Monetary Policy Rules in a Search Model of the Labor Market*

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Abstract

This paper studies the performance, in terms of volatility and welfare, of different monetary policy rules in an economy with two market frictions. We consider a &nancial friction that highlights the credit channel as the monetary transmission mechanism and a labor friction, that considerably ampli&es the effects of monetary policy. We &rst document some empirical facts including, the strong relation between prices and in! ation with the main measures of labor supply (i.e. a short run Phillips Curve) and the short run expansionary effects of monetary policy. We then build a model roughly consistent with these facts. We use our model to study output and in! ation volatility under different monetary policy rules, when the economy is subject to productivity and/or government spending shocks. We consider some of the rules widely discussed in the literature (i.e. Taylor Rules). In

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terms of output and inflation volatility, our results call for pure inflation targeting and/or interest rate smoothing when the economy is subject to productivity shocks. In terms of welfare, differences are negligible under the different policy rules considered (JEL Codes: E3, E52, C32).

1 Introduction

At least since Friedman [1968], the discussion on how the monetary authority should set and implement its policy has been at the center of monetary macroeconomics. The issue is relevant since, it is well known that in the presence of frictions such as sticky prices or financial rigidities, monetary policy can have short run real effects in the economy. Following the painful inflationary experience of the U.S. economy in the 70's and subsequent disinflation, economists and policymakers have become more interested in identifying the appropriate policy instruments, targets and institutional framework that the monetary authority should pursue in order to improve the economic well being of society.

We contribute to this vast literature by studying the performance of the economy under different interest rate rules and in the presence of two frictions that serve as transmission and amplifying mechanisms from monetary policy to the real side of the economy. As we'll explain below, these frictions where chosen so that the model was consistent with some important empirical facts. The first friction builds on the traditional and narrow view of the credit channel in which, due to a simple financial rigidity, the monetary authority is able to affect the cost of capital. The financial rigidity used is a cost of managing household's portfolio of deposits. Therefore, by reducing the cost of loans, monetary injections trigger an expansionary effect in the economy. The basic idea is the following. By using open market operations, the central bank can inject money into the economy. Since it is costly for agents to manage their portfolio of assets (agents give up resources when they change their stock of deposits at the financial intermediary) then after a monetary injection the nominal interest rates tends to fall due to the excess liquidity in the economy. By reducing the cost of loans, firms increase investment and labor demand.[1]

[1] This type of friction is motivated by the limited participation literature. It is closely

The second friction in the model focuses on the labor market. Rather than assuming that labor is allocated through a system of prices, we assume that labor is allocated through a matching technology as in the search literature.[2] We consider the simplest search model in which the separation rate is exogenous. As we'll see later, it turns out that this labor friction will considerably amplify the expansionary effects of monetary policy.

We start the paper by documenting some empirical facts that in our view, any model useful for the study of monetary policy should be able to reproduce. This list includes, the short run positive correlation between inflation and all measures of labor supply (i.e. The Phillips Curve), the negative correlation of prices with all measures of labor supply and the short run expansionary effects of monetary policy.[3] We then proceed to show how the different frictions in our model helps us to explain this features of data. In summary, our model is one in which monetary policy has real effects, and is roughly consistent with the reported empirical facts.[4]

The next step is to evaluate the performance in our model of different monetary policy rules. We focus on policy rules in which the monetary authority uses a feedback rule in which interest rates are set by reacting to different macroeconomic variables including, the deviations of inflation from targeted inflation. We consider cases in which the monetary authority reacts to deviations of output from trend (i.e. Taylor rules), or to deviations of unemployment from the natural rate of unemployment. Given the apparent interest rate smoothing observed in the Fed's policy, we also consider rules

related to the time cost introduced by Christiano and Gust [1999]. In particular, the modeling device used here is the one used by Cooley and Quadrini [1999a].

[2]Our labor market framework is similar to Andolfatto [1996], Cooley and Quadrini [1999a] and Cheron and Langot [1999].

[3]That is, in the short run, after a monetary injection, output and employment increase for several quarters before the effect fades away. This is what in this paper we call the Liquidity Effect. See for example Walsh [1998]. A narrower definition of the Liquidity Effect is typically found in the literature. The basic idea being that after a monetary injection to the economy, nominal interest rates fall, and this will tend to expand output and employment in the short run. In our model, we don't necessarily get that interest rates fall after a monetary injection (they just don't raise as much as the Fisher Effect imply), but output and employment do increase. See Christiano and Eichenbaum [1992] for a through out exposition.

[4]To the extent of my knowledge, the first authors to address these empirical facts in a similar framework were Cooley and Quadrini [1999] and Cheron and Langot [1999].

aimed to smooth interest rates. Finally, we evaluate two important forward looking reaction functions as in Clarida, Gali and Gertler [1998]. These correspond to rules that care about future in! ation deviations from target and future output gap. In particular, we evaluate two rules estimated for the U.S by the previous authors. One corresponds to the pre-Volcker period (pre-October 1979) and the other one, to the Volcker-Greenspan (post-October 1979).

The last few years have seen a surge of studies evaluating different policies in a wide variety of models. For example, Taylor [1998], reports the performance of different Taylor rules across many different models. The performance criteria he uses is output and in! ation variability. His main conclusion is that rules that set interest rates depending on the output gap and the deviation of in! ation from target (i.e. Taylor Rules) perform pretty well across all models. He makes a case for this robustness result as an important test for the desirability of such type of rules. Christiano and Gust [1999] study Taylor rules in a limited participation model. They abstract from volatility and take existence and stability of equilibria as their main performance criteria. They argue for a Taylor rule heavily weighted on in! ation relative to output. On the other hand, Rotemberg and Woodford [1998] address the same questions in an estimated sticky price model. They use volatility and welfare as their main criteria. They make a case for a rule aimed to reduce interest rate volatility and that is sensitive to deviations of in! ation from its target. Overall, there are many differences across these studies with regard to estimation, calibration of parameters, modeling devices and/or performance criteria[5].

This paper addresses the same questions as the authors above but our approach differs in at least two important features. First, we highlight labor market frictions as the main ampli&cation mechanism of monetary policy. It is not difficult to make a case for the presence of labor market frictions in the real world and moreover, we argue that any model useful as a laboratory for the study of monetary policy, should be able to reproduce such an stylized fact as the short run Phillips curve. Second, as opposed to Rotemberg and Woodford [1998] and Clarida, Gali and Gertler [1999], our model explicitly incorporates investment decisions by households. This is clearly a relevant issue to the extent that it is by affecting the cost of capital that the

[5] See also Clarida, Gali and Gertler [1999].

monetary authority is able to trigger real economic effects across the economy. Also, given the simpli&cations and notable abstractions from reality that each model assumes, it is desirable to test the robustness of any policy recommendation across many different modeling frameworks.

This paper is organized as follows. Section 2 highlights the comovements of prices, in! ation and the main measures of labor supply (hours per worker, total hours and number of employees)in post war U.S. data. The next two sections build a model consistent with these facts. Section 3 builds a simple model that rationalizes the liquidity effect. Section 4, modi&es the previous one by introducing a friction in the labor market. The model is one that preserves the main insight from the previous model, but assumes that labor is allocated by a matching technology. This is done in exactly the same way as in the search literature (Andolfatto [1996], Pissarides [1990]). The model is generally found to perform better than the previous, rationalizing most of the monetary facts highlighted in section 2. Section 5 considers different monetary policy rules and their performance in terms of volatility. The main rules are Taylor Rules, interest rate smoothing rules (or generalized Taylor Rules as studied by Rotemberg and Woodford [1998]), forward looking rules and another family of rules that respond to employment as opposed to output in the setting of interest rates. The latter is a natural rule to consider from the perspective of our model while it is also appealing from a practical point. The last section concludes.

2 The Facts.

Using different methodologies, many authors have explored and documented different regularities linking nominal and real macroeconomic variables. For post war U.S. data Cooley and Hansen [1995], and Kydland and Prescott [1990] report unconditional moments using the Hodrick and Prescott &lter to extract the cyclical component of the series. They &nd strong evidence of countercyclical prices (i.e. prices and output are negatively correlated) and a positive correlation between in! ation and output. Using the same methodology we will study and emphasize these two facts as well as the relation between the main nominal variables (prices and in! ation) and the main measures of labor supply (number of employees, total hours of labor and hours per worker).

Table 1 calculates the relevant statistics. Our sample consists of quarterly data from 1959:II to 1998:II. Since our model is one of a closed economy, in order to make consistent our measured output and our models output, we de&ne this as the sum of private consumption, investment and government expenditures[6]. All variables are in per capita terms where we use as our normalization variable the population over 16 years old. The price p is the GDP de! ator and in! ations is de&ned as $\text{Inf}_t = \log(p_t/p_{t-1})$. All variables, except for in! ation are logged before &ltering with the Hodrick and Prescott &lter. We use the standard parameter of $\lambda = 1600$ for quarterly data.

Without suggesting any type of causality relationship between the different variables, Table 1 makes a case for the following facts:

1). Prices are strongly countercyclical. In addition, prices are negatively correlated with all measures of labor supply (hours per worker, total hours and number of employees).

2). In! ation is slightly procyclical (or acyclical) in the sense that its correlation with output is positive but close to zero (see note No. 6) and it lags output by at least three quarters.

3) In! ation is highly correlated with most of the measures of labor supply. In particular, in! ation is strongly positively correlated with the number of employees and with total hours. It lags the number of employees and total hours by at least three quarters. We take this form of the Phillips Curve (i.e. the positive correlations of employment and total hours with in! ation), as an important empirical fact that we would like our model to be able to reproduce.

4) All measures of labor are highly volatile.

The above features are also present when we use &rst differences to extract the cyclical component of the variables (see Table I in Appendix I).

In addition to the above facts, many authors have used VAR□s to study the different effects of monetary policy and to trace the path from policy

[6] Table 1. reports an almost null correlation of output (as de&ned in the text) and in! ation. It is interesting to note how small is this number compared to what is reported in the literature, for example in Cooley and Hansen [1995] or Cooley and Quadrini [1999a].

to the real sector of the economy[7]. The effects of monetary policy refers to the short run non-neutrality. The path from monetary policy to the real sector of the economy mainly, output or employment, refers to the monetary transmission mechanism.

Cyclical Behavior of the U.S. economy: HP filtered, 1959:II - 1998:II								
	SD%	Cross-Correlations of Output with:						
Variable		(-3)	(-2)	(-1)	(0)	(1)	(2)	(3)
Y[8]	1.47	0.56	0.74	0.90	1.00	0.90	0.74	0.56
P	0.85	-0.67	-0.75	-0.78	-0.77	-0.69	-0.57	-0.42
INF	0.28	-0.36	-0.23	-0.11	0.03	0.22	0.36	0.45
	SD%	Cross-Correlations of Employment with:						
N	0.96	0.54	0.73	0.91	1.00	0.91	0.73	0.54
P	0.85	-0.79	-0.76	-0.68	-0.55	-0.38	-0.20	-0.01
INF	0.28	-0.09	0.08	0.24	0.39	0.51	0.56	0.57
	SD%	Cross-Correlations of Total Hours with:						
H	1.27	0.44	0.67	0.88	1.00	0.88	0.67	0.44
P	0.85	-0.74	-0.76	-0.73	-0.63	-0.49	-0.32	-0.12
INF	0.28	-0.19	-0.04	0.12	0.32	0.44	0.51	0.56
	SD%	Cross-Correlations of Hours per worker with:						
h	0.41	0.17	0.45	0.75	1.00	0.75	0.46	0.17
P	0.85	-0.31	-0.43	-0.50	-0.52	-0.49	-0.42	-0.32
INF	0.28	-0.35	-0.29	-0.18	0.01	0.11	0.18	0.31
Source: author calculations								
Table 1.								

Even though the subject has been extensively studied, it hasn't been settled. It turns out there is more consensus with regard to the former, the short run non-neutrality of money, than with regard to the later, the

[7] See for example: Christiano, Eichenbaum and Evans [1997].

[8] Output is defined as the sum of private consumption, investment and government expenditures. For a description of the data see Appendix III.

particular transmission mechanism. In the short run, monetary ease is expansionary therefore when the rate of growth of money supply increases, output increases. The particular transmission mechanism though, is more subtle. This paper relies on the liquidity effect to trigger the expansionary effects of monetary policy. Again, there is no consensus as to whether there is strictly speaking a liquidity effect. (i.e. nominal interest rates decrease after a monetary injection to the economy). Now, even though the effects monetary injections on interest rates is still a matter of debate, its effects on output and employment are empirically well established.[9] After a monetary injection to the economy, output and employment response looks hump shaped. That is, output and employment increase slowly, pick after a couple of quarters and then the expansionary effects fade away[10]. This hump shaped response of output after a monetary expansions is what in this paper we call the liquidity effect. We consider this an important empirical fact that any monetary model should be able to reproduce.

In summary, this paper is an attempt to build up a model capable of reproducing the above facts: The negative correlation between output and the general price level, the positive correlation between employment, total hours and hours per worker with in! ation, and the liquidity effect. In doing so, we will build con&dence on the model usefulness as a laboratory for the study of monetary policy.

3 A Simple Model of Monetary Transmission.

The &rst model of this paper, is a simple modi&cation of the basic RBC model with a cash in advance constraint in consumption. The modi&cation is intended to rationalize the liquidity effect and the expansionary effects of monetary policy.[11]The basic intuition is very simple. Firms demand cash in

[9] See Walsh [1998] for a general summary and a list of references.

[10] Christiano, Eichenbaum and Evans [1997] consider the case in which the Fed uses the short interest rate as its policy intrument. A contractionary monetary shock in their model, increases the Federal Funds Rate by 70 basis points. After two quarters there is a sustained decrease in real output of the order of 0.1 to 0.4 %. After 2 years, the contractionary effect fades away.

[11] This type of friction is motivated by the limited participation literature. It is closely related to the time cost introduced by Christiano and Gust [1999]. In particular the

order to pay the wage bill and &nance investment. All loans are intermediated through the banking system where households deposit their money and get paid the nominal interest rate. The friction we introduce is a cost in terms of resources for households changing their portfolio of deposits[12]. The central bank trades bonds with banks (&nancial institutions in general). By using open market operations the central bank can unexpectedly inject cash into the market. Since households are penalized for changing their portfolio of deposits at the &nancial intermediaries , the excess liquidity will tend to lower the interest rate. A fall in the interest rate lowers the cost of loans for &rms therefore, stimulating investment and labor demand.

The model economy consists of a representative household, a representative &rm and a representative &nancial intermediary. It is subject to two shocks, technological and government shocks. There is no population growth and we normalize population to unity.

3.1 Financial Intermediation.

Households do not lend directly to &rms. At the beginning of every period t, the state of the economy is completely revealed and households decide how much money D_{t+1}, they will deposit until the end of the period at the &nancial intermediary. At the same time, the &nancial institution decides how many bonds B_{t+1} to hold until the end of the period. These it buys from the central bank. Firms borrow cash in order to &nance the wage bill and investment. Formally, the supply of loanable funds in period t is: $D_{t+1} - B_{t+1}$ and the demand by &rms is $w_t p_t h + p_t I_t$, where w_t is the real wage, p_t is the general price level and h_t is the amount of labor supplied by the representative household. Ultimately, households are also the owners of the &nancial institutions. Since we assume there is perfect competition and free entry and exit, in equilibrium, &nancial intermediaries pro&ts are zero.

modeling device used here is the one used by Cooley and Quadrini [1999a].

[12]For example, the redemption of cereti&cates of deposits before their maturity date is tipically penalized by paying a lower interest rate than the one agreed at the time it was bought.

3.2 Firms.

Households own &rms which in turn own capital. Dividends are paid at the end of the period meaning that, since households face a cash in advance constraint, they cannot be used for current consumption. Since &rms act on behalf of its share holders they maximize pro&ts properly discounted by the marginal value of an additional unit of consumption that will only be available for consumption the next period. Formally, &rms problem is:

$$
\begin{aligned}
&\max E\sum_{t=0}^{\infty}\beta^{t+1}\tfrac{U_1(c_{t+1},h_{t+1})}{U_1(c_0,h_0)}\tfrac{p_t}{p_{t+1}}\pi_t^f \\
&k_{t+1} = (1-\delta)k_t + I_t
\end{aligned}
$$

Where the &rms pro&t is $\pi_t^f = F(k_t, h_t) - (1 + i_t)(w_t h_t + I_t)$, k_t is the stock of capital, δ is the rate of depreciation of capital, F is the production function and i_t is the nominal interest rate prevailing during period t. This speci&cation makes clear how the interest rate affects the cost of production.

3.3 Households.

Households demand cash to buy goods. Every period t, they decide how much cash to hold until next period M_{t+1}, how much to deposit at the &nancial intermediary until the end of the period D_{t+1}, they get paid their wage in cash at the beginning of the period , they get paid dividends from the &rm and the &nancial intermediary at the end of the period, d_t^f, and d_t^{int} respectively, they pay lump sum taxes τ_t and &nally, they pay in cash $\phi(D_t, D_{t+1})$, the cost of changing their portfolio of deposits at the &nancial intermediary. Therefore households problem is:

$$
\begin{aligned}
&\max E\sum_{t=0}^{\infty}\beta^t U\left(c_t, h_t\right) \\
&M_{t+1} + p_t c_t + p_t \tau_t = (M_t - D_{t+1}) + (1 + i_t)D_{t+1} + p_t w_t h_t - p_t\phi(D_t, D_{t+1}) + \\
&\qquad p_t d_t^f + p_t d_t^{int} \\
&p_t(c_t + \phi(D_t, D_{t+1})) \leq M_t - D_{t+1} + p_t w_t h_t
\end{aligned}
$$

3.4 Consolidated Monetary and Fiscal Authority.

Every period t the monetary authority prints money $M_{t+1} - M_t$ where M_t is the stock of money, collects taxes, pays interest on bonds B_{t+1} to the &nancial intermediary, &nance exogenous government expenditures g_t and collects at no cost the cost of intermediation $\phi(D_t, D_{t+1})$ (i.e. the cost of changing households portfolio). This assumption is not crucial for results to go through but it emphasizes the intertemporal distortions of this &nancial friction rather than the wealth effect of such a cost that if anything, should be rather small. Therefore the consolidated &scal and monetary authority budget constraint is:

$$M_{t+1} - M_t + p_t\tau_t + p_t\phi(D_t, D_{t+1}) = i_t B_{t+1} + p_t g_t$$

We assume government expenditures follow an exogenous autoregressive process:

$$Log(g_{t+1}) = \rho^g Log(g_t) + (1 - \rho^g) Log(g) + \varepsilon_{t+1}, \varepsilon_{t+1} \sim N(0, \sigma^g)$$

Where g is the mean of the process, ρ^g is the autocorrelation coefficient and σ^g is the standard deviation of the innovation process.

3.5 Monetary Policy.

Using open market operations, the monetary authority exogenously sets the rate of growth of money supply. In our model, the amount of money that can be used for transactions during period t is $M_t - B_t$. We take M as constant and specify monetary policy as:

$$M_{t+1} - B_{t+1} = (M_t - B_t)\mu_t$$

where $\log(\mu_t)$, the rate of growth of money supply, follows the following autoregressive process:

$$\log(\mu_{t+1}) = \rho^\mu \log(\mu_t) + \varepsilon_{t+1},\ \varepsilon_{t+1} \sim N(0, \sigma^\mu)$$

3.6 Functional Forms and Calibration.

We used the following standard functional forms in our model. The production technology is a Cobb-Douglas production function $F(k_t, h_t) = A_t^{tec} k_t^{\theta} (h_t)^{1-\theta}$ where θ is the share of capital in output and A_t^{tec} is an exogenous productivity shock assumed to follow the following autoregressive process:

$$Log(A_{t+1}^{tec}) = \rho^A Log(A_t^{tec}) + (1 - \rho^A) Log(A^{tec}) + \varepsilon_{t+1}, \varepsilon_{t+1} \sim N(0, \sigma^A)$$

where A^{tec} is the mean of the process.

We assume the instantaneous utility function to be separable: $U(c, h) = Log(c) + \Gamma(h)$, where $\Gamma(h) = \frac{B(1-h)^{1-\gamma}}{1-\gamma}$, B is a constant that we calibrate so that in steady state $h = \frac{1}{3}$, and $\frac{1}{\gamma}$ is the intertemporal elasticity of labor supply.

The cost of changing the portfolio of deposits is modeled as a simple quadratic function, $\phi(D_t, D_{t+1}) = \phi \left(\frac{D_{t+1} - D_t}{D_t} \right)^2$ where ϕ is a constant that determines the cost of changing deposits. The implicit assumption in this speci&cation is that in steady state, there are no &nancial costs for holding deposits at the &nancial intermediary.

Our calibration is completely standard except for the scale parameter ϕ. We choose ϕ such that the implied liquidity effect resembles the one documented in the empirical literature.[13] In any case, we provide some sensitivity analysis and stress its role in helping to reproduce the liquidity effect. The relevant parameter values are summarized in Table 2. The calibration of the exogenous government process is the same as in Christiano and Eichenbaum [1992].

Calibrated Parameters

β	γ	θ	ϕ	δ	ρ^A	ρ^μ	σ^A	σ^μ	h	g/y
0.99	2	0.36	0,10	0.025	0.99	0.67	0.006	0.008	1/3	0

Table 2.

[13] In another paper Riascos [2001], we show that with $\phi = 10$, our full model (see section 4) generates data embedded with the same dynamic response to monetary shocks observed in historical data when both sets of data are analized using exactly the same statistical tools.

In order to solve the model, we used the method of log linearization as described in King, Plosser and Rebelo [1988].

3.7 Dynamics.

Figure 1 reports the impulse response functions after an unanticipated and persistent monetary injection to the economy. That is, at time $t = 0$, the monetary authority sets the rate of growth of money $\log(\mu_0)$ to 0.8%, (one standard deviation) and announces the following policy for the following periods $\log(\mu_{t+1}) = \rho^{\mu} \log(\mu_t)$, where we set $\rho^{\mu} = 0.67$ (this is roughly the persistence we get when we estimate a &rst order autoregressive process for the rate of growth of M1 in the U.S. for the entire sample period). We report the impulse response functions for two values of ϕ, $\phi = 0$, and $\phi = 10$. All variables except for in! ation which is in levels, are expressed as percentage deviations from steady state. The dotted line represents the response of the economy with portfolio rigidities. The basic mechanism triggering the expansionary effect is fairly simple: After a monetary injection, since this excess liquidity at the &nancial intermediary will presumably reduce interest rates, households are willing to reduce their deposits. In the presence of adjustment costs to the portfolio of deposits, interest rates will □tend□ to fall. It might be the case that interest rates increase, as in fact is the case when adjustment costs are small (see the dotted line in &gure 1). The reason for this is that the Fisher effect dominates the liquidity effect therefore, interest rates rise, but not as much as what would be implied by expectations of future in! ation. The overall effect is a □fall□ in the cost of capital that stimulates &rms investment and labor demand. Notice how households adjust slowly their deposits in the presence of portfolio adjustment costs.

3.8 Simulations.

Table 3 reports the result of simulating the model by assuming the economy is only driven by technological shocks and where H stands for total hours worked per capita, which in this model corresponds to h, the amount of time supplied by each worker.

By looking at Table 3, we notice that the model performs bad in term of the size of the volatility of the economy. In general the bigger the ϕ, the lower

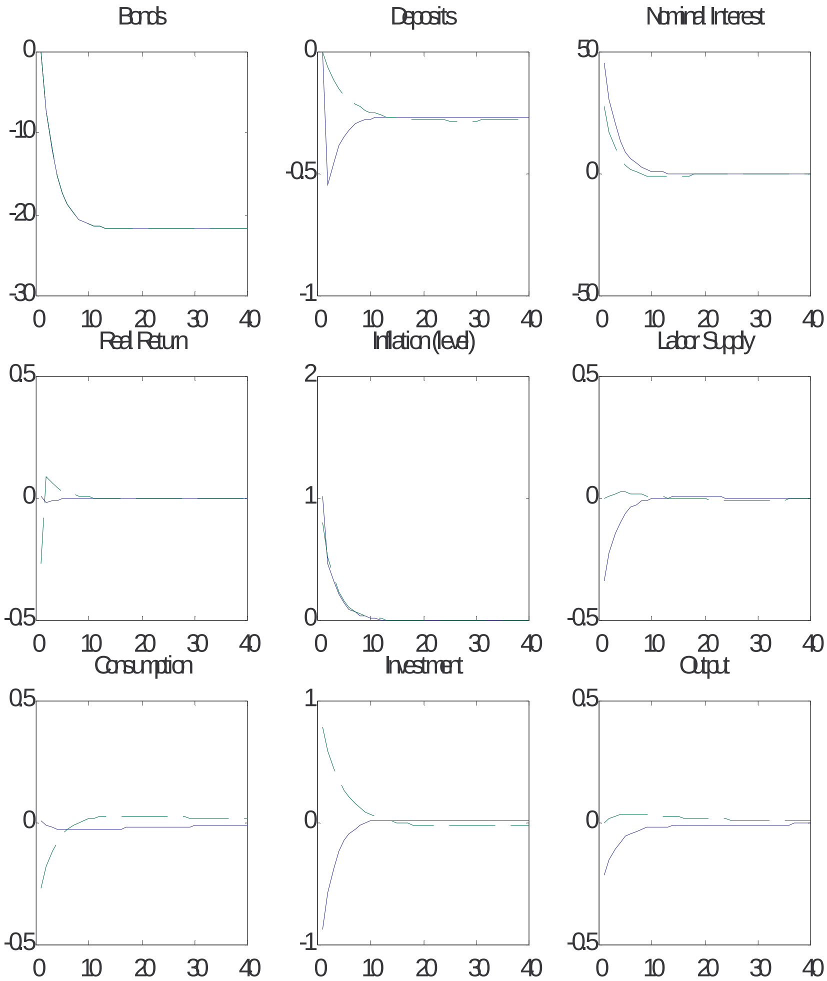

Figure 1: Impulse response functions after a one standard deviation increase in money supply. All variables except for in! ation (which is in levels) are in percentage deviations from steady state. The dotted line corresponds to the economy with portfolio adjustment costs. The other line corresponds to the frictionless economy.

the volatility of the economy. This is even more notable for this economy as opposed to our next model economy.[14] Clearly this is not a dimension we will use to judge our model. Also, the model fails to reproduce the Phillips curve in terms of output though, it does a pretty good job in terms of labor supply. Also it performs well with regard to the negative correlation of output and price. When in addition to technological shocks the economy is also subject to monetary shocks, the negative correlation of labor supply with prices is overturned.

The model's performance doesn't improve significantly when the economy is subject to persistent government shocks. Nevertheless, it does reduce the negative correlation of output and all measures of labor supply with prices.

It is worth to highlight the size of the response of the model economy to the different types of shocks. It turns out that the labor market frictions, that we will introduce in the next section, play a key role in amplifying monetary and government shocks.

Finally, we point out that this model implies a trivial dynamics for employment (everyone is employed). It also implies the same dynamics for total hours per capita and hours per worker per capita and therefore, the same relation to nominal variables. Clearly, this simple view of the labor market, though consistent with the expansionary effects of monetary policy, is unable to address the relation between all labor market variables and the most relevant nominal variables.

[14] For example, all else equal, when ϕ changes from 0 to 10, total hours volatility changes from 0.22 to 0.06 while, in our next model economy, employment changes from 0.32 to 0.22.

Cyclical Behavior of model economy I: HP &ltered*								
Technological Shocks, $\phi = 10$.								
	SD%	Cross-Correlations of Output with:						
Variable		(-3)	(-2)	(-1)	(0)	(1)	(2)	(3)
Y	0.79	0.26	0.46	0.71	1	0.71	0.46	0.26
P	0.79	-0.26	-0.46	-0.71	-1	-0.71	-0.46	-0.26
INF**	0.58	-0.21	-0.27	-0.32	-0.37	0.38	0.33	0.27
	SD%	Cross-Correlations of Total Hours with:						
H,h	0.06	0.62	0.81	0.95	1.00	0.95	0.81	0.62
P	0.76	-0.78	-0.79	-0.70	-0.48	-0.24	-0.05	-0.09
INF**	0.57	-0.09	-0.01	0.12	0.29	0.31	0.24	0.18
*Mean over 100 simulations of 150 each.								
**In! ation is measured as $\log\left(\frac{p_t}{p_{t-1}}\right)$								
Table 3								

4 Labor Search and Portfolio Rigidities.

The central idea is that trade in the labor market is an economic activity, uncoordinated, time consuming (i.e. for &rms, labor as well as capital require time to become productive and for households, &nding a job requires searching), and costly (&rms spend resources posting vacancies for being &lled). We look at the labor market as consisting of two sectors: one for trade and one for production, meaning that only unemployed workers look for a job (there is no on the job search). We take the separation process as exogenous[15].

There is large number of identical households, a large number of large &rms (i.e., each &rm hires many workers and posts many vacancies), a representative &nancial intermediary, a representative unemployment insurance &rm and a consolidated &scal and monetary authority (the Central Bank).

The economy is subject to technological shocks and government shocks. Let S_t stand for the state of all exogenous shocks realized at the beginning of period t. Population is normalized to unity.

[15] This speci&cation draws heavily on Andolfatto [1996] and Pissarides [1990].

4.1 The Labor Market.

At the beginning of every period, vacancies posted by &rms, and job searching workers are matched with a probability implicitly de&ned by the following aggregate matching technology:

$$X_t = F^m(V_t, eU_t) = A_t^m V_t^{\theta^m} (eU_t)^{1-\theta^m}$$

where X_t denotes the number of realized matches between workers and &rms vacancies (i.e. number of workers moving from unemployed to employed), V_t is the vacancy rate, U_t is the unemployment rate and e is the aggregate search intensity of the unemployed workers of the economy (we take e as exogenously given). This Cobb Douglas speci&cation is consistent with Blanchard-Diamond (1989) empirical study. Moreover, in a growing economy, it is the only one consistent with balanced growth.[16] For simplicity, we assume the separation rate s to be exogenous and constant. That is, if at the beginning of period t, n_t^j is the employment rate in &rm j, then sn_t^j will be the fraction out of total population that losses their job during the period.

The rate at which &rms &ll in their vacancies is: $q_t(\theta_t) = \frac{X_t}{V_t} = F^m(1, \theta_t^{-1})$ where $\theta_t = \frac{V_t}{eU_t}$ is called the labor market tightness, note that $q_t'(\theta_t) < 0$ (the more tight the labor market is, the harder is to &ll in vacancies for &rms). Its elasticity with respect to θ is, $1 - \theta^m \in (-1, 0)$

The rate at which households move from unemployment to employment per unit of search intensity is: $\theta_t q_t(\theta_t) = \frac{X_t}{eU_t}$. Hence, from the point of view of &rms, employment evolves according to:

$$n_{t+1}^j = (1-s)n_t^j + q_t(\theta_t)V_t^j \qquad \text{(for each \&rm } j\text{)}$$

where n_t^j is the employment rate during period t.

The dependence of the transition functions on the tightness of the labor market highlights the trading externalities implicit in the labor market search.

At the beginning of every period all shocks are realized. Firms and agents enter in a bargaining process in which the terms of the labor contract are

[16] See Pissarides [1990].

speci&ed. That is, the amount of labor input required, h and the real wage, w. Once the contract is speci&ed, &rms and households trade in all other markets.

4.2 Financial Intermediation.

The economic environment here is pretty much the same as the one of the previous model. Households hold deposits at the &nancial intermediary and demands cash for buying consumption goods. On the other side, &rms demand loans for paying the wage bill and &nance investment. The role of the &nancial sector is a passive one, it takes deposits from households, trade bonds with the monetary authority and makes loans to &rms. We assume they do not accumulate any assets.

4.3 Firms.

We assume that each &rm j requires many workers and posts many vacancies every period. Immediately after the bargaining process has &nished, &rms make their investment decisions I_t^j and post vacancies V_t^j. The information set for the &rm is: exogenous shocks, individual states k_t^j (&rms capital stock) and n_t^j (rate of employment of the &rm), and the corresponding aggregate ones.

Firms borrow from the &nancial intermediary in order to &nance investment and to pay the wage bill at the beginning of the period as required by the labor contract. At the end of the period, &rms pay dividends. Each household receives his corresponding amount of per capita total dividends. Because of the cash in advance constraint, dividends paid today (at the end of the period) can only be used for consumption until next period. Hence, form the point of view of households, one unit of dividends in period t is worth $\beta \frac{U_1(c_{t+1}^n, h_{t+1})}{U_1(c_t^n, h_t)} \frac{p_t}{p_{t+1}}$ units of consumption good at time t.[17] Since &rms are ultimately owned by households, then it is reasonable to assume the following behavior for the &rm.

[17] Actually $\frac{N_{t+1}U_1(c_{t+1}^n, h_{t+1}) + (1-N_{t+1})U_1(c_{t+1}^u, e)}{N_t U_1(c_t^n, h_t) + (1-N_t)U_1(c_t^u, e)} \frac{p_t}{p_{t+1}}$, but as we'll show later, the existence of a perfect insurance market for unemployment guarantees that in equilibrium $U_1(c_t^n, h_t) = U_1(c_t^u, e)$

$$\max E\sum_{t=0}^{\infty}\beta^{t+1}\frac{U_1(c^n_{t+1},h_{t+1})}{U_1(c^n_0,h_0)}\frac{p_t}{p_{t+1}}\pi^f_t$$
$$\begin{aligned} n_{t+1} &= (1-s)n_t + q_t(\theta_t)V_t \\ k_{t+1} &= (1-\delta)k_t + I_t \end{aligned}$$

Where $\pi^f_t = A^{tec}_t k^\theta_t (h_t n_t)^{1-\theta} - (1+i_t)(w_t n_t h_t + I_t) - V_t\kappa_t$ and κ_t is the real cost of posting one vacancy[18]. The corresponding dynamic programming problem is:[19]

$$\begin{aligned} V^f(k,n,K,N,S) &= \max\left\{\frac{\beta U_1(c^{n\prime},h')}{U_1(c^n,h)}\frac{p_t}{p_{t+1}}\pi^f_t + E\left[\frac{\beta U_1(c^{n\prime},h')}{U_1(c^n,h)}V^f(k',n',K',N',S')\right]\right\} \\ n_{t+1} &= (1-s)n_t + q_t(\theta_t)V_t \\ k_{t+1} &= (1-\delta)k_t + I_t \end{aligned}$$

4.4 Households.

Immediately after the bargaining process has &nished, households make their consumption $c^n, c^u$and &nancial decisions (cash holdings M_t and deposits D_t at the &nancial intermediary). In order to avoid the ex-post heterogeneity due to the employment status of each household, we assume there is a perfectly competitive insurance market (heterogeneity would considerably increase the complexity of solution). Every period households also choose $\overline{B}_t$, the amount of insurance they buy for the next period. Moreover, we also assume that this unemployment insurance must be bought with cash so that it plays a role only to the extent that there is no uncertainty on the workers employment status. If that wasn't the case, this additional security would be demanded

[18] We calibrate this cost in steady state to 10% of output. In order to abstract from substantial wealth effects, we asume this is not a social cost. That is, the government collects this at no cost and returns it to agents as a lump sum transfer.

In any case, one can always interpret this cost as an investment cost.

[19] The above sequence problem can be rewritten as:

$\max E\sum_{t=0}^{\infty}(\prod_{i=0}^{t} Q_i)\frac{\beta U_1(c^n_{t+1},h_{t+1})}{U_1(c^n_t,h_t)}\frac{p_t}{p_{t+1}}\pi^f_t$,

where $Q_i = \frac{\beta U_1(c^n_i,h_i)}{U_1(c^n_{i-1},h_{i-1})}$ (we de&ne $Q_0 = 1$).

by households, just because it allows to buy resources and exchange them for cash within the same period.

When the bargaining process is &nished, agents still don't know of their employment status therefore, they evaluate their decisions based on their expected value of being employed or unemployed. Once the contract is signed, they believe to have no power on the probability of being employed or unemployed (its only when they are bargaining that they consider the possibility of affecting their transition rate based upon their individual search effort).

It follows that households problem is:

$$\max E\left[\sum_{t=0}^{\infty}\beta^t(N_tU(c_t^n,h_t)+(1-N_t)U(c_t^u,e))\right]$$
$$M_{t+1}+p_tc_t^n+\overline{p}_t\overline{B}_t+p_t\tau_t=(M_t-D_{t+1})+(1+i_t)D_{t+1}+p_tw_th_t-$$
$$p_t\phi(D_t,D_{t+1})+p_td_t^f+p_td_t^{int}$$
$$M_{t+1}+p_tc_t^u+\overline{p}_t\overline{B}_t+p_t\tau_t=(M_t-D_{t+1})+(1+i_t)D_{t+1}+\overline{B}_t-$$
$$p_t\phi(D_t,D_{t+1})+p_td_t^f+p_td_t^{int}$$

$$p_t(c_t^n+\phi(D_t,D_{t+1}))+\overline{p}_t\overline{B}_t\leq M_t-D_{t+1}+p_tw_th_t$$
$$p_t(c_t^u+\phi(D_t,D_{t+1}))+\overline{p}_t\overline{B}_t\leq M_t-D_{t+1}+\overline{B}_t$$

Where $\overline{p}_t$ is the price of an insurance contract that promises to pay $\overline{B}_t$ in the event of being unemployed. The expected pro&ts of the representative insurance company are: $\overline{p}_t\overline{B}_t-(1-N_t)\overline{B}_t$. Perfect competition in the insurance market implies that in equilibrium, $\overline{p}_t=1-N_t$.

For future reference, we will assume household's instantaneous utility to be separable as in the previous model: $U(c_t^n,h_t)=\log(c_t^n)+\Gamma(h)$ and $U(c_t^u,e)=\log(c_t^u)+\Gamma(e)$.

4.5 Consolidated Monetary and Fiscal Authority.

In order to focus on price distortions rather than wealth effects, we assume the government collects at no cost, the cost of posting vacancies of each &rm and the cost of portfolio adjustment of each household. The government also prints money, issues debt (but never roles over the debt) and tax households. Therefore the consolidated monetary and &scal authority budget constraint is:

$$\tau_t + \frac{M_{t+1} - M_t}{p_t} + \kappa V_t + \phi(D_t, D_{t+1}) = \frac{i_t B_{t+1}}{p_t} + g_t$$

4.6 The Bargaining Process:Wages and labor supply.

In equilibrium, occupied jobs must yield a total return at least greater than or equal to the sum of the expected returns of a searching &rm and worker otherwise, there would be no rational for a matching function (for &rms and workers getting together).

Since all job-worker pairs are equally productive, the expected joint return of a new match must be equal to the present return of an existing match. Hence a realized job match actually yields a strictly positive economic rent equal to the expected search costs of the &rm and worker.

Before getting into details, we need a word on notation. In general, if x is a variable, x' denotes next period values. Let $V^f(k, n, K, N, S)$ be the value of the &rm. Using this notation, the value of an additional worker is:

$$J^f(k, n, K, N, S) = \frac{\partial V^f(k,n,K,N,S)}{\partial n} = \frac{\beta U_1(c^{n\prime}, h')}{U_1(c^n, h)} \frac{p}{p'} \left(\frac{\partial F^{tec}(k, hn)}{\partial n} - (1+i)wh \right) + (1-s)E\left[\frac{\beta U_1(c^{n\prime}, h')}{U_1(c^n, h)} J^f(k', n', K', N', S') \right]$$

This follows from the &rms dynamic programing problem and the envelope theorem. Note that prices (the stochastic process of prices) is taken as given by the &rm.

On the other hand, the additional value of posting one vacancy $V(k, n, K, N, S)$ satis&es:

$$V(k, n, K, N, S) = -\kappa + E\left[\frac{\beta U_1(c^{n\prime}, h')}{U_1(c^n, h)} (q(\theta) J^f(k', n', K', N', S') + (1 - q(\theta)) V(k', n', K', N'\right.$$

In equilibrium it must be the case that $V(k, n, K, N, S) = 0$, therefore:

$$\kappa = q(\theta) E\left[\frac{\beta U_1(c^{n\prime}, h')}{U_1(c^n, h)} J^f(k', n', K', N', S') \right]$$

That is, the cost of posting an additional vacancy must be equal to the present value of the expected return from an additional worker (a filled vacancy) next period (recall that $q(\theta) = \frac{X}{V}$)

Using the above to equations we can write:

$$J^f(k, n, K, N, S) = \frac{\beta U_1(c^{n\prime}, h')}{U_1(c^n, h)} \frac{p}{p'} \left(\frac{\partial F^{tec}(k, hn)}{\partial n} - (1+i)wh \right) + (1-s)\frac{\kappa}{q(\theta)}$$

We assume workers value a match according to the expected utility when employed as compared to the expected utility when unemployed. The match surplus in terms of consumption J^i, is equal to the difference between the value of being employed $E(k, n, K, N, S)$, and the value of being unemployed $U(k, n, K, N, S)$. If the negotiation succeeds then:

$E(k, n, K, N, S) = wh + \frac{\Gamma(h)}{U_1(c^n, h)} + E\left[\frac{\beta U_1(c^{n\prime}, h')}{U_1(c^n, h)}((1-s)E(k', n', K', N', S') + sU(k', n', K',\right.$

and if it doesn't:

$U(k, n, K, N, S) = \frac{\Gamma(e)}{U_1(c^n, h)} + E\left[\frac{\beta U_1(c^{n\prime}, h')}{U_1(c^n, h)}(e\frac{X_t}{eU}E(k', n', K', N', S') + (1 - e\frac{X_t}{eU})U(k', n', K',\right.$

Therefore the match surplus for workers satisfies:

$$J^i(k, n, K, N, S) = wh + \frac{\Gamma(h) - \Gamma(e)}{U_1(c^n, h)} + (1 - s - \frac{X}{U})E[\frac{\beta U_1(c^{n\prime}, h')}{U_1(c^n, h)} J^i(k', n', K', N', S')]$$

Taking into consideration the value of a match for firms and workers, the two parties now enter in a bargaining process from which the wage rate and labor supply will be set. A Nash solution turns out to be difficult and wouldn't give a constant sharing rule. For the time being, we simply assume a constant sharing rule. Let ξ, be there share of the surplus that corresponds to workers, therefore w and h must satisfy:

$$\frac{\xi}{1-\xi}\frac{J^f}{J^i} = 1$$

The equation above is the wage setting rule, it depends on the state of the economy and labor supply.

Substitution of the above equation in J^i and using again the sharing rule we get the real wage:

$$wh = \frac{\xi\left(\frac{\beta U_1(c^{n\prime},h')}{U_1(c^n,h^n)}\frac{p}{p'}\frac{\partial F^{tec}(k,nh)}{\partial n} + e\theta\kappa\right) + (1-\xi)\frac{(\Gamma(e)-\Gamma(h))}{U_1(c^n,h^n)}}{\xi(1+i)\frac{\beta U_1(c^{n\prime},h')}{U_1(c^n,h)}\frac{p}{p'} + (1-\xi)}$$

Finally we need to specify the amount of labor agreed on the contract. We assume labor supply is chosen to maximize total surplus (recall that wages depend on labor supply):

$$\max_h \ J^i + J^f$$

The &rst order conditions to the above problem imply the following input of labor:

$$\Gamma'(h) = -\frac{U_1(c^n,h)}{1+i}\frac{\partial^2 F^{tec}(k,hn)}{\partial h \partial n}$$

The above two equations determine h and w. Notice how labor demand is scaled down by the nominal interest rate.

Finally we can compute the !ow of dividends that each agent receives every period. Since we have normalized population to unity and households own &rms, individual dividends are equal to aggregate pro&ts ($d_t^f = \pi_t^f$). On the other hand, perfect competition in the &nancial sector implies that pro&ts from &nancial intermediation are zero ($d_t^{int} = 0$).

4.7 Monetary Policy

Since we seek to compare the performance of our previous model in the presence of frictions in the labor market, we specify monetary policy in exactly the same as we did before. That is, at the beginning of every period t, the monetary authority exogenously sets the rate of growth of money used for transactions: $M_t - B_t$. We take M as constant and specify monetary policy as:

$$M_{t+1} - B_{t+1} = (M_t - B_t)\mu_t$$

where $\log(\mu_t)$, the rate of growth of money supply, follows the following autoregressive process:

$$\log(\mu_{t+1}) = \rho^{\mu}\log(\mu_t) + \varepsilon_{t+1},\ \varepsilon_{t+1} \sim N(0, \sigma^{\mu})$$

4.8 Functional Forms and Calibration.

We used the following standard functional forms in our model. As we said before, the matching technology is assumed to take the Cobb-Douglass form: $F^m(V_t, eU_t) = A_t^m V_t^{\theta m}(eU_t)^{1-\theta^m}$. Each &rms production technology is a Cobb-Douglass production function $F(k_t, h_t n_t) = A_t^{tec} k_t^{\theta}(h_t n_t)^{1-\theta}$ where A_t^{tec} is an exogenous productivity shock that follows the same process as before.

The utility function is separable and contingent to agents employment status as in Andolfatto [1996]. When employed $U(c,h) = Log(c) + \frac{B_e(1-h)^{1-\gamma}}{1-\gamma}$, where B_e is a constant that we calibrate so that in steady state $h = \frac{1}{3}$ and $\frac{1}{\gamma}$ is the intertemporal elasticity of leisure. When agents are unemployed, $U(c,e) = Log(c) + \frac{B_u(1-e)^{1-\gamma}}{1-\gamma}$ where e is agents search intensity that we assume constant and B_u is constant that we calibrate in order to be consistent with a predetermined value of search intensity. Intuitively B_u should be less than B_e as agents value more leisure when they are employed. This turns out to be the case when e is set to $\frac{h}{2}$. In general terms our calibration is the same as the one presented in our &rst model and close to Andolfatto [1996] with regard to our search environment. Of particular interest is the parameter ξ, the workers share of the surplus of a match. Smaller values of ξ amplify the response of employment to shocks[20]. We took $\xi = 0.2$ as an reasonable intermediate value.

The cost of changing the portfolio of deposits is modeled in the same way as before. The relevant parameter values are summarized in Table 4 and 4.1.

β	γ	θ	ϕ	δ	ρ^A	ρ^g	ρ^{μ}	σ^A	σ^g	σ^{μ}
0.99	2	0.36	0,10	0.025	0.99	0.98	0.67	0.006	0.009	0.008
Table 4										

[20] This is comparable to what Cooley and Quadrini [1999a] report.

g/y	h	e	q	θ^m	ξ	s	$\frac{\kappa V}{Y}$
0,0.2	1/3	1/6	0.9	0.6	0.2	0.15	0.1
Table 4.1							

4.9 Dynamics.

Figure 2 reports the impulse response functions after an unanticipated and persistent monetary injection to the economy. We use $\phi = 0$, and $\phi = 10$ as in our &rst model. The dotted line represents the response of the economy with &nancial frictions. The qualitative response of the economy is the same as before but note how are monetary shocks considerably ampli&ed by the labor market frictions. The working mechanism is exactly the same as before, after a monetary injection, the inability for households to freely reduce their deposits at the &nancial intermediary drives interest rates down. By reducing the cost of capital, &rms demand more loans to &nance investment and pay the wage bill. The &nancial friction is set so that output expansion is quantitatively similar to the reported in the literature. Notice also the positive response of hours and employment. Again, hours per worker respond considerably more in the presence of labor market frictions. This is not surprising, given that &rms do not internalize the implicit externalities found in the labor market. Faced with a reduction in the real cost of capital (for example, after an increase in the rate of growth of money supply) &rms demand more labor so they post more vacancies. If they did internalized the aggregate effects of posting vacancies, they would face a trade-off between more vacancies but a lower probability of &lling vacancies (recall that the probability of &lling a vacancy depends on the aggregate amount of unemployed people as a proportion of the aggregate amount of vacancies). In the absence of this cost, &rms post more vacancies and hire more workers than when they do internalize the labor market externalities.

4.10 Simulations.

Table 5 reports the results of simulating our model when the economy is subject to only productivity shocks. The model is particularly successful in replicating the positive correlation of number of employes and total hours with in! ation. The same way as in our &rst model, the strong negative correlation with prices is due to the absence of demand shocks. The single major

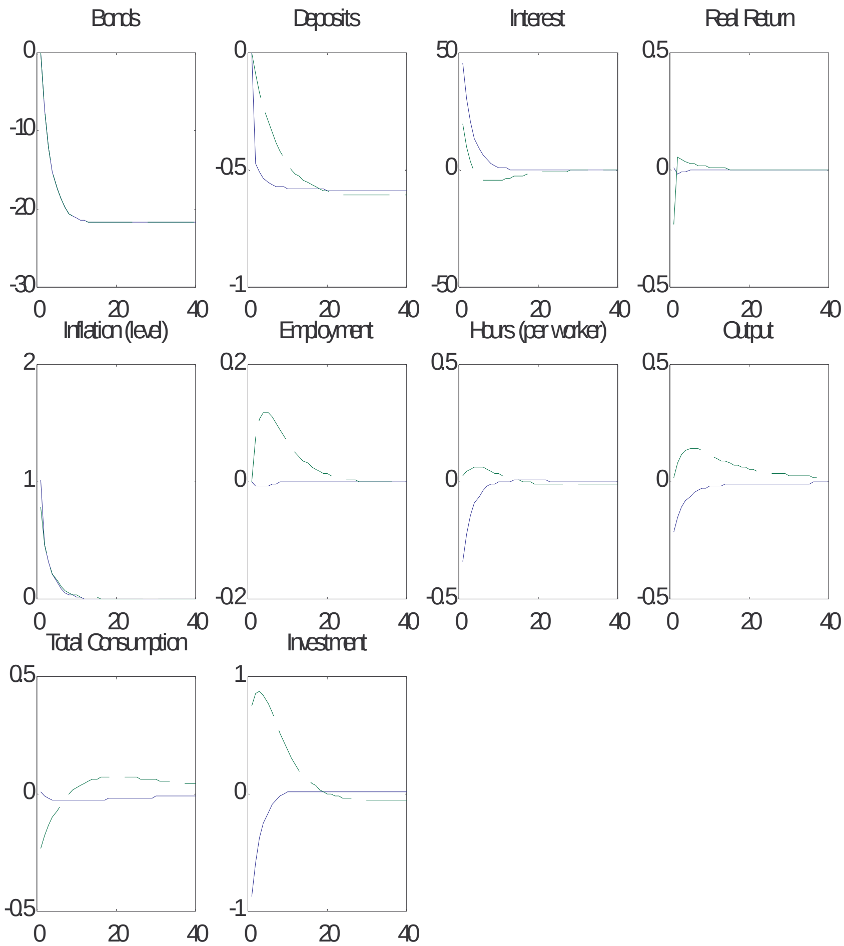

Figure 2: Impulse response functions after a one standard deviation increase in money supply. All variables except for in! ation (which is in levels) are in percentage deviations from steady state. The dotted line corresponds to the economy with portfolio adjustment costs. The other line corresponds to the frictionless economy.

shortfall of our model is with regard to the strong negative contemporaneous correlation of output with in! ation. Still, output clearly leads in! ation over the cycle as is also the case in the data (that is, the positive correlation of present output with in! ation is stronger with future values of in! ation than with past values, see Table 1). Also, as we pointed out for our previous model, volatility is reduced by ϕ but in smaller proportion and moreover, it is considerably enhanced by the labor market friction. [21]

Cyclical Behavior of model economy II: HP &ltered*								
Technological Shocks, $\phi = 10$.								
	SD%	Cross-Correlations of Output with:						
Variable		(-3)	(-2)	(-1)	(0)	(1)	(2)	(3)
Y[22]	0.87	0.27	0.47	0.72	1.00	0.72	0.47	0.27
P	0.87	-0.27	-0.47	-0.72	-1.00	-0.72	-0.47	-0.27
INF**	0.63	-0.23	-0.28	-0.33	-0.36	0.36	0.33	0.28
	SD%	Cross-Correlations of Employment with:						
N	0.22	0.53	0.74	0.91	1.00	0.91	0.74	0.53
P	0.87	-0.80	-0.90	-0.87	-0.59	-0.35	-0.15	-0.01
INF**	0.63	-0.21	-0.12	0.05	0.38	0.33	0.28	0.23
	SD%	Cross-Correlations of Total Hours with:						
H	0.17	0.59	0.77	0.92	1.00	0.92	0.77	0.59
P	0.86	-0.81	-0.80	-0.67	-0.35	-0.15	0.00	0.12
INF**	0.62	-0.08	0.02	0.19	0.43	0.27	0.21	0.16
*Mean over 100 simulations of 150 each.								
**In! ation is measured as $\log\left(\frac{p_t}{p_{t-1}}\right)$								
Table 5								

Again, government shocks do not improve substantially the models performance but they do reduce the strong negative correlation of output and prices.

[21] For example, when $\phi = 0$, employments volatility is 0.33.

[22] Output is de&ned in the same way as before.

5 Monetary Policy Rules.

Having built some con&dence in our model as a useful laboratory for the study of monetary policy, we now proceed to evaluate four different types of policy rules. The &rst two type of policies have been widely discussed in the literature, these are the Taylor Rules as &rst put forward in Taylor [1993] and what Rotemberg and Woodford [1998] called Generalized Taylor Rules. The former call for a policy that raises nominal interest rates when in! ation is above target or when output is above potential. The later, aims to smooth interest rates The third kind of policy is natural in two ways. First, in an economy subject to technological, it is not clear that a desirable policy would be one that offsets output variability, while it seems more natural to implement one that offsets employment ! uctuations. Recall that employment makes part the of the representative agents utility function. The second is that employment is a good indicator of the real economic activity and that employment data is available at higher frequency than output. That is, the third rule or what we call here the employment rule has also some practical advantages. The fourth rules are forward looking rules. They react to future deviations of in! ation from target and future output gap. In particular, we evaluate two rules estimated for the U.S by Clarida, Gali and Gertler. One corresponds to the pre-Volcker period (pre- October 1979) and the other one, to the Volcker-Greenspan (post-October 1979).

In order to gain some con&dence, and due to the strong restrictions imposed by our model we considered two different way of evaluating the performance of the economy under these different rules. In terms of welfare and in terms of volatility. In terms of welfare we where unable to pin down clean differences among the different rules. On the other hand, in terms of volatility we did &nd considerable differences. Taylor argues that this performance criteria across different models and rules, provides us with a useful robustness criteria for the desirability of a particular rule (a rule is robust if it produces desirable results in a variety of competing macroeconomic frameworks). For the sake of completeness, we also consider the models performance with respect to a simple constant money growth rule.

Formally, the different rules are speci&ed in the following way.

5.0.1 M-Rules

Since we seek to compare the performance of our previous model in the presence of frictions in the labor market, we specify monetary policy in exactly the same as we did before. That is, at the beginning of every period t, the monetary authority exogenously sets the rate of growth of money used for transactions: $M_t - B_t$. We take M as constant and specify monetary policy as:

$$M_{t+1} - B_{t+1} = (M_t - B_t)\mu_t$$

where $\log(\mu_t)$, the rate of growth of money supply, follows the following autoregressive process:

$$\log(\mu_{t+1}) = \rho^{\mu} \log(\mu_t) + \varepsilon_{t+1},\ \varepsilon_{t+1} \sim N(0, \sigma^{\mu})$$

5.0.2 R-Rules

Generalized Taylor Rules:

$$i_t = i + \rho(i_{t-1} - i) + \alpha(\pi_t - \pi) + \beta(Log(Y_t) - Log(Y)) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^r)$$

Where $\pi_t = Log(\frac{p_t}{p_{t-1}})$ and i, π, and Y are the respectively the steady state values of the nominal interest rate, in! ation (which is zero) and output. When $\alpha = 0, \beta = 0$ and $\rho = 0$, we have the constant interest rate rule. When $\rho = 0$ we have Taylor rule and when $\rho \neq 0$ we have the type of policy rule considered by Rotemberg and Woodford (1998).

Clarida Gali Gertler Rule:

Let i_t be the federal fund□s rate We assume the following reaction function for the interest rate:

$$i_t = \rho i_{t-1} + (1-\rho)(i_t^* + \alpha(E_{t+1}[\pi_t] - \pi) + \beta(Log(E_{t+1}[Y_t]) - Log(Y))) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^r),$$

where i_t^* is the federal fund□s target and the rest of the variables have the same meaning as before. It follows that

$$i_t = \rho(i_{t-1} - i^*) + (1-\rho)\alpha(E_{t+1}[\pi_t] - \pi) + (1-\rho)\beta(Log(E_{t+1}[Y_t]) - Log(Y))) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^r),$$

Where $\pi_t = Log(\frac{p_t}{p_{t-1}})$ and i, π, and Y are the respectively the steady state values of the nominal interest rate, in! ation (which is zero) and output. When $\rho = 0$ we have Taylor rule, when $\rho \neq 0$ we have the type of policy rule considered by Rotemberg and Woodford (1998).

Given our setting, it is natural to consider a rule that takes into account the employment rate of the economy. In general, employment data is good and reported frequently. Therefore we also consider the following rule.

Generalized Employment Rule:

$$i_t = i + +\rho(i_{t-1} - i) + \alpha(\pi_t - \pi) + \beta(Log(N_t) - Log(N)) + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^r),$$

6 Performance in terms of In! ation and Output variability.

Table 6 reports the performance of the model when the economy is subject to only technological or government shocks. Except for the adjustment cost parameter we use the same calibration as shown in Table 5. For Table 6 and 7 we used $\phi = 3$. The main reason for this is that with smaller costs, our model was stable across a wide range of policy functions. This allowed us to test the models performance using the same parameters for all the parametrizations of the different rules. Still, in a few cases, the model proved to be unstable.[23] Our results are robust to small variations of ϕ.

In order to make comparisons easier among the different rules, &gure 3 provides scatter plots of the different in! ation and output volatilities when

[23]Further research remains to be done in this direction, but some of the unstable solutions that we found were cleraly due to numerical errors in the implementation of the algorithms. When the eigenvalues of the fundamental dynamical system are close to one, very small errors can make the system unstable or stable. For example, allowing for &fteen decimal places sometimes resulted in unstable systems but an extra decimal place would overturn the result.

the economy is subject to technological shocks (upward graph) or government shocks (lower graph) and under each one of the rules considered in Table 6. All points closer to the origin in both graphs, correspond to rules where the monetary authority doesn't give any weight to the output gap. This makes a case for rules aimed to exclusively target the in! ation rate and/or rules aimed to smooth interest rates.

For the same parameters used for the generalized Taylor rules, generalized employment rules performed the same. In terms of the volatility of output and in! ation and independently of the shock, there is no important difference between these two type of rules.

Table 7 reports the results for our two forward looking rules. The parameters are taken from Clarida, Gali and Gertler [1988]. Here we &nd two interesting results. Under productivity shocks, the post-Volcker rule, characterized by a higher response of the monetary authority to future deviations of in! ation from the target compared to the pre-Volcker rule, performed much better in terms of in! ation and output variability. The results of the post-Volcker rule are as good as the results obtained with generalized Taylor rules that give no weight to the output gap. Under government spending shocks it was the opposite.

Finally, we performed different welfare calculations for the different rules. We did this in the following way. For example, we generated a long series of technological shocks (10000 data points). We then &xed a particular policy rule and calculated the implied equilibrium levels for consumption and employment. We then calculated welfare along that simulation. Next, we did exactly the same but using a different monetary policy rule but using the same series of technological shocks as before. Finally, we calculated the welfare difference of switching between the two rules. Since utility is a cardinal measure, we calculated the shadow price of one additional unit of output in steady state (notice that the steady state is the same for all monetary policy rules). By dividing the welfare difference by the shadow price, we get a measure of the difference in terms of initial units of output of switching between to rules. Our results were not sharp enough to clearly distinguish among the different rules. This is surprising since, in our model, monetary policy has real effects of the magnitudes observed in data. We conclude that welfare differences (in terms of initial units of output) are negligible across economies under the different policy rules considered.

			Volatilities			
Policy Rule			Tech. Shocks		Gov. Shocks	
			In! ation	Output	In! ation	Output
Constant Money Growth						
			0.59	0.87	0.20	0.09
Generalized Taylor Rules						
ρ	α	β				
0	0	0	0.12	0.94	N/A	N/A
0	0.5	0	N/A	N/A	0.44	0.12
0	1.0	0	0.18	0.97	0.16	0.03
0	1.5	0	0.08	0.91	0.07	0.07
0	0.5	0.5	N/A	N/A	N/A	N/A
0	1.0	0.5	N/A	N/A	1.11	0.54
0	1.0	1.0	N/A	N/A	N/A	N/A
0	1.5	0.5	N/A	N/A	0.21	0.23
0	1.5	1.0	9.50	6.52	N/A	N/A
0	1.5	1.5	N/A	N/A	1.58	0.76
0.5	0.5	0	0.15	0.97	0.20	0.03
0.5	1.0	0	0.07	0.93	0.06	0.08
0.5	1.5	0	0.04	0.91	0.04	0.08
0.5	1.0	0.5	6.52	6.59	0.5	0.5
0.5	1.0	1.0	N/A	N/A	N/A	N/A
1.0	0.5	0	0.08	0.92	0.08	0.08
1.0	0.5	0.5	N/A	N/A	N/A	N/A
1.0	1.0	0	0.04	0.93	0.05	0.08
1.0	1.0	0.5	4.17	1.57	0.09	0.14
1.0	1.0	1.0	8.65	8.01	0.67	0.63
1.5	0.5	0.0	0.07	0.95	0.07	0.08
1.5	0.5	0.5	1.56	1.58	0.12	0.15
1.5	1.0	0	0.05	0.91	0.05	0.09
1.5	1.0	0.5	0.59	1.18	0.07	0.11
1.5	1.0	1.0	2.53	3.24	0.18	0.22
1.5	1.5	0	0.03	0.93	0.04	0.08
1.5	1.5	0.5	0.37	1.11	0.05	0.10
1.5	1.5	1.0	1.0	1.61	0.09	0.14
1.5	1.5	1.5	6.26	7.78	0.29	0.35
Table 6 ($\phi = 3$)						

			Volatilities			
Policy Rule			Tech. Shocks		Gov. Shocks	
			In! ation	Output	In! ation	Output
Clarida - Gali - Gertler Rule (pre Volcker)						
ρ	α	β				
0.75	0.8	0.44	15.82	1.57	1.95	0.11
Clarida - Gali - Gertler Rule (post Volcker)						
0.66	1.8	0.12	0.21	1.02	4.8	0.12
Table 7 ($\phi = 3$)						

7 Conclusions.

This paper provides evidence and documents some facts linking monetary policy and the labor market. We highlighted the strong positive correlations of all measures of employment with in! ation (i.e. the Phillips Curve) and the short run expansionary effects of monetary policy (i.e. the Liquidity Effect). We have built a model that rationalizes these facts in a broad sense. Our &rst model, a standard dynamic general equilibrium model with &nancial intermediation frictions and without unemployment (a la Lucas-Rapping) was shown to be consistent with the liquidity effect. Nevertheless, the &rst model is unable to address some empirical facts put forward at the beginning of the paper including, the positive correlation of all measures of labor supply with in! ation and the observed employment volatility (using any measure of labor supply).

The next step was to build a more detailed model of the labor market but keeping the basic structure and intuition of the &rst one. This full model considerably ampli&es the effects of monetary policy and it was shown to be broadly consistent with the empirical facts at the beginning of the paper. Therefore, we argued that this model is particularly useful for the study of monetary policy.

We then proceeded to evaluate four different types of rules, some of them widely discussed in the literature. Taylor rules, Generalized Taylor Rules (i.e. rules aimed to smooth interest rates), what we call in our paper employment rules and two estimated forward looking rules for the U.S. We found considerable differences among the rules when compared in terms of the volatility

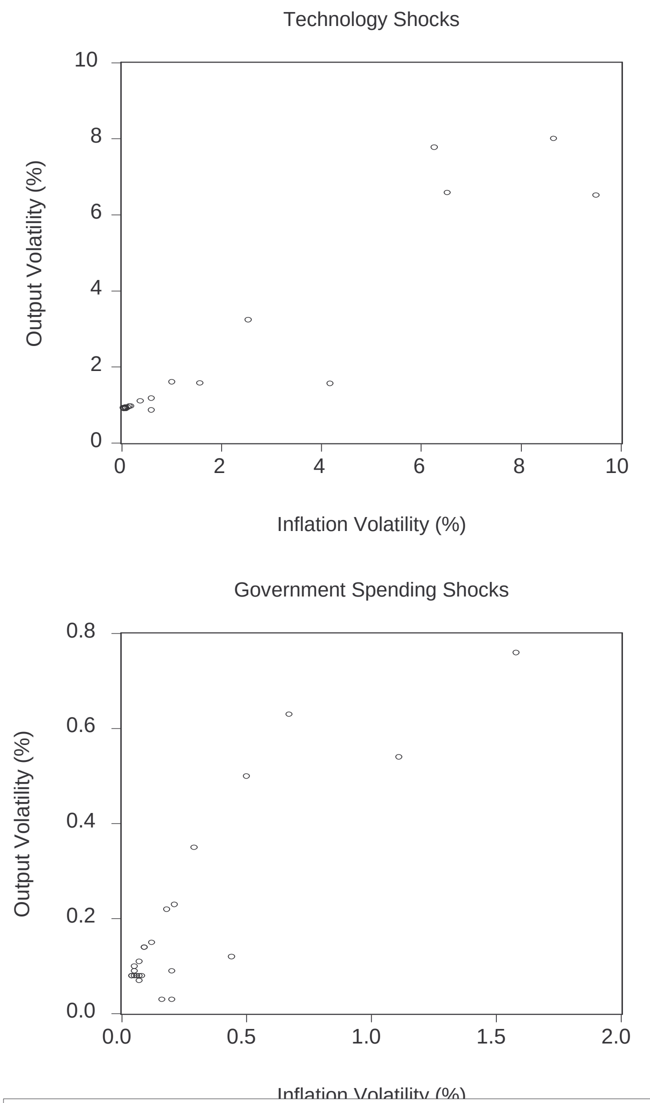

Figure 3: Scatter plot of output and inflation volatitlity from
Table 6. Upward graph corresponds to technology shocks.
Lower graph corresponds to government spending shocks.

Figure 3:

implied in the economy. Among all types of rules, none of them clearly dominates the other ones, but we argued that Taylor rules with considerable weight on the output gap don't necessarily perform better in terms of volatility. This result is in contrast to what is reported in Taylor [1998]. In general Taylor rules perform well but pure inflation targeting performs better as it is also reported by Christiano and Gust [1999]. On the other hand, rules aimed to smooth interest rates perform pretty well (as good as pure inflation targeting). This is consistent with the findings of Rotemberg and Woodford [1998]. The above results are independent of the type of shocks that drive the economy. Employment rules, performed similarly to their generalized Taylor rules counterparts. Again this is independent of the shock that drives the economy.

In terms of welfare, we found negligible differences across economies under different monetary policy rules.

Appendix 1

Cyclical Behavior of the U.S economy: First Differences, 1959:II - 1998:II								
	SD%	Cross-Correlations of Output with:						
Variable		(-3)	(-2)	(1)	(0)	(1)	(2)	(3)
Y[24]	0.77	0.29	0.33	0.44	1.00	0.44	0.33	0.29
P	0.62	-0.42	-0.41	-0.44	-0.45	-0.40	-0.35	-0.31
INF	0.28	-0.17	0.01	-0.07	-0.06	0.10	0.08	0.07
	SD%	Cross-Correlations of Employment with:						
N	0.96	0.54	0.73	0.91	1.00	0.91	0.73	0.54
P	0.62	-0.23	-0.23	-0.23	-0.16	-0.10	-0.04	-0.01
INF	0.28	-0.07	0.04	-0.01	0.13	0.14	0.12	0.07
	SD%	Cross-Correlations of Total Hours with:						
H	0.66	0.08	0.17	0.43	1.00	0.43	0.17	0.08
P	0.60	-0.28	-0.31	-0.34	-0.26	-0.21	-0.18	-0.13
INF	0.29	-0.07	-0.05	-0.06	0.14	0.11	0.05	0.10
	SD%	Cross-Correlations of Hours per worker with:						
h	0.30	-0.05	0.00	0.18	1.00	0.18	0.00	-0.05
P	0.60	-0.14	-0.18	-0.26	-0.22	-0.21	-0.25	-0.22
INF	0.29	-0.06	-0.10	-0.14	0.11	0.03	-0.10	0.06
Source: author calculations								
Table 1 (Appendix).								

[24] Output is de&ned as the sum of private consumption, investment and government expenditures. For a description of the data see Apendix II.

Appendix 2

All data is taken from DRI Basic Economics 1998. The different tags correspond to the ones used in the data set.

GCNQF: Personal consumption expenditures on nondurables. Billions of constant (1992) dollars, seasonally adjusted at annual rates.

GCSQF: Personal consumption expenditures on services. Billions of constant (1992) dollars, seasonally adjusted at annual rates.

GCDQF: Personal consumption expenditures on durables. Billions of constant (1992) dollars, seasonally adjusted at annual rates.

GGEQF: Government consumption expenditures and gross investment. Billions of constant (1992) dollars, seasonally adjusted at annual rates.

GIFQF: Private &xed investment. Billions of constant (1992) dollars, seasonally adjusted at annual rates.

LHEM: Total employed (household data) thousands of persons, seasonally adjusted, converted from monthly data (average over each period).

LW: Total private hours per week (household data) seasonally adjusted, converted from monthly data (average over each period).

LHUR: Total unemployment rate (household data), seasonally adjusted, converted from monthly data (average over each period).

LHELX: Employment ratio, help wanted ads divided by the number of unemployed workers, converted from monthly data (average over each period).

LHPAR: Labor force participation rate, total16+, converted from monthly data (average over each period).

P16: Total civilian non-institutional population.

GDPD: Gross domestic product: Implicit price de! ator (index, 1992=100). This is our measure of price level.

INF: Logarithmic deviation of GDPD.

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