Financial Markets and Unemployment*

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Abstract

We study the importance of financial markets for (un)employment fluctuations in a model with searching and matching frictions where firms issue debt under limited enforcement. Higher debt allows employers to bargain lower wages which in turn increases the incentive to create jobs. The transmission mechanism of 'credit shocks' is fundamentally different from the typical credit channel and the model can explain why firms cut hiring after a credit contraction even if they have not shortage of funds for hiring workers. The theoretical predictions are consistent with the estimation of a structural VAR whose identifying restrictions are derived from the theoretical model.

Keywords: Limited enforcement, wage bargaining, unemployment, credit shocks.

JEL classification: E24, E32, E44.

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1 Introduction

The recent financial turmoil has been associated with a severe increase in unemployment. In the United States the number of unemployed workers jumped from 5.5 percent of the labor force to about 10 percent and continues to stay close 9 percent despite more than three years have passed since the beginning of the recession. Because the financial sector has been at the center stage of the recent crisis and the volume of credit has dropped significantly, it may be possible that the contraction of credit is an important driving force of the unemployment hike. According to this view, employers are forced to cut investment and employment because they have difficulties raising funds. This is the typical 'credit channel' described in Bernanke and Gertler (1989) and Kiyotaki and Moore (1997).

Although there is some compelling evidence that the credit channel has played an important role at the beginning of the crisis when the volume of credit contracted sharply and the liquidity dried up, this channel appears less important for explaining the sluggish recovery of the labor market after the initial drop in employment. As shown in the top panel of Figure 1, the liquidity held by US businesses contracted in the first stage of the crisis, consistent with the view of a credit crunch. However, after the initial drop, the liquidity of nonfinancial businesses quickly rebounded and shortly after the crisis firms have completely rebuilt their liquidity. Therefore, in spite of the credit contraction (see bottom panel of Figure 1) firms seem to have enough resources to finance investment and hiring.

The fact that firms have rebuilt their liquidity poses some doubts that the standard credit channel is the primary explanation for the sluggish recovery of the labor market after the initial stage of the crisis. Should we then conclude that the credit contraction is irrelevant for the sluggish recovery of employment? In this paper we argue that, even if firms have enough funds to sustain their hiring plans, a credit contraction can still generate a cut in employment that is very persistent. This is not because lower debt impairs the hiring ability of firms but because, keeping anything else constant, it places workers in a more favorable bargaining position allowing them to negotiate higher wages. Therefore, the availability of credit affects the 'willingness', not (necessarily) the 'ability' to hire.

To illustrate the mechanism we use a theoretical framework that shares the basic ingredients of the models studied in Pissarides (1987) and Mortensen and Pissarides (1994) where firms are created through the random match-

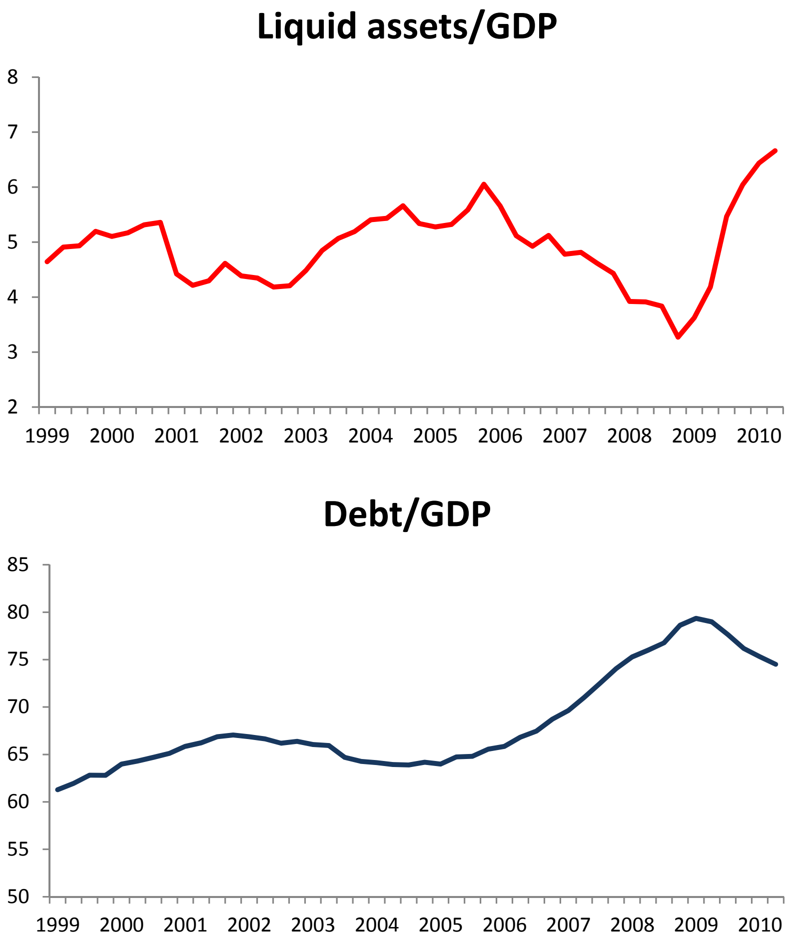

Figure 1: Liquidity and debt in the US nonfinancial business sector. *Liquidity* is the sum of foreign deposits, checkable deposits and currency, time and savings deposits. *Debt* is defined as credit markets instruments. Data is from the Flows of Funds Accounts.

ing of job vacancies and workers. We extend the basic structure of these models in two directions. First, we allow firms to issue debt under limited enforcement. Second, we introduce an additional source of business cycle fluctuations which affects directly the enforcement constraint of borrowers and the availability of credit.

Because of the matching frictions and the wage determination process based on bargaining, firms prefer to issue debt even if there is no fixed or working capital that needs to be financed. The preference for debt derives exclusively from the wage determination process, that is, bargaining, whose empirical relevance is shown in Hall and Krueger (2010). When wages are determined through bargaining, higher debt reduces the net bargaining surplus which in turn reduces the wages paid to workers. This creates an incentive for the employer to borrow until the borrowing limit binds. The goal is to study how exogenous or endogenous changes in this limit affect the dynamics of the labor market.

Central to our mechanism is the firm's capital structure as a bargaining tool in the wage determination process. Both anecdotal and statistical evidence point to this channel. Consider the anecdotal evidence first. An illustrative example is provided by the case of the *New York Metro Transit Authority.* In 2004 the company realized an unexpected 1 billion dollars surplus, largely from a real estate boom. The Union, however, claimed rights to the surplus demanding a 24 percent pay raise over three years.[1] Another example comes from Delta Airlines. The company weathered the 9/11 airline crisis but its excess of liquidity allegedly reduced the need to cut costs. This hurt the firm's bargaining position with workers and three years after 9/11 it faced severe financial challenges.[2]

[1]From *The New York Times*, *Transit Strike Deadline: How extra Money Complicates Transit Pay Negotiations*, 12/15/2005: "The unexpected windfall was supposed to be a boom[..] but has instead become a liability.[..] How, union leaders have asked, can the authority boast of such a surplus and not offer raises of more than 3 percent a year? Why aren't wages going up more?". In a similar vein: "The magnitude of the surplus [..] has set this year's negotiations apart from prior ones, said John E. Zuccotti, a former first deputy mayor. It's a much weaker position than the position the M.T.A. is normally in: We're broke and we haven't gotten any money [..]. The playing field is somewhat different. They haven't got that defense".

[2]From *The Wall Street Journal*, *Cross Winds: How Delta's Cash Cushion Pushed It Onto Wrong Course*, 10/29/2004: "In hindsight, it is clear now that Delta's pile of cash and position as the strongest carrier after 9/11 lured the company's pilots and top managers onto a dire course. Delta's focus on boosting liquidity turned out to be its

The idea that debt allows employers to improve their bargaining position is supported by several empirical studies in corporate finance. Bronars and Deere (1991) document a positive correlation between leverage and labor bargaining power, proxied by the degree of unionization. Matsa (2010) finds that firms with greater exposure to (union) bargaining power have a capital structure more skewed towards debt. Atanassov and Kim (2009) find that strong union laws are less effective in preventing large-scale layoffs when firms have higher financial leverage. Gorton and Schmid (2004) study the impact of German co-determination laws on firms' labor decisions and find that firms that are subject to these laws exhibit greater leverage ratios. Chen, Chen and Liao (2011) show that labor union strength relates positively to bond yield spreads.

All the aforementioned studies suggest that firms may use financial leverage strategically in order to contrast the bargaining power of workers. Although there are theoretical studies in the micro-corporate literature that investigates this mechanism (see Perotti and Spier (1993)), the implications for employment dynamics at the macroeconomic level have not been fully explored. The goal of this paper is to explore these implications. In particular, we study the response of the labor market to a shock that affects directly the availability of credit for employers. These shocks resemble the 'credit shocks' studied in Jermann and Quadrini (2009) but the transmission mechanism is fundamentally different. While in Jermann and Quadrini these shocks are transmitted through the standard credit channel (higher cost of financing employment), in our paper the financing cost does not change over time. Instead, the reduction in borrowing places firms in a less favorable bargaining position with workers and, as a result, they create fewer jobs.

Credit shocks can generate sizable employment fluctuations in our model. Furthermore, as long as the credit contraction is persistent—a robust feature of the data—the impact on the labor market is long-lasting. In this vein, the properties of the model are consistent with recent findings that recessions associated with financial crisis are more persistent than recessions associated with systemic financial difficulties. See IMF (2009), Claessens, Kose, and Terrones (2008), Reinhart and Rogoff (2009). Models with the standard credit channel such as Jermann and Quadrini (2009) can generate severe drops in employment in response to a credit contraction but cannot easily

greatest blessing and curse, helping the company survive 9/11 relatively unscathed but also putting off badly needed overhauls to cut costs".

generate the persistence.

There are other papers in the macro-labor literature that have embedded credit market frictions in search and matching models. Chugh (2009) and Petrosky-Nadeau (2009) are two recent contributions. However, the transmission mechanism proposed by these papers is still based on the typical credit channel. More specifically, since firms could be financially constrained, the cost of financing new vacancies plays a central role in the transmission of shocks. Also related is Wasmer and Weil (2004). They consider an environment in which bargaining is not between workers and firms but between entrepreneurs and financiers. In this model financiers are needed to finance the cost of posting a vacancy and the higher surplus extracted by financiers is similar to a higher cost of financing investments. Thus, the central mechanism is still of the credit channel type.[3]

In order to assess the empirical relevance of credit shocks for employed fluctuations, we estimate a structural VAR with both productivity and credit shocks. The two shocks are identified using short-term restrictions derived from the theoretical model. We find that the response of employment (and unemployment) to credit shocks is statistically significant and economically sizable. Although the VAR analysis does not allow us to separate the standard credit channel from the channel emphasized in this paper, the empirical results are consistent with the predictions of the model.

The paper is organized as follows. Section 2 presents the theoretical model. Section 3 provides analytical intuitions for the response of the economy to shocks and Section 4 conducts a quantitative analysis. Section 5 extends the baseline model in ways that improve the dynamics of wages. Section 6 conducts the empirical analysis based on a structural VAR and Section 7 concludes.

2 Model

There is a continuum of agents of total mass 1 with lifetime utility $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t c_t$. At any point in time agents can be employed or unemployed. They save in two types of assets: shares of firms and bonds. Risk neutrality implies that the expected return from both assets is equal to $1/\beta - 1$. Therefore, the net interest rate is constant and equal to $r = 1/\beta - 1$.

[3]Wasmer and Weil (2004) also discuss the possibility of extending the model with wage bargaining. However, the analysis with wage bargaining is not fully pursued in the paper.

Firms: Firms are created through the matching of a posted vacancy and a worker. Starting in the next period, a new firm produces output z_t until the match is separated. Separation arises with probability λ. An unemployed worker cannot be self-employed but needs to search (costlessly) for a job. The number of matches is determined by the function $m(v_t, u_t)$, where v_t is the number of vacancies posted during the period and u_t is the number of unemployed workers. The probability that a vacancy is filled is $q_t = m(v_t, u_t)/v_t$ and the probability that an unemployed worker finds a job is $p_t = m(v_t, u_t)/u_t$.

At any point in time firms are characterized by three states: a productivity z_t, an indicator of the financial conditions ϕ_t that will be described below, and a stock of debt b_t. The productivity z_t and the financial state ϕ_t are exogenous stochastic variables, common to all firms (aggregate shocks). The stock of debt b_t is chosen endogenously. Although firms could choose different levels of debt, in equilibrium they all choose the same b_t.

The dividend paid to the owners of the firm (shareholders) is defined by the budget constraint

$$d_t = z_t - w_t - b_t + \frac{b_{t+1}}{R},$$

where R is the gross interest rate charged on the debt. As we will see, R is different from $1 + r$ because of the possibility of default when the match is separated.

Timing: If a vacancy is filled, a new firm is created. The new firm starts producing in the next period, and therefore, there is no wage bargaining in the current period. However, before entering the next period, the newly created firm chooses the debt b_{t+1} and pays the dividend $d_t = b_{t+1}/R_t$ (the initial debt b_t is zero). There is not separation until the next period. Once the new firm enters the next period, it becomes an incumbent firm.

An incumbent firm starts with a stock of debt b_t inherited from the previous period. In addition, it knows the current productivity z_t and the financial variable ϕ_t. Given the states, the firm bargains the wage w_t with the worker and output z_t is produced. The choice of the new debt b_{t+1} and the payment of dividends arise after wage bargaining. After the payments of dividends and wages and after contracting the new debt, the firm observes whether the match is separated. It is at this point that the firm chooses whether to default. Therefore, each period can be divided in three sequential steps: (i) wage bargaining, (ii) financial decision, (iii) default. These sequential steps are illustrated in figure 2.

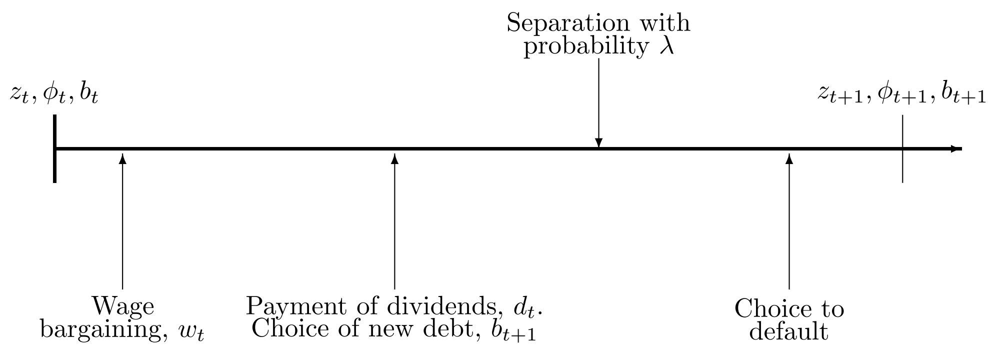

Figure 2: Timing for an incumbent firm

Remarks on timing: We would like to clarify the importance of the timing assumptions. Although this will become clear later, it will be helpful to stress the relevance of our assumptions here. First, the sequential timing of decisions for an *incumbent* firm is irrelevant for the dynamic properties of equilibrium employment. For example, the alternative assumption that incumbent firms choose the new debt before or jointly with the bargaining of wages will not affect the dynamics of employment. For *new* firms, instead, the assumption that the debt is chosen in the current period while wage bargaining does not take place until the next period is crucial for the results. As an alternative, we could assume that bargaining takes place in the same period in which a vacancy is filled as long as the choice of debt is made before going to the bargaining table with the new worker. For presentation purposes, we assumed that the debt is raised after matching with a worker (but before bargaining the wage). Alternatively, we could assume that the debt is raised before posting a vacancy but this would not affect the results. What is crucial is that the debt of a new firm is raised before bargaining for the first time with the new worker.

The second point we would like to stress is that the assumption that wages are bargained in every period is not important. We adopted this assumption in order to stay as close as possible to the standard matching model (Pissarides (1987)). In Section 5 we show that the employment dynamics do not change if we make different assumptions about the frequency of bargaining. All we need is that there is bargaining when a new worker is hired.

Financial contract and borrowing limit: We assume that lending is done by competitive intermediaries who pool a large number of loans. We refer to these intermediaries as *lenders*. The amount of borrowing is constrained by limited enforcement. After the payments of dividends and wages, and after contracting the new debt, the firm observes whether the match is separated. It is at this point that the firm chooses whether to default. In the event of default the lender will be able to recover only a fraction χ_t of the firm's value.

Denote by $J_t(b_t)$ the equity value of the firm at the beginning of the period, which is equal to the discounted expected value of dividends for shareholders. This function depends on the individual stock of debt b_t. Obviously, higher is the debt and lower is the equity value. It also depends on the aggregate states $\mathbf{s}_t = (z_t, \phi_t, B_t, N_t)$, where z_t and ϕ_t are exogenous aggregate states (shocks), B_t is the aggregate stock of debt and $N_t = 1 - u_t$ is employment. We distinguish aggregate debt from individual debt since, to derive the equilibrium, we have to allow for individual deviations. We use the time subscript t to capture the dependence of the value function from the aggregate states, that is, we write $J_t(b_t)$ instead of $J(z_t, \phi_t, B_t, N_t; b_t)$. We will use this convention throughout the paper.

We begin by considering the possibility of default when the match is separated. In this case the value of the firm is zero. The lender anticipates that the recovery value is zero in the event of separation and the debt will not be repaid. Therefore, in order to break-even, the lender imposes a borrowing limit insuring that the firm does not default when the match is not separated and charges an interest rate premium to cover the losses realized when the match is separated.

If the match is not separated, the value of the firm's equity is $\beta \mathbb{E}_t J_{t+1}(b_{t+1})$, that is, the next period expected value of equity discounted to the current period. Adding the present value of debt, $b_{t+1}/(1 + r)$, we obtain the total value of the firm. If the firm defaults, the lender recovers only a fraction χ_t of the total value of the firm. Therefore, the lender is willing to lend as long as the following constraint is satisfied

$$\chi_t \left[\frac{b_{t+1}}{1+r} + \beta \mathbb{E}_t J_{t+1}(b_{t+1}) \right] \geq \frac{b_{t+1}}{1+r}.$$

The variable χ_t is stochastic and affects the borrowing capacity of the firm. Henceforth, we will refer to unexpected changes in χ_t as 'credit shocks'.

By collecting the term $b_{t+1}/(1+r)$ and using the fact that $\beta(1+r) = 1$, we can rewrite the enforcement constraint more compactly as

$$\phi_t \mathbb{E}_t J_{t+1}(b_{t+1}) \geq b_{t+1}, \tag{1}$$

where $\phi_t \equiv \chi_t/(1-\chi_t)$. We can then think of credit shocks as unexpected innovations to the variable ϕ_t. This is the exogenous state variable included in the set of aggregate states $\mathbf{s}_t$.

We now have all the elements to determine the actual interest rate that lenders charge to firms. Since the loan is made before knowing whether the match is separated, the interest rate charged by the lender takes into account that the repayment arises only with probability $1 - \lambda$. Assuming that financial markets are competitive, the zero-profit condition requires that the gross interest rate R satisfies

$$R(1-\lambda) = 1 + r. \tag{2}$$

The left-hand side of (2) is the lender's expected income per unit of debt. The right-hand side is the lender's opportunity cost of funds (per unit of debt). Therefore, the firm receives b_{t+1}/R at time t and, if the match is not separated, it repays b_{t+1} at time $t+1$. Because of risk neutrality, the interest rate is always constant, and therefore, r and R bear no time subscript.

Firm's value: Central to the characterization of the properties of the model is the wage determination process which is based on bargaining. Before describing the bargaining problem, we define the value of the firm recursively taking as given the wage bargaining outcome. This is denote by $w_t = g_t(b_t)$. The recursive structure of the problem implies that the wage is fully determined by the states at the beginning of the period.

The equity value of the firm can be written recursively as

$$J_t(b_t) = \max_{b_{t+1}} \left\{ z_t - g_t(b_t) - b_t + \frac{b_{t+1}}{R} + \beta(1-\lambda)\mathbb{E}_t J_{t+1}(b_{t+1}) \right\} \quad (3)$$

subject to

$$\phi_t \mathbb{E}_t J_{t+1}(b_{t+1}) \geq b_{t+1}.$$

Notice that the only choice variable in this problem is the debt b_{t+1}. Also notice that the firm takes the current wage as given but it fully internalizes that the choice of debt b_{t+1} affects future wages. This is captured implicitly by the next period value $J_{t+1}(b_{t+1})$.

Because of the additive structure of the objective function, the optimal choice of b_{t+1} does not depend neither on the current wage $w_t = g_t(b_t)$ nor on the current liabilities b_t.

Lemma 1 *The new debt b_{t+1} chosen by the firm depends neither on the current wage $w_t = g_t(b_t)$ nor on the current debt b_t.*

Proof 1 *Since w_t and b_t enter the objective function additively and they do not affect neither the next period value of the firm's equity nor the enforcement constraint, the choice of b_{t+1} is independent of w_t and b_t.*■

As we will see, this property greatly simplifies the wage bargaining problem we will describe below.

Worker's values: In order to set up the bargaining problem, we define the worker's values ignoring the capital incomes earned from the ownership of bonds and firms (interests and dividends). Since agents are risk neutral and the change in the dividend of an individual firm is negligible for an individual worker, we can ignore these incomes in the derivation of wages.

When employed, the worker's value is

$$W_t(b_t) = g_t(b_t) + \beta \mathbb{E}_t \Big[(1-\lambda) W_{t+1}(b_{t+1}) + \lambda U_{t+1} \Big], \quad (4)$$

which is defined once we know the wage function $w_t = g_t(b_t)$. The function U_{t+1} is the value of being unemployed and is defined recursively as

$$U_t = a + \beta \mathbb{E}_t \Big[p_t W_{t+1}(B_{t+1}) + (1 - p_t) U_{t+1} \Big],$$

where p_t is the probability that an unemployed worker finds a job and a is the flow utility for an unemployed worker.

While the value of an employed worker depends on the aggregate states and the individual debt b_t, the value of being unemployed depends only on the aggregate states since all firms choose the same level of debt in equilibrium. Thus, if an unemployed worker finds a job in the next period, the value of being employed is $W_{t+1}(B_{t+1})$.

Bargaining problem: Let's first define the following functions

$$\hat{J}_t(b_t, w_t) = \max_{b_{t+1}} \Big\{ z_t - w_t - b_t + \frac{b_{t+1}}{R} + \beta(1 - \lambda) \mathbb{E}_t J_{t+1}(b_{t+1}) \Big\} \quad (5)$$

$$\widehat{W}_t(b_t, w_t) = w_t + \beta \mathbb{E}_t \Big[(1 - \lambda) W_{t+1}(b_{t+1}) + \lambda U_{t+1} \Big]. \quad (6)$$

These are the values of a firm and an employed worker, respectively, given an arbitrary wage w_t paid in the current period and future wages determined by the function $g_{t+1}(b_{t+1})$. The functions $J_t(b_t)$ and $W_t(b_t)$ were defined in (3) and (4) for a particular wage equation $g_t(b_t)$.

Given the *relative* bargaining power of workers $\eta \in (0, 1)$, the current wage is the solution to the problem

$$\max_{w_t} \ \hat{J}_t(b_t, w_t)^{1-\eta} \Big[\widehat{W}_t(b_t, w_t) - U_t \Big]^{\eta}. \quad (7)$$

Let $w_t = \psi_t(g; b_t)$ be the solution, which makes explicit the dependence on the function g determining future wages. The rational expectation solution to the bargaining problem is the fixed-point to the functional equation $g_t(b_t) = \psi_t(g; b_t)$.

We can now see the importance of Lemma 1. Since the optimal debt chosen by the firm after the wage bargaining does not depend on the wage, in solving the optimization problem (7) we do not have to consider how the choice of w_t affects b_{t+1}. Therefore, we can derive the first order condition taking b_{t+1} as given. After some re-arrangement this can be written as

$$J_t(b_t) \;=\; (1-\eta)S_t(b_t), \tag{8}$$

$$W_t(b_t) - U_t \;=\; \eta S_t(b_t), \tag{9}$$

where $S_t(b_t) = J_t(b_t) + W_t(b_t) - U_t$ is the bargaining surplus. As it is typical in search models with Nash bargaining, the surplus is split between the contractual parties proportionally to their relative bargaining power.

Choice of debt: Let's first rewrite the bargaining surplus as

$$S_t(b_t) = z_t - a - b_t + \frac{b_{t+1}}{R} + (1-\lambda)\beta\mathbb{E}_t S_{t+1}(b_{t+1}) - \eta\beta p_t \mathbb{E}_t S_{t+1}(B_{t+1}). \tag{10}$$

Notice that the next period surplus enters twice but with different state variables. In the first term the state variable is the individual debt b_{t+1} while in the second is the aggregate debt B_{t+1}. The reason is because the value of being unemployed today depends on the value of being employed in the next period in a firm with the aggregate value of debt B_{t+1}. Instead, the value of being employed today also depends on the value of being employed next period in the same firm. Since the current employer is allowed to choose a level of debt that differs from the debt chosen by other firms, the individual state next period, b_{t+1}, could be different from B_{t+1}. In equilibrium, of course, $b_{t+1} = B_{t+1}$. However, to derive the optimal policy we have to allow the firm to deviate from the aggregate policy.

Because the choice of b_{t+1} does not depend on the existing debt b_t (see Lemma 1), we have

$$\frac{\partial S_t(b_t)}{\partial b_t} = -1. \tag{11}$$

Before using this property, we rewrite the firm's problem (3) as

$$J_t \;=\; \max_{b_{t+1}} \left\{ z_t - g_t(b_t) - b_t + \frac{b_{t+1}}{R} + \beta(1-\lambda)(1-\eta)\mathbb{E}_t S_{t+1}(b_{t+1}) \right\} \tag{12}$$

subject to

$$(1-\eta)\phi_t \mathbb{E}_t S_{t+1}(b_{t+1}) \geq b_{t+1},$$

where we used $W_{t+1}(b_{t+1}) - U_{t+1} = \eta S_{t+1}(b_{t+1})$ from (8) and the surplus is defined in (10).

Denoting by μ_t the Lagrange multiplier associated with the enforcement constraint, the first order condition is

$$\eta - \Big[1 + (1-\eta)\phi_t\Big]\mu_t = 0. \tag{13}$$

In deriving this expression we used (11) and $\beta R(1-\lambda) = \beta(1+r) = 1$. We can then establish the following result.

Lemma 2 *.The enforcement constraint is binding* ($\mu_t > 0$) *if* $\eta \in (0,1)$.

Proof 2 *It follows directly from the first order condition (13)*.

A key implication of Lemma 2 is that, provided that workers have some bargaining power, the firm always chooses to maximum debt and the borrowing limit binds. To gather some intuition about the economic interpretation of the multiplier μ_t, it will be convenient to re-arrange the first order condition as

$$\mu_t = \underbrace{\left(\frac{1}{1+(1-\eta)\phi_t}\right)}_{\substack{\text{Total change}\\ \text{in debt}}} \times \underbrace{\left(\frac{1}{R} - \frac{1-\eta}{R}\right)}_{\substack{\text{Marginal gain}\\ \text{from borrowing}}}.$$

The multiplier results from the product of two terms. The first term is the change in next period liabilities b_{t+1} allowed by a marginal relaxation of the enforcement constraint, that is, $b_{t+1} = \phi_t(1-\eta)\mathbb{E}_t S(z_{t+1}, B_{t+1}, b_{t+1}) + \bar{a}$, where $\bar{a} = 0$ is a constant. This is obtained by marginally changing $\bar{a}$. In fact, using the implicit function theorem, we obtain $\frac{\partial b_{t+1}}{\partial \bar{a}} = \frac{1}{1+(1-\eta)\phi_t}$, which is the first term.

The second term is the net gain, actualized, from increasing the next period liabilities b_{t+1} by one unit (marginal change). If the firm increases b_{t+1} by one unit, it receives $1/R$ units of consumption today, which can be paid as dividends. This unit has to be repaid next period. However, the effective cost for the firm is lower than 1 since the higher debt allows the firm to reduce the next period wage by η, that is, the part of the surplus going to the worker. Thus, the effective repayment incurred by the firm is $1-\eta$. This cost is discounted by $R = (1+r)/(1-\lambda)$ because the debt is repaid only if the matched is not separated, which happens with probability $1-\lambda$. Therefore, the multiplier μ_t is equal to the total change in debt (first term) multiplied by the gain from a marginal increase in borrowing (second term).

2.1 Firm entry and general equilibrium

So far we have defined the problem solved by incumbent firms. We now consider more explicitly the problem solved by new firms. In this setup new firms are created when a posted vacancy is filled by a searching worker. Because of the matching frictions, a posted vacancy will be filled only with probability $q_t = m(v_t, u_t)/v_t$. Since posting a vacancy requires a fixed cost κ, vacancies will be posted only if the value is not smaller than the cost.

We start with the definition of the value of a filled vacancy. When a vacancy is filled, the newly created firm starts producing and pays wages in the next period. The only decision made in the current period is the debt b_{t+1}. The funds raised by borrowing are distributed to shareholders. Therefore, the value of a vacancy filled with a worker is

$$Q_t \quad = \quad \max_{b_{t+1}} \left\{ \frac{b_{t+1}}{1+r} + \beta(1-\eta)\mathbb{E}_t S_{t+1}(b_{t+1}) \right\} \tag{14}$$

subject to

$$\phi_t(1-\eta)\mathbb{E}_t S_{t+1}(b_{t+1}) \geq b_{t+1}.$$

Since the new firm becomes an incumbent starting in the next period, $S_{t+1}(b_{t+1})$ is the surplus of an incumbent firm defined in (10).

As far as the choice of b_{t+1} is concerned, a new firm faces a similar problem as incumbent firms (see problem (12)). Even if the new firm has no initial debt and it does not pay wages, it will choose the same stock of debt b_{t+1} as incumbent firms. This is because the new firm faces the same enforcement constraint and the choice of b_{t+1} is not affected by b_t and w_t as established in Lemma 1. This allows us to work with a 'representative' firm.

We are now ready to define the value of posting a vacancy. This is equal to $V_t = q_t Q_t - \kappa$. As long as the value of a vacancy is positive, more vacancies will be posted. Thus, in equilibrium we must have $V_t = 0$ and the free entry condition can be written as

$$q_t Q_t = \kappa. \tag{15}$$

In a general equilibrium all firms choose the same level of debt. Therefore, $b_t = B_t$. Furthermore, assuming that the bargaining power of workers is positive, firms always borrow up to the limit, that is, $B_{t+1} = \phi_t(1-\eta)\mathbb{E}_t S_{t+1}(B_{t+1})$. Using the free entry condition (15) Appendix A derives the wage equation

$$w_t = (1-\eta)a + \eta(z_t - b_t) + \frac{\eta[p_t + (1-\lambda)\phi_t]\kappa}{q_t(1+\phi_t)}. \tag{16}$$

The wage equation makes clear that the initial debt b_t acts like a reduction in output in the determination of wages. Instead of getting a fraction η of the output, the worker gets a fraction η of the output 'net' of debt. Thus, for a given bargaining power η, the larger is the debt and the lower is the wage received by the worker.

3 Employment response to shocks

In this section we investigate how the value of a filled vacancy Q_t is affected by a credit shock (change in ϕ_t) and by a productivity shock (change in z_t). Through the free entry condition, $q_t Q_t = \kappa$, we can then infer the impact on job creation. More specifically, if the value of a filled vacancy Q_t increases, the probability of filling a vacancy $q_t = m(v_t, u_t)/v_t$ must decline. Since the number of searching workers u_t is given in the current period, this requires an increase in the number of posted vacancies. Thus, more jobs are created.

Because of the general equilibrium effects of a shock, it is not possible to derive closed form solutions for the impulse responses. However, we can derive closed form solutions if we assume that the shock affects only a single (atomistic) firm. In this way we can abstract from general equilibrium effects and provide simple analytical intuitions. This is the approach we take in this section. The full general equilibrium responses will be shown numerically in the next section.

3.1 Credit shocks

Starting from a steady state equilibrium, suppose that there is one firm with a newly filled vacancy for which the value of ϕ_t increases. The increase is purely temporary and it reverts back to the steady state value starting in the next period. We stress that the change involves only one firm so that we can ignore the general equilibrium consequences of the change.

The derivative of Q_t with respect to ϕ_t is

$$\frac{\partial Q_t}{\partial \phi_t} = \left[\frac{1}{1+r} + \beta(1-\eta)\frac{\partial \mathbb{E}_t S_{t+1}(b_{t+1})}{\partial b_{t+1}}\right]\frac{\partial b_{t+1}}{\partial \phi_t}.$$

Applying the implicit function theorem to the enforcement constraint holding with equality, $b_{t+1} = \phi_t(1-\eta)ES_{t+1}(b_{t+1})$, we can rewrite the derivative as

$$\frac{\partial b_{t+1}}{\partial \phi_t} = \frac{(1-\eta)\mathbb{E}_t S_{t+1}(b_{t+1})}{1-(1-\eta)\phi_t \mathbb{E}_t \frac{\partial S_{t+1}(b_{t+1})}{\partial b_{t+1}}}.$$

Substituting $\partial \mathbb{E}_t S_{t+1}(b_{t+1})/\partial b_{t+1} = -1$ (see equation (11)) we obtain

$$\frac{\partial Q_t}{\partial \phi_t} = \frac{\eta(1-\eta)\beta \mathbb{E}_t S_{t+1}(b_{t+1})}{1+(1-\eta)\phi_t}, \tag{17}$$

where we have used $\beta = 1/(1+r)$.

Proposition 1 *Consider a positive credit shock for a newly created firm. If* $\eta \in (0,1)$*, the rise in* ϕ_t *increases the value of the firm* Q_t*.*

Proof 3 *It follows directly from (17) since* ϕ_t *and* $\mathbb{E}_t S_{t+1}(b_{t+1})$ *are positive*∎

Therefore, an increase in ϕ_t raises the value of a newly filled vacancy Q_t, provided that the worker has some bargaining power. The intuition for the above proposition is straightforward. If the new firm can increase its debt in the current period, the firm can pay more dividends now and less dividends in the future. However, the reduction in future dividends needed to repay the debt is smaller than the increase in the current dividends because the higher debt allows the firm to reduce the next period wages. Effectively, part of the debt will be repaid by the worker, increasing the firm's value today.

In deriving this result we assumed that the change in ϕ_t was only for one firm so that we could ignore the general equilibrium effects induced by this change. However, since ϕ_t is an aggregate variable, this change increases the value of a vacancy for all firms and more vacancies will be posted. The higher job creation will have some general equilibrium effects that cannot be characterized analytically. The full general equilibrium response will be shown numerically.

3.2 Productivity shocks

Although the main focus of the paper is on credit shocks, we also investigate how the ability to borrow affects the propagation of productivity shocks since most of the literature has focused on these shocks.

In general, productivity shocks generate an employment expansion because the value of a filled vacancy increases. This would arise even if the level of debt is constant, which is the case in the standard matching model. In the case in which the constant debt is zero we revert exactly to the standard matching model. However, if the debt is not constrained to be constant but changes endogenously, then the impact of productivity shocks on employment could be amplified.

As for the case of credit shocks, we consider a productivity shock that affects only one newly created firm. We can thus abstract from general equilibrium effects. We further assume that the productivity shock is persistent. The persistence implies that the new firm will be more productive in the next period when it starts producing. If the increase in z_t is purely temporary, the change will not have any effect on the value of a new match.

The derivative of Q_t with respect to z_t is

$$\frac{\partial Q_t}{\partial z_t} = \beta(1-\eta)\frac{\partial \mathbb{E}_t S_{t+1}(b_{t+1})}{\partial z_t} + \left[\frac{1}{1+r} + \beta(1-\eta)\frac{\partial \mathbb{E}_t S_{t+1}(b_{t+1})}{\partial b_{t+1}}\right]\frac{\partial b_{t+1}}{\partial z_t}.$$

Applying the implicit function theorem to the enforcement constraint $b_{t+1} = (1-\eta)\phi_t \mathbb{E}_t S_{t+1}(b_{t+1})$, we obtain

$$\frac{\partial b_{t+1}}{\partial z_t} = \frac{(1-\eta)\phi_t \mathbb{E}_t \frac{\partial S_{t+1}(b_{t+1})}{\partial z_t}}{1-(1-\eta)\phi_t \mathbb{E}_t \frac{\partial S_{t+1}(b_{t+1})}{\partial b_{t+1}}}.$$

Since $\partial \mathbb{E}_t S_{t+1}(b_{t+1})/\partial b_{t+1} = -1$ (see equation (11)), substituting in the derivative of the firm's value Q_t and using $\beta = 1/(1+r)$ we obtain

$$\frac{\partial Q_t}{\partial z_t} = \beta(1-\eta)\frac{\partial \mathbb{E}_t S_{t+1}(b_{t+1})}{\partial z_t} + \eta\left(\frac{(1-\eta)\phi_t\beta\frac{\partial \mathbb{E}_t S_{t+1}(b_{t+1})}{\partial z_t}}{1+(1-\eta)\phi_t}\right). \tag{18}$$

We can now compare this expression to the equivalent expression we would obtain if the borrowing constraint was exogenous. More specifically, we replace the enforcement constraint (1) with the borrowing limit $b_{t+1} \leq \bar{b}$

where $\bar{b}$ is constant. Under this constraint we have that $\partial b_{t+1}/\partial z_t = 0$. Therefore,

$$\frac{\partial Q_t}{\partial z_t} = \beta(1-\eta)\frac{\partial \mathbb{E}_t S_{t+1}(b_{t+1})}{\partial z_t}. \tag{19}$$

Comparing (18) to (19), we can see that when the borrowing limit is endogenous, there is an extra term in the derivative of Q_t with respect to z_t. This term is positive if $\eta > 0$. Therefore, the change in the value of a filled vacancy in response to a productivity improvement is bigger when the borrowing limit is endogenous. Intuitively, the increase in productivity raises the value of the firm. This allows for more debt which in turn increases the value of a filled vacancy Q_t.

Of course, this does not tell us whether the amplification effect is large or small. However, we can derive some intuition of what is required for the amplification effect to be large. In particular, as we can see from equation (18), we need that the value of a match is highly sensitive to the productivity shock, that is, we need $\frac{\partial \mathbb{E}_t S_{t+1}(b_{t+1})}{\partial z_t}$ to be large. This essentially requires large asset price responses to productivity shocks. In this sense the model shares the same features of the models proposed by Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) where the amplification of productivity shocks depends on the response of asset prices.

4 Simulation

In this section we present some quantitative results based on the numerical simulation of the model. We will see that the model can generate interesting dynamics of employment and financial flows. However, the dynamics of wages may appear in conflict with the properties of wages observed in the data. In the next section we will consider an extension of the model that generates similar dynamics of employment and financial flows but also more plausible responses of wages.

4.1 Calibration

We think of a period to be a quarter and set the discount factor to $\beta = 0.99$. The matching function takes the typical Cobb-Douglas form $m(v,u) = \xi v^{\alpha} u^{1-\alpha}$ where ξ is a constant. We set the matching parameter $\alpha = 0.7$. This is within the range of estimates found in the literature. For example, Petrongolo and Pissarides (2001) report that the range of estimates based on aggregate data on total hires is $0.6 - 0.7$. Using JOLTS data for 2000 and 2002, Hall (2003) estimates $\alpha = 0.765$. We should also acknowledge, however, that there are estimates with smaller numbers like in Shimer (2005). Different values of α do not affect the qualitative response of employment although it changes the magnitude. For the bargaining parameter η we follow the common practise of setting it to 0.5 in absence of direct evidence.

After normalizing the steady state value of productivity to 1, we turn our attention to the following five parameters: the steady state value of the enforcement variable $\bar{\phi}$, the utility flow for unemployed workers a, the separation rate λ, the cost to create a vacancy κ, and the constant in front of the matching function ξ. These five parameters are calibrated using the following conditions: (i) the steady state debt-to-output ratio is 0.1; (ii) the utility flow for unemployed workers a is 75% the steady-state value of wages; (iii) the steady state unemployment rate is 10 percent based on a broad definition of unemployment; (iv) the probability of filling a vacancy is 0.7; (v) the probability of an unemployed worker to find a job is 0.93.

The choice of the target for the debt-to-output ratio requires some explanation. Strictly speaking, this is much smaller than in the data. Typically, if we look at business debt over the value added of the business sector, a reasonable number is $B/Y = 2$ (when Y is measured quarterly). However, in our model we do not have physical capital while in the real economy physical capital is an important collateral for debt. Therefore, the debt we consider in the model is only the debt that is guaranteed by (lifetime) profits in excess of the opportunity cost of capital. Based on this observation, the stock of debt in the model should be relatively small. This justifies the 0.1 number.[4]

At this point we are only left with the parameters that characterize the stochastic process for the two shocks, credit and productivity. Assuming that the logarithm of ϕ_t and z_t follow independent first order autoregressive processes, we need to assign the persistence parameters, ρ_ϕ and ρ_z, and the standard deviations σ_ϕ and σ_z. For the productivity shock we set $\rho_z = 0.95$ and $\sigma_z = 0.01$, which are standard in the literature. For the parametrization of the credit shock, instead, we use the empirical properties of debt. Since the stock of debt is very persistent in the data, we set $\rho_\phi = 0.95$. Then we set $\sigma_\phi = 0.3$ so that the change in debt over GDP generated by the model with

[4]To see this more clearly, suppose that we add physical capital $\bar{K}$ to the model, which for simplicity is assumed to be fixed. Suppose also that in case of liquidation the residual value of physical capital is $\zeta\bar{K}$. Then the enforcement constraint would be $b_{t+1} \leq \zeta\bar{K} + \mathbb{E}_t J_{t+1}(b_{t+1})$. Thus, what we call debt in our model is the term $b_{t+1} - \zeta\bar{K}$.

both shocks is similar to the data. More specifically we target the volatility of $(B' - B)/Y$.

We would like to stress that the volatility of debt is crucial for evaluating the performance of the model. We can generate any volatility of employment by choosing the volatility of the credit shock. However, by imposing that the volatility of debt generated by the model cannot be at odd with the data, we remove this degree of freedom. The full set of parameter values are reported in Table 1.

Table 1: List of parameters

Description	*Value*
Discount factor for entrepreneurs, β	0.990
Relative bargaining power, η	0.500
Matching parameter, α	0.700
Matching parameter, ξ	0.762
Probability of separation, λ	0.103
Cost of posting vacancy, κ	0.298
Utility flow unemployed, a	0.714
Average productivity, $\bar{z}$	1.000
Productivity shock persistence, ρ_z	0.950
Productivity shock volatility, σ_z	0.010
Enforcement parameter, $\bar{\phi}$	0.868
Credit shock persistence, ρ_ϕ	0.950
Credit shock volatility, σ_ϕ	0.300

4.2 Responses to credit shocks

Figure 3 plots the responses of several variables to a negative credit shock: change in debt over output, employment, output and wages. Since the model is solved by linearizing around the steady state, the response to a positive credit shock will have the same shape but with the opposite sign. The numbers are percent deviation from the steady state.

As can be seen from the figure, the response of employment is sizable and quite persistent, reflecting the persistence of the shock. The mechanism that generates this dynamics should be clear by now. Since firms are forced to cut their debt, workers are able to negotiate higher future wages starting from

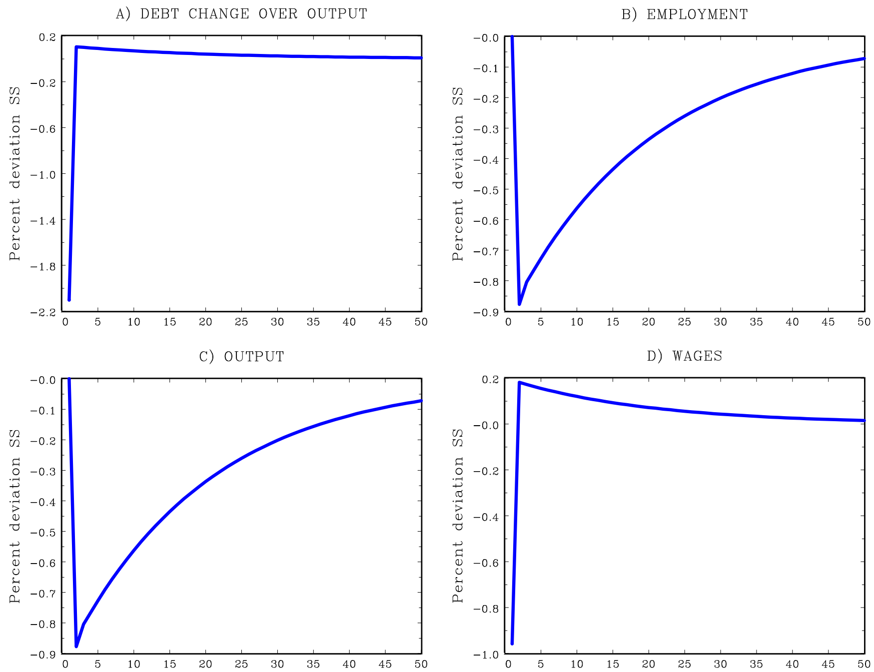

Figure 3: Impulse responses to a negative credit shock - Baseline model.

the next period. The response of wages is plotted in last panel of Figure 3. At impact the wage falls below the steady state but then, starting from the next period, it raises above the steady state. Since new firms start paying wages in the next period, what matters for job creation is the response starting in period 1, that is, one period after the shock. Thus, the anticipated cost of labor for new matches increase in response to a negative credit shock and this discourages job creation.

The initial drop in the wage of incumbent workers can be explained as follow. All bargaining parties understand that, starting from the next period wages are going to increase. Since the wage paid when the shock hits is bargained before changing the debt, the total net surplus has not changed yet (besides the changes induced by some general equilibrium feedbacks). This means that the lifetime values received by both parties remain the same. But then, if the value received by workers does not change at impact but there is the anticipation of higher future wages, the current wage has to decline.

It is interesting to observe that the credit shock does not affect the value received by 'incumbent' workers and firms (besides, again, the impact coming from general equilibrium effects). So it may appear counterintuitive why the firm chooses to borrow up to the limit if, effectively, this does not change the surplus and the division of the surplus. This is due to the lack of commitment from the firm. Since the new debt is chosen unilaterally by the firm after bargaining the wage, the firm prefers higher debt to reduce future wages. This is anticipated by workers who demand higher wages today to compensate for the lower wages received in the future. If the firm could credibly commit before bargaining the wage, it would agree not to raise the debt. This mechanism has some similarities with the model studied by Barro and Gordon (1983): since workers anticipate that the central bank inflates ex-post, they demand higher nominal wages today. Differently from that model, however, here there is not real costs from deviating, at least from the point of view of an individual firm. As long as new firms can choose the debt before bargaining with new workers, what happens once the firm becomes incumbent is irrelevant for the dynamics of employment.

More on the dynamics of wages Although the model generates a sizable dynamics of employment, the dynamics of wages may seem at odd with the data. Typically, wages tend to be pro-cyclical. For new hired workers, however, the model predicts the opposite. For incumbent workers the model predicts a pro-cyclical response at impact but it changes sign immediately after the shock hits. This also implies that the wages paid by incumbent firms are very volatile, contrary to the data. These unappealing properties of wages, however, will change in the extension of the model we will propose in Section 5. With these extensions the model will be also able to generate plausible dynamics of wages.

4.3 Responses to productivity shocks

Figure 4 plots the impulse responses to a negative productivity shock. We also report the response when the debt limit is exogenously fixed to the steady state value. In this case we impose the borrowing constraint $b_{t+1} \leq \bar{\phi}\bar{J}$, where $\bar{\phi}$ and $\bar{J}$ are the steady state values of the financial variable ϕ_t and the firm's value $J_t(b_t)$.

Productivity shocks are amplified somewhat when the borrowing limit is endogenous. However, the magnitude of the amplification is small. The main reason is because productivity shocks do not generate large changes

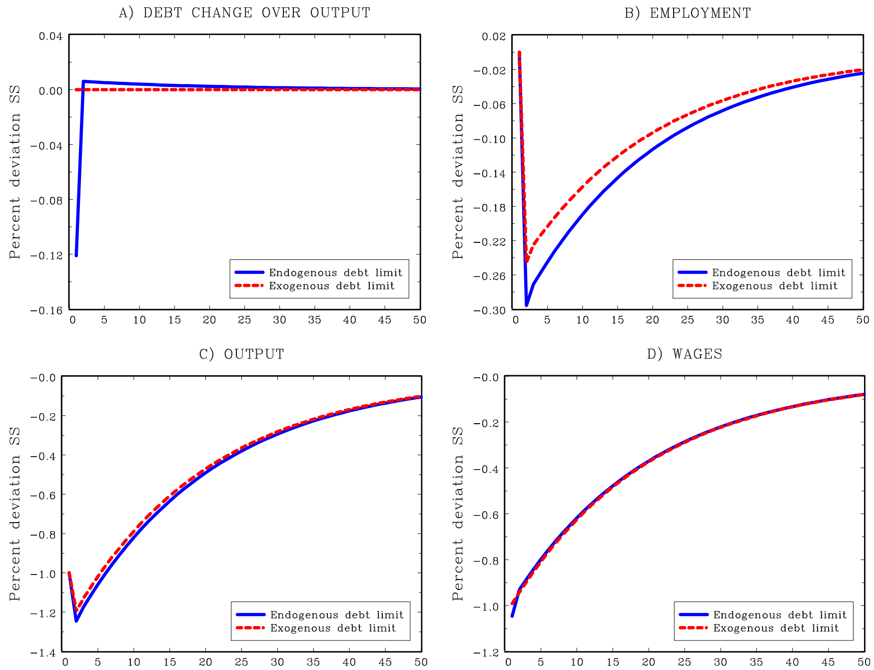

Figure 4: Impulse responses to a negative productivity shock - Baseline model.

in the value of the firm. Thus, as can be seen from the first panel, the change in debt is not large. As observed in Section 3.2, large amplification effects require sizable movements in $\mathbb{E}_t S_{t+1}(b_{t+1})$, that is, in asset prices. As it is well known, standard business cycle models have difficulties generating large fluctuations in asset prices and this is even harder when preferences are linear.

In general, the response of the economy to productivity shocks is similar to the standard matching model. This is not surprising since the version of the model with exogenous borrowing is essentially the standard matching model. Employment moves in the right direction but the size of the movement is small. Thus, most of the movements in output are (counter-factually) driven by productivity, not employment.

5 Model extension

As pointed out in the simulation of the baseline model with credit shocks, the dynamic properties of wages may appear at odd with the empirical properties. In particular, we have observed that the wages of new hired workers move counter-cyclically in response to credit shocks and the model generates very high volatility of wages. In this section we propose two extensions of the model that are capable of improving the dynamics of wages. First we assume that each firm is a monopolistic producer, that is, it produces a differentiated good used as an input in the production of final goods. The assumption of monopolistic competition is a very common assumption in macroeconomic models. The second assumption is that, after the initial wage bargaining when a new match is formed, wages are not renegotiated in every period. As we will see, the new features will have very minor implications for the dynamics of employment but will generate a more plausible dynamics of wages.

5.1 Monopolistic competition

Before describing the whole technical details, it would be helpful to clarify why monopolistic competition could change the response of wages to credit shocks.

A well known feature of models with monopolistic competition is that the demand for the differentiated good and the profits of each producer are increasing functions of aggregate production. In our model with equilibrium unemployment, aggregate production depends on how many matched are active which is also equal to the number of employed workers. Therefore, higher is the employment rate and higher is the demand for each intermediate good. Because of this, we will show below that the revenues of an individual firm can be written in reduced form as

$$\pi_t = \tilde{z}_t N_t^{\nu}. \tag{20}$$

The variable $\tilde{z}_t$ is a monotone transformation of productivity z_t and N_t is aggregate employment taken as given by an individual firm. We call this term net surplus flow instead of output for reasons that will become clear below. Therefore, the introduction of monopolistic competition only requires the replacement of firm level production z_t with the net surplus flows $\pi_t = \tilde{z}_t N_t^{\nu}$.

We can now easily describe how a credit shock affects wages. Thanks to the dependence of the surplus flow (20) from aggregate employment, a positive credit shock has two effects on the wages paid to newly hired workers. On the one hand, taking as given aggregate employment, the higher leverage allows firms to pay lower wages, which increases the incentive to hire more workers. On the other hand, the increase in aggregate employment N_t, raises the surplus flow π_t which, through the bargaining of the surplus, increases wages. Therefore, whether a credit shock is associated with an increase or decrease in the wages paid to new hires depends on the relative importance of these two effects. As we will see, the second effect could dominate for plausible calibrations.

5.1.1 Derivation of the surplus function (20).

Each firm, indexed by i, produces an intermediate good used in the production of final goods. The production function for final goods is

$$Y = \left(\int_0^N y_i^{\varepsilon} \mathrm{d}i \right)^{\frac{1}{\varepsilon}}. \tag{21}$$

Notice that the integral is over the interval $[0, N]$ since there are N producers equivalent to the number of employed workers. The inverse demand function is

$$P_i = Y^{1-\varepsilon} y_i^{\varepsilon - 1}, \tag{22}$$

where P_i is the unit price for intermediate good i in terms of final goods and $1/(1-\varepsilon)$ is the elasticity of demand.

To make the monopolist structure relevant, we need to introduce some margin along which the firm can change the quantity of intermediate goods produced. One way to do this is to assume that there is also an intensive margin in the use of labor. Suppose that the production function for good i takes the form

$$y_i = z l_i, \tag{23}$$

where l_i is hours supplied by the worker at the disutility cost $Al^{1+\varphi}/(1+\varphi)$. An alternative interpretation is that l_i represents costly utilization of labor.

The monopoly revenue is $P_i y_i$, that is, the unit price multiplied by output. Substituting the demand function (22) and the production function (23), the revenue can be written as $Y^{1-\varepsilon}(zl_i)^\varepsilon$. The optimal input l_i solves the problem

$$\max_{l_i} \left\{ Y^{1-\varepsilon}(zl_i)^\varepsilon - \frac{Al_i^{1+\varphi}}{1+\varphi} \right\}, \tag{24}$$

with first order condition $\varepsilon Y^{1-\varepsilon} z^\varepsilon l_i^{\varepsilon-1} = Al_i^\varphi$.

We can now impose the equilibrium condition $l_i = L$ and individual production becomes $y_i = zL$. Aggregate production is equal to $Y = zLN^{\frac{1}{\varepsilon}}$ and the unit price of intermediate goods is $P_i = P = N^{\frac{1-\varepsilon}{\varepsilon}}$. Finally, the individual revenue is equal to $zLN^{\frac{1-\varepsilon}{\varepsilon}}$.

Using these results in the first order condition for the intensive margin, we can solve for the input $L = \left(\frac{\varepsilon z}{A}\right)^{\frac{1}{\varphi}} N^{\frac{1-\varepsilon}{\varphi\varepsilon}}$. Then substituting in (24) and re-arranging, the revenue net of the disutility from working (net surplus flow) can be written as

$$\pi = \left[\left(\frac{\varepsilon}{A}\right)^{\frac{1}{\varphi}} \left(1 - \frac{\varepsilon}{1+\varphi}\right) \right] z^{\frac{1+\varphi}{\varphi}} N^{\frac{(1-\varepsilon)(1+\varphi)}{\varphi\varepsilon}}. \tag{25}$$

It is now easy to see the equivalence between this function and the net surplus flow reported in (20). If we define $\tilde{z} = \left[\left(\frac{\varepsilon}{A}\right)^{\frac{1}{\varphi}} \left(1 - \frac{\varepsilon}{1+\varphi}\right) \right] z^{\frac{1+\varphi}{\varphi}}$, which is a monotone function of z, and we define $\nu = \frac{(1-\varepsilon)(1+\varphi)}{\varphi\varepsilon}$, the surplus flow defined in (25) is exactly equal to (20).

5.1.2 Quantitative results

To calibrate the parameters that are also in the baseline model we use the same targets described in Section 4.1. In particular, the parameter a is calibrated to have a utility flow from unemployment equal to 75% the utility flow from employment. In the baseline model this requires a value of a equal to 75% the steady state wage. In the extended model, however, a is a smaller percentage because part of the wage compensates the worker for the disutility of working.

The new parameters are ε and φ. The first determines the price mark-up and the second the elasticity of labor supply. We set $\varepsilon = 0.8$ which implies a price mark-up of $1/\varepsilon - 1 = 0.25$. Then we choose the value of φ so that the labor supply is equal to 1, that is, $1/\varphi = 1$.

Figure 5 plots the impulse responses to a credit shock. We first notice that the responses of debt and employment are not very different from the baseline model. The dynamics of wages, however, is very different. In particular, the wage falls at impact and, contrary to the baseline model, it stays below the steady state for several periods. Therefore, the extended model generates a pro-cyclical dynamics of wages.

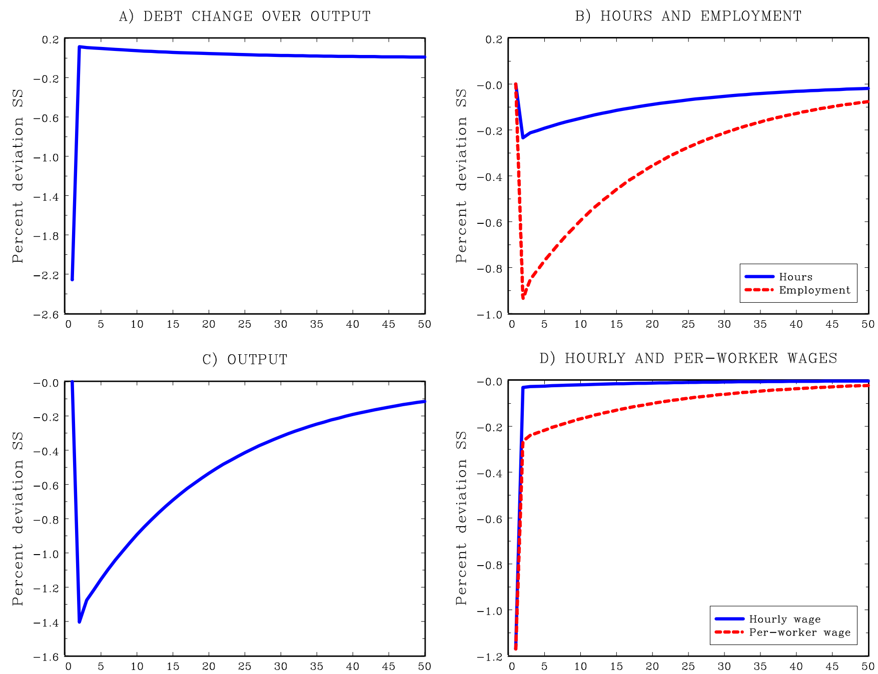

Figure 5: Impulse responses to a negative credit shock - Extended model.

Although the sign of the response of wages is now more in line with our prior, the model still generates large fluctuations in wages. In the next subsection we will consider a further extension that will correct for this.

5.2 Optimal labor contracts and infrequent negotiation

Although it is common in the searching and matching literature to assume that wages are renegotiated every period, in general there is not a theoretical or empirical justification for making this assumption. An alternative approach is to characterize the optimal contract and possible ways of implementing it.

Suppose that, when the worker is first hired, the parties bargain an optimal long-term contract. The optimal contract chooses the sequence of wages that paid to the worker at any point in time, contingent on all possible contingencies directly related to the firm. The state-contingent sequence of wages maximizes the total surplus which is shared according to the relative bargaining weight η. The sequence of wages must satisfy the participation constraints for the firm and the worker at any point in time. What this means is that, at any point in time, the value of the firm cannot be negative and the value for the worker cannot be smaller than the value of being unemployed.

It turns out that the sequence of wages that characterizes the optimal contract is not unique. The multiplicity has a simple intuition. Since production does not depend on wages, the choice of a different sequence does not affect the surplus of the match. For example, the firm could pay slightly lower wages at the beginning a slightly higher wages in later periods. This is also an optimal contract as long as the initial worker's value is the same and the participation constraints are not violated. The second condition is typically satisfied if η is not too close to 0 or 1 and there are only bounded aggregate shocks. The assumption of risk neutral agents plays a central role. With concave utility of at least one of the parties, like in Michelacci and Quadrini (2009), the optimal sequence of wages would be unique.

Given the multiplicity, we have different ways of implementing the optimal contract. One possibility is to choose a sequence of wages that is equal to the sequence obtained when the wage is re-bargained with some probability ψ. As long as this sequence does not violate the participation constraints, it also implements the optimal contract. Another way of thinking is that, when the firm and the worker meet, they decide not only the division of the surplus (through bargaining) but also the frequency with which they renew the contract. Since the parties are indifferent on the frequency, we could choose a frequency that seems more relevant empirically. Although from a theoretical point of view the choice of a particular frequency is arbitrary, it cannot be dismissed on the ground that it is suboptimal.

Appendix B derives the key equations under the assumption that wage contracts are renegotiated by each firm with probability ψ and wages stay constant until they are renegotiated. The net surplus generated by a match $S_t(b_t)$ is still given by (10) while the net value of an employed worker when the contract is renegotiated is

$$W_t(b_t) - U_t \ = \ \eta S_t(b_t) \ = \ \frac{w_t - a}{1 - \beta(1-\lambda)(1-\psi)} + \Omega_t(b_t), \qquad (26)$$

with the function $\Omega_t(b_t)$ defined recursively as

$$\Omega_t(b_t) = \eta\beta[(1-\lambda)\psi - p_t]\mathbb{E}_t S_{t+1}(b_{t+1}) + \beta(1-\lambda)(1-\psi)\mathbb{E}_t\Omega_{t+1}(b_{t+1}). \quad (27)$$

We can see from equation (26) that the worker's value has two components. The first component derives from contingencies in which the contract is not renegotiated. The second component derives from contingencies in which the contract is renegotiated.

5.2.1 Quantitative results

There is only one additional parameter to be calibrated. This is the parameter ψ which we set to 0.25. Given that quarterly calibration, this value implies that wages are renegotiated, on average, every year.

Figure 6 plots the impulse responses to a credit shock generated by the model with monopolistic competition and infrequent negotiation. The responses of debt and employment are not very different from the baseline model. Wages, however, co-move with employment (thanks to monopolistic competition already explored in the previous subsection) and their volatility is significantly smaller than employment (thanks to infrequent negotiation). Therefore, the consideration of monopolistic competition and infrequent bargaining allows the model to generate a dynamics of wages that is more in line with their empirical properties.

6 Empirical analysis

The theoretical analysis suggests that shocks to the borrowing ability could be important for employment fluctuations. In this section we investigate the importance of these shocks empirically using a structural VAR where the identifying restrictions are derived from the theoretical model studied in the previous sections.

We use a three dimensional VAR in the growth rates of TFP, Credit to the Private Sector, Employment. The inclusion of the TFP series is motivated by the need to separate the credit expansion induced by productivity shocks from credit expansions driven by other shocks. As we have seen in the theoretical model, productivity shocks have two effects on employment. In addition to the direct impact, productivity shocks are amplified through the expansion of credit that is made possible by the endogeneity of the borrowing limit. The explicit inclusion of the TFP series should separate the

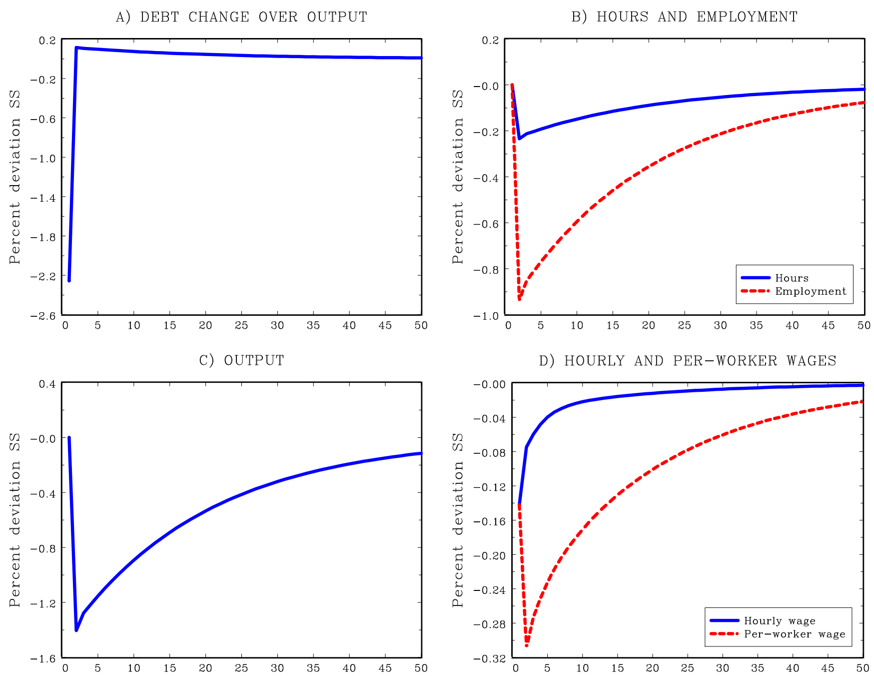

Figure 6: Impulse responses to a negative credit shock - Extended model.

credit expansion induced by productivity shocks from the credit expansion induced by other perturbations. We refer to other perturbations as 'credit shocks'.

The identification of the structural shocks is done through the imposition of zero short-term restrictions. To illustrate the identification assumptions it will be convenient to write down explicitly the VAR system as

$$(I - \mathbf{A}_1 L - \mathbf{A}_2 L^2 - ... - \mathbf{A}_n L^n) \begin{pmatrix} z_t \\ b_t \\ e_t \end{pmatrix} = \mathbf{P} \begin{pmatrix} \epsilon_{z,t} \\ \epsilon_{b,t} \\ \epsilon_{e,t} \end{pmatrix},$$

where L is the lag operator and n is the number of lags included in the VAR.

The vector (z_t, b_t, e_t) is the observed data. It includes the growth rate of TFP, the growth rate of private credit, and the growth rate of employment. A more detailed description of the data is provided below.

The vector $(\epsilon_{z,t}, \epsilon_{b,t}, \epsilon_{e,t})$ contains the orthogonalized disturbances. In order to assign a particular economic interpretation to these shocks, we impose that some of the elements of the matrix $\mathbf{P}$ are equal to zero. To be more specific, let's write the matrix in extensive form as

$$\mathbf{P} = \begin{pmatrix} p_{zz} & p_{zb} & p_{ze} \\ p_{bz} & p_{bb} & p_{be} \\ p_{ez} & p_{eb} & p_{ee} \end{pmatrix}.$$

By imposing that some of the elements of $\mathbf{P}$ are zero, we are assuming that some of the orthogonalized disturbances cannot have an immediate impact on some of the variables included in the system. For example, if we set $p_{eb} = 0$, the shock $\epsilon_{b,t}$ does not have an immediate impact on employment e_t. Since the identification of a three dimensional system requires at least three restrictions, we have to impose that at least three elements of the matrix $\mathbf{P}$ are zero. Thus, we start with the following restrictions:

1. Since TFP evolves exogenously in the model, credit shocks cannot affect TFP. Therefore, we set $p_{zb} = 0$.

2. Since an improvement in productivity affects employment with one period lag (due to the matching frictions), innovations to productivity cannot affect employment at impact. This requires $p_{ez} = 0$.

3. The same logic applies to credit shocks, that is, they also affect employment with one period lag. Therefore, innovations to the availability of credit cannot affect employment at impact, which requires $p_{eb} = 0$.

With these restrictions we can interpret $\epsilon_{z,t}$ as innovations to TFP, $\epsilon_{b,t}$ as innovations to the availability of credit, and $\epsilon_{e,t}$ as residual disturbances.[5]

Data: The estimation uses quarterly data over the period 1984.1-2009.3. The TFP growth is constructed using the utilization-adjusted TFP series constructed by John Fernald (2009). The growth in private credit is constructed using data from the Flow of Funds. Specifically, we use new borrowing (financial market instruments) for households and nonfinancial businesses dividend by the stock of debt (again, financial market instruments). For employment we have three series. The first series includes all civilian employment from

[5]An alternative way to generate a just-identified system is to assume (i) $p_{zb} = 0$, (ii) $p_{ze} = 0$, and (iii) $p_{eb} = 0$. Results based on this alternative identification scheme are similar and are available upon request.

the BLS. The second series includes all employees in private industries, also from the BLS. The third series includes all employees in the nonfarm sector, from the Current Employment Statistics survey.

Impulse responses: We first estimate the VAR system with e_t measured by 'employment in the private sector' and five lags ($n = 5$). Results using the other two definitions of employment (not reported) are similar.

The impulse response functions of Private Credit and Employment to credit and TFP shocks are plotted in Figure 7. As far as the credit shock is concerned, we see that this generates an expansion in the growth rate of private credit that lasts for many quarters. Therefore, these shocks tend to generate long credit cycles. Credit shocks generate an expansion in the growth rate of employment that is statistically significant for four quarters.

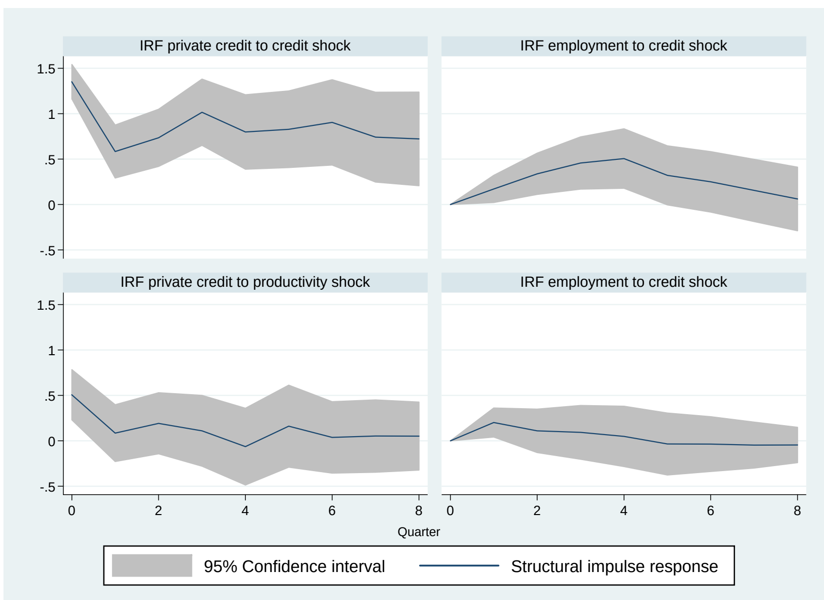

Figure 7: Three variables (exactly identified) VAR: TFP, private credit, employment.

TFP shocks also generate an expansion in the growth rate of private credit but the impact is much less persistent. The growth rate of employment goes up but the overall impact is smaller than the impact of credit shocks.

Overall, the results presented in Figure 7 are consistent with the properties of the theoretical model. In particular, we see that credit shocks have a statistical significant impact on employment and TFP shocks lead to a credit expansion. As long as a credit expansion allows for more job creation, the financial mechanism allows for some amplification of productivity shocks.

In alternative to employment as a measure of the labor market performance, we could use the unemployment rate. We re-estimate the VAR with the growth rate of TFP, Private Credit and Unemployment. For unemployment we use the measure provided by the BLS. The impulse responses to financial and productivity shocks are plotted in Figure 8. Also in this case we find that productivity shocks have a statistically significant impact on the growth rate of private credit and unemployment.

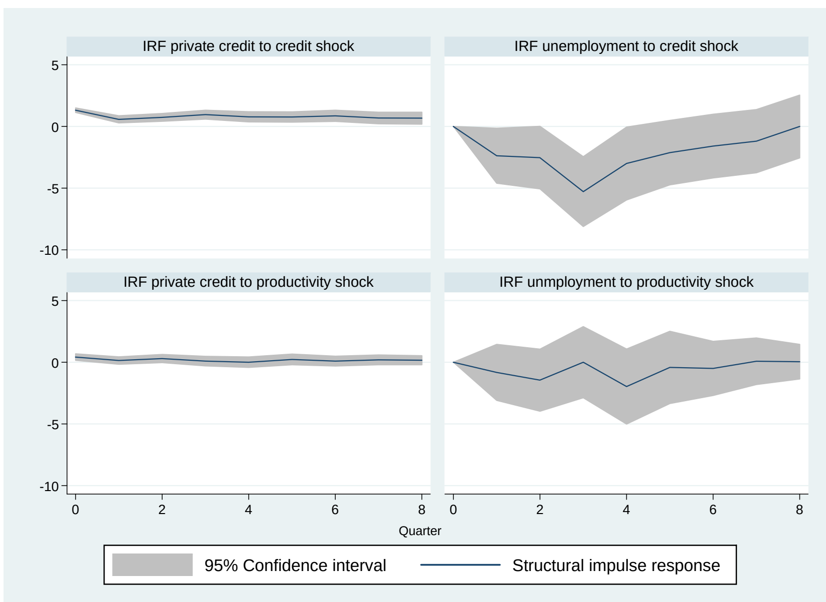

Figure 8: Three variables (exactly identified) VAR: TFP, private credit, unemployment.

Adding wages: Since wages plays a central role in the transmission of credit shocks, we now expand the VAR model by including wages. Wages are measured as Average Hourly Earnings for Total Private Industries from Bureau of Labor Statistics.

The VAR includes total factor productivity, z_t, private credit, b_t, employment, e_t and wages, w_t. The matrix P takes the form

$$\mathbf{P} = \begin{pmatrix} p_{zz} & p_{zb} & p_{ze} & p_{zw} \\ p_{bz} & p_{bb} & p_{be} & p_{bw} \\ p_{ez} & p_{eb} & p_{ee} & p_{ew} \\ p_{wz} & p_{wb} & p_{we} & p_{ww} \end{pmatrix}.$$

The identification is based on the following restrictions:

1. Since TFP evolves exogenously in the model, credit and other shocks cannot affect TFP. Therefore, we set $p_{zb} = p_{ze} = p_{zw} = 0$.

2. Since an improvement in productivity affects employment with one period lag (due to the matching frictions), innovations to productivity and credit cannot affect employment at impact. This requires $p_{ez} = p_{eb} = 0$.

3. Finally, the residual shocks to employment and wages are identified using a non-structural triangular restriction, that is, $p_{we} = 0$.

As can be seen from Figure 9, the impulse responses for private credit and employment are similar to the responses obtained with the three dimensional VAR. As far as wages are concerned, we observe that they first increase and then decrease. This is not inconsistent with the predictions of the model in response to a credit shock if we focus on the wages paid by incumbent firms. However, the responses are not statistically significant at 5% confidence interval.

Alternative identification: In the identification scheme adopted so far, we have imposed that financial shocks do not impact TFP, at least in the current period. This is consistent with the exogenous nature of productivity assumed in the theoretical model. However, we have not imposed in the VAR that the residual shock $\epsilon_{e,t}$ cannot have an immediate impact on TFP. Therefore, we now repeat the estimation imposing this additional restriction, that is, $p_{ze} = 0$. By doing so we have a total of four restrictions and the structural VAR is over-identified. The impulse responses, plotted in Figure 10, confirm the results obtained with the identification strategy adopted above.

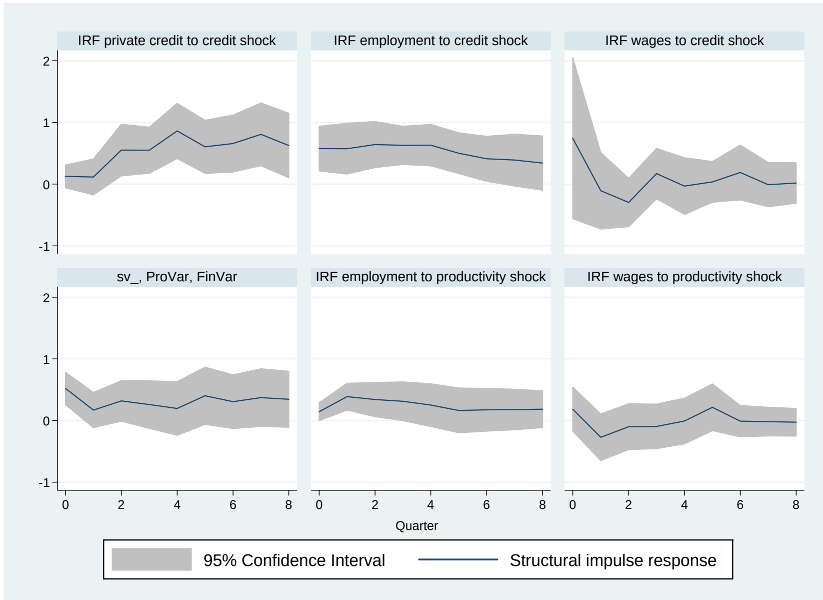

Figure 9: Four variables (exactly identified) VAR: TFP, private credit, employment and wages.

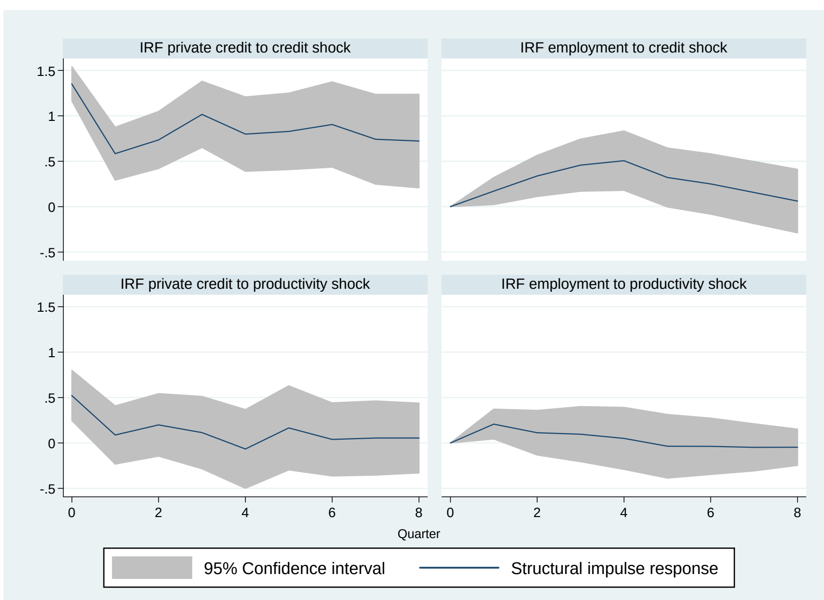

Figure 10: Three variables (over-identified) VAR: TFP, private credit and employment.

Discussion: The VAR results are consistent with the theoretical model. However, they do not allow us to separate the transmission mechanism of credit shocks emphasized in this paper from the typical credit channel. As far as the most recent crisis is concerned, the fact that liquidity has rebounded immediately after the crisis suggests that our mechanism could be more important for understanding the sluggish recovery. The standard credit channel, however, could have been more important in the initial stage of the crisis.

7 Conclusion

In this paper we have studied the importance of financial flows for employment (and unemployment) fluctuations. We have extended the basic matching model by allowing firms to issue debt under limited enforcement of financial contracts. Our approach goes beyond a mere cumulation of frictions, respectively in financial and labor markets. Firms have an incentive to borrow in order to affect wage bargaining as emphasized in the corporate finance literature. Our paper embeds this mechanism in a general equilibrium environment and investigates its role for the dynamics of aggregate employment.

In our model the ability to borrow can change exogenously in response to credit shocks or endogenously in response to productivity shocks. Independently of the sources of credit expansion, higher debt allows firms to bargain lower wages. Through this mechanism, credit shocks can generate large and persistent employment fluctuations. The determination of wages based on bargaining is central to these results.

The paper has also investigated the empirical relevance of credit shocks using a structural VAR where the shocks are identified with zero short-term restrictions derived from the theoretical model. The estimation of the VAR shows that the impact of these shocks on employment is statistically significant. Although these findings do not allow us to separate the transmission mechanism based on wage bargaining from the typical credit channel, they support the view that financial markets are important for the performance of the labor market.

Appendix

A Wage equation

Consider the value of a filled vacancy defined in (14). Using the binding enforcement constraint $b_{t+1} = \phi_t(1-\eta)\mathbb{E}_t S_{t+1}(B_{t+1})$ to eliminate b_{t+1}, the value of a filled vacancy becomes

$$Q_t = (1+\phi_t)\beta(1-\eta)\mathbb{E}_t S_{t+1}(B_{t+1}).$$

Next we use the free entry condition $V_t = q_t Q_t - \kappa = 0$. Eliminating Q_t using the above expression and solving for the expected value of the surplus we obtain

$$\mathbb{E}_t S_{t+1}(B_{t+1}) = \frac{\kappa}{q_t(1+\phi_t)\beta(1-\eta)}. \tag{28}$$

Substituting into the definition of the surplus—equation (10)—and taking into account that $b_{t+1} = \phi_t(1-\eta)\mathbb{E}_t S_{t+1}(B_{t+1})$, we get

$$S_t(B_t) = z_t - a - b_t + \frac{[1-\lambda-p_t\eta+\phi_t(1-\lambda)(1-\eta)]\kappa}{q_t(1+\phi_t)(1-\eta)}. \tag{29}$$

Now consider the net value for a worker,

$$W_t(B_t) - U_t = w_t - a + \eta(1-\lambda-p_t)\beta\mathbb{E}_t S_{t+1}(B_{t+1})$$

Substituting $W_t(B_t) - U_t = \eta S_t(B_t)$ in the left-hand-side and eliminating $\mathbb{E}_t S_{t+1}(B_{t+1})$ in the right-hand-side using equation (28) we obtain

$$\eta S_t(B_t) = w_t - a + \frac{\eta(1-\lambda-p_t)\kappa}{q_t(1+\phi_t)(1-\eta)} \tag{30}$$

Finally, combining (29) and (30) and solving for the wage we get

$$w_t = (1-\eta)a + \eta(z_t - b_t) + \frac{\eta[p_t + (1-\lambda)\phi_t]\kappa}{q_t(1+\phi_t)},$$

which is the expression reported in (16).

B Model with infrequent negotiation

Suppose that wages are negotiated (bargained) when a new match is formed and then they are renegotiated in future periods with some probability ψ. In the interim periods wages are kept constant.

To avoid some unnecessary complications, we make the following assumption:

Assumption 1 *The enforcement constraint takes the form $\phi_t \mathbb{E}_t J_{t+1}(b_{t+1}) \geq b_{t+1}$, where $J_{t+1}(b_{t+1})$ is the next period equity value of the firm when the next period wage is renegotiated with certainty.*

This assumption insures that the borrowing limit is independent of the current wage, which is different across firms depending on the renegotiation history. In this way all firms continue to choose the same debt even if they pay different wages. The assumption that the collateral value depends on the equity value of the firm when the next period wage is renegotiated with certainty can be justified with the assumption that, in case of default, wages are always renegotiated. Since the lender gets a fraction of the firm's value, this assumption implies that the collateral is a fraction ϕ_t of the equity value of the firm when the next period wage is renegotiated with certainty (since wages are renegotiated in case of default). See Section 2 for the derivation of the enforcement constraint.

The value for a newly hired worker who bargains the first wage at time t is

$$W_t(b_t) = w_t + \beta \mathbb{E}_t \Big\{ (1-\lambda) \Big[\psi W_{t+1}(b_{t+1}) + (1-\psi) \overline{W}_{t,t+1}(b_{t+1}) \Big] + \lambda U_{t+1} \Big\}, \quad (31)$$

where $\overline{W}_{t,t+1}(b_{t+1})$ is the value at time $t+1$ if there in not renegotiation and the worker receives the wage negotiated at time t. Therefore, the first subscript denotes the last period in which the wage was negotiated and the second subscript denotes the period in which the wage is paid.

The value of being unemployed is

$$U_t = a + \beta \mathbb{E}_t \Big[p_t W_{t+1}(B_{t+1}) + (1-p_t) U_{t+1} \Big]. \quad (32)$$

Subtracting (32) to (31) and re-arranging we get

$$\begin{aligned} W_t(b_t) - U_t \quad = \quad & w_t - a + \beta \mathbb{E}_t \Big\{ (1-\lambda) \Big[\psi \Big(W_{t+1}(b_{t+1}) - U_{t+1} \Big) + \\ & (1-\psi) \Big(\overline{W}_{t,t+1}(b_{t+1}) - U_{t+1} \Big) \Big] - p_t \Big(W_{t+1}(B_{t+1}) - U_{t+1} \Big) \Big\} \end{aligned} \quad (33)$$

Since in equilibrium $b_{t+1} = B_{t+1}$, we can rewrite the equation as

$$\begin{aligned} W_t(b_t) - U_t \quad = \quad & w_t - a + \beta \Big[(1-\lambda)\psi - p_t \Big] \mathbb{E}_t \Big(W_{t+1}(b_{t+1}) - U_{t+1} \Big) + \\ & \beta (1-\lambda)(1-\psi) \mathbb{E}_t \Big(\overline{W}_{t,t+1}(b_{t+1}) - U_{t+1} \Big) \end{aligned} \quad (34)$$

To simplify notations, define

$$\rho = \beta(1-\lambda)(1-\psi)$$
$$\delta_t = \beta\Big[(1-\lambda)\psi - p_t\Big]$$
$$\hat{W}_t(b_t) = W_t(b_t) - U_t$$
$$\hat{\overline{W}}_{\tau,t}(b_t) = \overline{W}_{\tau,t}(b_t) - U_t,$$

where $\tau \leq t$ is the time subscript for the last period in which the wage was renegotiated. If $\tau = t$ we have $\hat{\overline{W}}_{\tau,t}(b_t) = \hat{W}_t(b_t)$.

Using this notation, the net value of the worker can be written as

$$\hat{W}_t(b_t) \quad = \quad w_t - a + \delta_t \mathbb{E}_t \hat{W}_{t+1}(b_{t+1}) + \rho \mathbb{E}_t \hat{\overline{W}}_{t,t+1}(b_{t+1}) \tag{35}$$

The next period value without bargaining is

$$\hat{\overline{W}}_{t,t+1}(b_{t+1}) \quad = \quad w_t - a + \delta_{t+1} \mathbb{E}_{t+1} \hat{W}_{t+2}(b_{t+2}) + \rho \mathbb{E}_{t+1} \hat{\overline{W}}_{t,t+2}(b_{t+2}) \tag{36}$$

Substituting in (35) at $t+1$, $t+2$, $t+3$,..., the net value for the worker can be written as

$$\hat{W}_t(b_t) \quad = \quad \frac{w_t - a}{1-\rho} + \Omega_t(b_t), \tag{37}$$

where the function $\Omega_t(b_t)$ is defined as

$$\Omega_t(b_t) = \mathbb{E}_t \delta_t \hat{W}_{t+1}(b_{t+1}) + \rho \mathbb{E}_t \delta_{t+1} \hat{W}_{t+2}(b_{t+2}) + \rho^2 \mathbb{E}_t \delta_{t+2} \hat{W}_{t+3}(b_{t+3}) + ...$$

The function $\Omega_t(b_t)$ has a recursive structure and can be written recursively as

$$\Omega_t(b_t) = \delta_t \mathbb{E}_t \hat{W}_{t+1}(b_{t+1}) + \rho \mathbb{E}_t \Omega_{t+1}(b_{t+1}). \tag{38}$$

Using the bargaining outcome $\hat{W}_t(b_t) = \eta S_t(b_t)$ in (37) and (38), we obtain

$$\eta S_t(b_t) \quad = \quad \frac{w_t - a}{1-\rho} + \Omega_t(b_t), \tag{39}$$

$$\Omega_t(b_t) = \eta \delta_t \mathbb{E}_t S_{t+1}(b_{t+1}) + \rho \mathbb{E}_t \Omega_{t+1}(b_{t+1}). \tag{40}$$

Finally, the surplus is the same as in the baseline model, that is,

$$S_t(b_t) = z_t - a - b_t + \frac{b_{t+1}}{R} + (1 - \lambda - \eta p_t)\beta \mathbb{E}_t S_{t+1}(b_{t+1}). \tag{41}$$

B.1 Evolution of aggregate wages

Denote by $\bar{w}_{t-1}$ the average wage in period $t-1$. Then the average wage in period t is equal to

$$\bar{w}_t = \left(\frac{(1-\lambda)N_{t-1}}{N_t}\right)\Big[(1-\psi)\bar{w}_{t-1} + \psi w_t\Big] + \left(\frac{m(v_{t-1}, u_{t-1})}{N_t}\right) w_t, \tag{42}$$

where $m(v_{t-1}, u_{t-1})$ is the number of new matches.

To determine the average wage at time t, we need to know the average wage in the previous period and the share of employment that bargains a new wage at time t. This share is equal to

$$s_t = \frac{\psi(1-\lambda)N_{t-1} + m(v_{t-1}, u_{t-1})}{N_t}.$$

Using s_t, the average wage equation can be written as

$$\bar{w}_t = (1-s_t)\bar{w}_{t-1} + s_t w_t.$$

B.2 Summary

The consideration of infrequent negotiation is captured by the following equations

$$\eta S_t(b_t) = \frac{w_t - a}{1-\rho} + \Omega_t(b_t) \tag{43}$$

$$\Omega_t(b_t) = \eta \delta_t \mathbb{E}_t S_{t+1}(b_{t+1}) + \rho \mathbb{E}_t \Omega_{t+1}(b_{t+1}) \tag{44}$$

$$\bar{w}_t = (1-s_t)\bar{w}_{t-1} + s_t w_t \tag{45}$$

$$s_{t+1} = \frac{\psi(1-\lambda)N_t + m(v_t, u_t)}{N_{t+1}} \tag{46}$$

Notice that equation (43) replaces the equation for the worker's value in the baseline model with period-by-period bargaining. Equations (44)-(46) are additional. The set of state variables is expanded with the new states s_t and $\bar{w}_{t-1}$.

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