Financial Shocks, Job Destruction Shocks and Labor Market Fluctuations*

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14 December 2016

Abstract

This paper investigates the effect of financial shocks using a general equilibrium model that links the firm's flows of financing with labor market variables. The results show that financial shocks have sizeable effects on debt, dividend payout and wages. Shocks to the job destruction rate are important in explaining fluctuations in unemployment. The analysis also investigates the underlying driving forces of some key comovements in the data and finds shocks to the job destructions rate important.

JEL Classification: E32, E44.

Keywords: Business cycle, labor market frictions, financial shocks, job destruction shocks.

*This paper supersedes a previously circulated draft under the title "Financial Shocks and Labor Market Fluctuations." I am very grateful to an Associate Editor, two anonymous referees, Yunus Aksoy, Fabio Braggion, Tatiana Damjanovic, Wouter den Haan, Federico di Pace, Jordi Gali, Peter Ireland, Joao Madeira, Christopher Martin, Vincenzo Quadrini, Michał Rubaszek, Lydia Silver, Christoph Thoenissen, Carlos Thomas, Simon Wren-Lewis, and seminar participants at the Bank of England, Bank of Spain, De Nederlandsche Bank, Higher School of Economics, National Bank of Poland, University of Exeter, University of Birkbeck, University of Manchester, University of Oxford, University of Tilburg, University of Sheffield, the Annual Congress of the European Economic Association in the University of Gothenburg, the Money, Macro and Finance Research Group Conference in Birmingham University and Queen Mary University, the Royal Economic Society Annual Conference in Cambridge University, the Growth and Business Cycle in Theory and Practice in Manchester University, the Macroeconomics Conference in Bath University and the Unicredit Conference in Pavia University for extremely useful comments and suggestions. Please address correspondence to: Francesco Zanetti, University of Oxford, Department of Economics, Manor Road, Oxford, OX1 3UQ, UK. Email: francesco.zanetti@economics.ox.ac.uk.

1 Introduction

Recent research shows that shocks that originate in the financial sector are important factors in explaining business cycle fluctuations.[1] These studies show that perturbations that occur directly in the financial sector have non-trivial effects on the firm's funds availability that may amplify or dampen the response of macroeconomic variables to shocks. In this paper, we link the firm's flows of financing to labor market variables and investigate to what extent shocks that originate in the financial sector compete with alternative disturbances to affect key macroeconomic variables.

Evidence suggesting tight links between the firm's flows of financing and the labor market outlook clearly emerges from the data. Figure 1 plots debt issuance and unemployment from 1955 onwards and the shaded areas indicate recessions.[2] It is apparent from the figure that the two series have negative correlation, especially after the late 1970s, suggesting that recessions lead firms to restructure both their financial and labor market positions, by cutting debt and decreasing workforce. The procyclicality of debt issuing is well studied in the literature,[3] but no studies link the firm's financial flows with its labor market outlook. An important contribution of the analysis is to link the firm's financial decisions with adjustments in the labor market.

With this aim, we build on the real business cycle (RBC) literature and set up a fully-specified dynamic general equilibrium model based on agents' optimizing behaviour. We enrich the standard RBC framework with financial frictions that affect the firm's ability

[1] See recent studies by Nolan and Thoenissen (2009), Hall (2011), Mumtaz and Zanetti (2016) and references therein.

[2] The series for debt issuing is from the Flow of Funds Accounts from the Federal Reserve, while the unemployment rate is from the NIPA data set. Both series are linearly detrended. The empirical regularities hold if we use alternative detrending methods. See the appendix for a more detailed description of the data.

[3] See among others Covas and Den Haan (2011) and Jermann and Quadrini (2012) and references therein.

to raise funds and issue dividends and also with labor market frictions that introduce a matching technology into the firm's recruitment activities that generates equilibrium unemployment. In this way, we link the firm's flows of financing (i.e. debt and equity) with a detailed structure of the labor market and show that financial shocks distort the firm's hiring decision. We use the model to quantify interactions between financial and labor market variables and interpret comovements in the data. The analysis in the paper aims to investigate the effect of shocks to the financial decisions to the firms on labor market variables such as unemployment and vacancies. It is therefore important to embed labor market frictions, which enable the analysis to focus on unemployment and vacancy posting that would otherwise be absent from the model.

In order to use the theoretical framework to interpret the data, we calibrate the parameters that determine the steady state and estimate the parameters related to the exogenous disturbances using Bayesian methods. The estimation works to identify structural disturbances in the data based on the dynamic effects that they have on the model's observable variables. The model's reduced form enables us to extend the identification of shocks to the model's unobservable variables and to map the response of key macroeconomic variables to exogenous disturbances to the firm's neutral and investment-specific technologies, its finance position, job destruction rate, household's preference and government spending. Impulse response functions of the estimated model show that financial shocks are powerful in altering the firm's flows of financing and wages. In addition, the analysis points out that shocks to the job destruction rate are important for the dynamics of the unemployment rate. The analysis also suggests that the simultaneous presence of a detailed financial and labor market structure leaves the qualitative responses of variables to shocks unchanged compared to a version of the model that abstracts from labor market frictions. Forecast error variance decompositions show that financial shocks play a prime role for the dynamics of debt, dividend payout and wages in the short run,

whereas their effect on wages substantially diminishes in the long run.[4] Shocks to the job destruction rate drive the bulk of unemployment fluctuations in the long and short run, and their contribution to movements in output increases in the long run.[5] Technology shocks are the main drivers of output at all frequencies and they substantially contribute to fluctuations in wages in the long run.[6]

The use of a general equilibrium model enables additional novel analyses. In particular, the estimated model allows us to recover the unobservable shocks using a Kalman smoothing algorithm that uses the information contained in the full sample of the data. We show that the derived stochastic disturbances in the model track the underlying structural shocks in the data relatively well, as their dynamics and structural interpretation are in line with past recession episodes. In addition, we find that the series for financial shocks are able to track qualitative indicators of credit market tightness.

Finally, we use the theoretical model to investigate to what extent each shock generates some key high-frequency comovements in the data. In particular, we first look into the observed negative comovement between output and unemployment, and find that it is mainly driven by shocks to the job destruction rate together with a supporting role from preference and financial shocks. We then investigate the contribution of each shock to the observed negative comovement between unemployment and debt issuing, and find that disturbances to the job destruction rate and to investment-specific technology are important forces underneath the observed comovement. In the aftermath of a positive shock to the job destruction rate, unemployment and wages increase. The intra-period

[4] Financial shocks explain approximately 92%, 95% and 55% of short-run movements in debt, dividend payout and wages, respectively, and approximately 65%, 93% and 20% of long-run movements in the same variables.

[5] Shocks to the job separation rate explain approximately 30% of short- and long-run movements in unemployment. The contribution of these shocks to movements in output is approximately 3% in the short run and 23% in the long run.

[6] In the model, the stock of debt and unemployment are mainly driven by two coinciding, but orthogonal shocks, one driving unemployment (job destruction) and the other debt (financial shock).

loan needed to pay for production decreases and the firm increases debt issuance to finance production, thereby leading to a mild positive comovement between debt and unemployment, which counteracts the strong positive comovements generated by other shocks. Hence, overall the analysis again underlines the importance of disturbances to the job destruction rate in accounting for key comovements in the data.

Before proceeding, we discuss the context provided by related studies. Our work complements a growing number of studies that show the importance of financial frictions for aggregate fluctuations.[7] In particular, similar to Wasmer and Weil (2004), Nolan and Thoenissen (2009), Christiano et al. (2010), Jermann and Quadrini (2012) and Atolia et al. (2015) we assume that the financial sector acts as a source of macroeconomic fluctuations.[8] Garin (2015) provides a micro-founded model model with a financial sector and labor market frictions to study the effect of changes in the collateral requirements. Different from these aforementioned studies, we link the financial sector with a detailed description of the labor market, which includes unemployment, and we estimate the parameters of the exogenous processes to interpret fluctuations in the data.

A number of recent studies investigate the effect of financial frictions on the cyclical labor market dynamics. Our study is similar to the work by Monacelli et al. (2011),

[7]The results of this study are related to those in Shimer (2005), who finds that the job finding rate drives the bulk of fluctuations in unemployment. Our analysis instead shows that the job destruction rate becomes important for unemployment dynamics in the presence of financial friction, corroborating the findings in Fujita and Ramey (2009) and Yashiv (2007). As discussed below, the job separation rate determines the expected benefit of hiring an additional worker, which is critical for the scale of production and therefore the size of the firm's intra-period loan. Thus, in the presence of financial frictions, movements in the job separation rate play an important role for the borrowing of the firm, which determines the scale of production and it is therefore important for movements in unemployment.

[8]We embed financial frictions similar to Jermann and Quadrini (2012) since they reflect accurately important mechanisms in the economy (i.e. firms are allowed to have negative equity payouts and exogenous disturbances affect directly the financial sector of the economy) and replicate closely important dynamics in the data.

which underlines the importance of financial markets for unemployment fluctuations in a search and matching model where firms issue debt under limited enforcement. Our paper extends and complements their analysis across several dimensions. First, these authors focus on the relation between financial frictions and unemployment, whereas we investigate the effect of financial frictions on a broad set of macroeconomic variables, including wages and financial flows, and use the estimated model to interpret fluctuations in the data over the sample period. Second, our transmission mechanism is fundamentally different. These authors study the positive relation between credit contraction and unemployment by assuming that firms use financial leverage strategically in order to outweigh the bargaining power of workers and increase employment. In contrast, the transmission mechanism in our model is based on the standard credit channel that hinges on a higher cost of financing employment.

This paper is also related to Chugh (2013), Petrosky-Nadeau (2014) and Petrosky-Nadeau and Wasmer (2013), which show that credit market frictions in a search and matching model of the labor market address the lack of amplification and persistence to productivity shocks on labor market variables. Our paper differs from these studies across several dimensions. First, we have a different focus since we investigate the amplification mechanism of financial shocks as a source of business cycle fluctuations and the reaction of a broad set of macroeconomic variables, including aggregate flows of financing. Second, we estimate the theoretical framework and use it to study the model's transmission mechanism and to interpret economic developments in the data.

This paper is also related to Christiano et al. (2011) and Mumtaz and Zanetti (2016), which use medium-scale New Keynesian models to investigate the importance of financial frictions on a broad set of macroeconomic variables, including unemployment. Compared to these studies our model is different in many respects. In particular, these authors assume that financial frictions stem from the fact that borrowers and lenders have different information, as in Bernanke et al. (1999), and that collateral constraints are tied to the

real estate values or nominal debt, as in Silos (2007), Iacoviello (2005) and Rubio (2011). Instead, we introduce financial frictions using the enforcement constraint developed in Jermann and Quadrini (2012), which is shown to closely track qualitative indicators of credit markets. In addition, our model includes financial variables whose information is important to produce a measure of financial shocks based on the underlying credit conditions. Finally, whereas these studies mainly focus on the analysis of the transmission mechanism of shocks, we use the model to investigate key comovements in US data.

Finally, this paper examines and interprets recent data with the help of an estimated general equilibrium model, that is, within a similar analytic framework that Fernandez-Villaverde and Rubio-Ramirez (2007), Iacoviello and Neri (2010), Ireland (2011) and Khan and Tsoukalas (2011), to mention just a few related studies, use to consider various aspects of developments in US data. The focus here, however, is different as we investigate the joint effect of financial and labor market frictions.

The remainder of the paper is organized as follows. Section 2 lays out the model. Section 3 presents the econometric methodology and the data. Section 4 presents the results and analysis. Section 5 concludes.

2 The Model

This section lays out the theoretical model. The standard real business cycle model is enriched with financial and labor market frictions as in Jermann and Quadrini (2012) and Thomas (2008), respectively. The firms use equity and debt, and they finance working capital by raising funds with intra-period loans. Due to the uncertainty related to recovering these loans, firms face an enforcement constraint that generates financial frictions. The labor market relies on the assumption that the process of job searching and recruitment is costly, and a matching technology brings together unemployed workers to open vacancies. 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 parties' bargaining power. The match continues until the parties exogenously terminate the relationship. The model economy consists of a representative firm, a representative household and the government. The rest of this section describes the agents' preferences, technologies and the structure of the financial and labor markets.

2.1 The Representative Firm

During each period $t = 0, 1, 2, ...$, the representative firm employs n_t units of labor and uses k_t units of capital, in order to manufacture y_t units of goods according to the constant returns to scale production technology

$$y_t = f(a_t, k_t, n_t), \tag{1}$$

where $a_t = \Psi(a_{t-1}, \varepsilon_{at})$ is the neutral technology process, and ε_{at} is an i.i.d. shock. The firm's financial instruments are equity d_t and debt b_t, and, in order to make financial frictions binding, debt is preferred to equity for its tax advantage, as detailed in Hennessy and Whited (2005) and Jermann and Quadrini (2012). Letting r_t denote the net nominal interest rate, the effective gross interest rate for the firm, after tax rebate τ, is $R_t = 1 + r_t(1 - \tau)$. During each period $t = 0, 1, 2, ...$, by investing i_t units of output during period t, the firm increases the capital stock k_{t+1} available during period $t + 1$ according to

$$k_{t+1} = (1 - \delta_k)k_t + \nu_t i_t, \tag{2}$$

where δ_k is the capital depreciation rate, $\nu_t = \Psi(\nu_{t-1}, \varepsilon_{\nu t})$ is the investment-specific technology process, and $\varepsilon_{\nu t}$ is an i.i.d. shock.

The firm's budget constraint equals the difference between revenues from production, $f(a_t, k_t, n_t)$, plus new intertemporal debt, b_{t+1}/R_t, net of real equity payout, d_t, labor compensation, $w_t n_t$, where w_t is the real wage, investment compensation $\nu_t i_t$, a cost g_t

for each vacancy v_t posted, and repayment of intertemporal liabilities, b_t, such that

$$f(a_t, k_t, n_t) + b_{t+1}/R_t - d_t - w_t n_t - \nu_t i_t - g_t v_t - b_t = 0. \tag{3}$$

The firm cashes revenues after production takes place, and therefore uses the intra-period loan l_t to finance payment to workers, hiring and investment costs and issuing equity payout and net debt. Hence, the firm's intra-period loan is:

$$l_t = w_t n_t + g_t v_t + \nu_t i_t + d_t + b_t - b_{t+1}/R_t, \tag{4}$$

which implies that the intra-period loan is equal to the firm's production, $l_t = f(a_t, k_t, n_t)$.

We introduce financial frictions by assuming that the firm's ability to borrow is limited, since it can default on its obligations. Default may materialize after the realization of revenues but before repaying the intra-period loan. At this stage the firm's total liabilities are the intra-period loans, l_t, plus the new acquired debt, $l_t + b_{t+1}/R_t$. The asset for liquidation is represented by capital, as the liquidity holdings, $l_t - f(a_t, k_t, n_t)$, in principle part of the firm's asset, are not recovered by lenders since they are easily diverted. As in Jermann and Quadrini (2012), we assume that at the time of contracting the loan the liquidation value of capital is uncertain, and with probability ξ_t the lender can recover the full value of capital, whereas with probability $1 - \xi_t$ the lender recovers zero. Hence, the firm faces the enforcement constraint

$$\xi_t \left[k_{t+1} - b_{t+1}/(1 + r_t)\right] \geq l_t. \tag{5}$$

Equation (5) states that the expected value of the recoverable asset net of intertemporal debt must be at least higher than the intra-period loan needed to undertake production. Note that, as in Jermann and Quadrini (2012), the probability ξ_t is stochastic and depends on unspecified market conditions, such that $\xi_t = \Psi(\xi_{t-1}, \varepsilon_{\xi t})$, and $\varepsilon_{\xi t}$ is an i.i.d. shock.

To understand how equation (5) affects the firm's production decision, we can use equations (3) and (2) to substitute for $k_{t+1} - b_{t+1}/(1 + r_t)$, and $l_t = f(a_t, k_t, n_t)$ to

re-write equation (5) as

$$\xi_t \left[(1-\delta_k)k_t - w_t n_t - b_t - d_t - g_t v_t\right] \geq (1-\xi_t) f(a_t, k_t, n_t). \tag{6}$$

Equation (6) shows that in the aftermath of a positive financial shock (i.e. higher ξ_t), the firm can either increase the equity payout d_t, or wages w_t, or hiring v_t, since capital k_t, labor input n_t and debt b_t are given at the beginning of the period t. In the presence of labor market frictions it is costly for the firm to adjust labor aggregates and therefore the firm reacts to the positive financial shock by increasing equity payout. Hence, in order to introduce a trade-off between adjusting equity payout or labor input in the aftermath of a financial shock, we assume that the firm's payout is subject to adjustment costs. To formalize the rigidities affecting the substitution between labor input and equity payout, we assume that the actual cost for the firm is

$$\varphi(d_t) = d_t + \kappa(d_t - d)^2, \tag{7}$$

where $\kappa \geq 0$, and d is the steady-state level of equity payout. Note that, as discussed in Jermann and Quadrini (2012), equation (6) implies that the equity payout costs internalize pecuniary costs as well as a variety of other costs, such as the preference of managers for dividend smoothing, and the fact that underwriting fees display increasing marginal costs in the size of offering.[9]

We introduce labor market frictions by assuming a search and matching process in the labor market, as in Thomas (2008). Firms post a number of vacancies. Unemployed workers and vacancies, which we denote by u_t and v_t respectively, meet in the so-called matching technology, $m_t = m(v_t, u_t)$. Normalizing the size of the labor force to 1, u_t also represents the unemployment rate. Under the assumption of constant returns to scale in the matching technology, the matching probabilities for unemployed workers,

$$\frac{m(v_t, u_t)}{u_t} = m\left(\frac{v_t}{u_t}, 1\right) \equiv p\left(\frac{v_t}{u_t}\right),$$

[9] See Lintner (1956) and Altinkilic and Hansen (2000) respectively.

and for vacancies,

$$\frac{m(v_t, u_t)}{v_t} = m\left(1, \frac{1}{v_t/u_t}\right) \equiv q\left(\frac{v_t}{u_t}\right),$$

are functions of the ratio of vacancies to unemployment, also called labor market tightness. From now onwards, we denote labor market tightness by $x_t \equiv v_t/u_t$. Notice that $p'(x_t) > 0$ and $q'(x_t) < 0$, i.e. in a tighter labor market jobseekers are more likely to find jobs and firms are less likely to fill their vacancies. Notice also that $p(x_t) = x_t q(x_t)$. Therefore, by posting vacancies v_t that will be filled with probability $q(x_t)$, the firm increases the employment stock n_{t+1} available during period $t+1$ according to

$$n_t = (1 - \delta_{nt})n_{t-1} + q(x_t)v_t, \tag{8}$$

where $\delta_{nt} = \Psi(\delta_{nt-1}, \varepsilon_{\delta_n t})$ is the exogenous separation rate, and $\varepsilon_{\delta_n t}$ is an i.i.d. shock.[10] The problem for the firm is to maximize its total real expected equity payout, given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t d_t, \tag{9}$$

where $\beta^t \lambda_t$ measures the marginal utility value (defined below) to the representative household of an additional dollar in value during period t. Thus, the firm chooses $\{k_{t+1}, n_{t+1}, b_t, v_t, i_t, l_t\}_{t=0}^{\infty}$ to maximize its market value (9) subject to the budget constraint (3), the definition of the intra-period loan (4), the law of capital accumulation (2), the enforcement constraint (5) the law of employment (8), and the actual cost of equity payout (7) for all $t = 0, 1, 2, ...$ By substituting out $l_t = f(a_t, k_t, n_t)$ into the enforcement constraint (5) and i_t and v_t using the law of capital and labor equations (2) and (8) respectively into the firm's budget constraint (3), and by letting μ_t denote the non-negative Lagrange multiplier on the enforcement constraint (5), the first-order

[10] Extending the analysis to embed endogenous job destruction to investigate the implications for the contribution of financial shocks to aggregate fluctuations would certainly be a very useful extension for future research.

conditions for this problem are

$$E_t\beta_{t,t+1}\left[\varphi_d(d_t)/\varphi_d(d_{t+1})\right]\left\{(1-\delta_k)/\nu_{t+1}+\left[1-\mu_{t+1}\varphi_d(d_{t+1})\right]f_{k,t+1}\right\}+\mu_t\xi_t\varphi_d(d_t)=1/\nu_t, \tag{10}$$

$$w_t=(1-\mu_t\varphi_d(d_t))\,f_{n,t}-g_t/q(x_t)+E_t\beta_{t,t+1}\left[\varphi_d(d_t)/\varphi_d(d_{t+1})\right](1-\delta_{nt+1})g_{t+1}/q(x_{t+1}), \tag{11}$$

$$\varphi_d(d_t)\left[R_t/(1+r_t)\right]\mu_t\xi_t+E_t\beta_{t,t+1}\left[\varphi_d(d_t)/\varphi_d(d_{t+1})\right]R_t=1, \tag{12}$$

where E_t is the expectation conditional on information available in period t, $\beta_{t,t+1}=\beta\lambda_{t+1}/\lambda_t$ is the stochastic discount factor, $f_{x,t}$ denotes the marginal product of factor x at time t, and $\varphi_d(d_t)$ denotes the derivative of $\varphi(d_t)$ with respect to d_t. Equation (10) equates the expected contribution of an additional unit of capital (left-hand side, LHS) to its cost (right-hand side, RHS). Note that the expected productivity of capital is augmented by a wedge that depends on the tightness of the enforcement constraint, μ_{t+1}, as a tighter constraint increases the effective cost of capital and reduces its demand. In addition, a higher liquidation value of the firm increases the overall capital contribution. Equation (11) equates the wage (LHS) to the expected benefits of an extra unit of labor (RHS). Note that the latter comprises three elements. First, it depends on the marginal product of labor augmented by a wedge that depends on the tightness of the enforcement constraint, μ_{t+1}, as a tighter constraint increases the effective cost of labor and reduces its demand. Second, it depends on the cost of posting an extra vacancy, and, finally, on the expected future saving if the worker is retained during period $t+1$. Finally, equation (12) equates the benefits of issuing a bond (LHS) with its cost (RHS).

2.2 The Representative Household

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

$$E_0\sum_{t=0}^{\infty}\beta^t\varsigma_t U(c_t,n_t), \tag{13}$$

where the variable c_t is consumption, n_t is units of labor, β is the discount factor $0 < \beta < 1$, $\varsigma_t = \Psi(\varsigma_{t-1}, \varepsilon_{\varsigma t})$ is the preference process, and $\varepsilon_{\varsigma t}$ is an i.i.d. shock. The representative household enters the period with bond holdings b_t, it supplies n_t units of labor at the real wage rate w_t, and it earns the equity payout, d_t. The household uses its income to acquire new bonds $b_{t+1}/(1 + r_t)$, where $(1 + r_t)$ is the gross nominal interest rate, to consume, c_t, and to pay lump-sum taxes T_t to the government. Hence, the household's budget constraint is

$$b_t + w_t n_t + d_t = b_{t+1}/(1 + r_t) + c_t + T_t, \tag{14}$$

for all $t = 0, 1, 2, ...$ Thus, the household chooses $\{c_t, b_{t+1}\}_{t=0}^{\infty}$ to maximize its utility (13) subject to the budget constraint (14) for all $t = 0, 1, 2, ...$ Letting λ_t denote the non-negative Lagrange multiplier on the budget constraint (14), the first-order conditions for this problem are

$$\lambda_t = U_c(c_t, n_t), \tag{15}$$

and

$$\lambda_t = \beta E_t \lambda_{t+1}(1 + r_t), \tag{16}$$

where $U_c(c_t, n_t)$ denotes the marginal utility of consumption. According to equation (15), the Lagrange multiplier equals the household's marginal utility of consumption. Equation (16), once equation (15) is substituted in, is the representative household's Euler equation that describes the optimal consumption decision.

Given the presence of search frictions a realized job match yields some pure economic surplus. The split of this surplus between the firm and the worker is determined by the wage level. As in Pissarides (2000), the wage is set according to the Nash bargaining solution. In what follows, we describe the structure of the labor market to explicitly derive how the wage splits the surplus.[11]

[11] We make the standard assumption of perfect insurance of unemployment risk in the search and matching literature (i.e. all members pool their resources so as to ensure equal consumption). See

Labor market tightness, x_t, indicates the number of vacancies over the number of workers in search of a job. The cost of posting a vacancy is equal to g_t and, as in Blanchard and Gali (2010) and Mandelman and Zanetti (2014), is a function of labor market tightness x_t:

$$g_t = \Gamma x_t^{\alpha}, \tag{17}$$

where α is the elasticity of labor market tightness with respect to hiring costs such that $\alpha \geq 0$; and Γ is a scale parameter such that $\Gamma \geq 0$. As pointed out in Rotemberg (2008), this formulation encompasses the idea that the tighter the labor market the more costly hiring may be. Note that given the assumption of full participation, the unemployment rate, defined as the fraction of household members left without a job after hiring takes place, is

$$u_t = 1 - n_t. \tag{18}$$

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_{nt}. Hence, the marginal value of a new match is:

$$\mathcal{W}_t^n = w_t - \frac{\chi n_t^{\phi}}{\lambda_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left\{ \left[1 - \delta_{nt+1} \left(1 - p_{t+1} \right) \right] \mathcal{W}_{t+1}^n + \delta_{nt+1} \left(1 - p_{t+1} \right) \mathcal{W}_{t+1}^u \right\}. \tag{19}$$

This equation states that the marginal value of a job for a worker is given by the wage less the marginal disutility that the job produces to the worker, plus the expected-discounted net gain from being either employed or unemployed in period $t+1$.

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

$$\mathcal{W}_t^u = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[p_{t+1} \mathcal{W}_{t+1}^n + \left(1 - p_{t+1} \right) \mathcal{W}_{t+1}^u \right]. \tag{20}$$

Andolfatto (1996) and references therein.

This equation states that the marginal value of unemployment is made up of the expected-discounted capital gain from being either employed or unemployed in period $t+1$.

The structure of the model guarantees that a realized job match yields some pure economic surplus. The wage shares this surplus between the worker and the firm. As mentioned, 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 $0 < \eta < 1$. The difference between equations (19) and (20) determines the worker's economic surplus. The firm's surplus is simply given by the real cost per additional vacancy posted, g_t, as in Blanchard and Gali (2010), Mumtaz and Zanetti (2012) and Mumtaz and Zanetti (2015). Hence, the total surplus from a match is the sum of the worker's and firm's surpluses. The Nash wage bargaining rule for a match is

$$\eta g_t = (1-\eta)(\mathcal{W}_t^n - \mathcal{W}_t^u).$$

Substituting equations (19) and (20) into this last equation produces the agreed wage:

$$w_t = \chi n_t^{\phi}/\lambda_t + \zeta g_t - \beta\left(1-\delta_{nt+1}\right) E_t\left(\lambda_{t+1}/\lambda_t\right)\left(1-p_{t+1}\right)\zeta g_{t+1}, \tag{21}$$

where $\zeta = \eta/\left(1-\eta\right)$ is the relative bargaining power of the worker. Equation (21) shows that the wage equals the marginal rate of substitution between consumption and leisure (first term on the RHS) plus current hiring costs (second term on the RHS), minus the expected savings in terms of the future hiring costs if the match continues in period $t+1$ (third term on the RHS).

2.3 The Government

The government receives lump-sum taxes T_t from the household, to finance the tax benefit of the firm's debt and to sustain real government purchases G_t, such that

$$T_t = b_{t+1}/[1+r_t(1-\tau)] - b_{t+1}/(1+r_t) + G_t, \tag{22}$$

where government purchases follow the stochastic process $G_t = \Psi(G_{t-1}, \varepsilon_{Gt})$, and ε_{Gt} is an i.i.d. shock.

2.4 Aggregate Constraint and Model Solution

The aggregation of the firm's budget constraint (3), the household's budget constraint (14) and the government's budget constraint (22) yields the aggregate resource constraint

$$y_t = c_t + \nu_t i_t + g_t v_t + G_t. \tag{23}$$

In order to solve the system we need to parameterize the production technology, the matching function, the utility function and the exogenous disturbances. To parameterize the production technology, we use the standard Cobb-Douglas function:

$$y_t = a_t k_t^{1-\theta} n_t^{\theta}, \tag{24}$$

where $0 < \theta < 1$ represents the labor share of production. For the matching technology we use the standard matching function:

$$m_t = \overline{m} u_t^{\mu} v_t^{1-\mu}, \tag{25}$$

where $\overline{m}$ is a scaling factor and μ represents the elasticity of the matching function with respect to unemployment. For the utility function, we use the standard function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \varsigma_t \left[\ln c_t - \chi n_t^{1+\phi} / (1+\phi) \right], \tag{26}$$

where ϕ is the inverse of the Frisch elasticity of labor supply $\phi > 0$ and χ is the degree of disutility of labor $\chi > 0$.

The processes for a_t, ν_t and ς_t evolve according to

$$\ln(a_t) = \rho_a \ln(a_{t-1}) + \varepsilon_{at}, \tag{27}$$

$$\ln(\nu_t) = \rho_\nu \ln(\nu_{t-1}) + \varepsilon_{\nu t}, \tag{28}$$

and

$$\ln(\varsigma_t) = \rho_\varsigma \ln(\varsigma_{t-1}) + \varepsilon_{\varsigma t}, \tag{29}$$

with $0 < (\rho_a, \rho_\nu, \rho_\varsigma) < 1$, and where the zero-mean, serially uncorrelated innovations ε_{at}, $\varepsilon_{\nu t}$ and $\varepsilon_{\varsigma t}$ are normally distributed with standard deviation σ_a, σ_ν and σ_ς respectively. Finally, the processes for ξ_t, G_t and δ_{nt} evolve according to

$$\ln(\xi_t) = (1 - \rho_\xi) \ln(\xi) + \rho_\xi \ln(\xi_{t-1}) + \varepsilon_{\xi t}, \tag{30}$$

$$\ln(G_t) = (1 - \rho_G) \ln(G) + \rho_G \ln(G_{t-1}) + \varepsilon_{Gt}, \tag{31}$$

and

$$\ln(\delta_{nt}) = (1 - \rho_{\delta_n}) \ln(\delta_n) + \rho_{\delta_n} \ln(\delta_{nt-1}) + \varepsilon_{\delta_n t}, \tag{32}$$

where ξ, G and δ_n are the steady-state levels of the financial frictions, government purchases and the separation rate respectively, with $0 < \left(\rho_\xi, \rho_G, \rho_{\delta_n}\right) < 1$, and where the zero-mean, serially uncorrelated innovations $\varepsilon_{\xi t}$, ε_{Gt} and $\varepsilon_{\delta_n t}$ are normally distributed with standard deviation σ_ξ, σ_{Gt} and σ_{δ_n} respectively.

Hence, equations (3), (2)-(8), (10)-(12), (15)-(18), (21), (23)-(25), and (27)-(32) together with the definitions of $\beta_{t,t+1}$, $p(x_t)$, $q(x_t)$, and R_t describe the behavior of the 25 endogenous variables y_t, c_t, k_t, i_t, n_t, v_t, u_t, x_t, m_t, w_t, g_t, $p(x_t)$, $q(x_t)$, d_t, b_t, R_t, r_t, λ_t, $\beta_{t,t+1}$, a_t, ξ_t, G_t, z_t, ς_t and δ_{nt}. The equilibrium conditions do not have an analytical solution. Consequently, the system is approximated by loglinearizing its equations around the stationary steady state. In this way, a linear dynamic system describes the path of the endogenous variables' relative deviations from their steady-state value, accounting for the exogenous disturbances. The solution to this system is derived using Klein (2000).

3 Econometric Methodology, Data and Prior Distributions

In this section, we first present the econometric methodology and then we describe the data and the prior distributions for the Bayesian analysis.

We take the model to the data using Bayesian methods. To describe the estimation procedure, define Θ as the parameter space of the DSGE model, and $Z^T = \{z_t\}_{t=1}^T$ as the data observed. According to Bayes' Theorem the posterior distribution of the parameter is of the form $P(\Theta|Z^T) \propto P(Z^T|\Theta)P(\Theta)$, where $P(\cdot)$ indicates the distribution operator. This method updates the *a priori* distribution using the likelihood contained in the data to obtain the conditional posterior distribution of the structural parameters. 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 of convergence.[12] The posterior density $P(\Theta|Z^T)$ is used to draw statistical inference on the parameter space Θ. An and Schorfheide (2007) provide a detailed description of Bayesian simulation techniques applied to the DSGE models.

The econometric estimation uses US quarterly data for the period 1955:1-2010:2. We use data for output, y, consumption, c, capital stock, k, real wages, w, unemployment rate, u, and debt stock, d.[13] The series for output, consumption, capital, and debt stock are from the NIPA data, whereas the series for the unemployment rate are from the BLS data. Prior to the estimation, the logarithms of the series are linearly detrended. A detailed description of the data sources and construction is in the appendix.

[12] An appendix that details evidence of convergence is available upon request from the author.

[13] As a robustness check we have used the series for investment in place of the capital stock series. The results hold, since investment is related to the dynamics of capital stock. We prefer to use the capital stock series since it enables a closer theoretical characterization of financial shocks ξ_t, as from the enforcement constraint (5).

Our empirical strategy consists in calibrating the parameters that affect the steady-state equilibrium and estimating the remaining parameters (i.e. the payout adjustment cost parameter κ and the exogenous disturbances).[14] We first describe the calibrated parameters, whose numerical values are summarized in Table 1. We set the discount factor, β, equal to 0.99 to generate an annual real interest rate of 4%, as in the data. We calibrate the inverse of the Frisch intertemporal elasticity of substitution in labor supply, ϕ, equal to 1, which is in line with micro- and macro-evidence as detailed in Card (1994) and King and Rebelo (1999). We set the production labor share, θ, equal to 0.66, a value commonly used in the literature. We set the capital destruction rate, δ_k, equal to 0.025 as in King and Rebelo (1999), and the steady-state job destruction rate, δ_n, equal to 0.06 to match the CPS data as described in Fujita and Ramey (2009). We set the tax rebate, τ, equal to 0.35, as in Jermann and Quadrini (2012). The wage bargaining parameter, η, is set to 0.5, as it is standard in the search and matching literature.[15] As in Blanchard and Gali (2010), to satisfy the Hosios condition, which ensures that the equilibrium of the decentralized economy is Pareto efficient, we impose that the elasticity of labor market tightness with respect to hiring costs, α, is equal to the relative bargaining power of the worker, ζ, such that $\alpha = \zeta$.[16] The level parameter of the matching function, $\overline{m}$, is calibrated equal to 0.05 to match the steady-state vacancy-filling rate, $q(x_t)$, equal to 0.9,

[14] The approach is similar to Ireland (2004), Thomas and Zanetti (2009) and references therein. To produce robust estimates of the parameters in the model, the theoretical framework needs to be enriched with several additional features (such as capital adjustment costs, habit in consumption, nominal price and wage rigidities, and nominal shocks), as in Smets and Wouters (2007). Extending the analysis using a more elaborate model that allows for the estimation of all the parameters would certainly be a useful task for future research.

[15] We have performed an extensive sensitivity analysis on this parameter and established that results are similar across alternative calibrations of η. An appendix that provides details on robustness analysis is available on request to the author.

[16] See Hosios (1990) for the formal derivation of this condition. The Hosios condition that ensures Pareto efficiency of the decentralized economy continue to hold in presence of financial frictions.

as in Andolfatto (1996). We set the elasticity of the matching function, μ, equal to 0.5, as in Petrongolo and Pissarides (2001). We need to set a value for Γ, which determines the steady-state share of hiring costs over total output, gv/y. Following Gali (2010), who finds that $gv/y = 0.0014$ (i.e. the share of hiring costs over total output is slightly above one-tenth of a percentage point of GDP), the parameter Γ is set equal to 0.86.

The steady-state values of the neutral technological progress, a, the investment-specific technological progress, ν, and the preference shock, ς, are conveniently normalized equal to 1. The steady-state value of the disutility of labor, χ, is set equal to 1.22, in order to match the steady-state value of employment, n, equal to 0.95, the average share of the labor force employed during the post-war period. The steady-state value of the financial shock, ξ, is set equal to 0.13, in order to match the ratio of debt over GDP which is equal to 2.64 over the sample period for the nonfinancial business sector based on the data from the Flows of Funds (for debt) and NIPA (for business GDP). The steady-state value of the government purchases, G, is set equal to 0.66, in order to match the share of government consumption in GDP which is equal to 20%, in line with the average government spending share in our sample.

We estimate the remaining parameters pertaining to the payout adjustment cost parameter κ, exogenous disturbances ρ_a, ρ_ξ, ρ_G, ρ_z, ρ_ς, ρ_{δ_n}, σ_a, σ_ξ, σ_G, σ_z, σ_ς and σ_{δ_n}. Table 2 reports the prior distributional forms, means, standard deviations and 90% confidence intervals, for the complete set of parameters. The priors on these parameters are in line with existent studies and are harmonized across different shocks. We assume that the payout adjustment cost parameter κ has an inverse-gamma distribution with prior mean 0.2 and standard deviation of 0.1, as in Jermann and Quadrini (2012). We assume that the persistence parameters ρ_a, ρ_ξ, ρ_G, ρ_z, ρ_ς and ρ_{δ_n} are beta distributed, with a prior mean equal to 0.8 and a prior standard deviation equal to 0.1. The standard errors of the innovations σ_a, σ_ξ, σ_G, σ_z, σ_ς and σ_{δ_n} follow an inverse-gamma distribution with prior mean 0.1 and a prior standard deviation of 10 that corresponds to a rather

loose prior.

4 Results and Analysis

In this section, we first estimate the model and investigate its dynamic properties by using impulse response functions and forecasting variance decompositions. We then use the estimated model to study the dynamics of exogenous disturbances and to evaluate to what extent each shock contributes to key short-run comovements in the data.

4.1 Estimation Results and Model Dynamics

Table 3 reports the posterior mean estimates, standard errors and the 5th and 95th percentiles of the estimated parameters. In general, the values of the estimates are in line with related studies. The posterior mean of the payout adjustment cost κ is equal to 0.0165, of slightly smaller magnitude compared to the estimates in Jermann and Quadrini (2012). The posterior means of the autoregressive components show that shocks to investment-specific technology, preference and the job separation rate are more persistent than shocks to neutral technology, finance and government purchases. In addition, the posterior means of the volatilities of the stochastic processes show that shocks to the job separation rate are highly volatile, whereas the volatility of the other shocks is of similar magnitude across estimates. The magnitude of these estimates is in line with existing studies and the high volatility in the job destruction rate is similar to the estimates of the volatilities of the job destruction rate series in the data, as surveyed by Yashiv (2007).

To investigate how some key variables of the model react to exogenous disturbances, Figures 2-3 plot the impulse responses of selected variables to specified shocks for the benchmark model with both labor market and financial frictions (solid line) and the same model without labor market frictions (dashed line), obtained by setting the hiring cost

parameter, Γ, and the exogenous separation rate, δ_n, equal to zero.[17] In this way, as in Mumtaz and Zanetti (2016), we are able to assess the differences in the variables' responses between the two models and evaluate the contribution of labor market frictions over and above financial frictions. We begin by commenting the responses of the benchmark model. A few interesting results stand out. The left-panel of Figure 2 shows that in response to a positive neutral technology shock, output, consumption and investment rise, as in a standard RBC model. On the labor market side, the positive neutral technology shock induces the firm to post vacancies, as the surplus from establishing a work relationship is higher, generating a decrease in unemployment and an increase in wages. Higher costs of hiring and retaining workers reduce the firm's collateral, thereby inducing a decrease in debt issuing and dividend payouts, which reduces its financial exposure in order to meet a tighter enforcement constraint, as from equation (6). The right-panel of Figure 2 plots the variables' reactions to a positive financial shock. An increase in the probability of recovering a loan induces the firm to reduce its collateral by decreasing capital and increasing debt issuing. The reduction in capital suppresses investment on impact, which increases afterwards and causes consumption to fall. The firm increases hiring, thereby reducing unemployment. The improved financial position and higher working capital together with an increase in labor costs induce the firm to decrease dividend payouts, as from equation (6). It is worth noting that the effect of financial shocks are short-lived, as they disappear after 10 quarters, which echoes the findings in Jermann and Quadrini (2012). The left-panel of Figure 3 plots the variables' response to a positive preference shock. The shock increases consumption and output on impact, whereas investment and capital fall. Vacancies posting increases, leading to a fall in unemployment. The sharp increase in vacancies and fall in unemployment raises

[17] Zanetti (2015) reports impulse responses for a larger set of variables and each the shocks in the model. An appendix that details the reactions of the complete set of variables and shocks in the model is available on request to the author.

labor market tightness, which in turn increases the cost of posting vacancies, reducing the wage, as from equation (11). The increase in output induces the firm to adjust its financial position by raising equity payouts and reducing debt issuing, as implied by equation (6). The right-panel of Figure 3 plots the variables' responses to a positive shock to the job destruction rate. The shock increases unemployment and reduces output and investment. The firm contrasts the increase in the job destruction rate by posting vacancies, which are not, however, sufficient to generate a fall in unemployment. Hence, the rise in unemployment increases the marginal product of labor and raises wages. As the firm's working capital declines, debt issuing robustly rises. The increase in debt issuing, coupled with an increase in hiring costs, triggers a reduction in equity payouts. Overall, impulse response functions show that financial frictions have a significant impact on the firm's financial position and labor market variables such as vacancy posting, unemployment and wages. In addition, the analysis points out that shocks to the job destruction rate are important for the dynamics of the unemployment rate, since their effect outweighs the opposite reaction of vacancy posting. A comparison across the impulse responses of the benchmark model against those of the version of the same model without labor market frictions shows that the presence of a frictional labor market structure leaves the qualitative response of the variables broadly unchanged.[18]

To understand the extent to which each shock explains movements in the variables, Table 4 reports the forecast error variance decompositions for selected variables. The entries show that neutral and investment-specific technology shocks explain most of the short-run movements in output, while they contribute with financial shocks to explain the bulk of fluctuations in wages. Financial shocks are the main drivers of equity payout and debt issuing, whereas they make a limited contribution to explain output and unemployment fluctuations. Shocks to the job destruction rate explain almost one third

[18] Mumtaz and Zanetti (2016) conduct a similar exercise and outline the quantitative differences that search frictions generates in a model with financial frictions.

of fluctuations in unemployment at all frequencies and contribute with a similar magnitude to fluctuations in output in the long run, while they make a minor contribution to wages and are irrelevant for debt issuing and equity payout. In the long run, neutral and investment-specific technology shocks continue to have a prime role on output, and they increase their contribution to explain debt issuing. Neutral technology shocks become the key driver of wages, followed by financial shocks. The contribution of investment-specific technology shocks to debt issuing substantially rises over time, whereas it remains broadly constant for equity payout. In general, the contribution of government shocks to movements in the data is limited.

4.2 Exogenous Disturbances and Comovements

The advantage of conducting the analysis in a general equilibrium framework is that we can use the model to recover estimates of the individual shocks using a Kalman smoothing algorithm, which relies on information contained in the data. By feeding the recovered shocks into the theoretical model we are able to generate estimated time series for the model's endogenous variables, which we use to provide some additional insights on the model's dynamics.

It is instructive to use the model to derive a profile for each stochastic process in the model. To this aim, each entry in Figure 4 shows one exogenous process as derived from the estimated model and the shaded areas indicate recessions. A few interesting facts stand out. First, the derived neutral and investment-specific technology shocks are remarkably close to those estimated using alternative econometric procedures, as in Fisher (2006). In particular, the series for neutral technology shocks tracks the recessions relatively well and shows that the fall in the neutral technological process during the last recession is the highest compared to previous historical episodes. It is also interesting to note that the level of the investment-specific technology process, which can also be interpreted as the relative price of investment compared to output, declines from the

mid-1970s until the early 2000s, and shows an unprecedented, sharp increase during the last recession. To interpret the series for financial shocks properly it is important to note that the effects of financial shocks are mostly driven by unexpected changes in ξ_t rather than the overall level. With this in mind, the last recession stands out as the historical episode with the tightest credit conditions, followed by the 1981:Q3-1982:Q4 recession, a period in which bank failures reached a post-depression high and the Federal Deposit Insurance Corporation intervened to support the banking system. The series for shocks to the job destruction rate rises during each of the past recessions, in line with the labor market findings summarized in Davis et al. (2006). It is also interesting to note that this series quickly increases and reaches its highest peak during the last recession. Figure 5 compares movements in the changes of financial shocks, which approximate changes in the credit standards in the model, against movements in the Federal Reserve Board survey on credit market tightness (Senior Loan Officer Opinion Survey on Bank Lending Practices). It clearly emerges that the two series have similar dynamics. The series for shocks to government spending shows that on average recessions coincide with a rapid government purchases increase, followed by a substantial decrease in the immediate post-period recession. This is in line with the findings in Mountford and Uhlig (2009) based on VAR analysis and Fernandez-Villaverde et al. (2015) based on econometric estimation of fiscal policy rules that allow for time-varying volatility. In addition, the evidence points out that during the last recession government spending experienced the quickest increase and reached its highest peak during the sample period. Finally, the dynamics of the series for preference shocks documents that these disturbances were below trend from the late 1970s until the early 2000s, and they have robustly increased during the last recession. Interestingly, the profile of the preference shock is remarkably close to the estimates in Fernandez-Villaverde and Rubio-Ramirez (2007) that, as detailed by these authors, closely track the series for hours worked in the data. Overall these findings show that the stochastic disturbances in the model track the underlying structural shocks in

the data well, and, in addition, they also point out the unprecedented, sharp movements in the shocks that characterized the last recession.

Before concluding, we use the theoretical model to investigate to what extent each shock generates key high-frequency comovements in the data. We do so by feeding the theoretical model with each estimated shock individually, thereby tracing out the behavior of the variables in the presence of one specific shock. The bottom graph of Figure 6 reports the empirical negative comovement between output and unemployment in the data. The other entries plot the comovement between output and unemployment in the presence of one particular shock. It clearly emerges that shocks to the job destruction rate, household's preference and financial frictions are the main contributors to the negative comovement in the data. These shocks generate negative comovement between output and unemployment, whereas all the other disturbances produce less negative comovement. This evidence echoes our previous results and underlines the importance of preference, financial and job destruction rate shocks to account for this key comovement in the data.

It is also interesting to use the model to investigate how each shock generates the observed negative comovement between debt issuing and unemployment in the data, as reported in the bottom graph of Figure 7. Neutral technology shocks, financial shocks, preference shocks and government purchases lead to strong positive comovement between the variables. The positive contribution of these shocks, which would lead to strong positive comovement between debt issuing and unemployment, is diminished and aligned to data by the strong negative comovement generated by shocks to the investment-specific technology. Importantly, the mild comovement generated by shocks to the job destruction rate also contributes to diminish the positive comovements produced by the other shocks. This is evidence that the observed negative comovement between debt issuing and unemployment relies on shocks to the investment-specific technology and also the job destruction rate attenuates the strong positive comovement between the two variables

generated by the other shocks in the model. This finding suggests that shocks to the job destruction rate are also important in order to properly characterize links between the firm's flows of financing and labor market variables.

5 Conclusion

This paper develops a general equilibrium model that links aggregate flows of financing with unemployment to investigate to what extent shocks that originate in the financial sector affect key macroeconomic variables. The model is estimated using Bayesian methods on aggregate US data. The analysis establishes that financial shocks alter the firm's financial position and generate fluctuations in debt, equity payout and wages. In addition, the analysis points out that shocks to the job destruction rate are important for the dynamics of the unemployment rate.

The estimation of the model enables the identification of structural disturbances in the data based on the dynamic effects that they have on the model's observable variables. The derived shocks provide a reasonably good account of past recession episodes and the series for financial shocks tracks qualitative indicators of credit market tightness relatively well.

Finally, we use the theoretical model to investigate to what extent each shock generates some key business cycle comovements in the data. In particular, we first look into the observed negative comovement between output and unemployment and find that shocks to the job destruction rate together with preference shocks are mainly responsible for the negative comovement in the data. We then investigate the contribution of each shock to the observed negative comovement between unemployment and debt issuing. We find that shocks to the investment-specific technology and the job destruction rate are important forces behind the observed comovement. Overall the results stress the importance of job destruction rate disturbances in accounting for key comovements in the data.

This paper puts forward a number of interesting avenues for future research. First, it clearly emerges that financial shocks are an important source of fluctuations in wages. Future research should deepen the understanding of the links and interactions between developments in financial markets and labor remuneration. Second, the analysis shows that shocks to the job destruction rate are important for unemployment fluctuations, thereby suggesting that including an endogenous job destruction rate would certainly be a useful extension. Finally, it would be interesting to enrich the theoretical framework with nominal rigidities and extend the analysis to include a monetary authority and nominal variables such as inflation, which Aksoy et al. (2013) find to be important in understanding the links between financial intermediation and monetary policy. All these are outstanding tasks for future research.

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6 Appendix: Data Sources

The time series used to construct the six observable variables in the estimation are:

1. Output, y: Real Gross Domestic Product from the FRED database (mnemonics GDPC96) divided by the Civilian Noninstitutional Population from the FRED database (mnemonics CNP16OV).

2. Consumption, c: Real Personal Consumption Expenditures from the FRED database (mnemonics PCECC96) divided by the Civilian Noninstitutional Population from the FRED database (mnemonics CNP16OV).

3. Capital stock, k: NIPA database (Table 1.16, lines 19 and 24).

4. Real wages, w: Compensation of Employees: Wages & Salary Accruals from the FRED database (mnemonics WASCUR) divided by the Civilian Noninstitutional Population from the FRED database (mnemonics CNP16OV).

5. Unemployment rate, u: Civilian Unemployment Rate from the FRED database (mnemonics UNRATE).

6. Debt stock, b: Constructed using the equation: $b_{t+1} = b_t +$ *Net New Borrowing*. The series for *Net New Borrowing* is 'Net increase in credit market instruments of nonfinancial business' from the NIPA database (table F101, line 28). The initial nominal stock debt is set equal to 94.12, as from the value reported in the balance sheet data the Flow of Funds in 1952:Q1 for the nonfarm nonfinancial business (Table B.102, line 22 and Table B.103, line 24). Since this constructed stock of debt is measure in nominal term, we deflate it by the price index for business value added from the NIPA database (Table 1.3.4).

Table 1. Parameters Calibration

Parameter		Value
β	Discount factor	0.99
ϕ	Inverse of the Frisch intertemporal elasticity	1
θ	Labor share of production	0.66
δ_k	Capital destruction rate	0.025
δ_n	Steady-state job destruction rate	0.06
τ	Steady-state tax rebate	0.35
η	Steady-state worker bargaining power	0.5
α	Elasticity of labor market tightness	1
$\overline{m}$	Matching function scale parameter	0.05
μ	Matching function elasticity w.r.t. unemployment	0.5
Γ	Hiring cost scale parameter	0.86
a	Steady-state level of technology shock	1
ς	Steady-state level of preference shock	1
χ	Steady-state level of disutility of labor shock	1.2
ξ	Steady-state level of financial shock	0.13
G	Steady-state level of government purchases	0.66

Notes: The table shows values of the calibrated parameters.

Table 2. Prior Distribution of Parameters

Parameter		Prior distribution			
		Density	Mean	Standard Error	90% Interval
Adjustment Cost Parameter					
κ		Inverse Gamma	0.2	0.1	[0.095,0.387]
Autoregressive Component					
ρ_a	Technology shock	Beta	0.8	0.1	[0.615,0.939]
ρ_ξ	Financial shock	Beta	0.8	0.1	[0.615,0.939]
ρ_G	Government spending shock	Beta	0.8	0.1	[0.615,0.939]
ρ_ν	Investment specific shock	Beta	0.8	0.1	[0.615,0.939]
ρ_ς	Preference shock	Beta	0.8	0.1	[0.615,0.939]
ρ_{δ_n}	Job destruction shock	Beta	0.8	0.1	[0.615,0.939]
Stochastic Component					
σ_a	Technology shock	Inverse Gamma	0.1	10	[0.021,0.274]
σ_ξ	Financial shock	Inverse Gamma	0.1	10	[0.021,0.274]
σ_G	Government spending shock	Inverse Gamma	0.1	10	[0.021,0.274]
σ_ν	Investment specific shock	Inverse Gamma	0.1	10	[0.021,0.274]
σ_ς	Preference shock	Inverse Gamma	0.1	10	[0.021,0.274]
σ_{δ_n}	Job destruction shock	Inverse Gamma	0.1	10	[0.021,0.274]

Notes: The table shows the prior distributional forms, means, standard deviations and 90% confidence intervals of the model's estimated parameters.

Table 3. Posterior Distributions of Parameters

Parameter		Posterior distribution			
		Mean	Standard Error	5th Percentile	95th Percentile
Adjustment Cost Parameter					
κ		0.0165	0.0006	0.0159	0.0179
Autoregressive Component					
ρ_a	Technology shock	0.9561	0.0043	0.9473	0.9612
ρ_ξ	Financial shock	0.4984	0.0025	0.4929	0.4999
ρ_G	Government spending shock	0.7896	0.0033	0.7841	0.7944
ρ_ν	Investment specific shock	0.9715	0.0008	0.9704	0.9731
ρ_ς	Preference shock	0.9864	0.0002	0.9862	0.9868
ρ_{δ_n}	Job destruction shock	0.9729	0.0064	0.9631	0.9850
Stochastic Component					
σ_a	Technology shock	0.0104	0.0003	0.0099	0.0108
σ_ξ	Financial shock	0.0464	0.0011	0.0450	0.0488
σ_G	Government spending shock	0.0554	0.0011	0.0524	0.0567
σ_ν	Investment specific shock	0.0125	0.0001	0.0123	0.0128
σ_ς	Preference shock	0.0162	0.0002	0.0158	0.0164
σ_{δ_n}	Job destruction shock	0.1707	0.0003	0.1704	0.1716

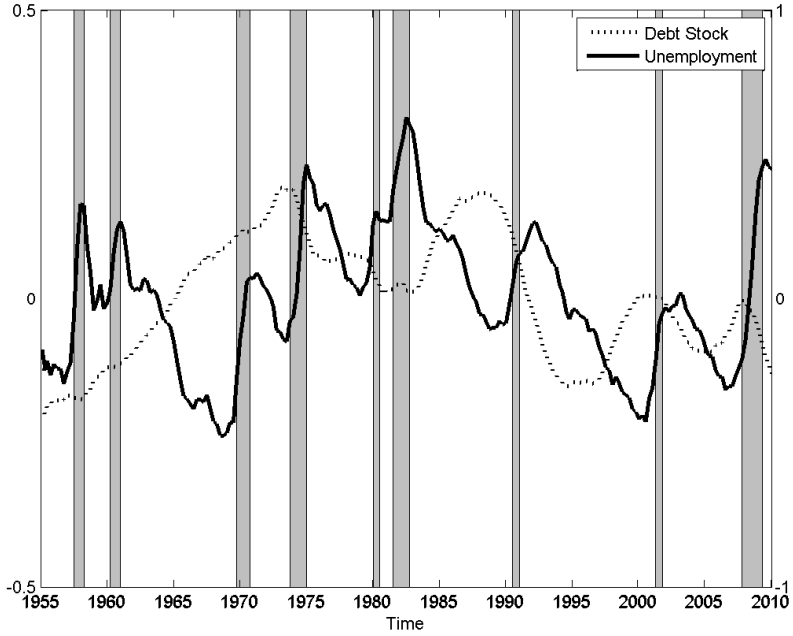
Notes: Each entry shows the posterior mean estimate with the standard error in brackets. To approximate the posterior distribution, a random walk Metropolis-Hastings algorithm is used, based on 50,000 replications, with the first 25,000 discarded as burn-in.

Table 4. Forecast Error Variance Decompositions

Quarters Ahead	Neutral Tech.	Finance	Government	Inv. Spec. Tech.	Preference	Job Destruction Rate
Output						
1	65.01	2.49	0.21	27.34	1.55	3.4
4	62.34	1.76	0.31	24.54	1.71	9.34
8	60.32	0.87	0.35	22.18	1.05	15.23
12	58.53	0.85	0.35	21.64	0.79	17.84
20	57.23	0.55	0.39	20.45	0.62	20.76
36	57.12	0.34	0.42	18.21	0.31	23.60
Unemployment						
1	41.45	4.10	0.42	18.43	5.28	30.32
4	40.32	3.56	0.45	18.12	8.79	28.76
8	38.76	3.21	0.48	17.78	12.23	27.54
12	35.32	2.56	0.51	17.23	17.15	27.23
20	32.87	2.12	0.53	16.67	21.03	26.78
36	31.67	1.45	0.53	16.21	23.69	26.45
Wages						
1	28.34	55.43	0.85	8.54	2.30	4.54
4	31.56	53.87	0.86	8.12	1.36	4.23
8	34.75	52.45	0.86	7.78	0.29	3.87
12	53.67	34.65	0.87	7.31	0.27	3.23
20	57.23	31.65	0.88	7.11	0.02	3.11
36	69.12	20.54	0.89	6.56	0.02	2.87
Dividends						
1	0.86	95.87	0.05	1.13	1.12	0.97
4	0.98	95.66	0.06	1.21	1.15	0.94
8	1.23	95.23	0.06	1.19	1.42	0.87
12	1.67	94.12	0.07	1.18	2.10	0.86
20	2.32	93.67	0.08	1.17	1.91	0.85
36	2.89	93.23	0.08	1.70	1.25	0.85
Debt						
1	6.50	92.23	0.03	0.12	0.88	0.24
4	7.45	91.34	0.04	0.26	0.08	0.83
8	11.49	85.86	0.04	0.55	0.05	2.01
12	12.02	82.12	0.05	1.81	1.77	2.23
20	15.34	74.23	0.07	3.79	4.32	2.25
36	17.65	65.76	0.07	7.72	5.79	3.01

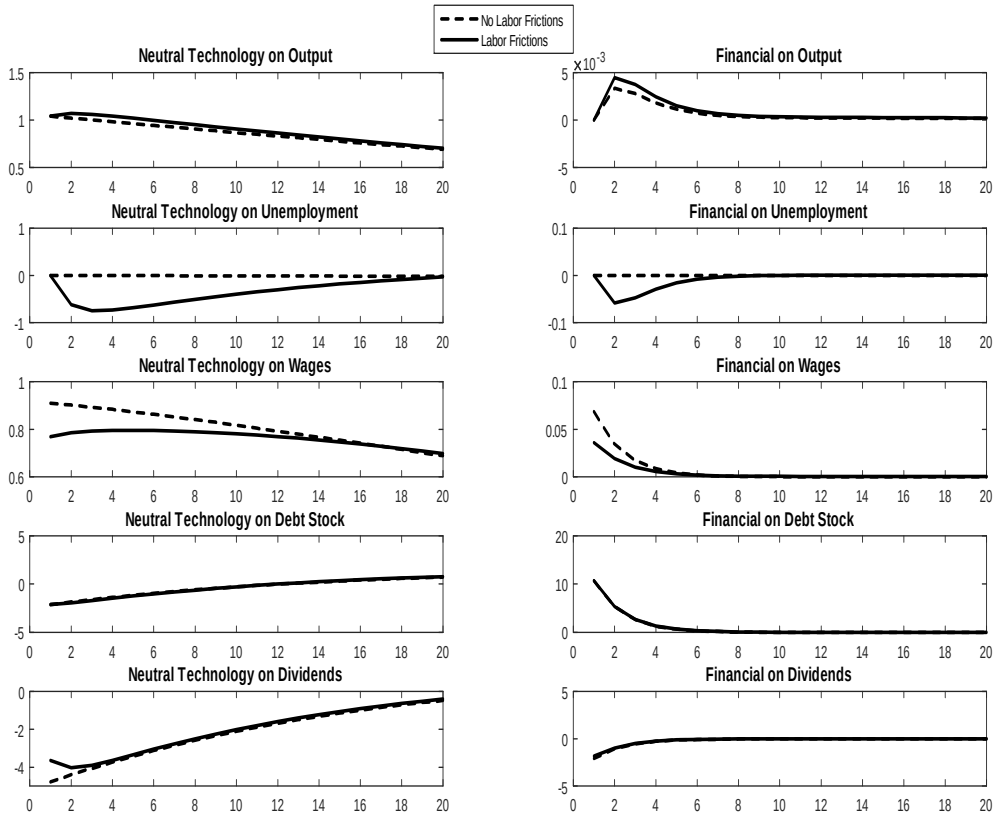
Notes: Forecast error variance decompositions are performed at the mean of the posterior distribution of the estimated parameters.

Figure 1. Debt Stock and Unemployment Rate



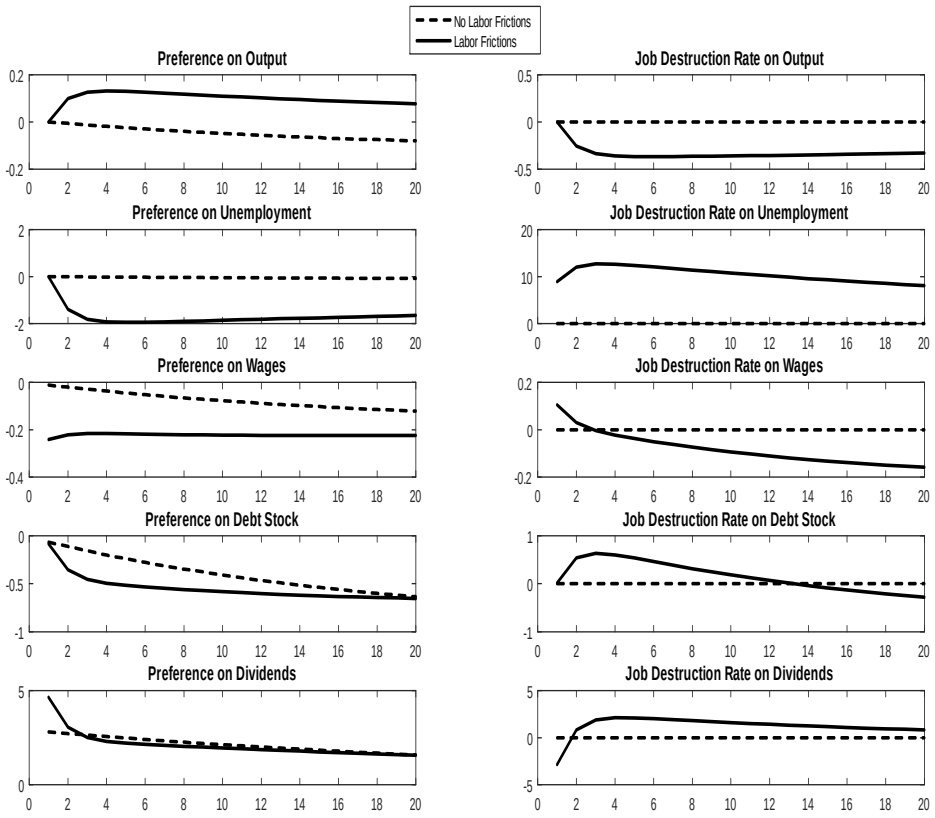
Notes: The figure plots the series for debt stock (y-axis labeling on the left) and unemployment rate (y-axis labeling on the right). Shaded areas indicate recessions. The series for debt stock is from the Flow of Funds Accounts from the Federal Reserve, while the unemployment rate is from NIPA data set. Both series are linearly detrended. The empirical regularities hold if we use alternative detrending methods. See the appendix for a more detailed description of the data.

Figure 2. Variables' Responses to Shocks



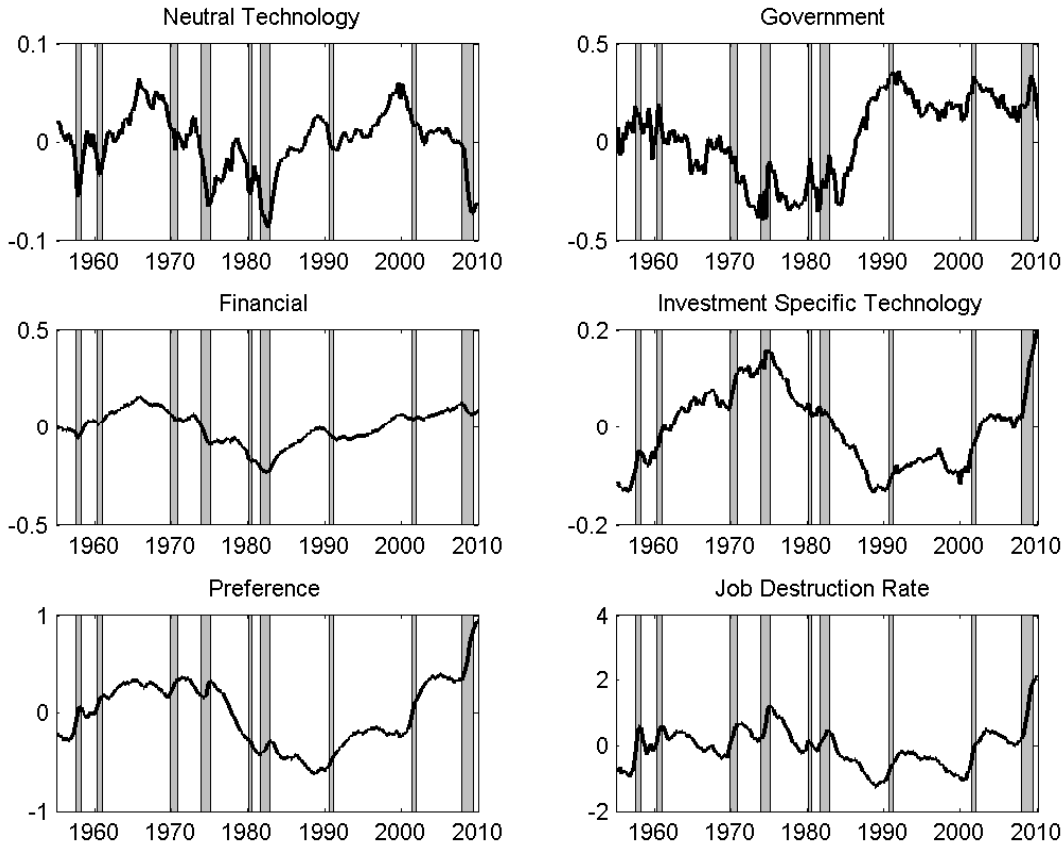
Notes: Each panel shows the percentage-point response in one of the model's endogenous variables to a one-standard-deviation innovation in one of the model's exogenous shocks. The solid line refers to the benchmark model with labor market and financial frictions whereas the dashed line refers to the model that abstracts from labor market frictions. Impulse responses are based on the mean of the posterior distribution of parameters. Periods along the horizontal axes correspond to quarter years.

Figure 3. Variables' Responses to Shocks



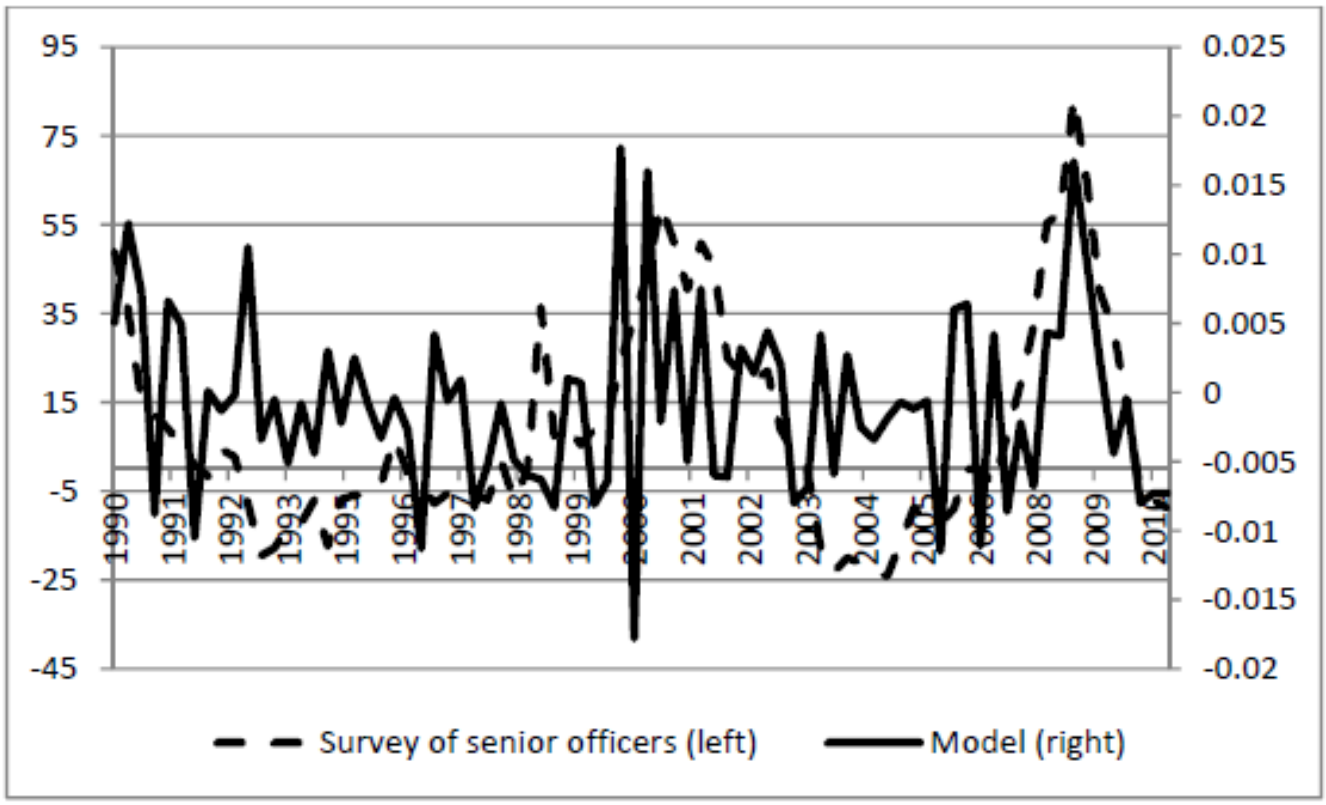
Notes: Each panel shows the percentage-point response in one of the model's endogenous variables to a one-standard-deviation innovation in one of the model's exogenous shocks. The solid line refers to the benchmark model with labor market and financial frictions whereas the dashed line refers to the model that abstracts from labor market frictions. Impulse responses are based on the mean of the posterior distribution of parameters. Periods along the horizontal axes correspond to quarter years.

Figure 4. Model Stochastic Processes



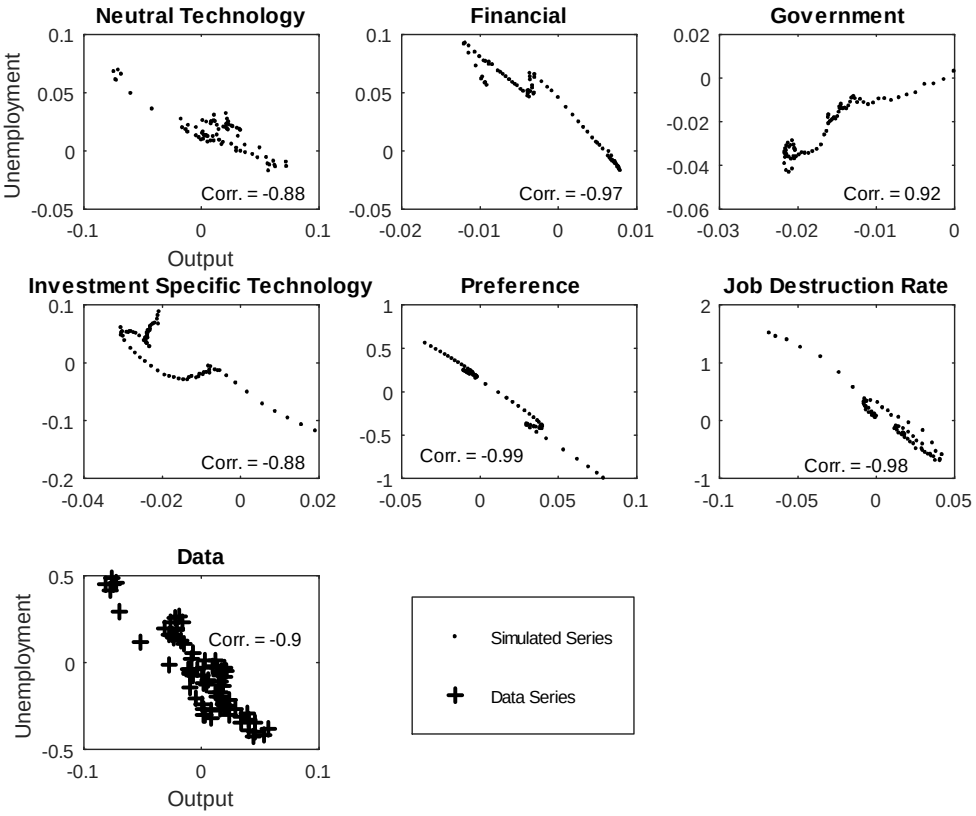
Notes: Each entry shows one exogenous process as derived from the estimated model and the shaded areas indicate recessions.

Figure 5. Credit Market Tightness



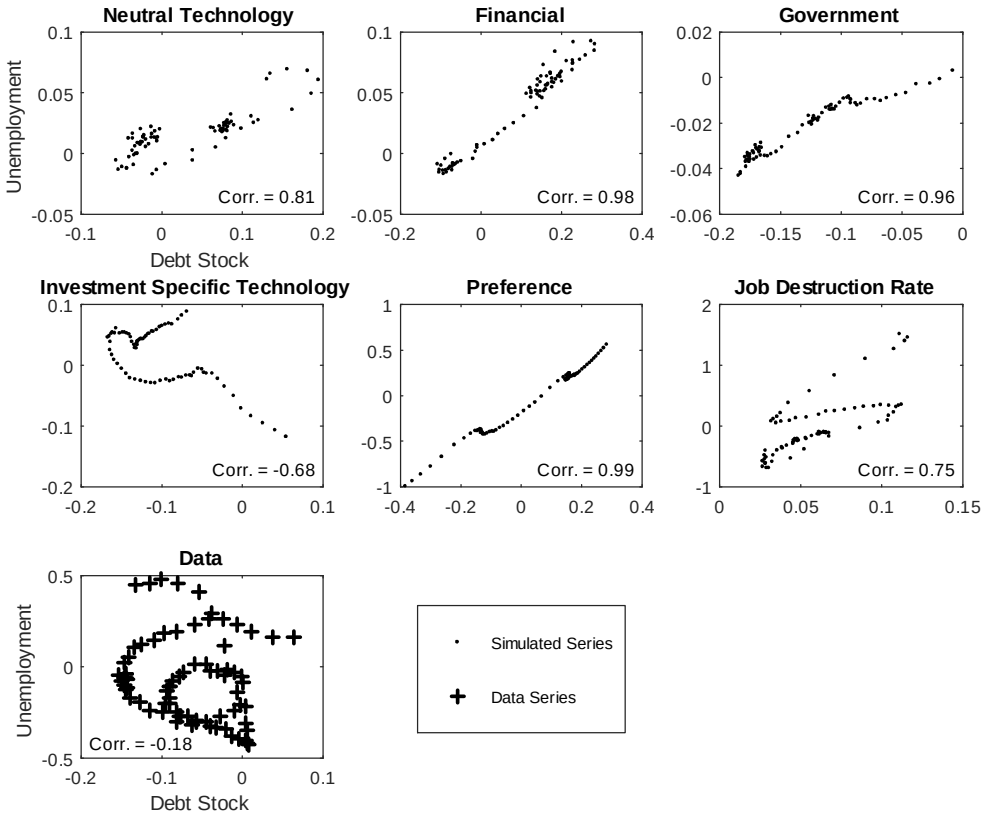
Notes: The figure compares movements in the changes of the financial shock in the model (solid line) against movements in the Federal Reserve Board survey on credit market tightness from the Senior Loan Officer Opinion Survey on Bank Lending Practices (dashed line). The left y-axis refers to the Federal Reserve Board survey and the right y-axis refers to the model.

Figure 6. Comovement Between Output and Unemployment



Notes: Each entry shows the comovement between output and unemployment in the presence of one specific shock. Each entry is generated by feeding the theoretical model with each estimated shock individually, thereby tracing out the behavior of the variables in the presence of one specific shock. The bottom graph reports the negative comovement between output and unemployment in the data.

Figure 7. Comovement Between Debt Stock and Unemployment



Notes: Each entry shows the comovement between debt stock and unemployment in the presence of one specific shock. Each entry is generated by feeding the theoretical model with each estimated shock individually, thereby tracing out the behavior of the variables in the presence of one specific shock. The bottom graph reports the negative comovement between debt stock and unemployment in the data.