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Credit Frictions and Labor Market Dynamics

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Abstract

We outline the case for credit frictions and a demand side aspect to labor market fluctuations. To illustrate the above proposition, we present a simple framework to analyze the joint dependence between a labor search problem in the labor market and a costly state verification problem in the credit market in the presence of price rigidities. Credit market imperfections amplify volatility of labor market variables to both supply and demand shocks, but to a much higher extent to demand shocks under rigid prices. The reason is that demand disturbances provide for a strong incentive to demand-constrained firms to adjust production and thereby labor factor.

Keywords: Credit and search frictions, unemployment, monetary policy

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1 Introduction

What role do credit market imperfections play in business fluctuations in general and in labor market dynamic in particular? This question has been always high in the agenda of both politicians and academicians as soon as the Great Depression, encouraged at that time by the fall down of the financial system that occurred immediately prior to the through. At a more formal level, the idea that credit imperfections, which may stem from moral hazard and adverse selection, could be relevant not only for corporate finance but also for macroeconomics has distilled in recent macroeconomic research, both theoretical and empirical (e.g. Bernanke and Gertler (1989) and Kiyotaki and Moore (1997)).

This paper outlines the case for credit frictions and a demand side aspect to labor market fluctuations, in light of the contributions of the credit frictions, labor search frictions and New Keynesian literature. It is widely acknowledged, since Shimer (2005), that the standard theory of equilibrium unemployment, the Mortensen-Pissarides search and matching model (see Mortensen and Pissarides (1994) and Pissarides (2000)), has difficulty to satisfactorily explain the unemployment volatility puzzle, namely, the empirical volatility of the vacancy-unemployment ratio relative to the volatility of labor productivity. We argue that introducing sticky prices, credit frictions and monetary policy shocks into a otherwise standard matching model helps to address the magnitude of the cyclical fluctuations in unemployment and vacancies. Whereas our model with only a productivity shock generates about the half of the fluctuations in the vacancy-unemployment ratio, our baseline model with a monetary policy shock produces the observed volatility in this key labor market variable.

This paper provides a theoretical framework regarding the direct influence of credit-market imperfections on firm operating behavior and the role of credit leverage as a propagation mechanism in the business cycle. In the model economy, firms need external funding to sponsor their vacancy creation. In particular, we highlight a quantitatively and economically significant relationship between a firm's financial position (the net worth of the firm) and the cyclicality of its labor force, reminiscent of the "financial accelerator" in Bernanke et al. (1999). All other things being equal, employment growth at more highly leveraged firms is more sensitive to demand and credit-market conditions over the business cycle. In other words, more highly leveraged firms will be less willing to create new vacancies, supporting the observation that an increase in credit leverage or tightening of lending conditions increases sensitivity of the macroeconomy to demand shocks.

The central mechanism that drives our results is the inverse relationship between the external finance premium and borrower's net worth, under credit market frictions and with the level of financing required held constant. To the extent that firm's net worth is procyclical (because of procyclicality of profits), the external finance premium will be countercyclical (as well as the default threshold on borrowing determining the split up of profits between lender and borrower), enhancing the swings in borrowing and thus in vacancy creation, and production. All other things being equal, a countercyclical external premium under a contractionary monetary policy, absent any other disturbances, translates into (i) higher recruiting cost for the labor force in comparison to an economy free of credit imperfections. Name this effect vacancy cost channel. In other words, highly leveraged and demand-constrained firms ought to exhibit greater labor-force adjustments in response to temporary fluctuations in demand and (to a lesser extent) in supply. Since recruiting costs affect directly the firm's surplus from an employment relationship with a worker, we observe (ii) higher upward pressure on the real wage (attained under a Nash bargaining schedule) in times of tighter money in comparison to a model that is free of credit imperfections. Name this effect the wage channel. Practically, this means that the real wage attains a level of rigidity due to the presence of credit frictions, and in addition, lowers the incentives of the firm to open new vacancies under a negative demand shock. Both effects, the vacancy cost channel and the wage channel of credit imperfections have been discussed in Petrosky-Nadeau (2008), however for a model with flexible prices driven only by a temporary productivity shock. It is worth stressing that credit frictions amplify supply shocks as well, due to the countercyclical external premium. But productivity shocks alone cannot explain the observed movements in employment under price rigidity. Moreover, in the general equilibrium framework we discuss the default threshold on borrowing is less sensitive to supply fluctuations (or at least to the shock in technology process).

There exists a large and growing literature which seeks to address the unemployment volatility puzzle (see, e.g., Hall (2005), Gertler and Trigari (2006), to name a few.). Most of that literature studies the type of wage schedule that induces real wage rigidity. Our main focus is different. We follow Sveen and Weinke (2008) and point at the importance of demand disturbances, and show that their role for employment volatility is enhanced by a plausible degree of price stickiness. Namely, under sticky prices (meaning demand constrained firms) demand disturbances give a strong incentive to firms to adjust the labor factor. However, we go a step further and claim that credit frictions can make up for the employment volatility that demand constraints alone cannot account for. Our theoretical findings is reaffirmed empirically by Sharpe (1993), who finds that the cyclicality and magnitude of a firm's labor force is to be inversely related to its size and financial position. This evidence is further reinforced by the conclusions of Gertler and Gilchrist (1994), who find that growth in sales, inventories, and bank debt of small manufacturing firms is more sensitive to monetary policy shocks than that of larger firms.

The impact of credit frictions on firm growth and investment decisions is of independent interest for another strand of research. Acemoglu (2001) argues that credit market frictions may be an important contributor to high unemployment in Europe. Wasmer and Weil (2004) develop a theoretical model involving credit and labor market restrictions, and demonstrate that both types of market imperfections can interact in a complementary way explaining pronounced differences in the unemployment dynamics between Europe and the U.S of America.

The outline of the paper is as follows. In the next section we present our theoretical framework. Section 3 discusses the importance of the credit sector for the real economy and for the unemployment volatility puzzle in particular. Section 4 concludes. Various technical details are relegated to appendices.

2 The Model Economy

The core framework is a closed economy DSGE model from Trigari (2006). The key modification is the inclusion of credit friction framework from Bernanke et al. (1999), that is in turn based on earlier work by Bernanke and Gertler (1990), Carlstrom and Fuerst (1997) and others. As a result, we assume that the economy is characterized by the following rigidities: price stickiness, credit market frictions, and search frictions. We also assume the economy is disturbed by: two transitory aggregate shocks, that of technology and monetary policy; and an idiosyncratic shock to wholesale goods producers' productivity.

The model is composed of households, firms and a government authority. Households work, save, and consume retail goods.

There are two types of firms: retailers and wholesale goods producers. The model revolves around the wholesale goods producers that are in general credit constrained. Credit constraints and associated agency problems accordingly have far reaching consequences in Bernanke et al. (1999). Wholesale producers manage the production of wholesale goods and hiring of new workers. They retain a large number of workers [1]. A matching technology determines the number of recruited as a function of the unemployment rate and the vacancy rate. Search frictions imply that it takes unemployed workers time to find a job and it takes firms time and resources to hire workers. Wholesale producers open vacancies using their own resources, as well as bank loans. The presence of asymmetric information between wholesale producers and lenders creates a credit friction which makes producers' demand for debt (and the decision on new vacancies respectively, that in turn is dependent on discounted marginal benefits of the jobs) depend on their net worth (financial position).

Retailers buy wholesale goods and bundle them into final goods. The retail goods are used for consumption purposes. Retailers are monopolistically competitive and set nominal prices on a staggered basis a la Calvo (1983). The retail sector is simply to provide the source of nominal price stickiness and give monetary policy a role in this model.

The assumption of sticky prices per se does not affect the employment volatility results. If the monetary authority keeps the inflation rate close to zero, all prices of final retail goods will converge to a common and constant value, and so sticky prices would have no tangible effects on the economy. However, the monetary authority in our economy is defined by a Taylor-type rule. Namely, the central monetary entity manages short-term interest rates in response to lagged nominal interest rates, the inflation rate, and the "output gap". This implies that uexpected monetary policy shocks have real effects because they induce movements in the inflation rate, which in turn distort the relative prices of final retail goods [2].

The fiscal authority finances its expenditures by lump-sum taxes and issue of nominal bonds.

[1]Wholesale firms are large in a sense that they do not consist of worker-job pair.

[2]Shimer (2008) notes in his comment to Sveen and Weinke (2008) that insofar as it can be ascertained that a Taylor rule does not perfectly describe past monetary policy, the Taylor rule is an incorrect specification of monetary policy. We acknowledge the deficiency of the Taylor rule, but consider that it is a reduced form way to capture demand disturbances, what is more, the central authority has a direct influence on the credit channel to the real economy, important for our analysis.

There are three technologies in the model economy: one for matching unemployed workers to job openings by wholesale goods firms; second one for producing the wholesale good using labor; and third one for transforming wholesale goods into retail goods.

Timing of events in the model economy can be summarized as follows:

- Aggregate shocks to productivity and monetary policy realize. The central bank adjusts the nominal interest rate. Stock of workers, employed from the previous period, break up exogenously with the wholesale firms and become unemployed. Matching outcomes from the previous period's recruiting are realized.
- Wholesale goods producers acquire loans, given their own net worth, from financial markets. Then, they decide on the new vacancies to open that will turn into matches in period $t+1$.
- Wage bargaining between worker and wholesale firm takes place.
- Idiosyncratic shock to the wholesale production realizes. Wholesale firms produce. A fraction of retail good firms is chosen to reset its price. Retail good firms guess demand and produce accordingly.
- Households shop.
- Financial markets open. Wholesale firms pay off loan services to the lender and wages to workers [3]. Retailers and wholesale producers pay profits to households [4]. Households pay taxes to the government. The government issues new bonds, repays old bonds and pays unemployment benefits. The household buys bonds from the government. Current wholesale producer's net worth realizes.

We now proceed to describe the behavior of the different sectors of the economy, along with the key resource constraints.

[3]Observe that the debt contract between wholesale firm and lender is an intra period one, contrary to Bernanke et al. (1999) who assume an inter period contract.

[4]We assume that each household owns an equal share in the wholesale goods production and retail goods sectors, and so receives an equal share of the distributed profits each period.

2.1 Search and Matching Technology

The labor market is subject to search frictions. To form new employment relationships wholesale firms must expend resources in order to open new working positions. Workers do not face job-finding costs. The matching technology which converts unemployed workers and vacancies into matches is given by:

$$l_t = \bar{l}\,(u_t)^{\psi_M}\left(v_t\right)^{1-\psi_M}, \quad 0 < \bar{l}, \quad 0 \leq \psi_M \leq 1, (1)$$

where l_t denotes the number of job matches created in period t, which become productive first in $t+1$. u_t represents the size of the unemployment pool in period t; v_t is the total number of job openings; $\bar{l}$ governs the efficiency of the recruiting process; and ψ_M is the elasticity of the matching function with respect to unemployment. Once normilizing the labor force to one, $u_t + n_t = 1$, u_t also represents the unemployment rate. n_t denotes employed workers in period t and respectively the employment rate. Vacancies and unemployed agents randomly produce new matches. The assumption of constant returns to scale recruiting techology is supported by Petrongolo and Pissarides (2001). It implies that on average with endogenous probability $f_t = \bar{l}\theta_t^{1-\psi_M}$ a worker changes her status from unemployment to employment in period t, while on average the wholesale firms fills a vacancy with endogenous probability $s_t = \bar{l}\theta_t^{-\psi_M}$ in period t. The ratio of vacancies to unemployment, $\theta_t = \frac{v_t}{u_t}$, is labor market tightness. In a stationary environment, the above probabilities define the mean duration of unemployment and unfilled vacancies respectively. Total employment is constrained by past vacancy opening and employment's law of motion is given by:

$$n_{t+1} = (1-\chi)\,n_t + l_t, \quad 0 \leq \chi \leq 1, \tag{2}$$

where χ is a constant exogenous separation rate. A flow $(1-\chi)$ of employed workers, n_t, continues working next period, and a flow of new matches, l_t, turns productive next period.

2.2 Households

There is a continuum of infinitely-lived households distributed uniformly on the unit interval. The representative household itself consists of continuum of family members indexed by $i \in [0,1]$ that have time-separable preferences over their consumption $c_{i,t}$ and their labor supply $h_{i,t}$ in period t. There is a measure $n_{i,t}$ of employed individuals in the household and a measure $u_{i,t}$ of unemployed individuals.

The household allocates total consumption, c_t, in order to maximize the sum of household utility, and so equalizes the marginal utility of consumption across individuals. Given the assumption of additive separability between consumption and leisure, this implies the household equalizes consumption across individuals. The household lifetime utility is given by [5]:

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ Ut\left(c_t\right) - \int_0^{n_{i,t}} K\left(h_{i,t}\right) di \right\}, \quad 0 < \beta < 1, \tag{3}$$

where $Ut\left(c_t\right)$ denotes household's utility from consumption and $K\left(h_{i,t}\right)$ is worker i's disutility from labor. The E_0 symbol denotes the expectation operator conditional on information available at date 0, and β is the subjective discount factor of the household. As in Andolfatto (1996) and Merz (1995), we assume that workers can insure themselves against earning uncertainty and unemployment. In order to do that workers pool all their income sources. Temporary preferences defined over consumption and work effort are given by:

$$Ut\left(c_t\right) = \log c_t, \quad K\left(h_{i,t}\right) = a_L \frac{h_{i,t}^{1+\sigma_L}}{1+\sigma_L}, \quad 0 < a_L,\, 0 \leq \sigma_L. \tag{4}$$

The positive scaling parameter a_L governs disutility of work. The inverse of the parameter σ_L reflects the elasticity of the labor supply of workers with respect to wages, holding consumption constant (i.e. the Frisch elasticity).

2.3 Household's Budget Constraint and Optimal Decisions

Each period, the household allocates its wealth to purchases of financial assets, purchases of consumption goods, and expenditures on lump-sum taxes. The household owns repre-

[5] We assume a cashless limit in the sense of Woodford (2003).

sentative shares of the goods-producing firms in the economy. It has the following sources of income: interest income on financial asset holdings, wages, unemployment benefits, and profits from the goods-producing firms. The household faces the period-by-period intertemporal budget constraint in real terms:

$$\frac{NB_{t+1}}{P_t}+c_t+t_t\leq R^N_{t-1}\frac{NB_t}{P_t}+\int_0^{n_{i,t}}w_{i,t}h_{i,t}di+\int_{n_{i,t}}^1 b_i^U di+\psi_t. \tag{5}$$

At the end of period t, the household decides on the amount of nominal government bonds, NB_{t+1}, to acquire. At the beginning of $t+1$, these pay nominal gross rate of return, R^N_t (from here on, variables given in capital letters denote nominal prices). The price of a unit of the consumption basket is P_t . t_t denotes real lump sum taxes/transfers from the fiscal authority. In period t, an employed household member i earns a real wage hour $w_{i,t}$. An unemployed household member receives real unemployment benefit of size b_i^U. Real labor earnings and unemployment benefits of the household are given by $\int_0^{n_{i,t}}w_{i,t}h_{i,t}di$ and $\int_{n_{i,t}}^1 b_i^U di$ respectively. ψ_t denotes cumulative real profits of the firms received by the household.

The representative household optimizes its life-time utility (3) by choosing consumption and bonds to hold subject to the household budget constraint (5). Denote λ_t the time-t Lagrange multiplier on the flow budget constraint. The following optimality conditions must hold:

$$\text{for}\, c_t: \quad \lambda_t=Ut_{c,t}=\left(c_t\right)^{-1}, \tag{6}$$

$$\text{for}\, NB_{t+1}: \quad \lambda_t=\beta \mathrm{E}_t\left\{\lambda_{t+1}\frac{R^N_t}{\pi_{t+1}}\right\}, \tag{7}$$

$$\lim_{j\to\infty}\beta^j\mathrm{E}_t\left\{\Lambda_{t,t+j}\frac{NB_{t+j}}{P_{t+j}}\right\}=0,\quad \forall t, \tag{8}$$

with the addition of (5) holding with equality. Equation (6) defines the marginal utility of consumption at period t, $Ut_{c,t}$. Denote $\pi_t=\frac{P_t}{P_{t-1}}$ period-t inflation. Equation (7) is the Euler condition for nominal bonds. It states that the household prefers expected marginal utility to be constant across time periods, unless the expected gross real return on bonds, $r_t=\frac{R^N_t}{\pi_{t+1}}$, exceeding household's time preference induces it to lower its consumption today relative to the future. Denote $\beta^j\Lambda_{t,t+j}=\beta^j\frac{\lambda_{t+j}}{\lambda_t}$ the household's pricing kernel between periods t and $t+j$. Equation (8) is a borrowing constraint that prevents the possibility of Ponzi schemes.

We can rewrite the household's problem, given its recursive structure, through an optimal value function as [6]:

$$Vh\left(n_{i,t}, NB_t\right) = \max_{\{c_t, NB_{t+1}\}} \left[Ut\left(c_t\right) - \int_0^{n_{i,t}} K\left(h_{i,t}\right) di + \beta \mathrm{E}_t \left\{ Vh\left(n_{i,t+1}, NB_{t+1}\right) \right\} \right]. \tag{9}$$

We need to find the value enjoyed by the household from the marginal job i. The value is defined as the change in the household's optimal utility from having an additional member employed. Taking the derivative of $Vh\left(n_{i,t}\right)$ in (9) with respect to $n_{i,t}$, subject to (2) and (5), we find the worker's surplus, $Vh_{n_i}\left(n_{i,t}\right)$:

$$\begin{aligned} \text{for}\, n_{i,t}: \quad Vh_{n_i}\left(n_{i,t}, NB_t\right) \equiv Vh_{n_i,t} &= \lambda_t w_{i,t} h_{i,t} - \lambda_t b_i^U - K\left(h_{i,t}\right) \\ &+ \left(1-\chi\right) \beta \mathrm{E}_t \left\{ Vh_{n_i}\left(n_{i,t+1}\right) \right\} - f_t \beta \mathrm{E}_t \left\{ Vh_{n,t+1} \right\}. \end{aligned} \tag{10}$$

There is a continuum of wholesale firms indexed by $z \in [0,1]$, employing $n_{z,t}$ number of workers. These open $v_{z,t}$ job vacancies any period. Observe that any two jobs i and z at the wholesale firm are identical (and for identical i and z, $Vh_{n_z,t+1}$ denotes the marginal value of worker i at firm z). Then, let $\mathrm{E}_t \left\{ Vh_{n,t+1} \right\} = \mathrm{E}_t \left\{ \int_0^{n_{z,t}} \frac{v_{z,t}}{v_t} Vh_{n_z,t+1} dz \right\}$ be the expected average worker's marginal value in period $t+1$ and $\frac{v_{z,t}}{v_t}$ be the probability of being matched to firm z. Thus, the value that the household enjoys from having worker i joining wholesale firm z consists of real wage net of labor unemployment benefit (in terms of marginal utility), minus the disutility of work effort that the employed member experiences, plus the future value of the job conditional on survival, $(1-\chi)\mathrm{E}_t \left\{ \beta Vh_{n_i,t+1} \right\}$, minus the value the worker would contribute to the household if she searched for a job, $f_t \mathrm{E}_t \left\{ \beta Vh_{n,t+1} \right\}$.

2.4 Production

This section provides an overview of the production agents/firms sector.

[6] Observe that all Bellman equations in this paper depend also on the aggregate state of the economy. For reduction of notations, we omit below this dependence.

2.4.1 Retailers

There is a continuum of monopolistic retailers of measure unity, each producing one differentiated consumption good of type $a \in [0,1]$, $y_{a,t}$. Retailers buy wholesale goods from wholesale producers in a competitive market at real price mc_t [7], differentiate them with a technology that transforms wholesale goods into retail goods at a fixed resource cost ϕ_R [8], then sell them to the households at nominal price $P_{a,t}$.

Final output is a constant elasticity of substitution composite of individual retail goods:

$$y_t = \begin{cases} \left(\int_0^1 y_{a,t}^{\frac{\varepsilon-1}{\varepsilon}} da\right)^{\frac{\varepsilon}{\varepsilon-1}} - \phi_R & \text{if } \left(\int_0^1 y_{a,t}^{\frac{\varepsilon-1}{\varepsilon}} da\right)^{\frac{\varepsilon}{\varepsilon-1}} > \phi_R \\ 0 & \text{otherwise} \end{cases}, \quad \varepsilon < 1, \tag{11}$$

where ε is the elasticity of substitution between different types of retail goods. Any retailer faces a demand curve given by:

$$y_{a,t} = \left(\frac{P_{a,t}}{P_t}\right)^{-\varepsilon} y_t. \tag{12}$$

where $P_t = \left(\int_0^1 P_{a,t}^{1-\varepsilon} da\right)^{\frac{1}{1-\varepsilon}}$ is the aggregate price index.

Retailers set nominal prices on a staggered basis. Following Calvo (1983), we assume that each period any retailer adjusts its price with probability $1-\zeta$. The adjustment probability is independent across time and across firms (i.e., it does not depend on how long a firm's price has been fixed). Retailers use the household's pricing kernel, $\beta^j \Lambda_{t,t+j}$, to discount their profits between periods t and $t+j$. If the retail firm a is permitted to optimize its price at time t, it chooses $P_{a,t} = P_{a,t}^o$ to optimize discounted profits:

$$\max_{\{P_{a,t}^o\}} \mathrm{E}_t \sum_{j=0}^{\infty} (\beta\zeta)^j \left\{ \Lambda_{t,t+j} \left[\frac{P_{a,t}^o}{P_{t+j}} y_{a,t+j} - mc_{t+j} y_{a,t+j} - \phi_R \right] \right\}, \tag{13}$$

[7] Observe that the relative price of wholesale goods, mc_t, coincides with the real marginal cost faced by retailers.

[8] We assume that the fixed resource cost, associated with marketing and distribution of the retail good, is proportional to the steady-state value of wholesale output. We choose the level of the fixed cost so that profit to the retail sector is zero in steady-state.

subject to (12). The current value of firm's profit is expressed as the total real revenue of its sales, $\frac{P^o_{a,t}}{P_{t+j}} y_{a,t+j}$, reduced by the total real costs, $mc_{t+j} y_{a,t+j} + \phi_R$. The first order condition of the retailer's optimizing behavior gives:

$$\mathrm{E}_t \sum_{j=0}^{\infty} (\beta \zeta)^j \left\{ \Lambda_{t,t+j} \left[\left(\frac{P^o_{a,t}}{P_{t+j}} \right)^{1-\varepsilon} - (1+\mu_P)\, mc_{t+j} \left(\frac{P^o_{a,t}}{P_{t+j}} \right)^{-\varepsilon} \right] y_{t+j} \right\} = 0, \tag{14}$$

where μ_P is a price mark-up. The mark-up is inversely related to the elasticity of demand, ε, as $1+\mu_P = \frac{1}{1-1/\varepsilon}$. In the case of perfect competition, when $\varepsilon = \infty$, the net mark-up over the marginal cost, mc_t, is zero, since $1+\mu_P$ converges to 1.

From the Calvo pricing assumption we get law of motion of the price level:

$$P_t = \left(\zeta \left(P_{t-1}\right)^{1-\varepsilon} + (1-\zeta) \left(P^o_t\right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}. \tag{15}$$

2.4.2 Finance and Wholesale Production

Wholesale producers manage the production of wholesale goods and hiring of new workers. They have infinite horizon for carrying out their projects. Wholesale firms open new vacancies using their own net worth, as well as loans from financial markets. The wholesale producer z uses the following wholesale constant return to scale technology:

$$y_{z,t} = \omega_{z,t} \tau^A_t h_{z,t} n_{z,t} \tag{16}$$

to generate a single wholesale good, $y_{z,t}$, at any given period t. Here, $n_{z,t}$ denotes workers employed at the wholesale firm at the beginning of period t who work $h_{z,t}$ hours per period each; τ^A_t is a stationary shock to technology; and $\omega_{z,t}$ is an idiosyncratic shock that affects the productivity of the whole workforce of the firm (independent of the time of recruiting of the workers). The shock $\omega_{z,t}$ is private information. It is an independent and identically distributed lognormal random variable with cumulative distribution function $F(\omega)$, over non-negative support, and mean one, $\mathrm{E}_{t-1}\{\omega_t\} = 1$. The riskiness of wholesale producers' projects is determined by the variance of the idiosyncratic shock, σ_ω. The variable τ^A_t follows the following process:

$$\log \tau^A_{t+1} = \rho_a \log \tau^A_t + \varepsilon^a_{t+1}, \quad 0 \le \rho_a < 1,$$

where $\varepsilon_t^a \overset{\text{iid}}{\sim} N\left(0, \sigma_a^2\right)$.

We now discuss the financing. In any period t, the wholesale producer decides on new vacancies to open at the cost of $\phi_V v_t$. The wholesale firm finances its vacancy openings with its own real net worth, $nw_{z,t}$, and an external loan, $db_{z,t}$, borrowed from financial markets. We suppose that $nw_{z,t} < \phi_V v_t$.

The marginal cost of external financing to the wholesale producer depends on financial conditions. The relationship with the lender is subject to an agency cost problem, which forces the producer to pay a premium on the loan. We follow Bernanke et al. (1999) in supposing a "costly state verification" where lenders must pay a monitoring cost to observe any single borrower's realized return. The monitoring cost is a proportion $0 \leq \mu < 1$ of the realized gross wholesale producer's output, i.e., the monitoring cost for producer z equals $d_{z,t} = \mu \omega_{z,t} mc_t \tau_t^A h_{z,t} n_{z,t}$.

Given that the aggregate shock to technology is known at the beginning of any period, the only uncertainty about the wholesale production's return is idiosyncratic to the firm. The wholesale producer signs a "standard debt contract" a la Gale and Hellwig (1985) with the lender. Absent any aggregate uncertainty, this specifies number of vacancies to open and loan amount to borrow, prior to the realization of the idiosyncratic shock. Given vacancies and loan amount, the optimal contract is characterized by a gross non-default rate of interest, $r_{z,t}^L$, and a cutoff level, $\bar{\omega}_{z,t}$. The non-default rate of interest is to be paid for the borrowed loan if $\omega_{z,t}$ is above the cutoff level. Producers who draw $\omega_{z,t}$ below the cutoff level go bankrupt and must turn everything they have to the lender. An advantage of this arrangement is that lenders do not have to monitor all wholesale producers. Given constant returns to scale, the cutoff $\bar{\omega}_{z,t}$ determines the division of net revenues between borrower and lender, and satisfies:

$$\bar{\omega}_{z,t} = \frac{r_{z,t}^L db_{z,t}}{\left(mc_t \tau_t^A - w_{z,t}\right) h_{z,t} n_{z,t}}. \tag{17}$$

In equilibrium, any lender holds a pooled and perfectly safe portfolio. Therefore, the lender can obtain its funds at a riskless, intra-period opportunity cost to funds which equals unity. Perfect competition and free entry on the financial market imply that lenders' net cash flow must be zero in each period, i.e., the expected return from the lending activity would equal the opportunity cost of finance:

$$(1-F(\bar{\omega}_{z,t}))\, r_t^L db_{z,t} + (1-\mu)\, G(\bar{\omega}_{z,t}) \left(mc_t \tau_t^A - w_{z,t} \right) h_{z,t} n_{z,t} = (\phi_V v_{z,t} - nw_{z,t}),$$

where $G(\bar{\omega}_{z,t}) = \int_0^{\bar{\omega}_{z,t}} \omega_{z,t} dF(\omega_{z,t})$ is the probability of monitoring. Denote $\Gamma(\bar{\omega}_{z,t}) = \bar{\omega}_{z,t}(1-F(\bar{\omega}_{z,t})) + G(\bar{\omega}_{z,t})$ the share of wholesale producer's earnings kept by the lender. Substituting out for $r_t^L db_{z,t}$ using (17), we can rewrite the above participation constraint for the lender as [9]:

$$(\Gamma(\bar{\omega}_{z,t}) - \mu G(\bar{\omega}_{z,t})) \left(mc_t \tau_t^A - w_{z,t} \right) h_{z,t} n_{z,t} = (\phi_V v_{z,t} - nw_{z,t}). \tag{18}$$

We can now write the wholesale producer's problem, given its recursive structure, through an optimal value function. Similar to the retailer, the wholesale firm uses the household's pricing kernel to discount future returns. More precisely, the producer chooses the optimal contract that maximizes its expected gross return [10]:

$$Vf(n_{z,t}) = \max_{\{v_{z,t}, \bar{\omega}_{z,t}\}} \left[(1-\Gamma(\bar{\omega}_{z,t})) \left(mc_t \tau_t^A - w_{z,t} \right) h_{z,t} n_{z,t} + \beta \mathrm{E}_t \left\{ \Lambda_{t,t+1} Vf(n_{z,t+1}) \right\} \right], \tag{19}$$

by selecting vacancies, $v_{z,t}$, and the cutoff level, $\bar{\omega}_{z,t}$, conditional on the firm's employment law of motion (2) and the participation constraint for the lender (18). Regarding the labor law of motion, we assume that the new matches at firm z at the beginning of period t are proportionate to the ratio of its vacancies to total vacancies in the economy, $\frac{v_{z,t}}{v_t}$. Thus, $\frac{v_{z,t} l_t}{v_t} = v_{z,t} s_t$ is hiring initiated by firm z. The optimal contract between wholesale producer and lender requires the two first-order conditions below to hold:

$$\text{for } v_{z,t}: \quad \frac{\phi_V \lambda_{z,t}^{\bar{\omega}}}{s_t} = \beta \mathrm{E}_t \left\{ \Lambda_{t,t+1} V f_n(n_{z,t+1}) \right\}, \tag{20}$$

$$\text{for } \bar{\omega}_{z,t}: \quad \lambda_{z,t}^{\bar{\omega}} \left(\Gamma^{\bar{\omega}}(\bar{\omega}_{z,t}) - \mu G^{\bar{\omega}}(\bar{\omega}_{z,t}) \right) = \Gamma^{\bar{\omega}}(\bar{\omega}_{z,t}), \tag{21}$$

[9] Bernanke et al. (1999) argue that, given the assumptions on $F(\omega)$, the expression on the left of the equality in the zero profit condition for the lender (18) below has an inverted U shape in $\bar{\omega}_{z,t}$. There is some unique interior maximum, $\bar{\omega}_{z,t}^{\star}$, and the lender would never choose $\bar{\omega}_{z,t}^{\star\star} > \bar{\omega}_{z,t}^{\star}$.

[10] Observe that the wholesale producer's Bellman equation depends on the aggregate state of the economy and, importantly, on the law of motion of the aggregate net worth, given in equation (24) below. For sake of simplification, we omit this dependence.

where $\lambda^{\bar{\omega}}_{z,t}$ is the time-t Lagrange multiplier on the lender's participation constraint. $\Gamma^{\bar{\omega}}(\bar{\omega}_{z,t})$ and $G^{\bar{\omega}}(\bar{\omega}_{z,t})$ denote first derivatives of $\Gamma(\bar{\omega}_{z,t})$ and $G(\bar{\omega}_{z,t})$ with respect to $\bar{\omega}_{z,t}$. The condition for vacancy posting equates the marginal cost of posting a vacancy (the expression on the left of the equality sign in (20)) with the discounted marginal benefit of the job (the expression on the right of the equality sign in (20)). The second first-order condition is related to the fact that the lender's return can simply be expressed as a function of the average cutoff value, $\bar{\omega}_t$ [11].

Let $Vf_n(n_{z,t})$ be the value to the wholesale firm of employing additional worker at time t:

$$\text{for}\, n_{z,t}: \quad Vf_n(n_{z,t}) = \lambda^{\bar{\omega}}_{z,t}\left(\Gamma(\bar{\omega}_{z,t}) - \mu G(\bar{\omega}_{z,t})\right)\left(mc_t\tau^A_t - w_{z,t}\right)h_{z,t} \\ + \left(1-\Gamma(\bar{\omega}_{z,t})\right)\left(mc_t\tau^A_t - w_{z,t}\right)h_{z,t} + (1-\chi)\beta \mathrm{E}_t\left\{\Lambda_{t,t+1}Vf_n(n_{z,t+1})\right\}. \tag{22}$$

The first and second terms on the right of the equality sign in (22) give the net return (marginal revenue product minus real wage) of an additional worker, under relaxing the financial conditions in terms of an increased ability to repay the loan, and under the optimal debt contract, respectively. The third term on the right captures the job's continuation value. Denote $\Omega(\bar{\omega}_{z,t}) = \lambda^{\bar{\omega}}_{z,t}\left(\Gamma(\bar{\omega}_{z,t}) - \mu G(\bar{\omega}_{z,t})\right) - \Gamma(\bar{\omega}_{z,t})$. Combining (20) and (22) we can rewrite the job creation condition as:

$$\frac{\phi_V \lambda^{\bar{\omega}}_{z,t}}{s_t} = \mathrm{E}_t\left\{\beta\Lambda_{t,t+1}\left[\left(1+\Omega(\bar{\omega}_{z,t+1})\right)\left(mc_{t+1}\tau^A_{t+1} - w_{z,t+1}\right)h_{z,t+1} + (1-\chi)\frac{\phi_V\lambda^{\bar{\omega}}_{z,t+1}}{s_{t+1}}\right]\right\}, \tag{23}$$

which states that the vacancy-creation cost incurred by the firm is equated to the discounted expected value of profits from the match. Profits from a match take into account wage cost and debt reimbursement cost (due to an additional worker) of that match. This condition is known as the free-entry condition and is one of the crucial equilibrium conditions of the labor sector.

Let us motivate our modeling choices somewhat more at this stage. First, we can observe from equation (23) that credit frictions drive a wedge, $\lambda^{\bar{\omega}}_{z,t}$, between the discounted

[11] The optimal loan contract between producers and lenders for each z producer has the property $\bar{\omega}_{z,t} = \bar{\omega}_t$, which is due to straightforward aggregation, explained below.

expected value of profits from the match and the vacancy-creation cost incurred by the firm absent any credit imperfections, ϕ_V/s_t. It is straightforward to show that $\partial\lambda^{\bar{\omega}}/\partial\bar{\omega} > 0$, and that in the limit $\lim_{\bar{\omega}\to 0}\lambda_{z,t}^{\bar{\omega}} = 1$. Second, we can show that $\lim_{\bar{\omega}\to 0}\Omega\left(\bar{\omega}_{z,t}\right) = 1$. That is, absent monitoring costs the vacancy creation condition reduces to the familiar job creation condition, as can be found in Mortensen and Pissarides (1994) [12].

What do credit friction imply for the vacancy creation condition? We stated the answer already in the introduction. To the extent that firm's net worth is procyclical, the external finance premium and the multiplier to the vacancy condition will be countercyclical, enhancing the swings in borrowing and thus in vacancy creation, and production. All other things being equal, a countercyclical external premium under a contractionary monetary policy, absent any other disturbances, translates into higher recruiting cost for the labor force in comparison to an economy free of credit imperfections, an effect we refer to as vacancy cost channel. In other words, firms facing downward trend in their net worth ought to exhibit greater labor-force adjustments in response to temporary fluctuations in demand and (to a lesser extent) in supply, owing to their diminished willingness to open job vacancies.

It is clear from the first order conditions (20) and (21) that each wholesale producer's standard debt contract is characterized by the same cutoff level and vacancy opening condition. This simplification owes to having constant returns in both production, bankruptcy and vacancy opening costs, and guarantees that aggregation is straightforward (see, e,g. Carlstrom and Fuerst (1997) and Bernanke et al. (1999)). It implies that loan costs faced by wholesale producers are proportional to the aggregate net worth and do not depend on any producer-specific variables.

The law of motion of aggregate wholesale producer's net worth (in consumption units) follows: $nw_{t+1} = \iota\left(1-\Gamma\left(\bar{\omega}_{z,t}\right)\right)\left(mc_t\tau_t^A - w_t\right)h_t n_t$. We make the assumption that wholesale firms retain ι of their profits towards next period net worth. $1-\iota$ of wholesale firm profits are paid into an insuarance scheme that covers for the loses faced by workers who supplied their labor to firms that went bankrupt [13]. This assumption ensures that wholesale producers' net worth, both now and in the future, will not be enough to fully finance their new vacancy openings. Firms that go bankrupt are free to search for credit

[12] The vacancy creation condition in Mortensen and Pissarides (1994), under our setup and notations is given by $\frac{\phi_V}{s_t} = \mathrm{E}_t\left\{\beta\Lambda_{t,t+1}\left[\left(mc_{t+1}\tau_{t+1}^A - w_{z,t+1}\right)h_{z,t+1} + (1-\chi)\frac{\phi_V}{s_{t+1}}\right]\right\}$.

[13] Bernanke et al. (1999) make the assumption that entrepreneurs have finite expected horizon for providing their services, with $\iota < 1$ being probability of their survival to the next period.

opportunities next period. Respectively, we can rewrite the expression for the net worth as:

$$nw_{t+1} = \iota \left(\left(mc_t \tau_t^A - w_t \right) h_t n_t - \left(1 + \frac{\mu G(\bar{\omega}_t) \left(mc_t \tau_t^A - w_t \right) h_t n_t}{\phi_V v_t - nw_t} \right) (\phi_V v_t - nw_t) \right). \tag{24}$$

Aggregate wholesale producer's net worth equals net revenues less repayment on borrowings. It is clear from the above equation that higher external premium to funds, $\frac{\mu G(\bar{\omega}_t) \left(mc_t \tau_t^A - w_t \right) h_t n_t}{\phi_V v_t - nw_t}$, leads to lower aggregate net worth in the next period. The external premium to funds is strictly positive for any $\mu > 0$.

2.5 Wage and Hour Bargaining

We assume, as in most of the labor search literature, that worker and wholesale firm bargain both over hourly wage and hours, at the individual level over the joint surplus of their match, $S_t = V f_n(n_t) + \frac{1}{\lambda_t} V h_n(n_t)$, expressed in terms of consumption units (i.e., household surplus is divided by marginal utility of consumption), according to the Nash bargaining solution. Given that in equilibrium all wholesale producers behave similarly (and every i and z at the firm are identical) we can drop the i and z subscripts. Bargaining takes place over hourly wage per worker, before the wholesale firm draws an idiosyncratic productivity, to maximize:

$$\max_{\{w_t, h_t\}} \left(V f_n(n_t) \right)^{1-\eta} \left(\frac{1}{\lambda_t} V h_n(n_t) \right)^{\eta}, \tag{25}$$

where $\eta \in (0, 1)$ is the worker's bargaining power in the wage negotiation process. The first-order condition of the Nash product with respect to w_t is:

$$\text{for } w_t: \quad -(1-\eta) \left(\frac{1}{\lambda_t} V h_n(n_t) \right) \underbrace{\left(\frac{\partial V f_n(n_t)}{\partial w_t} \right)}_{\delta^f} = \eta \left(V f_n(n_t) \right) \underbrace{\left(\frac{\partial \frac{1}{\lambda_t} V h_n(n_t)}{\partial w_t} \right)}_{\delta^w}, \tag{26}$$

where $\delta^w = h_t$ and $\delta^f = -\left(1+\Omega\left(\bar{\omega}_t\right)\right)h_t$. Using the above equation and employing optimal vacancy condition (20) yields:

$$(1-\eta)\,\beta\mathrm{E}_t\left\{\frac{\left(1+\Omega\left(\bar{\omega}_{t+1}\right)\right)}{\lambda_t}Vh_n\left(n_{t+1}\right)\right\} = \eta\beta\mathrm{E}_t\left\{\Lambda_{t,t+1}Vf_n\left(n_{t+1}\right)\right\} = \eta\frac{\phi_V\lambda_t^{\bar{\omega}}}{s_t}. \tag{27}$$

By combining conditions (10), (22), (26) and (27) we derive the following equilibrium wage rule:

$$\begin{aligned} w_t h_t = {} & \eta\left(mc_t\tau_t^A h_t + \frac{\phi_V\lambda_t^{\bar{\omega}}\theta_t}{1+\Omega\left(\bar{\omega}_t\right)}\right) + \eta\left(1-\chi-f_t\right)\frac{\phi_V\lambda_t^{\bar{\omega}}}{s_t}\left(\frac{1}{1+\Omega\left(\bar{\omega}_t\right)} - \frac{1}{1+\Omega\left(\bar{\omega}_{t+1}\right)}\right) \\ & + (1-\eta)\left(b^U + \frac{a_L}{\lambda_t}\frac{h_t^{1+\sigma_L}}{1+\sigma_L}\right). \end{aligned} \tag{28}$$

The equation expresses the total wage payment to the worker as a weighted average between the marginal revenue product of the worker plus the cost of replacing the worker (the first and second terms in first brackets on the right-hand-side), and the outside option of the worker plus the marginal disutility of labor, due to supplied hours (the third term in brackets on the right-hand-side). The bargaining weight, dividing the joint surplus of the match, determines how close the wage is to either the marginal product or to the outside option of the worker. It is obvious from the second term in brackets that the wholesale producer takes into account how the difference between current and future credit conditions would affect the cost of replacing the worker. Similar to the job creation condition, absent credit frictions the wage rule reduces to the familiar wage equation, as can be found in Mortensen and Pissarides (1994) [14].

What do credit friction imply for the wage rule condition? Since recruiting costs affect the wage, we observe higher upward pressure on the real wage in times of tighter money in comparison to a model that is free of credit imperfections. Namely, both the second term in brackets and the second term in first brackets on the right-hand-side in (28) exhibit upward countercyclical tendency. We refer to this effect as the wage channel of credit

[14] The total wage payment in Mortensen and Pissarides (1994), under our setup and notations is given by $w_t h_t = \eta\left(mc_t\tau_t^A h_t + \phi_V\theta_t\right) + (1-\eta)\left(b^U + \frac{a_L}{\lambda_t}\frac{h_t^{1+\sigma_L}}{1+\sigma_L}\right)$.

imperfections. Practically, this means that the real wage attains a level of rigidity due to the presence of credit frictions, and in addition, lowers the incentives of the firm to open new vacancies under a negative demand shock.

Hours per worker are chosen in a competitive labor market, so as to maximize the joint surplus of the employment relationship between a worker and a firm. However, the choice of hours is independent of the wage. Under the specified household utility function and the assumption of the large family, the maximization of the total surplus yields:

$$\text{for}\, h_t: \quad mc_t \tau_t^A = \frac{a_L h_t^{\sigma_L}}{\lambda_t}. \tag{29}$$

The condition equalizes the marginal product of labor to the worker's marginal rate of substitution between leisure and consumption. It also elucidates the driving forces of hours variation in the search model. A higher marginal utility of wealth, $Ut_{c,t}$, and a higher marginal product of labor all increase labor supplied, whereas it falls whenever the disutility of labor or the intertemporal preferences increase. It is worth noting that credit frictions do not affect the intensive margin of labor supply.

To the extent that both the wage rule and the vacancy creation condition reduce to their prototypes in Mortensen and Pissarides (1994), absent any monitoring costs and a change in the intensive margin condition, we have the marriage of the credit friction model with the labor search friction model nesting the labor search model in Mortensen and Pissarides (1994).

2.6 Government

The central bank adjusts the nominal interest rate, R_t^N, in response to deviations of inflation and output from their steady-state values. The monetary policy rule evolves according to:

$$\begin{aligned}\log\left(R_t^N\right) = &(1-\rho_m)\log\left(\frac{\pi}{\beta}\right) + \rho_m \log\left(R_{t-1}^N\right)\\ &+ (1-\rho_m)\left(\gamma_\pi \log\left(\frac{\mathrm{E}_t\left\{\pi_{t+1}\right\}}{\pi}\right) + \frac{\gamma_y}{4}\log\left(\frac{y_t}{y}\right)\right) + \varepsilon_t^m.\end{aligned} \tag{30}$$

Let $\rho_m \in [0,1)$, $1 < \gamma_\pi$ and $0 \leq \gamma_y$ are response coefficients to lagged interest rate, inflation and output, respectively. Variable without an index represents the steady state value of the corresponding variable. Let $\varepsilon_t^m \overset{\text{iid}}{\sim} N\left(0, \sigma_m^2\right)$ is an iid log-normal shock to the monetary policy stance.

The government budget constraint is:

$$\frac{NB_t}{P_t} + t_t = R_{t-1}^N \frac{NB_{t-1}}{P_t} + u_t b^U. \tag{31}$$

The government finances its expenditures by lump-sum taxes, t_t, and issue of nominal bonds, NB_{t+1}. We assume the government elastically supplies bonds until the bond market clears. The government makes expenditures on debt repayment and coupon, and unemployment benefits (the term involving b^U).

2.7 Market Clearing

In a competitive equilibrium, all agents' optimality conditions are satisfied and all markets clear. We assume a symmetric equilibrium throughout, which entails identical choices for all variables. We have $h_{z,t} = h_t$, for all t and z. Defining aggregates as the averages of firm specific variables, we have that $1 - u_t = n_t = n_{z,t} = \int_0^1 n_{z,t} dz$, $v_t = v_{z,t} = \int_0^1 v_{z,t} dz$ and $y_{z,t} = \int_0^1 y_t dz$. Furthermore, as $P_{a,t} = P_t$, $y_{a,t} = y_t$, for all t and a. Thus, retail firms produce the same amounts of output and face the same marginal costs mc_t. Finally, using the household budget contraint, firms profits, and the government constraint, the resulting aggregate income identity is:

$$(1 - \mu G(\bar{\omega}_t)) y_t = c_t + \phi_V v_t. \tag{32}$$

Equilibrium in the retail goods market requires that the production of the retail goods be allocated to private consumption by households. Final amount of consumption goods is reduced due to the presence of costs that originate from lender's monitoring of the wholesale production activity and from wholesale firms's job creation activity.

3 Results

The equations describing the model economy are collected in the Appendix. We solve the model by log-linearizing the equations characterizing equilibrium around the deterministic steady state. The resulting system of linear rational expectations difference equations is solved using DYNARE. Our goal is to analyze how credit market structure (we mean calibrated parameters about the credit sector) impact the observed business-cycle fluctuations in unemployment and job vacancies in response to technology and monetary policy shocks of a plausible magnitude. Before turning to the results we briefly discuss how the parameter values are chosen.

3.1 Calibration

We calibrate the model to the U.S. using data from 1951:q1 to 2005:q3. The sample coincides with the sample used in Sveen and Weinke (2008). All data are taken from the Federal Reserve Bank of St. Louis' database FRED II except for the Help Wanted Advertising Index which was obtained from the Conference Board. We use the Hodrick- Prescott filter with a conventional filter weight of 1,600 to extract the business cycle component from the data in logs.

The time unit of the model is meant to be a quarter. The calibrated parameter values and the targets are summarized in Table 1. The implied steady state values are given in Table 2.

We set the subjective discount factor to $\beta = 1.01^{-0.25}$, yielding an annual real interest rate of about 2.5 percent. We set the quarterly probability of separation at $\chi = 0.10$, consistent with Shimer (2005). We set the elasticity of matches with respect to unemployment to $\psi_M = 0.5$, which is in the range of reasonable values discussed by Petrongolo and Pissarides (2001). Setting the worker and firm matching rates to $s = 0.9$ and $f = 0.7$, respectively, we can calculate the number of vacancies that must be available for matching in steady state: $v = 0.09$. The bargaining wage power is set to a value of $\eta = 0.5$.

The parameters describing the household are standard. We choose the substitution elasticity for retail goods is $\varepsilon = 7$, as in Golosov and Jr. (2007), which implies a steady state mark-up of 17%. The curvature of disutility of work, $\sigma_L = 2$, follows the estimates of Domeij and Floden (2006). Parameter a_L is set to imply that those household members who are employed spend one-third of their available time working. We target a steady state replacement rate of $b^U/wh = 0.6$.

The parameter $\zeta = 0.8$ governs the degree of nominal rigidity, implies that the average duration of prices is set to 5 months, following Bils and Klenow (2004). The quarterly default rate $F(\bar{\omega})$ is set to 2%. Together with the monitoring cost of $\mu = 0.02$ we can find the steady state premium on external funding equal to 2%. Given the above choices, the free entry condition for vacancy posting and the wage equation pin down the vacancy cost ϕ_V. We choose standard quarterly deviations of technology innovations of size 0.0027 and monetary policy disturbances innovations of size 0.002, respectively. The rest of the calibrated parameters are given in Table 1.

3.2 Simulation and Main Findings

We now assess the extent to which aggregate disturbances (whose role is enhanced by the presence of sticky prices and credit frictions) are a quantitatively important explanation of the observed fluctuations in labor market variables.

The simulation results are presented in Table 3 in the Appendix. The model that features both supply and demand shocks is listed as "Baseline". The models driven only be demand shock or only by supply shock are listed as "Mon. pol. shocks" and "Tech. shocks", respectively. Under our calibration the standard deviation of the vacancy-unemployment ratio relative to the standard deviation of output is 11.89, compared to 16.3 in the data. It is obvious that credit frictions and price rigidities manage to reduce wage volatility, while greatly enhancing the labor market volatility of the extensive labor margin, and keep the volatility of the intensive labor margin low, even under low values for the Frisch coefficient of labor supply (similar to the microeconomic literature). The model performs very well regarding the Beveridge curve, keeping the strongly negative relationship between vacancy and unemployment rates, even for the demand shocks (a feature that the search model generally fails to pass). It is obvious that it is to a greater extent demand shocks that drive the volatility of the extensive labor input.

Figure 1 in the Appendix displays the dynamic response of the endogenous variables to a monetary policy shock, ε_t^m, in (30). In addition to displaying the responses implied by our benchmark model, we also display the responses implied by the simulated versions of the search model in Trigari (2006). The models are referred to as: 'search plus credit frictions' and 'search frictions', respectively. The size of the monetary policy shock is the same in each model, as well as calibration values.

Figure 2 in the Appendix displays the dynamic response of the endogenous variables to a shock in the technology neutral process, ε_t^a. In addition to displaying the responses implied by our benchmark model, we also display the responses implied by the simulated versions of the search model in Trigari (2006). The models are referred to as: 'search plus credit frictions' and 'search frictions', respectively. The size of the technology shock is the same in each model.

4 Conclusion

In this paper, we have studies credit and labor market frictions embedded in a conventional New Keynesian model: a labor search problem in the labor market and a costly state verification problem in the credit market. The first friction allows for endogenous equilibrium unemployment while the latter introduces riskiness of job creation. The claim of this paper is that credit markets may play an important role for the dynamics of the labor market. Counter-cyclical constraints on external finance are found to greatly increase the volatility of vacancies and unemployment through a powerful financial accelerator.

We plan to estimate the model with Bayesian techniques to assess the importance of the outlined framework, as well to quantify the significance of a busket of structural disturbances.

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Technical Appendix

A Analysis

A.1 Collecting equations

The equations characterizing the equilibrium are:

Marginal consumption:

$$\lambda_t = (c_t)^{-1}, \tag{A.1}$$

Aggregate demand:

$$(1 - \mu G(\bar{\omega}_t))\, y_t = c_t + \phi_V v_t, \tag{A.2}$$

Aggregate supply:

$$y_t = \tau_t^A h_t n_t - \phi_R, \tag{A.3}$$

Euler equation:

$$\lambda_t = \beta \mathrm{E}_t \left\{ \lambda_{t+1} \frac{R_t^N}{\pi_{t+1}} \right\}, \tag{A.4}$$

Real interest rate:

$$r_t = \mathrm{E}_t \left\{ \frac{R_t^N}{\pi_{t+1}} \right\}, \tag{A.5}$$

Optimal cutoff level:

$$\lambda_t^{\omega} = \frac{\Gamma^{\bar{\omega}}(\bar{\omega}_t)}{\Gamma^{\bar{\omega}}(\bar{\omega}_t) - G^{\bar{\omega}}(\bar{\omega}_t)}, \tag{A.6}$$

Lender's constraint:

$$0 = (\Gamma(\bar{\omega}_t) - \mu G(\bar{\omega}_t)) \left(mc_t \tau_t^A - w_t \right) h_t n_t - (\phi_V v_t - nw_t), \tag{A.7}$$

Net worth law of motion:

$$nw_{t+1} = \iota \left(\left(mc_t \tau_t^A - w_t \right) h_t n_t - \left(1 + \frac{\mu G(\bar{\omega}_t) \left(mc_t \tau_t^A - w_t \right) h_t n_t}{\phi_V v_t - nw_t} \right) (\phi_V v_t - nw_t) \right), \tag{A.8}$$

Phillips curve: (A.9)

$$P_t = \left(\zeta (P_{t-1})^{1-\varepsilon} + (1-\zeta) (P_t^o)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}, \tag{A.10}$$

$$\frac{P_t^o}{P_t} = (1+\mu_P)\,\mathrm{E}_t\left\{\frac{\sum_{j=0}^{\infty}(\beta\zeta)^j\Lambda_{t,t+j}\left(\frac{1}{P_{t+j}}\right)^{1-\varepsilon}\pi_{t,t+j}mc_{t+j}y_{t+j}}{\sum_{j=0}^{\infty}(\beta\zeta)^j\Lambda_{t,t+j}\left(\frac{1}{P_{t+j}}\right)^{1-\varepsilon}y_{t+j}}\right\}, \tag{A.11}$$

Unemployment:

$$u_t = 1 - n_t, \tag{A.12}$$

Matching function:

$$l_t = \bar{l}u_t^{\psi_M}v_t^{1-\psi_M}, \tag{A.13}$$

Employment law of motion:

$$n_{t+1} = (1-\chi)\,n_t + l_t, \tag{A.14}$$

Job creation condition:

$$\frac{\phi_V\lambda_{z,t}^{\bar{\omega}}}{s_t} = \mathrm{E}_t\left\{\beta\Lambda_{t,t+1}\left[\left(1+\Omega\left(\bar{\omega}_{z,t+1}\right)\right)\left(mc_{t+1}\tau_{t+1}^A - w_{z,t+1}\right)h_{z,t+1} + (1-\chi)\,\frac{\phi_V\lambda_{z,t+1}^{\bar{\omega}}}{s_{t+1}}\right]\right\}, \tag{A.15}$$

Wage bargaining rule:

$$w_th_t = \eta\left(mc_t\tau_t^Ah_t + \frac{\phi_V\lambda_t^{\bar{\omega}}\theta_t}{1+\Omega\left(\bar{\omega}_t\right)}\right) + \eta\left(1-\chi-f_t\right)\frac{\phi_V\lambda_t^{\bar{\omega}}}{s_t}\left(\frac{1}{1+\Omega\left(\bar{\omega}_t\right)} - \frac{1}{1+\Omega\left(\bar{\omega}_{t+1}\right)}\right)$$
$$+(1-\eta)\left(b^U + \frac{a_L}{\lambda_t}\frac{h_t^{1+\sigma_L}}{1+\sigma_L}\right), \tag{A.16}$$

Labor supply (hour condition):

$$mc_t\tau_t^A = \frac{a_Lh_t^{\sigma_L}}{\lambda_t}, \tag{A.17}$$

Taylor rule:

$$\log\left(R_t^N\right) = (1-\rho_m)\log\left(\frac{\pi}{\beta}\right) + \rho_m\log\left(R_{t-1}^N\right)$$
$$+(1-\rho_m)\left(\gamma_\pi\log\left(\frac{\mathrm{E}_t\left\{\pi_{t+1}\right\}}{\pi}\right) + \frac{\gamma_y}{4}\log\left(\frac{y_t}{y}\right)\right) + \varepsilon_t^m. \tag{A.18}$$

B Analytical expressions for the idiosyncratic wholesale producer's shock

The idiosyncratic productivity disturbance ω_t has a log-normal distribution:

$$\log \omega_t \sim N\left(-0.5\sigma_\omega^2, \sigma_\omega^2\right).$$

Given this distributional assumption, it is convinient to express the default threshold in the standardized form:

$$\bar{z}_t = \frac{\log \bar{\omega}_t + 0.5\sigma_\omega^2}{\sigma_\omega}.$$

$F(\cdot)$ and $nf(\cdot)$ denote respectively cumulative distribution function and standard normal density function. We can express the expected gross share of profits to the lender $\Gamma(\bar{\omega}_{t+1})$, capital production value in case of default $G(\bar{\omega}_{t+1})$ and their first and second derivatives with respect to the cut-off value as follows:

$$\begin{aligned}
\Gamma(\bar{\omega}_{t+1}) &= \bar{\omega}_{t+1}\left(1 - F(\bar{z}_{t+1})\right) + F(\bar{z}_{t+1} - \sigma_\omega), \\
G(\bar{\omega}_{t+1}) &= F(\bar{z}_{t+1} - \sigma_\omega), \\
\Gamma^{\bar{\omega}}(\bar{\omega}_{t+1}) &= 1 - F(\bar{z}_{t+1}), \\
G^{\bar{\omega}}(\bar{\omega}_{t+1}) &= \frac{nf(\bar{z}_{t+1})}{\sigma_\omega}, \\
\Gamma^{\bar{\omega}\bar{\omega}}(\bar{\omega}_{t+1}) &= -\frac{nf(\bar{z}_{t+1})}{\bar{\omega}_{t+1}\sigma_\omega}, \\
G^{\bar{\omega}\bar{\omega}}(\bar{\omega}_{t+1}) &= -\frac{\bar{z}_t}{\sigma_\omega}\frac{nf(\bar{z}_{t+1})}{\bar{\omega}_{t+1}\sigma_\omega},
\end{aligned}$$

where $F(\bar{z}_{t+1})$ quantifies the probability of default, and the expected realization of the productivity in the event of default is $F(\bar{z}_{t+1} - \sigma_\omega)$.

C Tables

Table 1: Parameters and their calibrated values

Parameter	Value	Explanation; Target/Reference
Household sector		
β	$1.01^{-0.25}$	time-discount factor; matches annual real rate of 2.5 percent;
σ_L	1	curviture on labor supply aversion;
a_L	35	scaling factor to disutility of work; targets $h = 1/3$;
η	0.5	bargaining power of workers; conventional value;
Wholesale goods producing sector		
ε	7	elasticity of substitution between goods; targets $1+\mu_P = 1.17$;
ζ	0.8	Calvo stickiness of prices; avg. duration of 5 months;
ϕ_R	0.0417	fixed cost associated with wholesale production; targets zero wholesale profits;
τ^A	1	technological progress; normalization;
$F(\bar{\omega})$	0.02	percent of firms that go into bankruptcy in a period;
μ	0.02	percent of realized profits lost in bankruptcy;
ι	1-0.0238	percent of profits kept to next period net worth;
Labor goods producing sector		
ψ_M	0.5	elasticity of matches w.r.t.number of unemployed;
χ	0.1	exogenous period rate of separation;
ϕ_V	0.038	vacancy posting cost;
$\bar{l}$	0.09	efficiency of matching; targets $f = 0.9$ and $s = 0.7$;
Government		
ρ_m	0.75	interest rate smoothing; conventional Taylor rule;
γ_π	1.5	response to inflation; conventional Taylor rule;
γ_y	0.25	response to output; conventional Taylor rule;
b^U	0.17	unemployment benefits; targets replacement rate $b/wh = 0.6$;
Correlation of Shocks and Size of Innovations		
ρ_a	0.95	autocorr. of technology shock;
σ_a	0.0027	std. dev. of innov. to tech. shock;
σ_m	0.002	standard deviation of innovation to Taylor rule.

Notes: The Table reports calibrated parameter values. The model is calibrated to the U.S. using data from 1951:q1 to 2005:q3; see the main text for details.

Table 2: Steady state

Variable	Value	Description
y	0.25	output
$\frac{c}{y}$	0.98	consumption to output ratio
$\frac{whn}{y}$	0.97	period wage to output ratio
$\frac{n}{k-n}$	3.2	net worth to debt ratio
$\frac{d}{y}$	0.0032	transfers to entrepreneurs to output ratio
v	0.09	vacancies to labor force ratio
u	0.12	unemployment rate
f	0.7	probability of finding a job within a period
s	0.9	probability of finding a worker within a period
$\frac{\phi_V v}{y}$	0.015	banks monitoring costs to output ratio

Notes: Steady state for some variables implied by the calibration in Table 1.

Table 3: Results from baseline calibration

Model	$\frac{std(v/u)}{std(y)}$	$corr(v,u)$	$std(y)$	$\frac{std(n)}{std(y)}$	$\frac{std(h)}{std(y)}$	$\frac{std(w)}{std(y)}$
US data	16.3	-0.88	1.60	0.76	0.32	0.56
Tech. shocks	8.07	-0.95	1.50	0.63	0.33	0.34
Mon. pol. shocks	14.91	-0.23	0.89	0.80	0.62	1.18
Baseline	11.89	-0.72	1.60	0.66	0.43	0.61

Notes: The Table reports the simulation results attained under the baseline calibrated parameter values.

D Figures

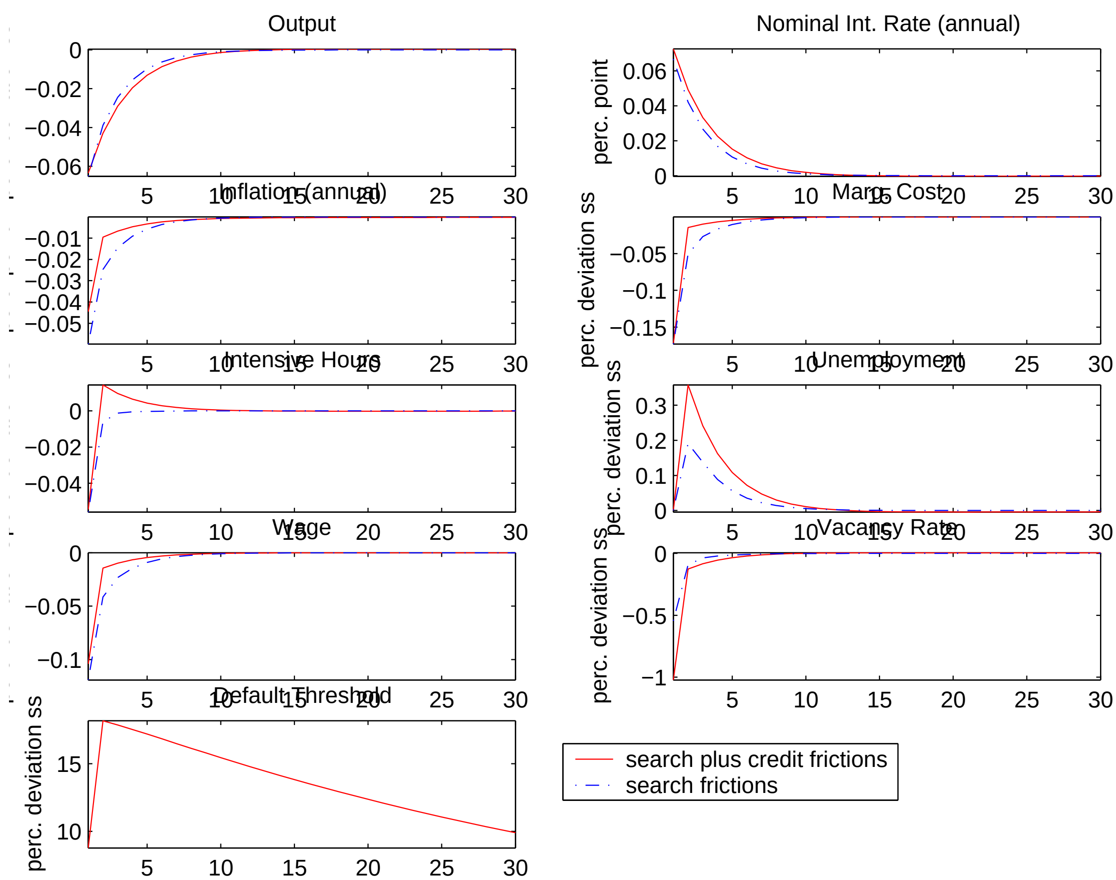

Figure 1: Response to a shock in monetary policy

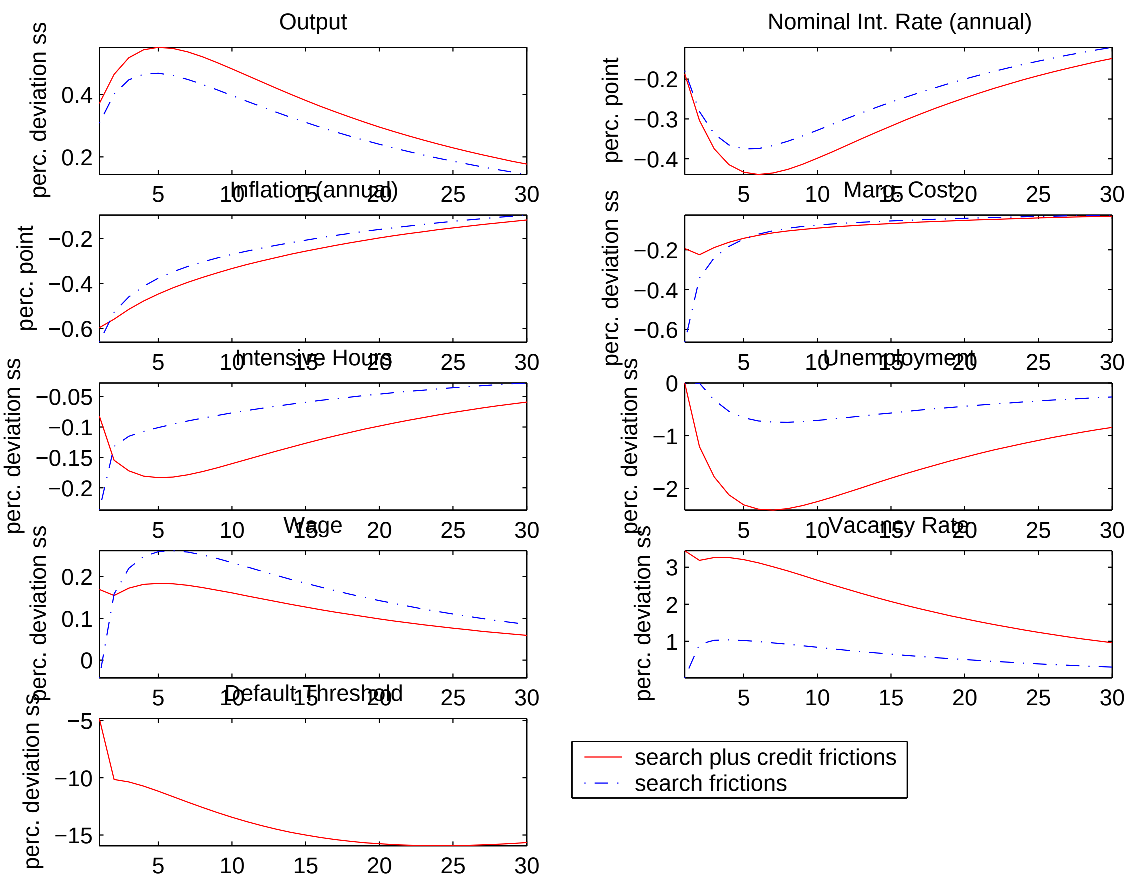

Figure 2: Response to a shock in the technology neutral process