive monitoring costs the rules are much less different, suggesting that a smaller change in policy suffices for stabilization when imperfect credit markets are considered. 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 output stabilization after 1981:3. The degree of financial frictions is reduced by 10% after 1981:2. Finally, regarding shocks, money demand processes vary between subsamples, whereas technology innovations remain relatively stable across time, which may have affected the stabilizing objectives of monetary authorities over time.

This paper is part of a line of research that tries to show the effects of financial frictions in the effects of monetary policy. The analysis in this paper suggests there is a role for financial frictions in the stabilization and destabilization of the economy. Therefore, the following step is to study which is the optimal monetary policy in a framework when there are financial frictions that amplify and to some extent also propagate the effects of exogenous shocks over the cycle. Another important question to answer is whether central banks should react to asset prices of any other indicator of financial economic activity. These topics are left for future research.

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A Tables

Table 1a: Instability tests (I)

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 significance level of 10%, 5%, and 1%.
respectively. The number of parameters is p=9 and $\pi_0 = 30\%$.

Table 1b: Instability tests (II)

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 significance level of 10%, 5%, and 1%.
respectively. The number of parameters is p=13 and $\pi_0 = 25\%$.

Table 2: Estimated moments

	1959:4-1979:2	1981:3-2000:3	1959:4-1979:2	1979:3-2000:3
	Value	Value	(*Pre-Volcker*)	(*Post-Volcker*)
σ_y	1.5928 (0.2486)	0.9065 (0.1517)	1.5929 (0.2422)	1.3060 (0.3751)
σ_π	0.2867 (0.0512)	0.1600 (0.0137)	0.2867 (0.0491)	0.1998 (0.0277)
σ_R	0.3820 (0.0571)	0.2643 (0.0354)	0.3821 (0.0555)	0.3655 (0.0550)
σ_{rp}	0.1394 (0.0296)	0.1354 (0.0306)	0.1395 (0.0284)	0.1332 (0.0319)
$\rho(R_t, \pi_{t-1})$	0.4123 (0.1060)	0.2360 (0.0768)	0.4125 (0.1008)	0.1390 (0.1131)
$\rho(R_t, \pi_t)$	0.3170 (0.0789)	0.1722 (0.0968)	0.3171 (0.0783)	0.0767 (0.0936)
$\rho(R_t, \pi_{t+1})$	0.2313 (0.0907)	0.0586 (0.1342)	0.2314 (0.0960)	-0.0376 (0.1168)
$\rho(R_t, y_{t-1})$	0.1088 (0.0760)	0.4962 (0.0973)	0.1087 (0.0812)	0.1762 (0.0947)
$\rho(R_t, y_t)$	-0.1791 (0.1001)	0.3016 (0.1041)	-0.1792 (0.1053)	-0.1214 (0.1043)
$\rho(R_t, y_{t+1})$	-0.3740 (0.1122)	0.1188 (0.1194)	-0.3741 (0.1169)	-0.2635 (0.1348)
$\rho(y_t, rp_{t-1})$	-0.5092 (0.0545)	0.2003 (0.1268)	-0.5092 (0.0600)	-0.1189 (0.1070)
$\rho(y_t, rp_t)$	-0.2950 (0.0572)	0.2361 (0.0992)	-0.2951 (0.0616)	-0.0715 (0.0978)
$\rho(y_t, rp_{t+1})$	-0.0394 (0.0823)	0.2184 (0.0940)	-0.0394 (0.0828)	0.0007 (0.0758)
$\rho(y_t, y_{t-1})$	0.8650 (0.0242)	0.9067 (0.0163)	0.8650 (0.0247)	0.8667 (0.0216)
$\rho(\pi_t, \pi_{t-1})$	0.5004 (0.1011)	0.2114 (0.0883)	0.5005 (0.1051)	0.2403 (0.0857)
$\rho(R_t, R_{t-1})$	0.8151 (0.0399)	0.8954 (0.0302)	0.8151 (0.0389)	0.7610 (0.0901)

Standard errors in parentheses.

Table 3. Calibration results (I)

$\mu_c = 0$	γ_π (s.e.)	γ_y (s.e.)	γ_r (s.e.)	ρ_a (s.e.)	ρ_ν (s.e.)	σ_a^ε (s.e.)	σ_ν^ε (s.e.)	J_stat
1959:4-1979:2	0.9928 (0.0000)	0.0741 (0.0296)	0.3441 (0.0973)	0.9347 (0.0158)	0.8699 (0.2757)	0.0702 (0.0386)	0.0070 (0.0035)	15.83
1981:3-2000:3	0.7577 (0.1427)	0.1421 (0.0259)	0.6760 (0.0869)	0.9967 (0.0326)	0.7528 (0.0940)	0.0329 (0.0184)	0.0043 (0.0009)	51.49
$\mu_c = 0.2$								
1959:4-1979:2	1.1132 (0.0000)	0.1044 (0.0262)	0.2371 (0.0269)	0.9844 (0.3823)	0.9978 (3.3521)	0.0043 (0.0006)	0.0086 (0.0094)	3.78
1981:3-2000:3	1.0749 (0.0000)	0.2139 (0.0287)	0.3327 (0.0479)	0.8175 (0.1692)	0.9999 (0.6513)	0.0022 (0.0005)	0.0025 (0.0015)	29.87

Standard errors in parentheses.

Table 4. Calibration results (II)

	γ_π (s.e.)	γ_y (s.e.)	γ_r (s.e.)	ρ_a (s.e.)	ρ_ν (s.e.)	σ_a^ε (s.e.)	σ_ν^ε (s.e.)	μ_c	J_stat
1959:4-1979:2	0.9571 (0.2104)	0.0533 (0.0306)	0.3879 (0.1340)	0.9342 (0.0673)	0.9000 (0.3627)	0.0900 (0.0738)	0.0086 (0.0013)	0.0220 (0.0067)	1.28
1981:3-2000:3	0.9624 (0.0053)	0.1538 (0.0058)	0.4269 (0.0742)	0.9947 (0.3165)	0.9900 (33.01)	0.0900 (0.0302)	0.0003 (0.0106)	0.0199 (0.0008)	5.82

Standard errors in parentheses.

Table 5: Estimated moments (μ_c variable)

	1959:4-1979:2		1981:3-2000:3	
	Data	Model	Data	Model
σ_y	1.5928 (0.2486)	1.4660 (0.2486)	0.9065 (0.1517)	0.7770 (0.1060)
σ_π	0.2867 (0.0512)	0.2689 (0.0512)	0.1600 (0.0137)	0.1431 (0.0107)
σ_R	0.3820 (0.0571)	0.3697 (0.0571)	0.2643 (0.0354)	0.2565 (0.0279)
$\rho(R_t, \pi_{t-1})$	0.4123 (0.1060)	0.4264 (0.1060)	0.2360 (0.0768)	0.2183 (0.0452)
$\rho(R_t, \pi_t)$	0.3170 (0.0789)	0.5316 (0.0321)	0.1722 (0.0968)	0.2419 (0.0359)
$\rho(R_t, \pi_{t+1})$	0.2313 (0.0907)	0.8964 (0.0228)	0.0586 (0.1342)	0.5940 (0.0311)
$\rho(R_t, y_{t-1})$	0.1088 (0.0760)	0.1193 (0.0760)	0.4962 (0.0973)	0.4840 (0.0784)
$\rho(R_t, y_t)$	-0.1791 (0.1001)	0.3033 (0.0568)	0.3016 (0.1041)	0.6677 (0.0721)
$\rho(R_t, y_{t+1})$	-0.3740 (0.1122)	0.3493 (0.0566)	0.1188 (0.1194)	0.7005 (0.0658)
$\rho(y_t, y_{t-1})$	0.8650 (0.0242)	0.8464 (0.0242)	0.9067 (0.0163)	0.8944 (0.0138)
$\rho(\pi_t, \pi_{t-1})$	0.5004 (0.1011)	0.4591 (0.1011)	0.2114 (0.0883)	0.0521 (0.0690)
$\rho(R_t, R_{t-1})$	0.8151 (0.0399)	0.8137 (0.0399)	0.8954 (0.0302)	0.8595 (0.0185)

Standard errors in parentheses.

Table 6. Alternative calibrations of the interest rate rule (μ_c calibrated)

	$\tilde{\gamma}_\pi$	*(s.e)*	$\tilde{\gamma}_y$	*(s.e.)*	γ_r	*(s.e)*
Lagged rule						
1959:4-1979:2	1.56	(0.14)	0.09	(0.02)	0.39	(0.05)
1981:3-2000:4	1.68	(0.01)	0.27	(0.01)	0.43	(0.07)
Current rule						
1959:4-1979:2	1.78	(0.00)	0.16	(0.12)	0.62	(0.12)
1981:3-2000:4	2.65	(0.00)	0.28	(0.14)	0.77	(0.18)
Forward-looking rule						
1959:4-1979:2	1.84	(0.78)	0.28	(0.06)	0.60	(0.00)
1981:3-2000:4	1.46	(0.54)	0.32	(0.03)	0.49	(0.00)

Standard errors in parentheses.

Table 7. Model selection	*1959:4-2000:3*	
	AIC	*BIC*
Keeping interest rate rule fixed	0.1916	0.2089
Keeping shock processes fixed	0.1771	0.1932
Keeping monitoring costs fixed	0.2136	0.2334

Table 8: Estimated moments

	1959:4-1979:2				1981:3-2000:3			
	Data	Model-1	Model-2	Model-3	Data	Model-1	Model-2	Model-3
σ_y	1.5928 (0.2486)	0.6124 (0.1332)	0.4792 (0.1043)	1.2026 (0.1432)	0.9065 (0.1517)	0.5143 (0.1156)	0.6352 (0.0907)	0.7265 (0.1134)
σ_π	0.2867 (0.0512)	0.1116 (0.0265)	0.0916 (0.0250)	0.2373 (0.0256)	0.1600 (0.0137)	0.1237 (0.0109)	0.1447 (0.0107)	0.1321 (0.0136)
σ_R	0.3820 (0.0571)	0.1929 (0.0334)	0.1659 (0.0288)	0.3259 (0.0340)	0.2643 (0.0354)	0.2572 (0.0273)	0.2375 (0.0229)	0.2670 (0.0273)
$\rho(R_t, \pi_{t-1})$	0.4123 (0.1060)	0.0059 (0.0344)	0.0951 (0.0373)	0.3656 (0.0367)	0.2360 (0.0768)	0.1185 (0.0579)	0.1715 (0.0573)	0.2022 (0.0571)
$\rho(R_t, \pi_t)$	0.3170 (0.0789)	-0.0018 (0.0537)	0.1111 (0.0544)	0.4476 (0.0269)	0.1722 (0.0968)	0.1589 (0.0575)	0.1948 (0.0555)	0.2015 (0.0683)
$\rho(R_t, \pi_{t+1})$	0.2313 (0.0907)	0.5244 (0.0608)	0.6042 (0.0590)	0.8082 (0.0335)	0.0586 (0.1342)	0.6356 (0.0467)	0.6147 (0.0397)	0.5099 (0.0558)
$\rho(R_t, y_{t-1})$	0.1088 (0.0760)	0.3236 (0.0489)	0.3300 (0.0480)	0.1966 (0.0581)	0.4962 (0.0973)	0.5637 (0.0670)	0.3888 (0.0653)	0.5405 (0.0620)
$\rho(R_t, y_t)$	-0.1791 (0.1001)	0.5240 (0.0552)	0.5292 (0.0557)	0.3860 (0.0631)	0.3016 (0.1041)	0.7548 (0.0627)	0.5772 (0.0729)	0.7215 (0.0586)
$\rho(R_t, y_{t+1})$	-0.3740 (0.1122)	0.5346 (0.0493)	0.5496 (0.0507)	0.4061 (0.0588)	0.1188 (0.1194)	0.7057 (0.0716)	0.6334 (0.0703)	0.7684 (0.0452)
$\rho(y_t, y_{t-1})$	0.8650 (0.0242)	0.7690 (0.0143)	0.7906 (0.0142)	0.8168 (0.0149)	0.9067 (0.0163)	0.8349 (0.0102)	0.8518 (0.0155)	0.8683 (0.0146)
$\rho(\pi_t, \pi_{t-1})$	0.5004 (0.1011)	0.0856 (0.0647)	0.1259 (0.0510)	0.3986 (0.0554)	0.2114 (0.0883)	0.0867 (0.0758)	0.1046 (0.0653)	0.1193 (0.0771)
$\rho(R_t, R_{t-1})$	0.8151 (0.0399)	0.7774 (0.0122)	0.7857 (0.0140)	0.7759 (0.0150)	0.8954 (0.0302)	0.8432 (0.0153)	0.8313 (0.0131)	0.8708 (0.0119)

Standard errors in parentheses.

Figures

Figure 1: The evolution of output, inflation, federal funds rate and a measure of risk premium in the US during 1959:4-2000:3.