Labor and Financial Frictions and Aggregate Fluctuations*

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Abstract

This paper develops a New Keynesian model that embeds labor market search frictions into a New Keynesian model with financial frictions as in Bernanke, Gertler and Gilchrist (1999). Labor market frictions generate two competing effects on aggregate fluctuations. First, they dampen the reaction of the firm's cost of external finance, decreasing the effect of financial frictions on macroeconomic aggregates, thereby reducing aggregate fluctuations. Second, they increase the reaction of employment, capital and production, thereby magnifying aggregate fluctuations. The overall effect depends on the nature of the shock. The reaction of macroeconomic aggregates is stronger for monetary policy and technology shocks, while weaker for labor supply and preference shocks. Labor market frictions increase the overall variables' persistence to shocks.

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1 Introduction

Developments in the credit markets play an important role for the amplification and propagation of shocks. Seminal work by Bernanke, Gertler and Gilchrist (1999) show that asymmetric information in credit markets generates a negative relationship between the firms' financial value and the cost of raising external funds, whose interaction amplifies the magnitude and persistence of macroeconomic fluctuations. Subsequent studies show that allowing for financial frictions in macroeconomic models enables a more accurate account of aggregate fluctuations.[1] A parallel realm of the literature, initiated by Merz (1995) and Andolfatto (1996), shows that labor market frictions are important to describe the amplification and persistence of macroeconomic shocks.

The aim of this paper is to merge these strands of the literature together and investigate the effect of the links between labor and financial frictions on aggregate fluctuations by using a dynamic, stochastic, general equilibrium (DSGE) model characterized by nominal price rigidities. In particular, we focus on the following question: how do labor market frictions interact with financial frictions to alter the magnitude and persistence of fluctuations in nominal variables and economic activity?

Existing models with financial frictions, with a few noticeable exceptions, as detailed below, assume that adjustments in the labor market are costless. In this paper instead we assume that labor market frictions prevent the competitive allocation of resources and it is costly to hire new workers. In this way, the functioning of the labor market interacts with financial frictions to influence production, capital accumulation and investment. Our modeling strategy is to set up a New Keynesian model with financial frictions as in Bernanke, Gertler and Gilchrist (1999, henceforth BGG) enriched with labor market frictions as in Blanchard and Galí (2010). To establish the importance of labor market frictions and their interaction with financial frictions, we estimate two versions of the model using macroeconomic time-series data for the US from the seventies onwards. First, a version characterized by financial frictions and a frictionless labor market, as in BGG and, second, a version that also allows for labor market frictions. In this way, we are able to evaluate the importance of labor market frictions over and above the BGG model with financial frictions. Furthermore, the estimated model enables an empirically-grounded investigation on the effects of both frictions

[1] Recent noticeable contributions are Christensen and Dib (2008), De Graeve (2008), and Nolan and Thoenissen (2009) among others.

on aggregate fluctuations.

Econometric estimation shows that the data strongly prefer the model that includes both labor and financial frictions, over and above the model with financial frictions only. The presence of labor market frictions leaves the sign of the response of key macroeconomic variables to shocks substantially unchanged compared to the model with a frictionless labor market. However, labor market frictions generate two competing effects on aggregate fluctuations. On the one hand, by affecting the firm's real cost of repaying existing debt, they diminish the reaction of the external finance premium to shocks, thereby dampening the effect of financial frictions on macroeconomic aggregates. For instance, in the aftermath of a contractionary monetary policy shock (i.e. an increase in the nominal interest rate) inflation falls by less due to labor market frictions, which, because of a debt-deflation effect, decreases the real cost of servicing existing debt and consequently attenuates the fall in the firm's net worth. A higher net worth generates a lower leverage ratio, which attenuates the increase in the external finance premium, thereby increasing aggregate fluctuations and dampening the effect of financial frictions. On the other hand, labor market frictions alter the firm's employment and production decisions, and amplify the reaction of macroeconomic aggregates, reinforcing the effect of financial frictions. For instance, in the aftermath of a contractionary monetary policy shock the firm robustly decreases hiring, employment, investment and production, thereby reinforcing the contraction in economic activity. Hence, in principle, labor market frictions may either magnify or dampen the effect of financial frictions on aggregate fluctuations. For monetary policy and technology shocks, labor market frictions reduce the effect of financial frictions and dampen the response of macroeconomic aggregates, since the robust decrease in employment and production outweighs the rise in investment triggered by lower costs of servicing external debts. On the contrary, for cost-push and preference shocks labor market frictions stimulate investment and economic activity, due to the lower external finance premium induced by the reduction in the real cost of repaying existing debt. Moreover, irrespective of the shock, labor market frictions increase the overall variables' persistence, which reinforces the findings in Walsh (2005).

The econometric estimation identifies the model's structural parameters and characterizes the unobservable shocks that hit the US economy over the sample period. We establish that the presence of labor market frictions leaves the estimates of the model's parameters in line with related studies that abstract from both labor and financial frictions, as in Smets and Wouters (2007). This also echoes the findings in Christensen and Dib (2008), De Graeve

(2008) and Iacoviello and Neri (2010) who show that the inclusion of a more detailed functioning of asset markets in models with financial frictions leaves the estimates of the structural parameters of the model substantially unchanged. Furthermore, in line with these related studies, we find that monetary policy reacts more strongly to inflation rather than output fluctuations. Interestingly, the estimated mild degree of nominal price rigidities implies that firms change prices every two and a half quarters on average, which is shorter than the macro estimates of approximately one year in Sbordone (2002). However, this is in line with estimates based on microdata, as in Klenow and Kryvtsov (2008), showing that the coexistence of labor market and financial frictions enables macro models to generate a degree of nominal price rigidities consistent with micro estimates.

We find that shocks to preferences, labor supply and technology are highly persistent, unlike cost-push shocks. Moreover, shocks to technology and preferences play a primary role in explaining macroeconomic fluctuations in the long run and also monetary policy shocks play a supporting role in the short run, while cost-push shocks play a minimal role. These results reinforce the findings in models without financial and labor market frictions as in Smets and Wouters (2007) and Ireland (2007), as well as models that considered separately either financial frictions, as in Christensen and Dib (2008) and De Graeve (2008), or labor market frictions, as in Gertler, Sala and Trigari (2008). Finally, using a Kalman filter on the model's reduced form we provide estimates for the unobservable shocks that characterize the US economy. In general, we find that the magnitude of shocks has decreased from the mid-1980s until 2008. Furthermore, we find that the volatility of monetary policy shocks declined during the same period. These findings corroborate the results of empirical studies by Sims and Zha (2006), Gambetti, Pappa and Canova (2008) and Benati and Mumtaz (2007), which detected a period of macroeconomic stability triggered by a lower volatility of shocks in the US from the mid-1980s until 2008.

The remainder of the paper is structured as follows. Section 2 discusses the connections to the existing literature. Section 3 presents the model. Section 4 discusses the data, the empirical methodology and results, and Section 5 concludes.

2 Connections to the Existing Literature

As mentioned in the outset, this paper contributes to and merges together two realms of the literature. First, it enriches the BGG financial accelerator framework with a more realistic functioning of the labor market. Recent studies by Christensen and Dib (2008), De Graeve (2008) and Nolan and Thoenissen (2009) show that financial frictions improve the empirical performance of a standard New Keynesian model. However, these studies assume a frictionless labor market. A growing number of research shows that labor market frictions is a key element to replicate important stylized facts in the US data.[2] Our paper points out that labor market frictions, over and above financial frictions, are highly supported by the data, and they work together with financial frictions to amplify or dampen the variables' reaction to shocks. Along these lines, Wasmer and Weil (2004) show that an integrated model with labor and credit market imperfections, produced by search costs in both labor and credit markets, works towards amplifying macroeconomic volatility. Ernst, Mittnik and Semmler (2010) enrich this framework with endogenous credit frictions in the form of state-dependent bond-issuing costs, thereby allowing financial matching efficiency to depend on the firm's net worth. They find that the interaction between labor and capital markets generates multiple equilibria that may magnify the transmission mechanism of macroeconomic shocks. Christiano, Trabandt and Walentin (2009) develop a large-scale DSGE model that includes financial and labor market frictions into an open economy model characterized by a complex banking system and multi-sector firms and they estimate it using Swedish data. The results of these papers follow from the strategic interactions between financial intermediaries, entrepreneurs and workers, while in our setting the amplification mechanism is based, as in BGG or Kiyotaki and Moore (1997), on fluctuations in the firm's leverage ratio and their effect on the cost of external finance.

This paper also contributes to the growing literature that investigates the effect of labor market frictions on aggregate fluctuations. Gertler, Sala and Trigari (2008), Krause, Lopez-Salido and Lubik (2008), Christoffel, Kuester and Linzert (2006), Ravenna and Walsh (2008) and Thomas (2008) embed labor market frictions into a standard New Keynesian model and show that the enriched model matches the data more closely. We enrich this realm of research by showing that labor market frictions have important consequences on the working of the BGG model with financial frictions, as they either magnify or dampen the effect of exogenous disturbances on macroeconomic aggregates, depending on the nature of the shock.

[2] See, among others, Merz (1995), Andolfatto (1996) and more recently Hall (1999), Gertler and Trigari (2009) and references therein.

3 The Economic Environment

The theoretical model combines the financial accelerator framework of BGG, as detailed in Christensen and Dib (2008) and Nolan and Thoenissen (2009), with labor market frictions as in Blanchard and Galí (2010). The model economy is comprised of households, entrepreneurs, capital producers, a continuum of retailers indexed by $i \in [0,1]$, and a monetary authority.

In the financial market, asymmetric information between entrepreneurs and financial intermediaries creates financial frictions which make the entrepreneurs demand of capital depend on their financial strength. The labor market is similar to Blanchard and Galí (2010) and is based on the assumption that the processes of job search and recruitment are costly for both the firm and the worker. Job creation takes place when a firm and a searching worker meet and agree to form a match at a negotiated wage, which depends on the joint surplus from working. The match continues until the parties exogenously terminate the relationship.

The goods market is comprised of entrepreneurs, capital producers, and a continuum of retailers indexed by $i \in [0,1]$. During each period $t = 0, 1, 2, \ldots$, entrepreneurs manufacture intermediate goods using capital and labor, borrow from financial intermediaries who convert households' deposits into business financing for the purchase of capital. Entrepreneurs acquire labor by hiring new workers from the households and they purchase capital from capital producers. The adjustment of both labor and capital is costly. To adjust labor entrepreneurs recruit workers at a constant cost per hire and it takes time to build up labor. Capital producers face costs of adjusting the capital stock, which, as in Kiyotaki and Moore (1997), make the asset price volatility contribute to the volatility in entrepreneurial net worth. During each period $t = 0, 1, 2, \ldots$, retailers purchase intermediate goods from the entrepreneurs and sell them in a monopolistic competitive market at an established price. To introduce nominal rigidities in the model, each retailer is allowed to set a new price with probability φ, as in Calvo (1983). The presence of nominal rigidities enables the monetary authority to influence the behavior of real variables in the short run.

The monetary authority is modelled with a modified Taylor (1993) rule as in Clarida, Galí and Gertler (1998): it adjusts the nominal interest rate in response to deviations of inflation and output growth from their steady-state values.

The next subsections describe the agents' tastes, technologies, the policy rule, and the structure of the goods and labor markets in detail.

3.1 The Representative Household

During each period $t = 0, 1, 2, \ldots$, the representative household maximizes the expected utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[e_t \ln C_t - \chi_t N_t^{1+\phi}/(1+\phi) \right], \tag{1}$$

where the variable C_t is consumption, N_t is unit of labor, β is the discount factor $0 < \beta < 1$, and e_t and χ_t are the aggregate preference and labor supply shocks that follow the autoregressive processes

$$\ln(e_t) = \rho_e \ln(e_{t-1}) + \varepsilon_{et}, \tag{2}$$

and

$$\ln(\chi_t) = (1-\rho_\chi)\ln(\chi) + \rho_\chi \ln(\chi_{t-1}) + \varepsilon_{\chi t}, \tag{3}$$

where $(\rho_e, \rho_\chi) < 1$. The zero-mean, serially uncorrelated innovations ε_{et} and $\varepsilon_{\chi t}$ are normally distributed with standard deviation σ_e and σ_χ. The representative household enters period t with deposits D_{t-1}, which pay interest, providing $R_{t-1}D_{t-1}$ additional units of currency, where R_t represents the gross nominal interest rate between t and $t+1$. At the beginning of the period, the household receives a lump-sum nominal transfer T_t from the central bank and another lump-sum nominal transfer Π_t, which include profits from retailers and equity from entrepreneurs who exit business. The household supplies N_t units of labor at the wage rate W_t to entrepreneurs and if unemployed receives unemployment benefits B_t during period t. The household uses its income for consumption, C_t, and carries D_t deposits into period $t+1$, subject to the budget constraint

$$\left[R_{t-1}D_{t-1} + W_t N_t + \Pi_t + T_t + (1-N_t)B_t\right]/P_t = C_t + D_t/P_t, \tag{4}$$

for all $t = 0, 1, 2, \ldots$.[3] Thus the household chooses $\{C_t, D_t\}_{t=0}^{\infty}$ to maximize its utility (1) subject to the budget constraint (4) for all $t = 0, 1, 2, \ldots$. Letting $\pi_t = P_t/P_{t-1}$ denote the gross inflation rate, and Λ_t the non-negative Lagrange multiplier on the budget constraint (4), the first-order conditions for this problem are

$$\Lambda_t = e_t/C_t, \tag{5}$$

and

$$\Lambda_t = \beta R_t E_t(\Lambda_{t+1}/\pi_{t+1}). \tag{6}$$

[3] As in Merz (1995) and Andolfatto (1996), to avoid distributional issues from heterogeneity in income, members of the household are able to perfectly insure each other against fluctuations in income.

According to equation (5), the Lagrange multiplier must equal the households' marginal utility of consumption. Equation (6), once equation (5) is substituted in, is the households Euler equation that describes the optimal consumption decision.

3.2 The Labor Market

During each period $t = 0, 1, 2, \ldots$, the flow into employment results from the number of workers who survive from the exogenous separation, and the number of new hires, H_t. Hence, total employment evolves according to

$$N_t = (1 - \delta_n)N_{t-1} + H_t, \tag{7}$$

where N_t and H_t represent the number of workers employed and hired by firm i in period t, and δ_n is the exogenous separation rate and $0 < \delta_n < 1$. It is convenient to introduce the variable x_t, the job finding rate:

$$x_t = H_t/U_t, \tag{8}$$

and assume, as in Blanchard and Galí (2010), full participation in the labor market such that

$$U_t = 1 - (1 - \delta_n)N_{t-1} \tag{9}$$

is the beginning of period unemployment.

Let $\mathcal{W}_t^N$, and $\mathcal{W}_t^U$, denote the marginal value of the expected income of an employed, and unemployed worker respectively. The employed worker earns a wage, suffers disutility from work, and might lose her job with probability δ_n. Hence, the marginal value of a new match is:

$$\mathcal{W}_t^N = \frac{W_t}{P_t} - \chi_t \frac{N_t^{\phi}}{\Lambda_t} + \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t} \left\{ \left[1 - \delta_n \left(1 - x_{t+1}\right)\right] \mathcal{W}_{t+1}^N + \delta_n \left(1 - x_{t+1}\right) \mathcal{W}_{t+1}^U \right\}. \tag{10}$$

This equation states that the marginal value of a job for a worker is given by the real wage reduced for the marginal disutility of working and the expected-discounted net gain from being either employed or unemployed during period $t + 1$.

The unemployed worker expects to move into employment with probability x_t. Hence, the marginal value of unemployment is:

$$\mathcal{W}_t^U = \frac{B_t}{P_t} + \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t} \left[x_{t+1} \mathcal{W}_{t+1}^N + \left(1 - x_{t+1}\right) \mathcal{W}_{t+1}^U\right]. \tag{11}$$

This equation states that the marginal value of unemployment is made up of unemployment benefits together with the expected-discounted capital gain from being either employed or unemployed during period $t+1$. Similarly to Thomas and Zanetti (2009), unemployment benefits are set as a proportion, ρ_b, of the established wage, such that $B_t = \rho_b W_t$, where ρ_b represents the replacement ratio.

The structure of the model guarantees that a realized job match yields some pure economic surplus. The share of this surplus between the worker and the firm is determined by the wage level. The wage is set according to the Nash bargaining solution. The worker and the firm split the surplus of their matches with the absolute share η, and $0 < \eta < 1$. The difference between equation (10) and (11) determines the worker's surplus. To keep the model simple, as in Pissarides (2000), we assume that the firm's surplus is given by the real cost per hire, κ. Hence, the total surplus from a match is the sum of the worker's and the firm's surpluses. The wage bargaining rule for a match is

$$\eta\kappa = (1-\eta)(\mathcal{W}_t^N - \mathcal{W}_t^U).$$

Substituting equations (10) and (11) in this last equation produces the agreed wage:

$$W_t/P_t = \chi_t N_t^{\phi}/\Lambda_t + B_t/P_t + \kappa\left[\eta/\left(1-\eta\right)\right]\left\{1-\beta\left(1-\delta_n\right)E_t\left(\Lambda_{t+1}/\Lambda_t\right)\left(1-x_{t+1}\right)\right\}, \quad (12)$$

where η is the bargaining power of the worker. Equation (12) gives the wage consistent with the wage bargaining. It shows that the wage equals the disutility of working, plus unemployment benefits together with current hiring costs, and the expected savings in terms of the future hiring costs if the match continues in period $t+1$.

3.3 The Goods Market

As described, the production sector is comprised of entrepreneurs, capital producers and retailers indexed by $i \in [0,1]$, characterized by staggered price-setting as in Calvo (1983).

3.3.1 The Entrepreneurs

As in BGG, entrepreneurs use labor and capital to manufacture goods and borrow funds from financial intermediaries to acquire the capital used in the production process. Entrepreneurs are risk neutral and face a constant probability ν to survive the next period. This ensures that the entrepreneurs' net worth would never exceed the value of new capital acquisition. To finance new acquisitions entrepreneurs issue debt contracts to cover the capital acquisition in excess of net worth.

During each period $t = 0, 1, 2, ...$, entrepreneurs acquire capital, K_{t+1}, at the real price q_t, such that the total cost of new capital acquisition is $K_{t+1}q_t$. The acquisition is financed using their net worth, ω_t, and issuing debt contracts of the amount of $K_{t+1}q_t - \omega_t$ to financial intermediaries, which purchase debt by using the households' deposits at the cost R_t.

As in BGG, we express the expected gross return of holding a unit of capital, $E_t r^K_{t+1}$, to depend on the expected return on capital and the expected marginal financial cost, such that

$$E_t r^K_{t+1} = E_t \left[\Xi_{t+1} \alpha \frac{Y_{t+1}}{K_{t+1}} + (1 - \delta_k) q_{t+1} \right] / q_t, \tag{13}$$

where Ξ_{t+1} is the real marginal cost at $t+1$, $\Xi_{t+1}\alpha Y_{t+1}/K_{t+1}$ is the real marginal productivity of capital at $t+1$, and $(1-\delta_k)q_{t+1}$ is the cost of acquiring a unit of capital at $t+1$. Equation (13) represents the demand for new capital and states that the return on capital depends inversely on the level of investment, due to diminishing returns.

Asymmetry of information between entrepreneurs and financial intermediaries and associated monitoring costs breaks down the Modigliani-Miller Theorem and makes the entrepreneurs' external borrowing costs higher than internal funds. As shown in BGG, the external finance premium, $S(\cdot)$, depends on the entrepreneur's leverage ratio, $K_{t+1}q_t/\omega_t$, whose elasticity depends on the structure of the financial contracts.[4] In this setting, the external financing cost equates the premium for external funds plus the real opportunity cost of investing in risk-free deposits:

$$E_t r^K_{t+1} = E_t \left[S(\cdot)(R_t / E_t \pi_{t+1}) \right], \tag{14}$$

where $R_t/E_t\pi_{t+1}$ is the real interest rate (i.e the risk-free rate). Note that, as shown in BGG, the higher the leverage ratio the higher the external finance premium, i.e. $S'(\cdot) > 0$, and, similarly, in the limiting case in which all the new acquisitions are financed through the entrepreneur's net worth, the external finance premium disappears, such that the cost of external finance equals the risk-free rate (i.e. $S(1) = 1$). Note that equation (14) represents the demand of capital, which, up to a first-order approximation, becomes

$$\hat{r}^K_{t+1} = \hat{R}_t - \hat{\pi}_{t+1} + \psi(\hat{q}_t + \hat{K}_{t+1} - \hat{\omega}_t),$$

where ψ is the elasticity of the external finance premium respect to the leverage ratio and a hat superscript denotes the variable's deviation from its steady state.

[4] BGG reports the complete derivation of the external finance premium and its elasticity to the leverage ratio.

As in BGG, the aggregate entrepreneurial net worth is given by

$$\omega_{t+1} = \nu \upsilon_t + (1-\nu) g_t, \tag{15}$$

where ν is the probability of the entrepreneurs to survive to the next period, υ_t is the net worth of entrepreneurs at time $t-1$ who are still in business at time t, and g_t is the transfer that surviving entrepreneurs receive from those who perish during the current period. The net worth of the entrepreneurs who survive is equal to the ex-post value of capital, $r_t^K K_t q_{t-1}$, minus the cost of borrowing, $E_{t-1} r_t^K (K_t q_{t-1} - \omega_t)$, such that

$$\upsilon_t = r_t^K K_t q_{t-1} - E_{t-1} r_t^K (K_t q_{t-1} - \omega_t). \tag{16}$$

During each period $t = 0, 1, 2, ...$, entrepreneurs hire N_t units of labor from the households and K_t units of capital from the capital producers, in order to produce Y_t units of good according to the constant returns to scale production technology

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha}, \tag{17}$$

where the aggregate technology, A_t, follows the autoregressive process

$$\ln(A_t) = \rho_a \ln(A_{t-1}) + \varepsilon_{at}, \tag{18}$$

where $0 < \rho_a < 1$. The zero-mean, serially uncorrelated innovation ε_{at} is normally distributed with standard deviation σ_a. The capital stock evolves according to

$$K_{t+1} = (1-\delta_k) K_t + I_t, \tag{19}$$

where $0 < \delta_k < 1$ is the capital depreciation rate and I_t is investment. The entrepreneurs maximize their total value of profits given by

$$E_0 \textstyle\sum_{t=0}^{\infty} \beta^t \Lambda_t (\Theta_t / P_t), \tag{20}$$

subject to the constraints imposed by (7), (17) and (19). In equation (20), the term $\beta^t \Lambda_t$ measures the marginal utility value to the household of an additional dollar in profits received during period t and

$$\Theta_t / P_t = Y_t - N_t W_t / P_t - H_t \kappa - I_t q_t \tag{21}$$

for all $t = 0, 1, 2, ...$ Thus, the entrepreneurs choose $\{N_t, H_t, K_t, I_t\}_{t=0}^{\infty}$ to maximize the profit (21) subject to the production technology (17), the law of employment accumulation (7) and the law of capital accumulation (19). Solving equation (7) for H_t, and equation (19) for I_t and substituting the outcomes into equation (21), and letting Ξ_t denote the non-negative Lagrange multiplier on equation (17), yields to the first-order conditions[5]

$$\frac{W_t}{P_t} = \frac{\Xi_t}{\Lambda_t}(1-\alpha)\frac{Y_t}{N_t} - \kappa E_t \left[1 - \beta(1-\delta_n)\frac{\Lambda_{t+1}}{\Lambda_t}\frac{1}{\pi_{t+1}}\right], \tag{22}$$

and

$$\Lambda_t q_t = \beta E_t \left[\Xi_{t+1}\alpha\frac{Y_{t+1}}{K_{t+1}} + \Lambda_{t+1}q_{t+1}(1-\delta_k)\right]. \tag{23}$$

Equation (22) is the entrepreneurs' labor demand condition which equates the real wage with the marginal product of labor minus the hiring costs to pay in period t, plus the expected saving on the hiring costs foregone in period $t+1$, if the job is not dismissed. Equation (23) is the standard Euler equation for capital, which links the intertemporal marginal utility of consumption with the real remuneration of capital. Note that equation (22) gives the wage consistent with the firm's profits maximization. In equilibrium, the bargained wage (12) equates the firm's wage (22).

3.3.2 Capital Producers

During each period $t = 1, 2, 3, \ldots$, capital producers manufacture capital goods and sell them to entrepreneurs. They use final goods from retailers and are subject to the quadratic capital adjustment costs $(\chi_K/2)(I_t/K_t - \delta_k)^2 K_t$, so that asset price volatility contributes to the volatility in entrepreneurial net worth. Hence, capital producers choose $\{I_t\}_{t=0}^{\infty}$ to maximize their profits

$$q_t I_t - I_t - (\chi_K/2)(I_t/K_t - \delta_k)^2 K_t.$$

This yields the first-order condition

$$q_t = 1 + (\chi_K)(I_t/K_t - \delta_k), \tag{24}$$

which is the standard Tobin's Q equation of investment, and represents the supply curve for new capital. Equation (24) equates the price of capital with its marginal adjustment cost. As in Kiyotaki and Moore (1997), equation (24) enables asset price volatility to affect the entrepreneurial net worth, which is an important mechanism of shocks propagation in BGG.

[5]Note that the non-negative Lagrange multiplier Ξ_t can also be interpreted as the entrepreneur's real marginal cost.

3.3.3 Retailers

There is a continuum of monopolistically competitive retailers indexed by $i \in [0,1]$. Retailers buy goods from the entrepreneurs, transform each unit of these goods into a unit of retail goods and re-sell them at an established price. During each period $t = 0, 1, 2, ...$, each retailer i faces the following demand curve for its own product

$$Y_t(i) = \left[P_t(i)/P_t\right]^{-\theta_t} Y_t,$$

where θ_t is the time-varying elasticity of demand for each intermediate good, as first introduced by Ireland (2004) and Smets and Wouters (2007), which acts as a cost-push shock and follows the autoregressive process

$$\ln(\theta_t) = (1 - \rho_\theta)\ln(\theta) + \rho_\theta \ln(\theta_{t-1}) + \varepsilon_{\theta t}, \tag{25}$$

where $\rho_\theta < 1$. The zero-mean, serially uncorrelated innovation $\varepsilon_{\theta t}$ is normally distributed with standard deviation σ_θ. During each period $t = 0, 1, 2, ...$, each retail firm sets prices as described by Calvo (1983), such that a fraction $(1 - \varphi)$ of retail firms sets a new price, while the remaining fraction φ charges the previous period's price updated for the steady-state inflation. Hence, firm i that sets a new price $P_t(i)$ in time t maximizes

$$E_0 \sum_{k=0}^{\infty} (\beta\varphi)^k \left(\Lambda_{t+k}/\Lambda_t\right) \left\{ \left[P_t(i)/P_t\right]^{-\theta_t} Y_{t+k} \left[P_t(i)/P_{t+k} - \Xi_{t+k}\right] \right\},$$

where Ξ_t is the real marginal cost. First-order conditions for this problem are

$$P_t^*(i) = \frac{\theta_t \sum_{k=0}^{\infty} (\varphi\beta)^k E_t \left(\Lambda_{t+k} P_{t+k}^{\theta_t} Y_{t+k} \Xi_{t+k}\right)}{(\theta_t - 1) \sum_{k=0}^{\infty} (\varphi\beta\pi)^k E_t \left(\Lambda_{t+k} P_{t+k}^{\theta_t - 1} Y_{t+k}\right)}, \tag{26}$$

where $P_t^*(i)$ is the price chosen by the retailer and P_t is the aggregate price index

$$P_t = \left[\varphi P_{t-1}^{1-\theta_t} + (1-\varphi) P_t^{*1-\theta_t}\right]^{\frac{1}{1-\theta_t}}. \tag{27}$$

Using equations (26) and (27) yields the standard Phillips curve

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + k_p \left(\hat{\Xi}_t + \hat{\theta}_t\right), \tag{28}$$

where the coefficient $k_p \equiv (1 - \beta\varphi)(1 - \varphi)/\varphi$.

3.4 The Monetary Authority

During each period $t = 0, 1, 2, \ldots$, the monetary authority conducts monetary policy using a modified Taylor (1993) rule,

$$\ln(R_t/R) = \rho_y \ln(Y_t/Y_{t-1}) + \rho_\pi \ln(\pi_t/\pi) + \varepsilon_{vt}, \tag{29}$$

where R and π are the steady-state values of the nominal interest rate and inflation. The zero-mean, serially uncorrelated policy shock ε_{vt} is normally distributed, with standard deviation σ_v. According to equation (29), the monetary authority adjusts the nominal interest rate in response to movements in output growth and inflation from their steady-state levels. As pointed out in Clarida, Galí and Gertler (1998) this modelling strategy for the central bank consistently describes the conduct of monetary policy in the US.

3.5 Equilibrium and Solution

In a symmetric, dynamic, equilibrium, all agents make identical decisions, so that $Y_t(i) = Y_t$, $N_t(i) = N_t$, $H_t(i) = H_t$, $D_t(i) = D_t$, and $P_t(i) = P_t$, for all $i \in [0, 1]$ and $t = 0, 1, 2, ...$ In addition, the market clearing conditions $D_t = D_{t-1} = 0$ and $T_t + (1 - N_t)B_t = 0$ must hold for all $t = 0, 1, 2, ...$ The aggregate market clearing condition states that output is the sum of consumption, investment, the aggregate costs of hiring, the adjustment costs of capital, and the monitoring costs of loans,[6]

$$Y_t = C_t + I_t + H_t\kappa + (\chi_K/2)(I_t/K_t - \delta_k)^2 K_t. \tag{30}$$

The model describes the behavior of 22 variables $\{Y_t, I_t, C_t, N_t, K_t, H_t, U_t, B_t, x_t, R_t, \pi_t, \omega_t, \upsilon_t, r_t^K, \Xi_t, q_t, W_t, \Lambda_t, e_t, \chi_t, A_t, \theta_t\}$. The equilibrium is then described by the representative household's first-order conditions (5) and (6), the law of employment (7), the definition of the job finding rate (8), the definition of unemployment accumulation (9), the agreed wage (12), expected gross return of holding a unit of capital (13), the external financing cost (14), aggregate entrepreneurial net worth (15), the surviving entrepreneurs' net worth (16), the production technology (17), the labor demand equation (22), the cost for new capital (24), the law of capital accumulation (19), the Phillips curve (28), the monetary authority policy rule (29), the aggregate resource constraint (30), the definition of unemployment benefits ($B_t = \rho_b W_t$)

[6] Note that since the costs of monitoring loans have a little impact on the dynamic of the model, as detailed in BGG and Gilchrist and Leahy (2002), we can safely abstract from them.

and the specifications of the disturbances for the preference shock (2), the labor supply shock (3), the technology shock (18), and the cost-push shock (25).[7]

The equilibrium conditions do not have an analytical solution. Instead, the model's dynamics is characterized by log-linearizing them around the steady state. The solution to the system is derived using Klein (2000), which is a modification of Blanchard and Kahn (1980), and takes the form of a state-space representation. This latter, as detailed below, can be conveniently used in the estimation procedure.

4 Estimation and Findings

The econometric estimation uses US quarterly data for output, unemployment, the nominal interest rate, inflation and real wages for the sample period 1970:1 through 2009:3. Output is defined as real gross domestic product; unemployment is defined as the civilian unemployment rate; the nominal interest rate is defined as quarterly averages of the Federal Funds rate; inflation is defined as the quarterly growth rate of the GDP deflator; and real wages are defined as the real compensation in the non-farm business sector. All the data are taken from the FRED database. The data are demeaned and the output series is expressed in per capita terms prior to the estimation.

As in other similar studies, such as Christensen and Dib (2008), a first attempt to estimate the model led to unreasonable values for some parameters. More sensible results obtain when these parameters are fixed prior to the estimation. Thus we calibrate the value of the following parameters. We set the production capital share, α, equal to 0.33, a value commonly used in the literature. We set the discount factor, β, equal to 0.99 to generate an annual real interest rate of 4%, as in the data. We set the disutility parameter, χ, equal to 2.5 to match the steady-state unemployment rate of approximately 6%, as in the data. The fraction of hiring costs of total output, κ, is set equal to 0.11, as in Blanchard and Galí (2010), so that hiring costs represent approximately 1% of total output. We set the capital depreciation rate, δ_k, equal to 0.025 as in King and Rebelo (1999), to produce a 10% annual depreciation rate. The steady-state value of the elasticity of substitution between intermediate goods, θ, is set equal to 10 that implies the equilibrium mark-up approximately equal to 11%, as suggested in Rotemberg and Woodford (1999). We set the capital adjustment cost parameter, χ_k, equal

[7] Note that the model that embeds labor market frictions nests the standard BGG model once the cost of posting a vacancy is set to zero, $\kappa = 0$, and the exogenous separation parameter is set to zero, $\delta_n = 0$.

to 0.25, as suggested in BGG. We calibrate the steady-state interest rate on external funds equal to the average of the business prime loan rate over the sample period, as in BGG and Christensen and Dib (2008). This gives a gross external finance premium, $S(\cdot)$, of about 1.03, or 3.0% annualized and on a net basis. We set the steady-state capital to asset ratio equal to 2. This value implies a firm leverage ratio, defined as the ratio of debt to assets, of 0.5. Finally, we set the survival rate of entrepreneurs, ν, equal to 0.96, in line with BGG.

We estimate the remaining parameters $\{\delta_n, \eta, \phi, \rho_b, \psi, \varphi, \rho_\pi, \rho_y, \rho_a, \rho_\theta, \rho_e, \rho_\chi, \sigma_a, \sigma_\theta, \sigma_e, \sigma_\chi, \sigma_v\}$ using Bayesian methods, as described in Schorfheide (2000). The solution of the linearized DSGE model results in a state-space representation of the reduced form. The Kalman filter can be used to evaluate the likelihood function of the state-space model and this is then combined with the prior distribution of the parameters to derive the posterior for a given set of parameter values. In order to approximate the posterior distribution, we employ the random walk Metropolis-Hastings algorithm. We use 50,000 replications and discard the first 25,000 as burn-in. We save every 25th remaining draw. The sequence of retained draws is stable providing evidence on convergence.[8]

As detailed above, we estimate two versions of the model. First, a model with both labor market and financial frictions and, second, the standard BGG model with financial frictions only, obtained by setting the cost of posting a vacancy, κ, and the exogenous separation rate, δ_n, equal to zero. In this way, we are able to empirically assess the difference across the two models and evaluate the contribution of labor market frictions over and above the BGG model with financial frictions. Table 1 reports the prior distributional forms, means, standard deviations and 90% confidence intervals for the model that embeds both labor and financial frictions. The standard BGG model uses the same priors for the common parameters, and sets κ and δ_n to zero. In order to enable comparisons with the literature we use the prior distributions for the shocks, the Calvo parameter, and monetary policy parameters from Smets and Wouters (2007). For the labor market parameters we resort to a variety of studies. The prior mean of the job destruction rate, δ_n, is set to 0.03, as estimated in Fujita and Ramey (2009); the prior mean of the wage bargaining parameter, η, is set to 0.5, as standard in the literature; the prior mean of the inverse of elasticity of labor supply, ϕ, is set to 1, similarly to Blanchard and Galí (2010); and the prior mean of the elasticity of the external finance premium with respect to a change in the leverage position of entrepreneur, ψ, is set to 0.04, as in BGG. The prior distribution on these parameters are set large enough to cover

[8] An appendix that details evidence on convergence is available upon request from the authors.

the relevant domain.

In order to establish what theoretical framework fits the data more closely, we use the marginal log-likelihood of each model to compute the posterior odds ratio. The marginal or the integrated log-likelihood represents the posterior distribution, with the uncertainty associated with parameters integrated out, and therefore it also reflects the model prediction performance. The marginal likelihood is approximated using the modified harmonic mean, as detailed in Geweke (1999). Considering that this criterion penalizes overparametrization, the model with labor market frictions does not necessarily rank better if the extra frictions do not sufficiently help in explaining the data. As from the last row of Table 2, the marginal log-likelihood associated with the model with both labor and financial frictions is equal to 2266.1, while the one associated with the BGG model is equal to 2183.6. To econometrically test the extent to which the model with both financial and labor market frictions improves the fit of the data, we use the posterior odds ratio. This measure is computed as the difference between the marginal log-likelihood of the model that embed both labor and financial frictions and the marginal log-likelihood of the BGG model with financial frictions only. The posterior odds ratio is equal to $e^{82.5}$, which represents very strong evidence in favour of the model with labor market frictions.

Table 2 displays the value of the posterior mean of the parameters together with their lower 5% and upper 95% bounds.[9] Column 2 reports the BGG model, and column 3 reports the model with both labor and financial frictions. The posterior mean estimates are remarkably close among models, indicating that parameter estimates are consistently and robustly estimated across the two different settings. This reinforces the findings in Christensen and Dib (2008), De Graeve (2008) and Iacoviello and Neri (2010) who show that despite financial frictions enhance a more detailed functioning of the economy, they leave the values of the estimated parameters substantially unchanged compared to the standard New Keynesian model without financial frictions. The estimate of the job destruction rate, δ_n, is equal to 0.04, indicating that on average approximately 4% of jobs disappears in every quarter, which is in line with the recent estimates by Jolivet, Postel-Vinay and Robin (2006). The posterior mean of the wage bargaining parameter, η, is equal to 0.822 that is close to the estimate in

[9] It is worth noting that the prior and posterior distributions of the parameters are different, supporting the presumption that the data are informative about the values of the estimated parameters. An appendix that shows the prior and posterior densities for each estimated parameter is available upon request from the authors.

Gertler, Sala and Trigari (2008). The posterior mean of the inverse of the Frisch intertemporal elasticity of substitution in labor supply, ϕ, equals to 1.411, which implies a labor supply elasticity approximately equal to 0.7. This is consistent with the value suggested by Rogerson and Wallenius (2007) and more generally with the calibrated values used in the macro literature as advocated by King and Rebelo (1999). The posterior mean of the replacement ratio parameter, ρ_b, is equal to 0.372, which is in line with the estimate in Nickell (1997) and Krause, Lopez-Salido and Lubik (2008). The posterior mean of the elasticity of the external financial premium parameter, ψ, is equal to 0.045, which is remarkably close to the value used in BGG and similar to the estimate in Christensen and Dib (2008). The posterior mean of the degree of nominal price rigidities, φ, is equal to 0.608, implying that firms change prices every two and a half quarters on average, which is lower than the empirical estimates of approximately one year in Sbordone (2002). Hence, the coexistence of labor and financial frictions enables the model to generate a degree of nominal price rigidities in line with estimates from microdata, as in Klenow and Kryvtsov (2008).

The parameters' estimates of the Taylor rule in equation (29) characterize the conduct of monetary policy. The estimate of the reaction coefficient to the fluctuations of output growth, ρ_y, is 1.271, and the estimate of the reaction coefficient to the fluctuations of inflation from the inflation target, ρ_π, is 1.844. These estimates suggest that the nominal interest rate reacts more strongly to fluctuation in inflation than output. This is in line with the estimates in Smets and Wouters (2007) and Ireland (2007) and the empirical evidence in Clarida, Galí and Gertler (1998).

The estimates of the autocorrelation coefficients of the exogenous disturbances show that technology shocks are highly persistent, with the posterior mean of ρ_a equal to 0.974. On the other hand, preferences, labor supply and cost-push shocks are less so, with the posterior mean of ρ_e, ρ_χ and ρ_θ equal to 0.944, 0.942 and 0.942 respectively. The estimates of the volatility of the exogenous disturbances shows that preference and labor supply shocks are slightly more volatile, with σ_e and σ_χ equal to 0.035 and 0.079 respectively, while technology, monetary policy and cost-push shocks are of lower magnitude, with σ_a, σ_θ and σ_v equal to 0.026, 0.041 and 0.029 respectively. Clearly, these values suggest that differences among shocks are not sizable.

To investigate how the variables of the model react to each shock, Figures 1-5 plot the impulse responses of selected variables to one standard deviation of each of the exogenous shocks. In each figure the dashed line shows the reaction of the BGG model with financial frictions only, and the solid black line shows the model that also includes labor market frictions.

Figure 1 shows the reaction of key aggregates to a one standard deviation monetary policy shock (i.e. contractionary monetary policy). The qualitative dynamics is similar across models although labor market frictions modify the variables' quantitative response. A monetary policy shock induces the firm to cut back on the input of production, and the household to decrease consumption. Lower consumption generates a sharp fall in output, which reduces inflation. Lower inflation, together with the rise in the nominal interest rate, increases the firm's cost of servicing the external debt thereby reducing its net worth and raising the costs of external finance. The external finance premium is lower in the presence of labor market frictions, but the reaction of investment is similar across models, contrary to the working of the financial accelerator channel, which predicts a higher investment in the economy with lower finance premium. Why is the effect of financial frictions contained? Labor market frictions generate two competing effects on investment. On the one hand, they dampen the reaction of inflation which decreases the real cost of repaying existing debt. Hence, the fall in the firm's net worth is contained and the associated cost of external finance premium is lower, which stimulates investment, in line with the financial accelerator channel. On the other hand, in the presence of labor market frictions, a positive monetary policy shock induces the firm to adjust labor input by reducing hiring on impact and increasing it afterwards, which generates similar dynamics in the job finding rate. In the presence of labor market frictions, the wage is a function of expected job finding rate, as from equation (12). A tigh job finding rate raises the wage and keeps it higher than in the model without labor frictions. A higher wage makes labor input more expensive which, combined with the initial fall in hiring, suppresses employment, capital and investment. This mechanism counteracts the increase in investment that the lower external finance premium generates and leads to an overall sharper fall in investment in the model with labor market frictions. It is worth noting a few more differences across models. First, the model with labor market frictions displays a stronger reaction of key macroeconomic variables, such as output, capital and consumption. Second, in the aftermath of the shock, the variables' persistence is higher in the presence of labor market frictions, in line with the finding of Walsh (2005).

Figure 2 shows the reaction of key variables to a one standard deviation technology shock. In the aftermath of the shock, output and consumption rise. Labor input fall, since improved technology enables higher production with lower labor input for a given demand, as first pointed out by Galí (1999). The increase in technology reduces the unit cost of production, which lowers inflation. The fall in inflation increases the real cost of repaying existing debt, which reduces the firm's net worth. The decrease in the firm's value increases its leverage ratio and generates higher external financing costs. Hence the firm's cost of external finance rises. Note that in the model with labor market frictions the firm's finance premium is lower, which, in principle, as predicted by the financial accelerator channel, should lead to a higher investment. However, the contraction in investment is stronger for the model with labor market frictions. The reason for this is straightforward. In the presence of labor market frictions the firm aggressively reduces hiring on impact and raises it afterwards. This leads to a higher wage than in a frictionless labor market. Decreased hiring coupled with an elevated wage leads to a sharper reduction in employment that suppresses capital and investment. This effect outweighs the increase in investment that a lower finance premium generates and generates an overall stronger response and persistence of investment.

Figure 3 shows the reaction of key variables to a one standard deviation cost-push shock. In the aftermath of the shock, inflation rises and output falls sharply, which triggers a decrease in the nominal interest rate, as dictated by the Taylor rule. The rise in inflation decreases the cost of servicing the external debt which increases the firm's net worth and reduces the costs of external finance. In the model with labor market frictions the external finance premium reduces less in reaction to the shock and leads to a milder fall in investment, consistent with the financial accelerator channel. This effect outweighs the reduction in investment generated by reduced hiring, employment and production. Hence, the overall reaction of investment is stronger in the presence of labor market frictions.

Figure 4 shows the response of key aggregates to a one standard deviation consumption preference shock. In the aftermath of the shock, as explained below, some of the variables' responses differ across models. In the model without labor frictions, inflation and output increase on impact and, due to the Taylor rule, the nominal interest rate increases. A higher nominal interest rate raises the cost of servicing external debt which dampens the firm's net worth. Investment and capital decrease, inducing a reduction in the firm's leverage ratio, which lowers the external finance premium. In the presence of labor market frictions, the firm reduces hiring in the aftermath of the shock, which leads to a substantial fall in employment that suppresses capital and investment. The fall in output attenuates the increase in the nominal interest rate compared to the economy without labor market frictions. The reduced increase in nominal interest rate, coupled with a stronger increase in inflation, decreases the cost of servicing the external debt, thereby raising the firm's net worth and decreasing the costs of external finance. A lower finance premium attenuates the contraction in investment. Hence, in the case of a consumption preference shock, the financial accelerator mechanism leads to increased investment and outweighs the reduction in investment that lower hiring, employment and production generate.

Figure 5 shows the reaction of key variables to a one standard deviation labor supply shock. In the aftermath of the shock, inflation rises and output falls substantially, which, due to the Taylor rule, generate a fall in the nominal interest rate. The increase in inflation reduces the cost of servicing the external debt, which increases the firm's net worth and reduces the external finance premium. In the presence of labor market frictions the reduction in the premium is lower, which, in principle, should prompt a stronger fall in investment compared to the model without labor market frictions. However, the model with labor market frictions displays a more contained fall in employment, induced by the subdued rise in wage in response to the fall in the job finding rate. The contained fall in employment and production sustains investment, which overall increases in the presence of labor market frictions.

Looking across all these impulse responses provides some insights into how the presence of labor market frictions affects the transmission mechanism of a standard New Keynesian framework with financial frictions. For all shocks, with the exception of preference shocks, the presence of labor market frictions does not affect the sign of the variables' response to shocks. This is similar to the findings in Christensen and Dib (2008), De Graeve (2008) and Iacoviello and Neri (2010) who show that adding a more detailed structure of the banking sector in the standard BGG model leaves the variables' response to shocks broadly unchanged. However, we find that labor market frictions significantly amplify the reaction of key macroeconomic variables such as output, investment and the input of production to technology and monetary policy shocks. Moreover, labor market frictions increase the persistence of key macroeconomic variables.

Finally, to understand the extent to which movements of each variable are explained by each shock, Table 3 reports the asymptotic forecast error variance decompositions of selected variables for the estimated model with labor market frictions. The results show that technology shocks explain short-run movements in output, consumption and inflation, while nominal interest rate shocks play an important role in driving short-run fluctuations in the nominal interest rate and a supporting role in inflation and output. On the other hand, in the long run, technology shocks play a primal role on output, consumption and investment, while preference shocks explain a sizable fraction of fluctuations in the nominal interest rate. Nominal interest rate shocks compete with technology and preference shocks to explain movements in inflation.

To detail how the exogenous shocks have evolved during the estimation period, Figure 6 plots estimates of the shocks using the Kalman smoothing algorithms from the state-space representation of the estimated model with both labor and financial frictions. In general, we find that the magnitude of shocks has somewhat decreased in the period from the mid-1980s until the late 2000s. Furthermore, we find that the volatility of monetary policy shocks declined during the same period. These findings corroborate the results of empirical studies by Sims and Zha (2006), Gambetti, Pappa and Canova (2008) and Benati and Mumtaz (2007), which detected a period of macroeconomic stability triggered by a lower volatility of shocks in the US from the mid-1980s until 2008.

5 Conclusion

This paper has investigated the interactions between labor and financial frictions by using a dynamic, stochastic, general equilibrium model. Our modelling strategy consisted in setting up a standard New Keynesian model with financial frictions as in BGG enriched with labor market frictions as in Blanchard and Galí (2010). To establish the importance of labor market frictions and their interaction with financial frictions, we estimated two versions of the model using macroeconomic time-series data for the US from the seventies onwards. First, a version characterized by financial frictions only, as in BGG and, second, a version that also allows for labor market frictions. The econometric estimation shows that the data prefer the model with both labor and financial frictions. Labor market frictions generate two competing effects on aggregate fluctuations. On the one hand, they dampen the reaction of the firm's external finance premium, thereby reducing the effect of financial frictions on macroeconomic aggregates. On the other hand, they magnify the reaction of employment, investment and production, thereby reinforcing the effect of financial frictions and magnifying aggregate fluctuations. The overall effect depends on the nature of the shock. The reaction of macroeconomics aggregates is stronger for monetary policy and technology shocks, while weaker for labor supply and preference shocks. Labor market frictions increase the overall variables' persistence to shocks.

The analysis of this paper is conducted using labor market frictions based on the labor market search paradigm and financial market frictions based on asymmetric information in credit markets, which is only one possible way of analyzing the links between labor and financial frictions. It would be interesting to establish whether the same results carry over to other environments such as models with an articulated banking sector (Christiano, Motto and Rostagno (2008) and Dib (2010)), models with a well-defined housing sector (Iacoviello (2005) and Iacoviello and Neri (2010)), and models with endogenous job destruction (Den Haan, Ramey and Watson (2000) and Thomas and Zanetti (2009)). To establish to what extent the results hold for refinements of the theoretical framework remains an outstanding task for future research.

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Table 1. Summary Statistics for the Prior Distribution of the Parameters

Parameters		Prior distribution			
		Density	Mean	Standard Deviation	90% Interval
δ_n	Job destruction rate	Beta	0.03	0.005	[0.022,0.039]
η	Wage bargaining power	Beta	0.5	0.05	[0.419,0.583]
ϕ	Inverse of the Frisch elasticity	Gamma	1	0.05	[1.420,1.582]
ρ_b	Replacement ratio	Beta	0.35	0.01	[0.191,0.523]
ψ	Elasticity of the finance premium	Beta	0.04	0.01	[0.025,0.058]
φ	Calvo price parameter	Beta	0.4	0.05	[0.318,0.483]
ρ_π	Taylor rule response to inflation	Gamma	1.5	0.1	[1.342,1.666]
ρ_y	Taylor rule response to output	Gamma	0.25	0.05	[0.173,0.339]
Autoregressive parameters					
ρ_a	Technology	Beta	0.9	0.1	[0.691,0.997]
ρ_θ	Cost-push	Beta	0.5	0.1	[0.335,0.665]
ρ_e	Preferences	Beta	0.5	0.1	[0.335,0.666]
ρ_χ	Labor supply	Beta	0.5	0.1	[0.336,0.661]
Standard deviations					
σ_a	Technology	Inverse Gamma	0.1	10	[0.021,0.288]
σ_θ	Cost-push	Inverse Gamma	0.1	10	[0.021,0.288]
σ_e	Preferences	Inverse Gamma	0.1	10	[0.021,0.283]
σ_χ	Labor supply	Inverse Gamma	0.1	10	[0.021,0.288]
σ_v	Monetary policy	Inverse Gamma	0.1	10	[0.021,0.267]

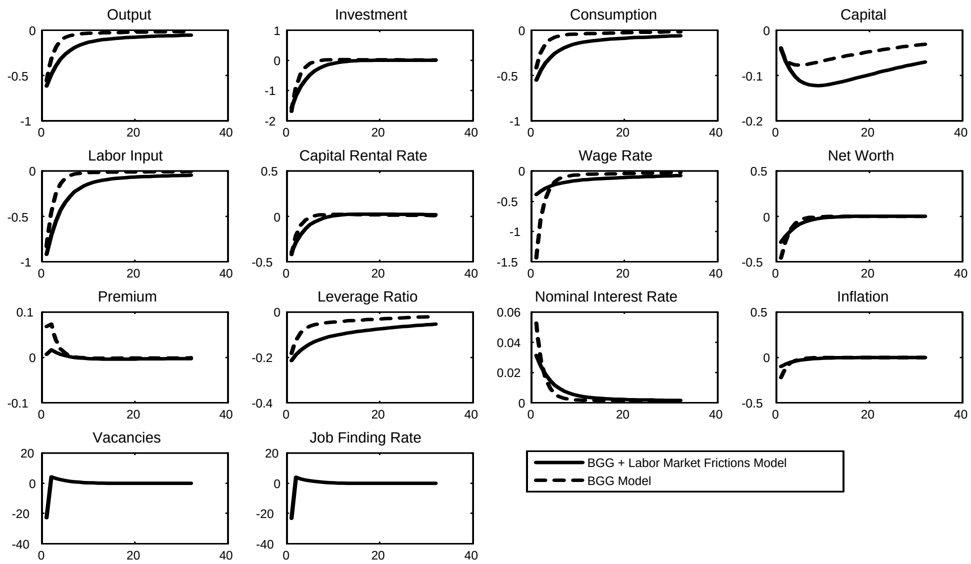
Table 2. Summary Statistics for the Posterior Distribution of the Parameters

Parameters		FF Model			Search Model		
	(1)	(2)			(3)		
		Mean	5%	95%	Mean	5%	95%
δ_n	Job destruction rate	-	-	-	0.04	0.029	0.059
η	Wage bargaining power	-	-	-	0.822	0.807	0.849
ϕ	Inverse of the Frisch elasticity	1.224	1.146	1.303	1.411	1.348	1.521
ρ_b	Replacement ratio	0.378	0.361	0.395	0.372	0.362	0.381
ψ	Elasticity of the finance premium	0.034	0.027	0.052	0.045	0.039	0.058
φ	Calvo price parameter	0.754	0.711	0.791	0.608	0.574	0.712
ρ_π	Taylor rule response to inflation	1.775	1.649	1.904	1.844	1.689	2.049
ρ_y	Taylor rule response to output	0.987	0.855	1.134	1.271	1.165	1.373
Autoregressive parameters							
ρ_a	Technology	0.957	0.939	0.978	0.974	0.953	0.994
ρ_θ	Cost-push	0.716	0.647	0.788	0.942	0.914	0.964
ρ_e	Preferences	0.919	0.905	0.934	0.944	0.929	0.954
ρ_χ	Labor supply	0.966	0.954	0.977	0.942	0.914	0.965
Standard deviations							
σ_a	Technology	0.026	0.023	0.029	0.026	0.023	0.028
σ_θ	Cost-push	0.047	0.039	0.061	0.041	0.037	0.049
σ_e	Preferences	0.034	0.031	0.038	0.035	0.031	0.039
σ_χ	Labor supply	0.032	0.029	0.036	0.079	0.067	0.097
σ_v	Monetary policy	0.028	0.025	0.031	0.029	0.026	0.032
Marginal log-likelihood		2183.6			2266.1		

Table 3. Asymptotic Forecast Error Variance Decomposition

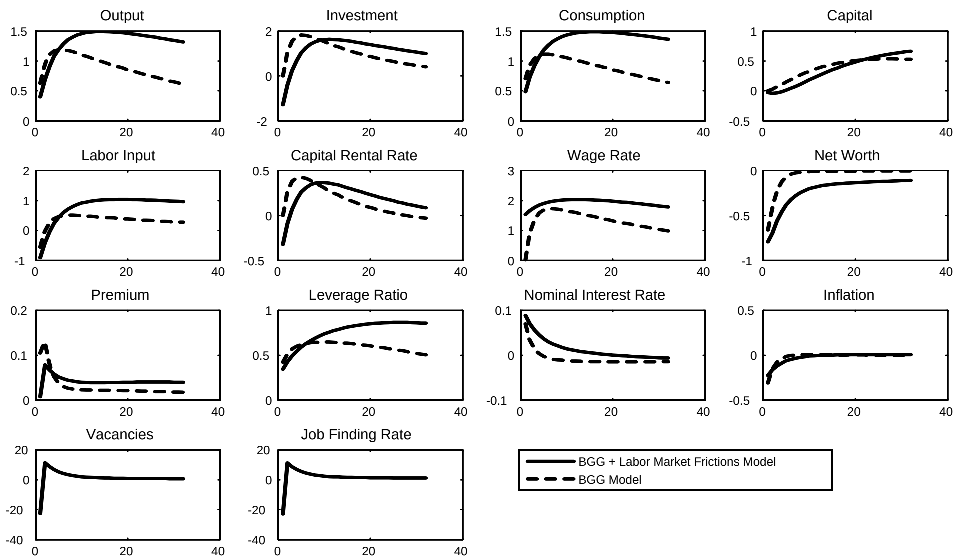
	Output	Consumption	Investment	Inflation	Interest Rate
			One Quarter		
σ_a	59.4672	89.2756	26.5762	64.0031	34.2309
σ_v	34.7488	8.5403	20.0751	29.7557	40.7166
σ_θ	2.6632	0.3887	8.4353	1.2858	7.2565
σ_e	1.6431	0.0759	29.3008	3.9724	16.5191
σ_χ	1.4777	1.7196	15.6126	0.9831	1.2769
			One Year		
σ_a	71.9515	83.3107	18.0344	60.9255	29.1741
σ_v	13.8843	8.3203	27.6107	26.5408	24.3082
σ_θ	5.5025	2.8135	16.7477	1.5617	8.9095
σ_e	4.8068	1.7606	33.6475	9.3138	35.8333
σ_χ	3.8549	3.7949	3.9597	1.6582	1.7749
			Five Years		
σ_a	80.7563	83.6687	51.2493	57.4603	20.5544
σ_v	2.2066	1.7879	5.5285	24.6366	13.7167
σ_θ	3.5112	2.9582	9.1725	1.5469	5.5334
σ_e	8.5321	6.7536	28.2489	14.6683	58.9919
σ_χ	4.9938	4.8315	5.8008	1.6878	1.2037
			Infinite		
σ_a	86.6696	87.5002	69.679	57.2247	21.3116
σ_v	0.7936	0.6548	2.9262	24.4209	11.4181
σ_θ	1.4933	1.3458	4.6892	1.549	4.8045
σ_e	7.6075	7.1261	18.3709	15.0929	61.1265
σ_χ	3.436	3.3731	4.3347	1.7127	1.3393

Figure 1. Impulse Responses to one-standard-deviation Monetary Policy Shock



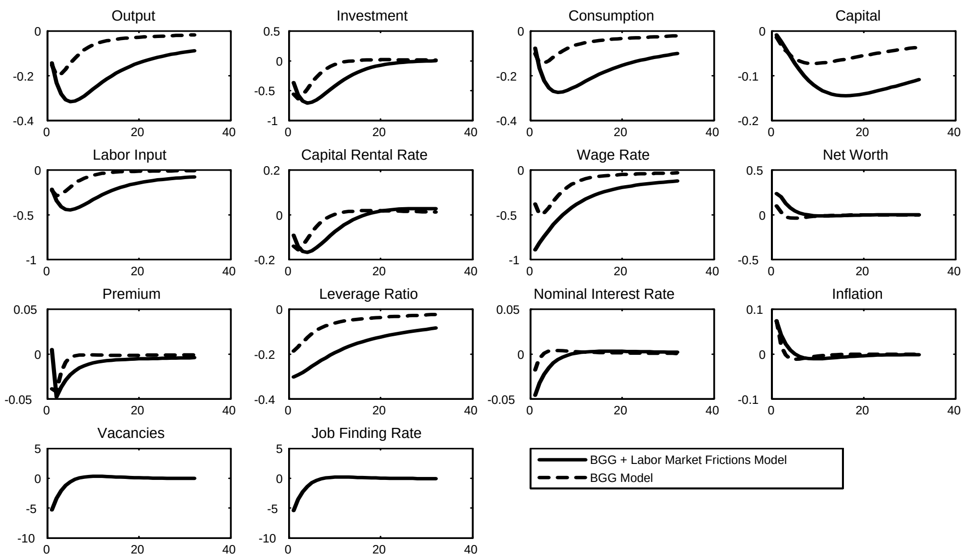
Notes: Each entry shows the percentage point response of one of the model's variables to a one-standard-deviation monetary policy shock. The dashed line reports the response of the BGG model with financial frictions, and the solid line reports the response of the model that also includes labor market frictions.

Figure 2. Impulse Responses to one-standard-deviation Technology Shock



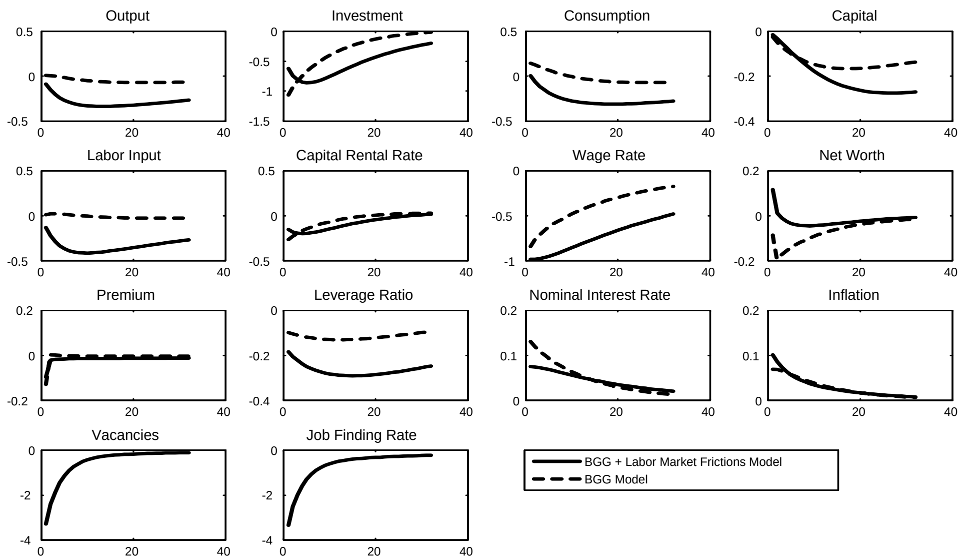
Notes: Each entry shows the percentage point response of one of the model's variables to a one-standard-deviation neutral technology shock. The dashed line reports the response of the BGG model with financial frictions, and the solid line reports the response of the model that also includes labor market frictions.

Figure 3. Impulse Responses to one-standard-deviation Cost-push Shock



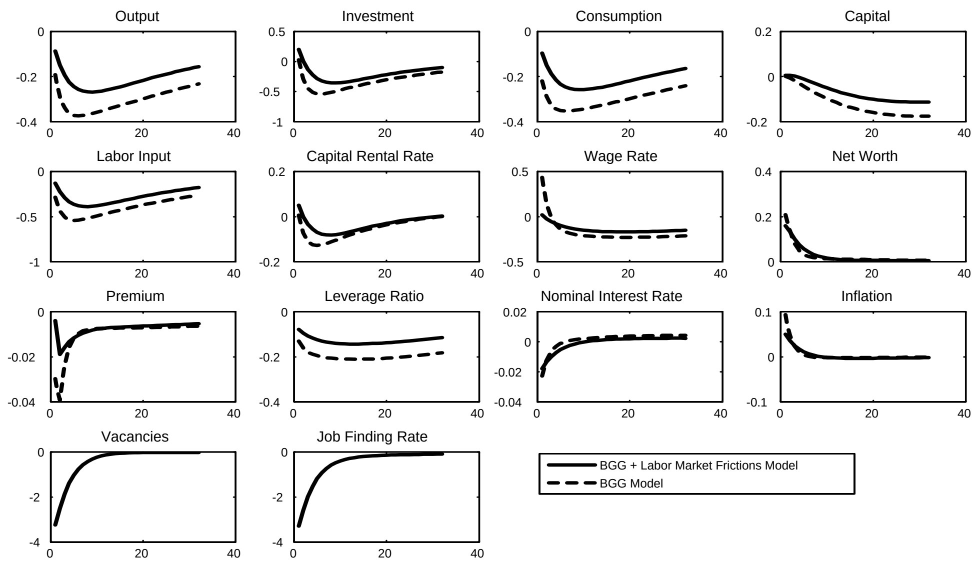
Notes: Each entry shows the percentage point response of one of the model's variables to a one-standard-deviation cost-push shock. The dashed line reports the response of the BGG model with financial frictions, and the solid line reports the response of the model that also includes labor market frictions.

Figure 4. Impulse Responses to one-standard-deviation Preference Shock



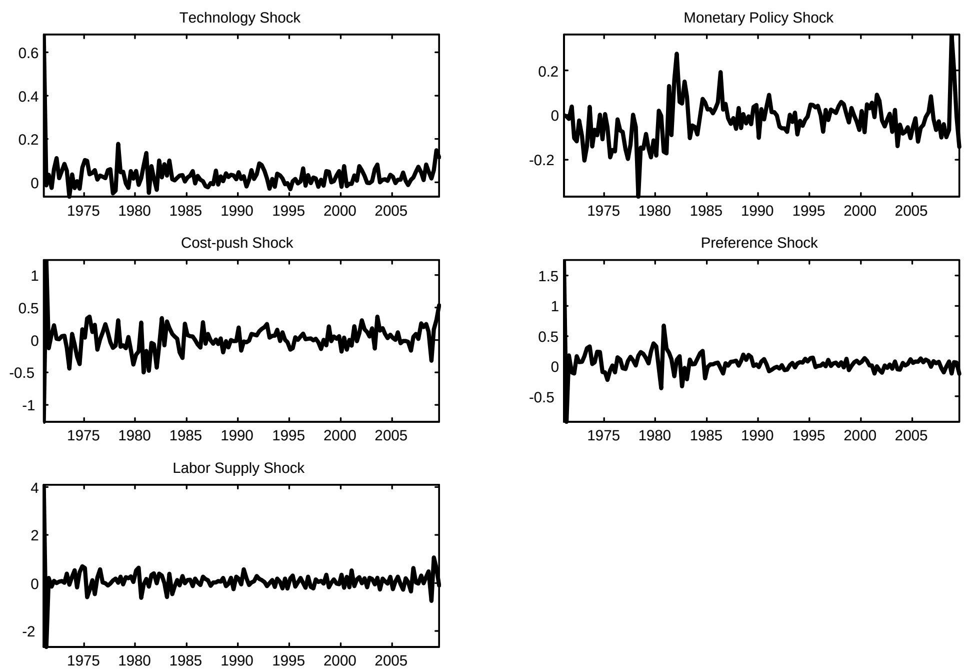
Notes: Each entry shows the percentage point response of one of the model's variables to a one-standard-deviation preference shock. The dashed line reports the response of the BGG model with financial frictions, and the solid line reports the response of the model that also includes labor market frictions.

Figure 5. Impulse Responses to one-standard-deviation Labor Supply Shock



Notes: Each entry shows the percentage point response of one of the model's variables to a one-standard-deviation labor supply shock. The dashed line reports the response of the BGG model with financial frictions, and the solid line reports the response of the model that also includes labor market frictions.

Figure 6. Smoothed Estimates of Technology, Monetary Policy, Cost-push, Preference, and Labor supply Shocks



Notes: Each entry shows the shock estimate using the Kalman smoothing algorithms from the state-space model with labor market frictions.