Borrowing Constraints, Collateral Fluctuations, and the Labor Market*

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Abstract

This paper studies the effects of imperfections in the financial sector on the cyclical properties of unemployment and job creation. I develop a general equilibrium model with capital accumulation in which labor market frictions prevent the costless adjustment of employment. Financial frictions arise from an imperfect enforcement contract, which links a firm's ability to borrow to the value of its collateralizable assets. I find that while productivity shocks account primarily for fluctuations in investment and output, exogenous changes in collateral requirements are important in driving fluctuations in labor market variables. The model can account for the persistent reduction in both output and leverage that follows a contraction in credit availability. Furthermore, it is able to explain 80% of the variation in job creation observed in the data.

JEL Classification: E24; E32; E37; E44; J63; J64.

Keywords: Financial Frictions; Unemployment; Labor markets; Search and matching; Financial Shocks.

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1 Introduction

The 2008 financial crisis has highlighted the need for a better understanding of the extent to which financial frictions can affect macroeconomic aggregates. The fact that a tightening of credit conditions was followed by a substantial increase in unemployment rates suggests that understanding how fluctuations in job creation are affected by changes in the availability of credit for firms not only constitutes an important theoretical exercise, but also an essential policy matter. Nevertheless, the literature has yet to focus on how exogenous changes in collateral requirements affect both labor markets and the hiring decision of firms in a fully stochastic and dynamic general equilibrium environment. Motivated by this, I develop a model with these characteristics and in which credit constraints affect the hiring decisions of firms.

The 2008 recession is distinguished by the extent to which credit conditions deteriorated. The data show that both the supply (banks) and the demand (firms) side reported a marked increase in credit market tightness during the last contractionary episode.[1] Using data from the Flow of Funds Accounts, Figure 1a plots the net percentage of surveyed domestic banks that reported having tightened the standards for loans to both small and large firms, along with the cyclical component of real GDP.[2] Similarly, Figure 1b shows a measure of credit availability obtained from the National Federation of Independent Business that indicates the net percentage of respondents who, conditional on seeking credit in the previous three months, reported more difficulty in obtaining credit. The timing of the two series is noteworthy: the decrease in output during the 2008 recession was preceded by a contraction in credit availability.

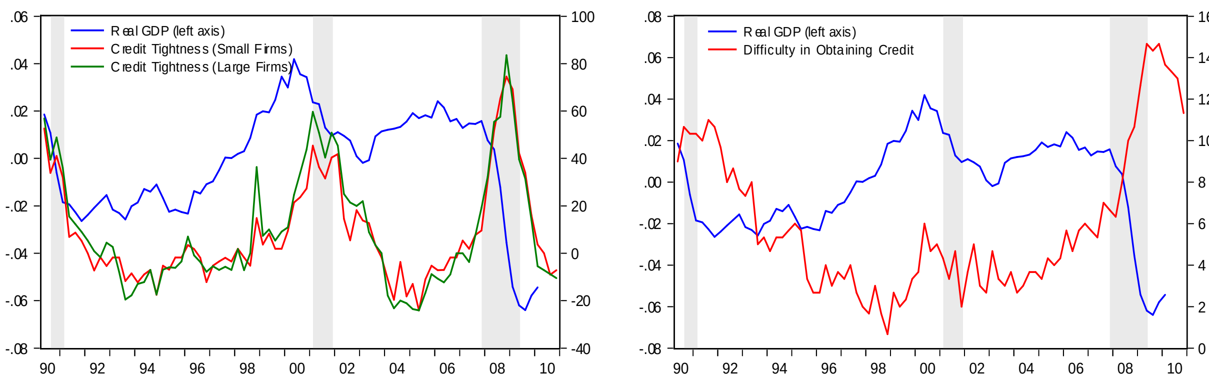
While the recent reduction in output was larger than in any other modern recession, it has been the behavior of unemployment that has highlighted the importance of understanding the effects of financial frictions on the cyclical fluctuations of labor market variables. The behavior of unemployment can be seen in Figure 2a. The figure reveals the striking rise in unemployment during the 2008-2009 period. It is again worth noting that the worsening in credit conditions leads the rise in unemployment, suggesting that credit availability could be affecting the ability of firms to create new jobs. In this regard, panel Figure 2b shows the relationship between vacancies and credit tightness. Again, the deterioration in credit conditions seems to lead the contraction in job creation during the last recession.

This paper presents a general equilibrium environment with frictions in both labor and financial markets that is well suited to study the importance of a contraction in credit

[1] All the data presented in the paper is described in Appendix E.

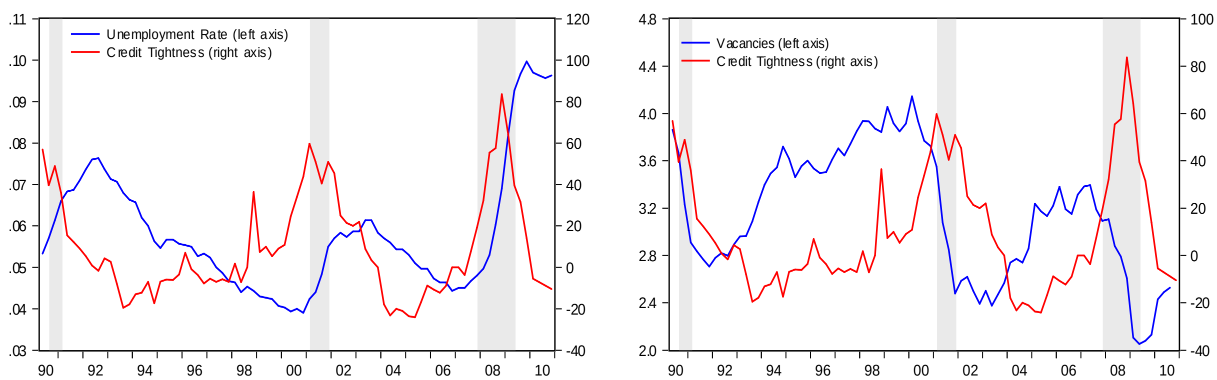
[2] Net percentage refers to percentage of banks that reported having tightened the standards to firms minus the percentage that reported having eased the standards.

availability in generating an increase in unemployment as sharp as the one recently experienced. Can a framework with these characteristics bring us closer to explaining the volatility observed in labor market variables? Moreover, what fraction of these fluctuations can be explained by variations in the availability of credit? What are the implications of a sudden increase in credit tightness in an economy in which firms are financially constrained and there are costs and frictions associated with hiring workers? Does the degree of firms' leverage have a large effect on both steady-state unemployment and fluctuations in labor market variables? This paper contributes to the literature by developing a stochastic dynamic general equilibrium environment that is suited to answer these questions.



(a) GDP and Credit Tightness (Supply) (b) GDP and Credit Tightness (Demand)

Figure 1: Output and Credit Conditions



(a) Credit Tightness and Unemployment (b) Credit Tightness and Job Creation

Figure 2: Credit Market Tightness and Labor Market Variables

I model financial frictions as arising from a contract with imperfect enforcement, in the spirit of Kiyotaki and Moore (1997). A firm's ability to borrow is constrained to be less than a fraction of its collateralizable assets. The collateral consists of the stock of capital owned by the firm at the beginning of the period. Subjecting the firm to this type of collateral constraint has the advantage that it provides a direct link between collateral requirements and asset prices, which some authors argue played an important role in the 2008 financial crisis.[3] Recent studies, most noticeably Jermann and Quadrini (2009) and Perri and Quadrini (2011), have emphasized the importance of financial shocks in generating fluctuations in macroeconomic aggregates. Like these studies, I introduce exogenous variations in collateral requirements, which I will refer to as 'credit shocks'. These variations are meant to capture the uncertainty in credit conditions faced by firms. The hypothesis is that this interaction will introduce a channel by which movements in collateral requirements will drive fluctuations in labor market variables.

The model has two types of agents. Households provide labor and funds. Capitalists do not supply labor, but rather own the firms (and thus own the capital stock). In the model, firms can finance their operations through the use of debt (issued to households) or equity and are subject to a cash flow mismatch that requires them to take intra-period loans. As the possibility of default is assumed to arise at the end of the period, both inter- and intra-period loans are subject to the collateral requirement. A negative credit shock, i.e. tightening of credit conditions, reduces the amount the firm can borrow against its collateral.

The labor market is modeled as a search and matching environment. This will introduce frictions that will make hiring a costly process. It follows that periods in which the availability of credit is tight are also periods in which it is relatively more costly to post vacancies. As firms are financially constrained, a reduction in credit will directly affect the ability of firms to create jobs, thus generating higher unemployment. Since it takes several periods until hiring can catch up with the worker separations that occur every period, this creates a persistent effect of credit shocks in labor markets. The decrease in borrowing that follows a contraction creates a deleveraging consistent with the evidence that 'bad times' are periods in which firms reduce their level of debt relative to their level of production (Reinhart and Reinhart (2010)).

Working capital requirements induce firms to cut job creation following a tightening in credit conditions and this effect is amplified by the way wages are determined, i.e. through a bargaining problem. The bargaining position of firms will not be constant but will depend upon credit market conditions. A contraction in credit will improve the bargaining position of firms by increasing the sensitivity of the firm's surplus to changes in wages. Therefore, relative to a standard search-and-matching model, small changes in wages will generate larger movements in labor market variables, in particular employment and job-creation.

I carry out a quantitative exercise in which the mean and the standard deviation of the process that governs the credit shock in the model are calibrated to match the empirical

[3] See for instance Geanakoplos (2009) and Krishnamurthy (2010).

features of the debt-to-GDP ratio. The baseline model is successful in generating volatility in the extensive margin and generates an unemployment rate that is twice as volatile as GDP. Although this is still less than the relative volatility of unemployment we observe in the data which, depending on the detrending could be up to more than seven times higher, it represents a significant improvement from standard models that generate an unemployment rate whose volatility is similar to that of output. Fluctuations in credit tightness can account for more than 80% of the variation observed in vacancies and more than 50% of the fluctuations observed in labor market tightness. I find that while productivity shocks are important in generating movements in output and investment, credit shocks are responsible for an important share of the fluctuations observed in labor market variables. This result is mainly driven by a low sensitivity of wages with respect to credit shocks, so changes in financial conditions do not fully translate into changes in wages, therefore generating movements along the extensive margin. Put differently, fluctuations in collateral requirements are a promising means of explaining business cycle movements in labor market variables.

Furthermore, I find that if firms face, on average, tighter constraints, then the response of labor market variables to financial shocks is greater. That is, increasing the mean value for collateral requirements increases the extent to which firms decrease job creation following a negative credit shock, and it also increases the persistence of unemployment.

The rest of the paper is organized as follows. The next section discusses previous research. Section 3 describes the model in detail. Section 4 describes the calibration and presents and discusses the main results of the paper. Finally, section 5 concludes.

2 Literature Review

This paper adds to a growing literature that seeks to understand the effects of exogenous and unexpected changes in the availability of credit on macroeconomic aggregates. Recent papers have explored the extent to which these variations in collateral requirements influence the dynamic response of economic variables. For instance, Jermann and Quadrini (2009) and Perri and Quadrini (2011), show that credit shocks are important in amplifying fluctuations in macroeconomic variables, in particular in total hours.[4]

Despite the important insights provided by these studies, they are not able to study variations in the extensive margin, which is responsible for most of the fluctuations in total hours (Rogerson and Shimer (2011)). While assuming indivisible labor, as in Hansen (1985), is

[4]With an environment in which there is a fixed-supply asset that is used as an input in the production function, Liu et al. (2010) also find that credit shocks are important in generating fluctuations and that credit constraints can have a significant impact in amplifying those shocks.

suitable for the study of employment, models with imperfect labor markets allow for studying a richer set of flows such as vacancies, job-creation, job-finding rates, etc. Moreover, models with labor frictions explicitly account for hiring costs and thus provide an important channel by which financial constraints can affect job creation. For this reason I depart from perfect labor markets and incorporate search frictions à la Mortensen and Pissarides (1994) using the representative household framework developed in Merz (1995) and Andolfatto (1996). Furthermore, by having wages determined as a solution to a Nash bargaining problem, the paper incorporates a more general theory regarding the process for wage negotiation.

This paper is also connected with studies that have sought to resolve what has become known as the 'Shimer puzzle', regarding the inability of the Pissarides (1987) matching model to explain the fluctuations in unemployment observed in the data. In order to account for this issue, some studies have focused on alternative parameterizations of key parameters of the model (Hagedorn and Manovskii (2008)), while others have focused on the wage determination process, which according to Shimer (2005), is responsible for the model's failure to match the data.[5]

Petrosky-Nadeau (2011), addressing the puzzle, studies the effects of financial frictions on labor market variables. His model differs in that he incorporates financial frictions that arise from a problem of asymmetric information as in Carlstrom and Fuerst (1997)). The asymmetric information between financial intermediaries and firms implies that firms are able to access funds as long as they commit to the payment of the required interest rate. Put differently, in his environment, a worsening of credit conditions takes the form of an increase in lending rates.[6] He finds that asymmetric information between financial intermediaries and borrowers can increase both the magnitude and persistence of unemployment fluctuations.[7] Using the same environment to model financial frictions, Chugh (2009) incorporates physical capital accumulation and brings the study of Petrosky-Nadeau (2011) closer to the DSGE search literature.

While these papers have improved our understanding of how financial frictions could bring our models closer to the data, this paper departs from them by assuming that financial frictions arise from a different source. In order to study the role of exogenous changes in the

[5]Among other studies, Shimer (2004), Hall (2005), and Gertler and Trigari (2009) have also addressed this issue.

[6]This increase is a direct consequence of the costly state verification assumption. In the Carlstrom and Fuerst (1997) framework, as the likelihood of default increases, the asymmetric information between lenders and financial intermediaries also implies an increase in the monitoring costs. As the costs of monitoring are spread among all firms, the increase in these costs raises the cost of financing for all firms in the economy.

[7]With a dynamic extension of Wasmer and Weil (2004) in which search frictions are present in both financial and labor markets, Petrosky-Nadeau and Wasmer (2011) show that the introduction of financial frictions can amplify considerably the responses of labor market variables to productivity shocks.

availability of credit, given by changes in collateral requirements, I model financial frictions as arising from a contract with imperfect enforcement, in the spirit of Kiyotaki and Moore (1997). Hence, in this paper, negative credit shocks will be akin to a tightening of credit conditions of the type documented above.

A contemporaneous paper by Monacelli et al. (2011) focuses on a different channel through which financial shocks are transmitted. Although the environment in my paper, a DSGE-search model, differs from the their study, it is also important to mention other aspects that differentiate my work from theirs. The authors seek to capture evidence, found in the corporate finance literature (see Matsa (2010)), that suggests that the level of a firm's borrowing affects its bargaining position. For that purpose, they incorporate financial frictions in the framework proposed by Pissarides (1987) and Mortensen and Pissarides (1994). In their framework, periods of low credit availability are periods in which workers have a more favorable bargaining position, which reduces the incentives for job creation and allows them to extract higher wages. This differs from my paper, in which periods of low credit availability are periods in which firms have a stronger bargaining position. The latter is due to the fact that the surplus the firm obtains from forming a match is, during those periods, more sensitive to change in wages. In addition, while changes in bargaining position are important for the results, my paper also focuses on the traditional credit channel: changes in the cost of financing employment will be the main mechanism through which fluctuations in collateral requirements will be transmitted. Put differently, in this paper, following a tightening of credit firms will be forced to reduce both investment and employment because they have difficulty raising funds, not because workers are able to extract higher wages.[8] In addition, another important distinction is that Monacelli et al. (2011) do not allow for physical capital accumulation in their model. Besides adding realism, incorporating physical capital allows for studying the dynamic response of investment, and since capital will be used as collateral it will provide a direct link between between asset prices and collateral requirements.

3 The Model Economy

The baseline model has two types of agents: workers and entrepreneurs (which I also will refer to as capitalists). These agents interact in an environment characterized by frictions in the labor market and in the financial sector. I assume market segmentation in the sense that workers cannot hold shares in the firms, which are exclusively owned by entrepreneurs.

[8] The behavior of wages in my model differs from theirs in that it generates, during a recession caused by credit contraction, a reduction in wages even in an environment in which firms are competitive.

Therefore, the only asset that is available to workers is a one-period riskless bond issued by capitalists.

There is a continuum of firms that hire labor and accumulate physical capital in order to produce a homogeneous good and transfer dividends to its owners, the entrepreneurs. Similarly, and as is common in DSGE search models since the seminal work of Merz (1995) and Andolfatto (1996), it is assumed that each household consists of a measure one continuum of family members and within each household there is perfect risk-sharing so that regardless of the status of each member (employed or unemployed), consumption is equalized across members. I will use the terms firms and managers interchangeably throughout the paper.

In this environment, financial frictions are assumed to result from a contract with imperfect enforcement as in Kiyotaki and Moore (1997). This implies that firms face collateral requirements that limit their ability to borrow. I further assume that capitalists are more impatient than households. This impedes firms from accumulating enough assets in order to avoid the constraint and, as will be shown later, implies that in steady state the borrowing constraint will be binding. Given the solution method that will be employed, this is a crucial assumption.

With the underlying assumption that it is costly for firms to incorporate workers, labor market frictions are introduced in the spirit of Mortensen and Pissarides (1994) and, as is common in the literature that focuses on labor search frictions, wages will be determined as the solution to a bargaining problem between workers and firms.

Before describing the characteristics of financial and labor markets, I present the main features of households, capitalists, and firms. Finally I will introduce the optimization problems faced by households and firms.

3.1 Households

As is common in DSGE search models, I will assume that there is a representative household in the economy and it is composed of a continuum of family members of measure one.[9] The household pools the income of all its members and allocates consumption in order to maximize utility. In order to do so, it equalizes the marginal utility of consumption across all individuals, independent of their labor market status. Assuming a utility function with separability between consumption and leisure, this implies perfect risk sharing, so that individuals all have the same level of consumption. Households maximize lifetime utility,

$$\mathrm{E}_t \sum_{j=0}^{\infty} \beta_h^j \left[\ln(c_{t+j}) - \varphi n_{h,t+j}\right]$$

[9] See for instance Merz (1995) or Andolfatto (1996).

where c_h is household consumption, φ is the disutility of work, $n_{h,t}$ is the measure of individuals that are employed at time t, and β_h is the household's discount factor.

While employed individuals earn wages, w_t, unemployed members receive unemployment benefits, s. Unemployment benefits are financed through the payment of a lump-sump tax, T_t. The households have access to financial markets. Specifically, they have the possibility of smoothing consumption across periods by purchasing a one-period riskless bond, a_t. The households' flow of funds constraint can be written as,

$$c_t + \frac{a_{t+1}}{R_t} + T_t \leq w_t n_{h,t} + a_t + (1 - n_{h,t})s$$

3.2 Capitalists and Firms

As in Perri and Quadrini (2011), capitalists derive utility from the consumption financed out of dividends obtained from their ownership of firms. A crucial assumption is that those agents are risk-averse, and therefore they would like to avoid fluctuations in their consumption.[10] Since what is important for the purposes of this paper is that there are costs associated with changes in dividends, an alternative specification would be to assume, as in Jermann and Quadrini (2009), that firms are subject to adjustment costs regarding dividend payout.

Capitalists have access to the financial sector only through the firm. This implies that entrepreneurs consume all the dividends received, d_t, and their lifetime utility function is $\sum_{j=0}^{\infty} \beta_c^{t+j} u(d_{t+j})$ where β_c is their discount factor. Consequently, their stochastic discount factor is given by $\Lambda^c_{t|t+j} = \beta_c^j u'(d_{t+j}) / u'(d_t)$. As mentioned, I assume that capitalists are relatively more impatient than households, i.e. $\beta_h > \beta_c$. This assumption is common in the literature and its importance will become clear once I discuss the borrowing constraint faced by firms.

Firms maximize the expected future stream of dividends, discounted by the stochastic discount factor of capitalists (firms' owners). Therefore, the firm's objective can be written as

$$\max \mathbb{E}_t \sum_{j=0}^{\infty} \Lambda^c_{t|t+j} d_{t+j}$$

Firms can borrow via a one-period riskless bond, b_{t+1}, whose gross interest rate is R_t. They utilize a standard Cobb-Douglas technology that uses capital, k, and labor, n_c, to produce a homogeneous good. Specifically,

$$y_t = z_t k_t^{\alpha} n_{c,t}^{1-\alpha}$$

[10]This assumption, also present in Perri and Quadrini (2011), can be justified on the basis of several empirical studies, in particular the pioneering work of Lintner (1956) and, more recently, Brav et al. (2005).

where z_t is the level of total factor productivity (TFP).

Firms choose, at time t, the level of capital that is going to be used in the production process at $t+1$. The law of motion for capital accumulation is

$$k_{t+1} = (1-\delta)k_t + i_t$$

where i_t is investment and δ is the constant depreciation rate. In addition, firms face costs associated with adjusting their investment, given by the function, $\Phi(i_t, k_t)$ whose structure will be specified below.

3.3 Labor Markets

Job matches are obtained from a Cobb-Douglas matching technology $m(u_t, v_t) = \bar{e}u_t^{\phi}v_t^{1-\phi}$, where $\bar{e}$ reflects the efficiency of the matching process and u_t and v_t are unemployment and vacancies posted by firms in period t, respectively. The probability that a firm fills a vacancy is given by $\mu(\theta_t) \equiv m(u_t, v_t)/v_t = \bar{e}\theta_t^{-\phi}$, where $\theta_t \equiv v_t/u_t$ represents the labor market tightness. Equivalently, $f(\theta_t) \equiv m(u_t, v_t)/u_t = \bar{e}\theta_t^{1-\phi}$ is the *job-finding rate.*

Every period, a fraction x of all employed workers are exogenously separated from firms. Therefore, employment is given by the previous period's workers that were not separated plus all the employees matched this period. Formally,

$$n_t = (1-x)n_{t-1} + m(u_t, v_t) \tag{1}$$

Since the population is normalized to one, unemployment in period t is given by

$$u_t = [1 - f(\theta_t)]\, u_{t-1} + x n_{t-1} \tag{2}$$

3.3.1 Financial Markets

In addition to the intertemporal loan, b_{t+1}, firms are required, due to a cash-flow mismatch, to raise funds via intra-period loans, l_t. Therefore, and following the recent literature, I assume that firms face working-capital needs that have to be satisfied by obtaining an intra-period loan to cover dividends as well as the total cost of production. Although many papers have incorporated working capital needs in the specification of the firm's problem, I will follow Jermann and Quadrini (2009) and assume that payments to workers, shareholders, investment expenditures, expenses related with creating a vacancy and hiring a worker, and current debt net of new issue, have to be made before the realization of revenues.[11] Therefore, the intra-period loan can be written as,

$$l_t = d_t + w_t n_{c,t} + \iota v_t \mu(\theta_t) + \psi(v_t) + i_t + \Phi(i_t, k_t) + b_t - \frac{b_{t+1}}{R_t}$$

Note that $l_t = y_t$. One can think of l_t as being the liquid funds that the firm possesses.[12]

Financial frictions arise due to the existence of costly contract enforcement. This implies that, due to the possibility of default that is assumed to arise before the payment of the intra-period loan and after production has taken place, firms are subject to a collateral requirement that is derived from an optimal contract. Furthermore, as is common in models that derive optimal contracts in the presence of working capital loans, following a default financial intermediaries can confiscate the capital but not what the firm has produced. In other words, the liquid funds cannot be recovered, only the installed capital. Explicitly, I am making the following assumptions,

Assumption 1 *The possibility of default arises at the end of the period, before the intra-period loan is due but after production is observed.*

Assumption 2 *Following a default, and before next period's capital is incorporated, financial intermediaries confiscate the firm and sell each unit of physical capital at* $\eta_t q_{k,t}$.

Assumption 3 *Following a default, production cannot be seized.*

These assumptions, similar to the ones present in Hart and Moore (1994) and Perri and Quadrini (2011), imply that firms are constrained in their ability to borrow. Specifically, the inter-period and intra-period loans are, as in Kiyotaki and Moore (1997), limited by their holdings of capital. However, since liquidation entails a costly process, lenders are only able recuperate a fraction η_t of the value of the physical capital stock held by the firm at time t. This value is given by $q_{k,t}k_t$, where $q_{k,t}$ is the shadow price of capital, measured in terms of consumption units. I follow Liu et al. (2010) by interpreting η_t as an exogenous "collateral shock," which reflects the uncertainty in the tightness of the credit market. From the lender's perspective, η_t captures the uncertainty with respect to the liquidation value of the firm and its dynamics are represented with the following stochastic process

$$\ln \eta_t = (1 - \rho_\eta) \ln \bar{\eta} + \rho_\eta \ln \eta_{t-1} + \epsilon_{\eta,t}$$

[11] See for instance Neumeyer and Perri (2005), Boz et al. (2009) and, recently, Perri and Quadrini (2011) and Abo-Zaid (2011) for other studies that incorporate working capital needs in the modeling of the firm.

[12] A similar interpretation is present in Perri and Quadrini (2011) and Jermann and Quadrini (2009).

with

$$\eta_t \sim \mathcal{N}(0, \sigma_\eta)$$

where $\bar{\eta}$ is the mean value of the process and ρ_η is its persistence.

I will further assume that,

Assumption 4 *In the case of default, financial intermediaries have no bargaining power in the debt re-negotiation and they do not value the stock of workers within the firm.*

Now I can state the following proposition, whose derivation is provided in Appendix B,

Proposition 1 *Under assumptions 1-4, the following enforcement constraint can be derived as an incentive compatible contract between financial intermediaries and firms:*

$$l_t + \frac{b_{t+1}}{R_t} \leq \eta_t q_{k,t} k_t \tag{3}$$

Since the model does not feature idiosyncratic shocks and I have assumed a continuum of firms, I focus on an equilibrium in which all firms are alike, i.e. a symmetric equilibrium where all the firms behave in the same way. This will allow me to assume a representative firm.

3.3.2 Household's Optimization Problem

Recall that $f(\theta_t)$ is defined as the job-finding rate, which the household takes as given. Hence, from the household's perspective, employment evolves according to

$$n_{h,t} = (1-x)n_{h,t-1} + f(\theta_t)u_t$$

Every period households will choose the level of consumption, c_t, the level of employment, $n_{h,t}$, and the number of riskless bonds in order to maximize expected discounted utility over consumption and leisure. Letting $\omega_t^h = \{n_{h,t-1}, a_t\}$ be the vector of individual states for households and $\Omega_t = \{K_t, n_{t-1}; z_t, \eta_t\}$ be the vector of aggregate states, the problem can be summarized as[13]

$$H_t\left(\omega_t^h; \Omega_t\right) = \max_{\{c_t, n_{h,t}, a_t\}_{t=0}^{\infty}} \left\{\ln(c_t) - \varphi n_t + \mathbb{E}_t \beta_h H_{t+1}\left(\omega_{t+1}^h; \Omega_{t+1}\right)\right\} \tag{4}$$

subject to

$$c_t + \frac{a_{t+1}}{R_t} + T_t = w_t n_{h,t} + a_t + u_t s \tag{5}$$

[13]Note that since the intra-period loans provided to the firms at the beginning of the period are repaid at the end of the period, they do not affect the household's decision and therefore they are being omitted in the problem.

The first-order conditions with respect to consumption and to riskless assets give the usual consumption Euler equation

$$1 = R_t \beta_h \, \mathrm{E}_t \, \frac{c_t}{c_{t+1}} \tag{6}$$

In the following sections, I will denote the discounted intertemporal marginal rate of substitution as $\Lambda^h_{t|t+1} \equiv \beta_h \left(c_t / c_{t+1} \right)$ which at the optimum will be equal to the household's stochastic discount factor.

3.3.3 Firm's Optimization Problem

Managers determine the measure of workers that will be active in the production process at period t, $n_{c,t}$, by posting vacancies, v_t. The costs associated with the latter are given by the function $\psi(v_t)$ which can be linear, concave, or convex depending on whether the marginal cost of vacancy postings are constant, diminishing, or increasing.[14] Since the probability that a firms fills a vacancy is given by $\mu(\theta_t)$, the total hiring of the firm at time t is given by $v_t \mu(\theta_t)$. The evolution of the number of workers in the firm is then,

$$n_{c,t} = (1 - x) n_{c,t-1} + v_t \mu(\theta_t)$$

The current workforce is the number of workers that were in the firm in the last period and were not separated, $(1 - x) n_{c,t-1}$, plus the total number of new hires, $v_t \mu(\theta_t)$.

In addition to these hiring costs, it is assumed that for each successful match firms have to pay a fixed cost, ι, as a 'start-up' cost. These costs are meant to capture costs associated with incorporating hired workers into the production process, such as training costs.[15] Consequently, the budget constraint faced by firms can be written as

$$z_t k_t^{\alpha} n_{c,t}^{1-\alpha} + \frac{b_{t+1}}{R_t} = d_t + w_t n_{c,t} + i_t + \Phi(i_t, k_t) + \iota v_t \mu(\theta_t) + \psi(v_t) + b_t$$

Firms, maximize capitalist's wealth by choosing dividends, d_t, the number of vacancies to post, v_t, the new debt that is going to be issued, b_{t+1}, the next period's capital stock, k_{t+1}, and the level of investment, i_t. Defining $\omega^e_t = \{k_t, n_{c,t-1}, b_t\}$ as the vector of individual states for the firm and as $\mathbf{r_t}$ the vector of choice variables, the problem can be written as

$$J_t \left(\omega^e_t ; \Omega_t \right) = \max_{\{\mathbf{r_t}\}_{t=0}^{\infty}} \left\{ d_t + \mathbb{E}_t \Lambda^c_{t|t+1} J_{t+1} \left(\omega^e_{t+1} ; \Omega_{t+1} \right) \right\} \tag{7}$$

[14] See Chugh (2009) for a similar treatment of the vacancy-posting costs.

[15] See for instance, Bartel (2000) and Acemoglu and Pischke (1998) for evidence in this regard. Acemoglu and Pischke (1998) show that if the current employer has more information regarding the employee's ability relative to other firms this encourages the current employer to pay for the training costs.

subject to

$$z_t k_t^{\alpha} n_{c,t}^{1-\alpha} - d_t + \frac{b_{t+1}}{R_t} - b_t - \Phi\left(i_t, k_t\right) = w_t n_{c,t} + i_t + \iota v_t \mu(\theta_t) + \psi(v_t) \tag{8}$$

$$k_{t+1} = (1-\delta)k_t + i_t \tag{9}$$

$$d_t + w_t n_{c,t} + \iota v_t \mu(\theta_t) + \psi(v_t) + i_t + \Phi(i_t, k_t) + b_t \leq \eta_t q_{k,t} k_t \tag{10}$$

$$n_{c,t} = (1-x) n_{c,t-1} + v_t \mu(\theta_t) \tag{11}$$

When optimizing, the individual firm takes as given the probability that a vacancy will be filled, $\mu(\theta_t)$, the gross interest rate, R_t, the stochastic discount factor, $\Lambda^e_{t|t+1}$, and the wage, w_t.

Letting $\mu_{c,t}, \mu_{k,t}, \mu_{b,t}$, and $\mu_{c,t}$ denote, respectively, the multipliers on the budget constraint, (8), the capital law of motion, (9), the borrowing constraint, (10), and the law of motion for employment, (11), the first-order necessary conditions can be written as

$$d_t: \quad \mu_{c,t} = 1 - \mu_{b,t} \tag{12}$$

$$b_t: \quad \frac{1}{R_t} = \mathbb{E}_t \Lambda^c_{t|t+1} \frac{\mu_{c,t+1}}{\mu_{c,t}} + \mathbb{E}_t \Lambda^c_{t|t+1} \frac{\mu_{b,t+1}}{\mu_{c,t}} \tag{13}$$

$$i_t: \quad q_{k,t} = (1+\Phi_i)\left(1 + \frac{\mu_{b,t}}{\mu_{c,t}}\right) \tag{14}$$

$$k_t: \quad q_{k,t} = \mathbb{E}_t \Lambda^c_{t|t+1} \left\{ \frac{\mu_{c,t+1}}{\mu_{c,t}} \left[\alpha z_{t+1} \left(\frac{n_{c,t+1}}{k_{t+1}} \right)^{1-\alpha} - \Phi_k + q_{k,t+1}(1-\delta) \right] + \frac{\mu_{b,t+1}}{\mu_{c,t}} \left(\eta_{t+1} q_{k,t+1} - \Phi_k \right) \right\} \tag{15}$$

$$v_t: \quad \frac{\mu_{c,t}}{\mu_{c,t}} = \left[\frac{\iota \mu(\theta_t) + \psi'(v_t)}{\mu(\theta_t)} \right] \left(1 + \frac{\mu_{b,t}}{\mu_{c,t}} \right) \tag{16}$$

where Φ_i and Φ_k are the first derivative of the investment adjustment cost function with respect to investment and capital, respectively.

3.3.4 Job Creation

The job-creation equation is necessary to solve the bargaining problem and analyze how financial frictions can affect the incentives of firms to create jobs; the first step in deriving it is to obtain the marginal value of having an extra worker in the firm. The marginal value of an extra worker, $\mathbf{J}_{n,t}$ can be obtained from taking the derivative of the firm's value function,

$\mathbf{J}_t$, with respect to employment. Formally,

$$\mathbf{J}_{n,t} = \left[(1-\alpha)z_t\left(\frac{k_t}{n_{c,t}}\right)^{\alpha} - w_t\right] - w_t\frac{\mu_{b,t}}{\mu_{c,t}} + \mathbb{E}_t\Lambda^c_{t|t+1}\frac{\mu_{c,t+1}}{\mu_{c,t}}(1-x)\mathbf{J}_{n,t+1} \tag{17}$$

The term in brackets corresponds to the net return of having an extra worker in the firm, while the third term is the present discounted value of the hired worker. The second term is a measure of how current credit conditions, captured by the multiplier on the borrowing constraint, affect the marginal value of having an extra worker. A tighter credit condition (higher μ_b) reduces the net value of the workers since wages are relatively more costly. Put differently, the working capital requirement on wages reduces the marginal benefit of hiring a worker by a factor of $\gamma\mu_{b,t}/\mu_{c,t}$.

The job-creation equation is obtained by combining (16) and (17) to get:

$$\begin{aligned}\frac{\iota\mu(\theta_t)+\psi'(v_t)}{\mu(\theta_t)}\left(1+\frac{\mu_{b,t}}{1-\mu_{b,t}}\right) =& (1-\alpha)z_t\left(\frac{k_t}{n_{c,t}}\right)^{\alpha} - w_t\left(1+\frac{\mu_{b,t}}{1-\mu_{b,t}}\right)\\ &+ \mathbb{E}_t\Lambda^c_{t|t+1}\frac{\mu_{c,t+1}}{\mu_{c,t}}(1-x)\left[\frac{\iota\mu(\theta_{t+1})+\psi'(v_{t+1})}{\mu(\theta_{t+1})}\left(1+\frac{\mu_{b,t+1}}{1-\mu_{b,t+1}}\right)\right]\end{aligned} \tag{18}$$

Condition (18) equates the marginal cost of hiring an employee with its marginal benefit net of wages. Note that in the absence of financial frictions the borrowing constraint disappears and so does the multiplier μ_b. The job-creation equation in a standard DSGE search model is a particular case of (18), in which households and capitalists have the same discount factor and there are no credit frictions:

$$\frac{\iota\mu(\theta_t)+\psi'(v_t)}{\mu(\theta_t)} = (1-\alpha)z_t\left(\frac{k_t}{n_{c,t}}\right)^{\alpha} - w_t + \mathbb{E}_t\Lambda^h_{t|t+1}(1-x)\left[\frac{\iota\mu(\theta_{t+1})+\psi'(v_{t+1})}{\mu(\theta_{t+1})}\right] \tag{19}$$

It should be clear now how credit constraints affect the firm's ability to create jobs and how credit shocks can have a persistent effect on unemployment. Consistent with other studies that focus on other forms of financial imperfections, financial frictions represented by borrowing constraints create a wedge in the standard job-creation equation.[16] To the extent the constraint is binding, if firms need to finance the costs associated with vacancy posting and with incorporating a worker into the production process, the marginal cost of hiring an employee is increased by a factor of $\mu_{b,t}/(1-\mu_{b,t})$. Defining the latter term as $\Psi(\mu_{b,t})$ then, since $\Psi_{\mu_b} > 0$, a shock that makes the constraint tighter will significantly reduce the

[16] See for instance Petrosky-Nadeau (2011).

ability of firms to create jobs by increasing the marginal cost associated with hiring a worker. This multiplier, as expected, will be influenced by fluctuations in collateral requirements. Financial constraints introduce a direct mechanism that captures the interaction between credit availability and job creation.

In contrast with Petrosky-Nadeau (2011), productivity shocks in this environment will not generate important movements in labor market variables. This is due to the fact that under borrowing constraints productivity shocks, besides not generating important movements in the price of capital (the asset used as collateral), move the incentive of firms to post vacancies in the same direction that they move the constraint. Put differently, periods characterized by low realizations of TFP are periods in which the firms would not be willing to increase their hiring.[17] Iterating forward the job-creation equation yields,

$$\frac{\iota\mu(\theta_t)+\psi'(v_t)}{\mu(\theta_t)}\left(1+\frac{\mu_{b,t}}{1-\mu_{b,t}}\right)=\mathbb{E}_t\sum_{j=0}^{\infty}\prod_{i=0}^{j}(1-x)\,\Lambda^c_{t+j|t+j+1}\left[F_n(k_{t+j},n_{c,t+j})-w_{t+j}\right] \quad (20)$$

where F_n is the marginal product of labor. Expression (20) shows that the marginal cost of creating a vacancy and hiring an employee is equal to the expected discounted marginal profit of doing so. In particular, the marginal benefits are not only being discounted by the intertemporal marginal rate of substitution but also by the probability that the match is separated in a future period. Due to the reduced survival probability, the value of having an extra employee is being discounted at a higher rate.

3.4 Wage Bargaining and Equilibrium

Since the goal of this paper is to study the effects of credit shocks in the presence of frictions in the labor markets, I depart from other recent papers that have focused on the effects of credit shocks on macroeconomic aggregates by assuming that wages are not determined in a Walrasian market.[18] As is common in the labor search literature, wages are determined as the solution to a Nash bargaining problem between workers and firms. Moreover, I assume that the cost associated with incorporating a newly-hired worker into production is paid before negotiation takes place. This means that wages for newly hired workers are determined

[17] This is consistent with previous research that finds that neutral technology shocks fail to generate strong financial multiplier effects due to the fact they do not move asset prices by much (Kocherlakota (2000), Cordoba and Ripoll (2004), and Liu et al. (2010)). The reason is because since those shocks move dividends and loan rates in the same direction, they do not generate large fluctuations in the price of the collateral asset and hence, as mentioned by Liu et al. (2010), their impact does not work through the credit constraints that affect the firm's ability to borrow.

[18] Example of these studies are Liu et al. (2010) and Jermann and Quadrini (2009).

just as for existent workers.[19] Letting $\theta \in (0,1)$ be the bargaining power of workers in the negotiation of wages, the wage is a solution to the following problem

$$w_t^* = \underset{w_t}{\operatorname{argmax}} \, \mathbf{J}_{n,t}^{1-\theta} \mathbf{H}_{m,t}^{\theta} \tag{21}$$

where $\mathbf{H}_{m,t}$ is the household's marginal value of having one more worker employed. The first-order conditions are given by,

$$\varrho_t \mathbf{J}_{n,t} = (1 - \varrho_t) \mathbf{H}_{m,t}$$

where

$$\varrho_t = \frac{\theta}{\theta + (1-\theta)\left(1 + \frac{\mu_{b,t}}{1-\mu_{b,t}}\right)}$$

This differs from the usual applications of Nash bargaining in that the firm's effective bargaining position, ϱ_t, is now a function of the credit conditions because any changes in wages affect the marginal value of having an extra worker employed, $\mathbf{J}_{n,t}$.[20] Intuitively, a tighter credit constraint, i.e. a higher $\mu_{b,t}$, benefits the firm's bargaining position since its surplus becomes relatively more sensitive to movements in wages. Although a tighter credit constraint may dampen the reduction in wages that may follow a negative shock, it will also increase the sensitivity of the firm with respect to changes in wages, generating more movements in labor market variables.

The solution to the problem given by (21) is derived in detail in Appendix A. Specifically,

$$\begin{aligned} w_t^* =& \frac{\theta}{1+\vartheta_t}\left[F_n + (1-x)\mathbb{E}_t \frac{\mu_{e,t+1}}{\mu_{e,t}} \Lambda^e_{t|t+1} \frac{\iota\mu(\theta_t) + \psi'(v_t)}{\mu(\theta_t)}(1+\varpi_t)\right] + (1-\theta)\left(\frac{\varphi}{\mu_{h,t}} + \tau\right) \\ &- \mathbb{E}_t \frac{\theta}{1+\vartheta_{t+1}}\left[\Lambda^h_{t|t+1} \frac{\iota\mu(\theta_{t+1}) + \psi'(v_{t+1})}{\mu(\theta_{t+1})}(1+\varpi_{t+1})\left(1 - x - f\left(\theta_{t+1}\right)\right)\right] \end{aligned} \tag{22}$$

where $\vartheta_t = 1 + \mu_{b,t}/(1-\mu_{b,t})$, $\varpi_t = 1 + \mu_{b,t}/(1-\mu_{b,t})$.

In words, the wage that solves the Nash bargaining problem will be a convex combination of the value of an extra worker for the firm and the marginal rate of substitution between consumption and leisure for the household. As a particular case, if the discount factors were the same for both the firm and the households, and the borrowing constraint were not binding ($\mu_{b,t} = 0$), the wage would be the static split

[19] Chugh (2009) and Hristov (2010) also impose the bargained wage to both newly-hired and existent workers.

[20] This comes from the fact that in the usual applications of the Nash bargaining the derivative of the job creation equation with respect to wages is equal to one however, with working capital requirements that is no longer the case.

$$w_t^* = \theta \left[(1-\alpha) z_t \left(\frac{k_t}{n_t} \right)^{\alpha} \right] + (1-\theta)(\varphi c_t + \tau)$$

which is the standard solution to DSGE search models with frictionless financial markets.

Now that all aspects of the model have been discussed, a recursive equilibrium of the model can be defined:

Definition 1 (Equilibrium) *A recursive equilibrium is defined as a set of i) firm's policy functions* $d(\omega^c;\Omega), n_c(\omega^c;\Omega), k(\omega^c;\Omega), b(\omega^c;\Omega), i(\omega^c;\Omega)$, *and* $v(\omega^c;\Omega)$; *ii) household's policy functions* $c(\omega^h;\Omega)$, $n_h(\omega^h;\Omega)$, *and* $a(\omega^h;\Omega)$; *iii) the government has a balanced budget so that* $s = T$, *iv) prices* $w(\Omega)$ *and* $R(\Omega)$; *and v) law of motion for the aggregate states,* $\Omega_{t+1} = \psi(\Omega_t)$, *such that: i) firms' policies satisfy conditions (12)-(16); ii) household's policy function satisfies (6); iii) the wage is determined by (22); iv)* R_t *clears the market for the riskless asset such that* $a_t = b_t$; *v) labor demanded by firms is equal to labor supplied by workers,* $n_c(\omega^c;\Omega) = n_h(\omega^h;\Omega)$; *vi) law of motion* $\psi(\Omega)$ *is consistent with individual decisions and with the stochastic processes for* z *and* η.

4 Quantitative Analysis

This section discusses the calibration of parameters used in the quantitative analysis, briefly discusses the solution method, and presents the main results.

4.1 Benchmark Parametrization

The functional forms for preferences, adjustment costs, and vacancy costs are presented in Table 1. The investment adjustment cost function is given by a standard increasing and convex function which, as usual, does not have any effect on steady state values ($\bar{i} = \delta \bar{k}$). As in Perri and Quadrini (2011), capitalists are assumed to have a standard CRRA utility function. The choice for specifying a general formulation for vacancy posting costs follows Chugh (2009). While in the baseline case it is assumed that the function is linear, I will study the implications of different assumptions regarding its curvature as a robustness exercise.

Table 1: Functional Forms

Function	Description	Functional form
$u(d_t)$	Utility of capitalists	$\frac{d_t^{1-\sigma}-1}{1-\sigma}$
$\Phi(i_t, k_t)$	Investment adjustment cost	$\frac{\xi}{2}\left(\frac{i_t}{k_t} - \bar{\delta}\right)^2 k_t$
$\psi(v_t)$	Vacancy creation cost	κv_t^{χ}

The values of the parameters for the baseline case can be seen in Tables 2 and 3. The parameter that governs the disutility of labor, φ, is chosen to match a steady state unemployment rate of 10%. Since the model does not account for non-participation, this target is higher than the average US unemployment rate so that unemployment in the model can be interpreted as being a mix between unemployed and partially out of the labor force workers.[21]

The unit of time is taken to be a quarter. As is standard in the literature, the elasticity of labor in the production function is set to 0.33 while the quarterly depreciation rate for capital is set to 2%. The parameter that regulates the curvature of the investment adjustment cost function is set to 2. This value, although in the high end of the values used in the literature, does not significantly affect the quantitative or qualitative properties of the model.

The parameter chosen for the separation rate is set to 6%, a value also present in Petrosky-Nadeau (2011), and based on the evidence presented by Rotemberg (2006). The 'start-up' cost is set to 0.9, so that these costs (training cost, physical equipment, etc.) account for two months worth of wages in the steady state. Although it is difficult to find evidence to calibrate this parameter, it seems reasonable to assume that employers incur total costs that represent less than 7% of the total wages paid over the average tenure when incorporating a new worker into production. Unemployment benefits, s, are set to 0.6, implying a replacement ratio s/w, of 0.44. This value is a conservative one, and is in the lower spectrum of the values found in the literature.[22] With this low level, the model will not have significant amplification through this channel, since a higher replacement ratio implies that the worker's surplus from a match is not very high. This generates more incentives for firms to post vacancies and increases the amplification of labor market variables in response to productivity shocks (Hagedorn and Manovskii (2008)).

The standard deviations for the productivity shock and the credit shock are jointly calibrated to match the standard deviations observed in the data for both output and the debt-to-GDP ratio. The mean of the latter process is set to target the empirical mean of the same ratio, i.e. setting the steady-state collateral requirement to 50% of the value of the physical capital stocks delivers a debt-to-GDP ratio equal to 2.[23]

Finally, given that the model contains a large number of continuous state variables, I solve it by relying on a quadratic approximation around the non-stochastic steady state, as

[21] For analogous reasons, 10% of unemployment is also chosen in the calibration presented in Chugh (2009) and Petrosky-Nadeau (2011). Similarly, in order to account for discouraged workers workers and workers that are not strongly attached to the labor force, Krause and Lubik (2007) set a target of steady state unemployment of 12%. Values higher than these can be found in Andolfatto (1996) (43%) and Trigari (2009) (25.3%).

[22] For instance, Rotemberg (2006) uses a replacement ratio of 0.9 while Petrosky-Nadeau (2011) choses a much lower value of 0.75.

[23] Perri and Quadrini (2011) also set the mean of the loan-to-value ratio equal to 0.5.

presented in Schmitt-Grohe and Uribe (2004).[24]

Table 2: Value of parameters

Parameter	Description	Value	Source/Rationale
β_h	Household's discount factor	0.99	Carlstrom & Fuerst (1998)
β_c	Entrepreneurs' discount factor	$0.947\beta_h$	Carlstrom & Fuerst (1998)
φ	Disutility of labor	0.26	$\bar{u} = 10\%$
s	Unemployment benefits	0.60	$s/\bar{w} = 0.44$
α	Share of capital in the production function	0.33	Literature
ξ	Investment adjustment cost	2	Literature
δ	Capital depreciation rate	0.02	Literature
$\bar{x}$	Separation rate	0.06	Rotemberg (2006)
ϕ	Elasticity of matches w.r.t. unemployment	0.50	Chugh (2009)
τ	Worker's bargaining power	0.40	Literature
$\bar{e}$	Efficiency of the match	0.69	Match $\mu(\bar{\theta}) = 0.9$
ι	'Start-up' or 'Training' cost	0.90	Two months of wages
κ	Vacancy cost	0.18	$\bar{v}\kappa/\bar{y} = 0.5\%$
χ	Curvature of vacancy creation costs	1	Constant returns

Table 3: Parameters for Stochastic Processes

Parameter	Description	Value	Source/Rationale
$\bar{\eta}$	Steady-state credit market tightness	0.50	Match $\bar{b}/\bar{y} = 2$
ρ_z	Persistence of aggregate productivity	0.95	Chugh (2009)
ρ_η	Persistence of credit shock	0.97	Liu et. al. (2010)
σ_z	Standard deviation of productivity shock	0.0108	Match $\sigma_y = 0.0265$
σ_η	Standard deviation of credit shock	0.0096	Match $\sigma_{b/y} = 0.0731$

4.1.1 Impulse Response: TFP Shock

Next I present results from impulse response analysis of a shock that occurs at period 1. In the following graphs the scale represents gross percentage deviations from the steady state, except for the job-finding rate, which represents percentage point deviations from steady state.

Figure 3 shows the response of some of the variables of the model to a one standard deviation positive shock to aggregate productivity. Most of these movements conform with standard intuition. Following a positive technology shock firms increase their hiring, with vacancies increasing on impact almost by 3%. At the same time, unemployment decreases, causing an even larger increase in labor market tightness (θ) and a movement along the Beveridge curve. The increase in investment is also significant (4% on impact). This reflects the fact that capital is the only asset that can be used as collateral and the positive shock provides firms with an incentive to increase their stock of it. The persistence of the shock

[24] More details are given in the D.

translates into persistence in the variables of interest as well. The increase in household's consumption is strong. As entrepreneurs increase their borrowing in response to the productivity shock, the interest accrued on higher debt holdings allows households to afford a higher level of consumption.

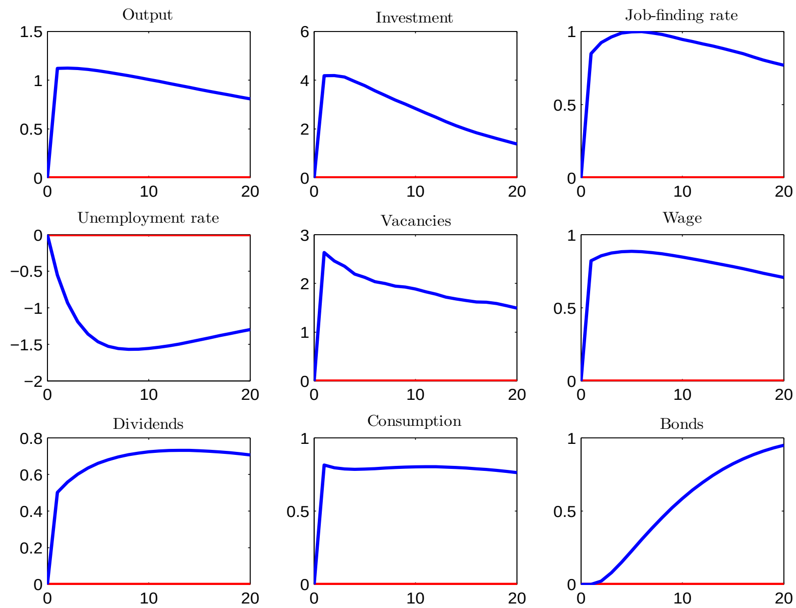


Figure 3: TFP Shock

4.1.2 Impulse Response: Credit Shock

Figure 4 plots the response to a one standard deviation negative shock to credit market tightness. In other words, firms' leverage is exogenously decreased and firms are able to borrow a smaller fraction of their collateral.

On impact all variables respond as one might expect. The credit shock decreases the firm's ability to access funding and the firm responds by decreasing investment, employment, and borrowing. The reduction of investment decreases future levels of the capital stock, which in turn further decreases the firm's ability to borrow, thus serving as an endogenous propagation mechanism. The persistent reduction in investment follows from the shock: since the credit constraint is tighter for several periods, the increase in the value of relaxing it is long lasting (the increase in μ_b is persistent), which in turn causes a prolonged increase in the marginal cost of investing.

With respect to labor market variables, there is a significant cut in vacancies on impact and even though they recover within one year, this leads to a persistent increase in unemployment. The latter takes more than 2.5 years to return to its steady-state value. It is important to mention that, contrary to Monacelli et al. (2011), who find that periods in which credit is tighter are favorable to workers, in this case the tightening in credit conditions causes unemployment to rise despite the behavior of wages, which on impact decrease by more than 1.5%.

Following the shock, firms also reduce their level of borrowing. This deleveraging is consistent with recent empirical evidence that suggests that periods in which the ability to borrow is reduced are characterized by a reduction in the firm's debt holdings. This, in turn, implies a reduction in the payment of interest which allows firms to distribute more dividends. Put differently, the negative shock reduces the firms' ability to borrow, which in turn diminishes loan liabilities and therefore leads to an increase in net worth. The household, on the other hand, responds on impact by increasing their consumption since the reduction in interest rates decreases the incentive to save. In later periods, however, both lower wages and the reduced interest payments received from firms bring consumption below the steady state. As the deleveraging is very persistent, so is the longer term reduction in consumption.

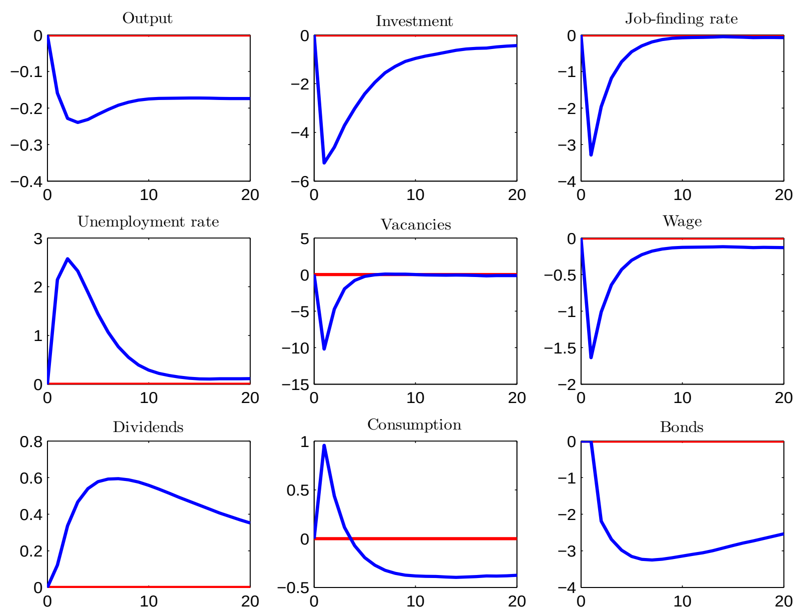


Figure 4: Negative Credit Shock

4.2 Business Cycles

Table 4 shows some standard business cycle statistics from the data alongside their counterparts from the model's simulation. The data are from the first quarter of 1951 to the last quarter of 2010. Each moment is calculated as the difference between the log level of each series and the trend obtained by filtering the data using a Hodrick-Prescott filter with a smoothing parameter of 100,000 as in Shimer (2005).

From the business cycle statistics it can be seen that the model performs quantitatively well in accounting for most of the cross-correlations and volatilities. Recall that the volatility of output was a target of the calibration so it is not a surprise that the model matches its value. The model generates a slightly higher volatility of investment, but it does a good job in matching its persistence and its correlations with other macroeconomic variables. The correlations of average labor productivity, y/n, are also qualitatively in line with the data and even though its volatility is higher in the model, its persistence is nearly matched. The model, however, cannot account for the low procyclicality of labor productivity observed in the data for the entire sample. This suggests that financial frictions and credit shocks, as introduced in this environment, are not *per se* able to account for the switch in cyclicality of labor productivity and other changes regarding fluctuations in US macroeconomic aggregates experienced after the mid-eighties.[25]

For this sample, the model accounts for roughly half of the variations observed in labor market tightness and nearly 80% of the variation in vacancies. However, it falls short in generating fluctuations in unemployment of similar magnitude to those in the data. Nevertheless, unemployment volatility is 2.1 times that of output, which is a significant improvement from standard labor search models that generate variations of unemployment that fall well short of those in output.[26] Introducing financial frictions that arise from a costly state verification problem, Petrosky-Nadeau (2011) presents a model that can generate unemployment that is 2.37 times more volatile than output. The shortcoming of the baseline model presented here with respect to Petrosky-Nadeau (2011) is not surprising if we consider that by giving firms the possibility of accumulating physical capital (absent in the cited study), the model presented here introduces another margin by which firms can respond to shocks.

The model also is able to generate a very persistent unemployment rate. As will be discussed later, this propagation is not caused by credit shocks. The persistence of output, labor productivity, and investment also align with the values observed in the data. Even though the model cannot account for the persistence in vacancies and labor market tightness, it performs quantitatively well in matching most of its cross correlations. In particular, the model captures quite well the Beveridge curve – the strong negative relationship between vacancies and unemployment – observed in the data. Overall, the model quantitatively captures some of the most relevant economic aggregates for the U.S. economy for the post-Second World War period.

[25] See Garin et al. (2011) for a description of these changes as well as a framework that can account for them.

[26] See for instance Shimer (2005) and Petrosky-Nadeau and Wasmer (2011).

Table 4: Business Cycles Statistics

		u	v	θ	i	y	y/n
Data							
σ		0.1987	0.1678	0.3486	0.1041	0.0265	0.0145
ρ		0.9496	0.9360	0.9457	0.8807	0.9416	0.8904
	u	1	-0.8695	-0.9609	-0.6942	-0.8836	-0.2677
	v		1	0.9932	0.7811	0.8040	0.3033
Correlation	θ			1	0.7635	0.8627	0.2996
Matrix	i				1	0.8119	0.4813
	y					1	0.5389
	y/n						1
Model							
		u	v	θ	i	y	y/n
σ		0.0552	0.1354	0.1782	0.1407	0.0265	0.0223
ρ		0.8643	0.3027	0.4715	0.6910	0.9085	0.8855
	u	1	-0.6935	-0.8368	-0.8835	-0.7372	-0.5974
	v		1	0.9748	0.8625	0.4705	0.3660
Correlation	θ			1	0.9291	0.5859	0.4632
Matrix	i				1	0.7057	0.5925
	y					1	0.9823
	y/n						1

The moments from the model were obtained by simulating it for 237 periods (the number of periods in the data sample) and repeating the exercise 500 times. The first and second moments reported in the table are the values obtained from calculating the median across simulations.

4.3 Importance of Credit Shocks

To evaluate the contribution of credit shocks in generating fluctuations in labor market variables, I simulate the model with one shock at a time. Table 5 reports the results obtained from simulating the model with only aggregate productivity shocks and another simulation with only credit disturbances.

Relative to the benchmark, the model with only productivity shocks does a better job in matching the cross correlations of labor market variables and output observed in the data. Furthermore, having only productivity shocks noticeably increases the persistence of unemployment, vacancies, and labor market tightness. Nevertheless, it is clear that the model lacks amplification in terms of labor market variables. In particular, fluctuations in job creation and labor market tightness are reduced by more than 50% relative to the model in which both shocks are present.

The high responsiveness of wages to productivity shocks is reflected in a high elasticity of wages with respect to productivity, which is equal to 0.9230. This is significantly higher than the value observed in the data (0.53).[27] Given this high elasticity, it is not surprising

[27]This elasticity, which can be denoted by $\zeta_{z,w}$, is calculated as the product of the correlation coefficient between wages and productivity (0.8306), and the relative standard deviations of wages and productivity (1.096); formally $\zeta_{z,w} = \rho_{z,w} (\sigma_w/\sigma_z)$ (the regression coefficient of wages on productivity, with both variables

that the model with only TFP shocks does not generate enough fluctuations in labor market variables.

Table 5: Business Cycles Statistics

		u	v	θ	i	y	y/n
Model with only TFP shocks							
σ		0.0304	0.0600	0.0972	0.0957	0.0262	0.0221
ρ		0.9787	0.9033	0.9440	0.9295	0.9092	0.8850
Correlation Matrix	u	1	-0.8741	-0.9541	-0.8345	-0.9248	-0.8924
	v		1	0.9795	0.9659	0.9890	0.9943
	θ			1	0.9420	0.9937	0.9835
	i				1	0.9467	0.9522
	y					1	0.9970
	y/n						1
Model with only credit Shocks							
		u	v	θ	i	y	y/n
σ		0.0377	0.1214	0.1494	0.1023	0.0040	0.0033
ρ		0.7333	0.1564	0.2715	0.4859	0.8784	0.9102
Correlation Matrix	u	1	-0.6709	-0.7979	-0.9365	-0.6721	0.4625
	v		1	0.9823	0.8696	0.2786	-0.5166
	θ			1	0.9433	0.3961	-0.5367
	i				1	0.6277	-0.4352
	y					1	0.3457
	y/n						1

The moments from the model were obtained by simulating it for 237 periods (the number of periods in the data sample) and repeating the exercise 500 times. The first and second moments reported in the table are the values obtained from calculating the median across simulations.

The importance of credit shocks in generating cyclical movements in labor market variables is made clear by looking at the behavior of the model with only those disturbances. The relative success of credit shocks in generating fluctuations in the labor market can be traced back to the job-creation equation previously discussed. Relative to a standard model, the wedge introduced in the job-creation equation in the model with borrowing constraints acts as a mechanism that amplifies the dynamic response of firms to shocks that reduce their ability to borrow. Despite generating less persistence in labor market variables, almost half of the variations in unemployment, vacancies, and labor market tightness can be accounted for by only having exogenous fluctuations in collateral requirements.

Consequently, relative to TFP shocks, wages are quite unresponsive with respect to financial disturbances, evidenced by a very low elasticity. Put differently, with an elasticity of wages with respect to credit shocks of 0.2820, credit shocks do not affect wages significantly, which implies more movements along the extensive margin.

in log-scale).

4.4 Further Experiments

This section examines the sensitivity of the results to changes in different parameters of the model and it performs some quantitative experiments. I will start by studying the effects of different values of some of the parameters of the model.

4.4.1 Importance of Unemployment Benefits

A key parameter in the model is the value chosen for unemployment benefits. Because by increasing the payments that household obtain from non-market activities, the surplus of forming a match decreases; therefore an increase in productivity will tend to generate larger changes in the surplus, increasing the incentives of posting vacancies.

Table 6: Relevance of Unemployment Benefits

Low Unemployment Benefits ($s = 0.4$)							
		u	v	θ	i	y	y/n
σ		0.0447	0.0977	0.1343	0.1371	0.0252	0.0230
ρ		0.8215	0.2814	0.4591	0.6700	0.9034	0.8909
Correlation Matrix	u	1	-0.7427	-0.8734	-0.8902	-0.6570	-0.5616
	v		1	0.9748	0.8642	0.4236	0.3466
	θ			1	0.9252	0.5270	0.4392
	i				1	0.6864	0.6114
	y					1	0.9928
	y/n						1
High Unemployment Benefits ($s = 0.8$)							
		u	v	θ	i	y	y/n
σ		0.0688	0.2151	0.2630	0.1488	0.0299	0.0206
ρ		0.9038	0.3102	0.4513	0.7358	0.9191	0.8681
Correlation Matrix	u	1	-0.6148	-0.7643	-0.8823	-0.8300	-0.5891
	v		1	0.9785	0.8256	0.5071	0.3576
	θ			1	0.9059	0.6317	0.4465
	i				1	0.7426	0.5866
	y					1	0.5347
	y/n						1

The moments from the model were obtained by simulating it for 237 periods (the number of periods in the data sample) and repeating the exercise 500 times. The first and second moments reported in the table are the values obtained from calculating the median across simulations.

The performance of the model under two different parameterizations of the value of unemployment benefits can be seen in Table 6. The model does reasonably well under both scenarios in terms of matching the cross-correlations observed in the data. As expected, higher unemployment benefits cause an increase in the volatility of labor market variables.

Specifically, the replacement rate, i.e. the ratio $s/\bar{w}$, under the scenario in which unemployment benefits are set to 0.6 is equal 0.57, a value significantly lower than the ones commonly used in the literature.[28] Nevertheless the model with this parametrization produces a standard deviation of unemployment that is almost 1.8 times that of output, which is still considerably higher than the relative volatility generated by a standard frictionless model.

4.4.2 Investment Adjustment Costs

An important parameter of the model is the curvature of the investment adjustment cost function, which directly affects the value of capital, q_k. Therefore, it is important to examine whether the performance of the model in the baseline case is driven by the relatively high value for the parameter that regulates the magnitude of those costs, ξ.

Table 7: Importance of Investment Adjustment Costs

Small Investment Adjustment Costs ($\xi = 0.5$)							
		u	v	θ	i	y	y/n
σ		0.0516	0.1177	0.1585	0.1503	0.0266	0.0225
ρ		0.8888	0.3639	0.5383	0.7093	0.9115	0.8874
	u	1	-0.7082	-0.8516	-0.8612	-0.7598	-0.6406
	v		1	0.9732	0.8775	0.5160	0.4276
Correlation	θ			1	0.9321	0.6306	0.5261
Matrix	i				1	0.6917	0.5958
	y					1	0.9860
	y/n						1

The moments from the model were obtained by simulating it for 237 periods (the number of periods in the data sample) and repeating the exercise 500 times. The first and second moments reported in the table are the values obtained from calculating the median across simulations.

Table 7 presents those results. Reducing the value of ξ from 2 to 0.5 does not qualitatively affect the results obtained in previous sections.[29] Facing lower costs of adjusting investment, firms are more willing to respond to shocks by adjusting on that dimension. This, as expected, increases the volatility of investment, while reducing its persistence. By decreasing the costs of adjusting investment the costs of adjusting employment are relatively higher, leading to a small reduction in the volatility of labor market variables. This reduction, however, does not qualitatively affect previous conclusions.

4.4.3 Relevance of Margin Requirements

One important matter from a policy perspective is how the extent to which firms are constrained, as measured by their collateral requirements, affects the dynamics of the model

[28]For instance, in Hagedorn and Manovskii (2008) the implied replacement ratio is equal to 0.96 while Rotemberg (2006) chooses a value of 0.9; meanwhile Petrosky-Nadeau (2011), choosing a conservative parametrization for unemployment benefits, sets a value of 0.75.

[29]This conclusion remains unchanged for values much lower than 0.5.

and the steady state value of unemployment. In addition, if the collateral requirements that arise from the financial friction are important in generating fluctuations, one should expect that as margin requirements increase so should a firm's response to economic conditions. Here I perform an exercise to study the extent to which that is true.

The dynamic responses of the model to both shocks are presented in Figures 5 and 6 which, differing from previous plots, only show the impulse responses for 10 periods.[30] Borrowing constraints do not seem to considerably affect the impulse responses of output and investment, although they do slightly increase the persistence of unemployment with respect to productivity shocks. More importantly, as firms are more constrained the response of vacancies becomes more sluggish. This is in line with the empirical evidence presented by Fujita and Ramey (2007), who show, using reduced form VARs, that the empirical peak of vacancies in response to a neutral productivity shock occurs several periods after the shock.

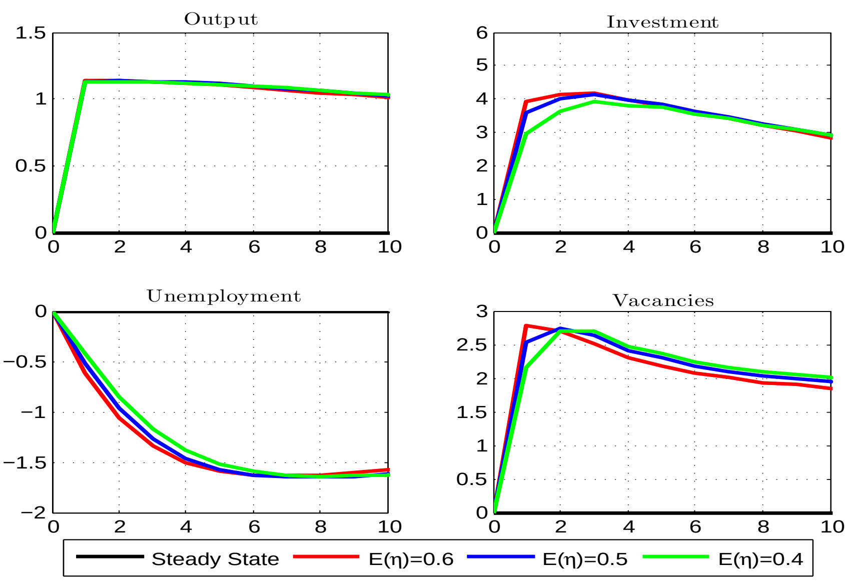


Figure 5: Positive TFP Shock

The results are very different when considering the response to a financial shock with different steady state values for the collateral requirement. Besides reducing vacancies by more on impact, higher margins also generate a considerably more persistent response of unemployment. The degree to which firms are constrained also affects the response of investment. In the case in which the loan-to-value ratio is equal to 60%, investment decreases on impact by 7% points from its steady state value; with a loan-to-value ratio of 40% the reduction is more than 10%. The reduction in both vacancy posting and investment generates a small

[30]The reason for presenting the results in this fashion is that the response differs most in the alternative scenarios within the first 2 years, the differences in the responses are better appreciated by having fewer periods.

but very persistent contraction in output.

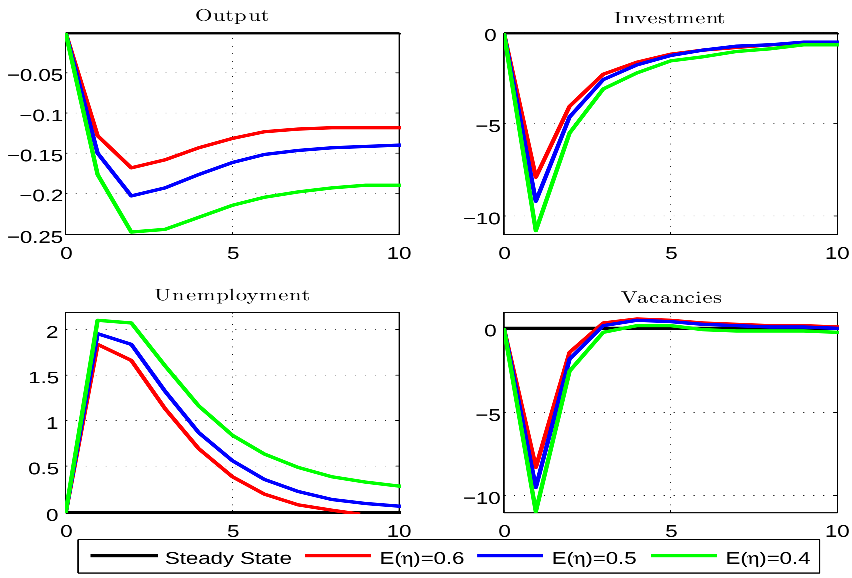


Figure 6: Negative Credit Shock

Table 8: Effects of Different Collateral Requirements

	$\bar{\eta}$		
	0.4	0.5	0.6
$\bar{u}$	0.111	0.10	0.092
σ_u	0.0594	0.0552	0.0531
σ_y	0.0268	0.0265	0.0263

Steady-state values and volatilities for the three different values of steady-state collateral are shown in Table 8. The findings are consistent with Acemoglu (2001), who shows that financial frictions affect the steady-state values of unemployment. In the present model, the reduction in the latter comes from reducing the ability of firms to borrow by increasing the collateral requirements. Consider the case in which $\eta = 0.6$; that is, financial intermediaries require a margin equal to 40%, and hence leverage is equal to 2.5.[31] Steady state unemployment in this case is equal to 9.3%, with a standard deviation relative to output of 2.12. Reducing η from 0.6 to 0.4, that is reducing leverage ratios by 1/3, raises steady state unemployment by almost 2 percentage points. The relative volatility, in turn, increases by 5%.

[31]The leverage is the reciprocal of the margin, while the margin is equal to one minus the loan-to-value ratio or 1-η. Therefore the leverage is defined as $1/(1-\eta)$.

5 Conclusion

This paper examines how firms that are constrained in their ability to borrow are affected by fluctuations in financial conditions and, in particular, how these constraints affect both the capacity and their incentives to post vacancies and create new jobs. In order to address this issue, and to analyze the extent to which variations in collateral requirements can influence unemployment and job creation, I provide a stochastic general equilibrium environment with labor market frictions. The model is well suited to study the dynamics of unemployment and job creation that follow a tightening in credit availability, similar to the events associated with the so-called "Great Recession."

I find that productivity shocks are important in generating fluctuations in aggregates such as output and investment, but they are not able to generate significant fluctuations in labor market variables. On the other hand, I find that fluctuations in collateral requirements can indeed generate significant movements in key labor market variables. Specifically, credit shocks have important effects in accounting for fluctuations of key labor market variables like unemployment, vacancy posting, and labor market tightness. This results from the fact that while wages are very sensitive to productivity shocks, credit shocks are not. Because changes in collateral requirements do not translate into large changes in wages, these disturbances have large effects on the ability of firms to create jobs. In addition to this, I find that if firms face, on average, tighter collateral constraints, then the response of labor market variables to financial shocks is greater. In other words, reducing the steady state value collateral value of capital increases the extent to which firms decrease job creation following a negative credit shock, and increases the persistence of unemployment.

In future research it would be useful to endogenize the collateral fluctuations that, in this paper, were taken as a reduced form way of capturing the varying financial conditions faced by firms. A more complete panorama of the iteration between unemployment, asset prices, and their linkages with credit conditions would be accomplished by explicitly modeling the financial sector.

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A Nash Bargaining

In order to set up the optimization problem, I need to define the marginal value of having an family member matched from the household perspective, $\mathbf{H}_{m,t}$. Note that from the household's perspective, employment evolves according to

$$n_{h,t} = (1 - x_t)n_{h,t-1} + f(\theta_t)u_t$$

The value function associated with having an extra member working was defined as $\mathbf{H}_t$.[32] Therefore, the envelope condition is given by

$$\mathbf{H}_{n,t} = -\varphi + \mu_{h,t}w_t + \beta_h \left[(1 - x)\mathbf{H}_{n,t+1} + x\mathbf{H}_{u,t+1}\right] \tag{23}$$

where $\mu_{h,t}$ is the Lagrange multiplier on the budget constraint and $\mathbf{H}_{u,t}$ is the value of having an extra family member unemployed during next period. Similarly, the value of having an extra unemployed member at time t is given by

$$\mathbf{H}_{u,t} = \mu_{h,t}\tau + \beta_h \left[(1 - f(\theta_t))\,\mathbf{H}_{u,t+1} + f(\theta_t)\mathbf{H}_{n,t+1}\right] \tag{24}$$

The household's marginal surplus of a match is therefore defined as

$$\mathbf{H}_{m,t} = \frac{\mathbf{H}_{n,t} - \mathbf{H}_{u,t}}{\mu_{h,t}} \tag{25}$$

The firm's marginal value of having a additional employee case is obtained from the job creation equation (17):

$$\begin{aligned}\frac{\iota\mu(\theta_t) + \psi'(v_t)}{\mu(\theta_t)}(1 + \varpi_t) = &(1 - \alpha)z_t\left(\frac{k_t}{n_{e,t}}\right)^{\alpha} - w_t(1 + \vartheta_t) \\ &+ \mathrm{E}_t\,\Lambda^c_{t|t+1}\frac{\mu_{c,t+1}}{\mu_{c,t}}(1 - x)\left[\frac{\iota\mu(\theta_{t+1}) + \psi'(v_{t+1})}{\mu(\theta_{t+1})}(1 + \varpi_{t+1})\right]\end{aligned}$$

where $\vartheta_t = 1 + \mu_{b,t}/(1 - \mu_{b,t})$, $\varpi_t = 1 + \mu_{b,t}/(1 - \mu_{b,t})$, and $\Lambda^c_{t|t+1}$ is the stochastic discount factor of the representative firm. Defining $\mathbf{J}_{n,t} \equiv \frac{\iota\mu(\theta_t)+\psi'(v_t)}{\mu(\theta_t)}(1 + \varpi_t)$ as the marginal value of a worker to the firm, and incorporating the fact that in equilibrium $n_{e,t} = n_{h,t}$, the job creation equation can be written as

$$\mathbf{J}_{n,t} = (1 - \alpha)z_t\left(\frac{k_t}{n_t}\right)^{\alpha} - w_t(1 + \vartheta_t) + \mathrm{E}_t\,\Lambda^c_{t|t+1}\frac{\mu_{c,t+1}}{\mu_{c,t}}(1 - x_t)\mathbf{J}_{n,t+1} \tag{26}$$

[32] State variables are being omitted for the sake of notation.

Now that both the value function for the household and the entrepreneur were defined, I can formalize the problem explicitly. The wage that solves the generalized Nash Bargaining maximizes, every period, the weighted geometric average of the gains from trade,

$$w_t^* = \underset{w_t}{\operatorname{argmax}}\, \mathbf{J}_{n,t}^{1-\theta} \mathbf{H}_{m,t}^{\theta} \tag{27}$$

where $\theta \in (0,1)$ is the bargaining power of workers in the process of wage negotiation. The solution to this problem is given by the standard Nash bargaining rule,[33]

$$\varrho_t \mathbf{J}_{n,t} = (1-\varrho_t)\mathbf{H}_t \tag{28}$$

where $\varrho_t = \frac{\theta}{\theta+(1-\theta)(1+\vartheta_t)}$.

After arranging some terms the joint surplus of the match, S_t can be written as

$$\begin{aligned}
\mathbf{S}_t &= \mathbf{J}_{n,t} + \mathbf{H}_{m,t} \\
&= F_n - \vartheta_t w_t - \tau - \frac{\varphi}{\mu_{h,t}} + (1-x)\,\mathrm{E}_t\left[\frac{\mu_{c,t+1}}{\mu_{c,t}} \Lambda^c_{t|t+1} \mathbf{J}_{n,t+1} + \Lambda^h_{t|t+1} \mathbf{H}_{m,t+1}\right] \\
&\quad - \Lambda^h_{t|t+1} f\left(\theta_{t+1}\right) \mathbf{H}_{m,t+1}
\end{aligned}$$

where F_n is the marginal product of labor. Using equation (28) and the fact that $\mathbf{S}_t = \mathbf{J}_{n,t} + \mathbf{H}_{m,t}$ I can write $\mathbf{J}_{n,t} = (1-\varrho_t)\mathbf{S}_t$ and $\mathbf{H}_{m,t} = \varrho_t \mathbf{S}_t$. Using the both the former and the latter in the definition of the joint surplus,

$$\begin{aligned}
\mathbf{S}_t =& F_n - \vartheta_t w_t - \tau - \frac{\varphi}{\mu_{h,t}} + (1-x)\,\mathrm{E}_t\left[\frac{\mu_{c,t+1}}{\mu_{c,t}} \Lambda^c_{t|t+1} \left(1-\varrho_t\right) \mathbf{S}_{t+1} + \Lambda^h_{t|t+1} \varrho_{t+1} \mathbf{S}_{t+1}\right] \\
&- \varrho_{t+1} \Lambda^h_{t|t+1} f\left(\theta_{t+1}\right) \mathbf{S}_{t+1}
\end{aligned} \tag{29}$$

Multiplying both sides of equation (29) by $(1-\varrho_t)$

$$\begin{aligned}
\left(1-\varrho_t\right) \mathbf{S}_t =& \left(1-\varrho_t\right) \left(F_n - \vartheta_t w_t - \tau - \frac{\varphi}{\mu_{h,t}}\right) - \left(1-\varrho_t\right) \varrho_{t+1} \Lambda^h_{t|t+1} f\left(\theta_{t+1}\right) \mathbf{S}_{t+1} \\
&+ (1-x)\left(1-\varrho_t\right) \mathrm{E}_t\left[\frac{\mu_{c,t+1}}{\mu_{c,t}} \Lambda^c_{t|t+1} \left(1-\varrho_t\right) \mathbf{S}_{t+1} + \Lambda^h_{t|t+1} \varrho_{t+1} \mathbf{S}_{t+1}\right]
\end{aligned} \tag{30}$$

Now, using the fact that $\mathbf{J}_{n,t} = (1-\varrho_t)\mathbf{S}_t = \frac{\iota\mu(\theta_t)+\psi'(v_t)}{\mu(\theta_t)}\left(1+\varpi_t\right)$, the definition of ϱ_t, after solving for w_t^* and arranging terms, equation (30) the wage that solves the Nash bargaining

[33] The first order necessary condition of equation (27) is given by $\theta \frac{\partial \mathbf{H}_{m,t}}{\partial w_t} \mathbf{J}_{n,t} + (1-\theta) \frac{\partial \mathbf{J}_{n,t}}{\partial w_t} \mathbf{H}_{m,t} = 0$.

is obtained:

$$\begin{aligned} w_t^* =& \frac{\theta}{1+\vartheta_t}\left[F_n + (1-x)\frac{\mu_{c,t+1}}{\mu_{c,t}}\Lambda^c_{t|t+1}\frac{\iota\mu(\theta_t)+\psi'(v_t)}{\mu(\theta_t)}(1+\varpi_t)\right] + (1-\theta)\left(\frac{\varphi}{\mu_{h,t}}+\tau\right) \\ & - \frac{\theta}{1+\vartheta_{t+1}}\left[\Lambda^h_{t|t+1}\frac{\iota\mu(\theta_{t+1})+\psi'(v_{t+1})}{\mu(\theta_{t+1})}(1+\varpi_{t+1})(1-x-f(\theta_{t+1}))\right] \end{aligned} \tag{31}$$

B Derivation of the Enforcement Constraint

The value of the firm at time t can be written as

$$J_t\left(\omega_t^c;\Omega_t\right) = d_t + \mathrm{E}_t\,\Lambda^e_{t|t+1}J_{t+1}\left(\omega^c_{t+1};\Omega_{t+1}\right)$$

where $\mathbf{s}_t$ is the vector of aggregate states at period t. From Assumption 1 the value of not defaulting, $v^{f,n}$ is

$$v^{f,n} = \mathrm{E}_t\,\Lambda^c_{t|t+1}J_{t+1}\left(\omega^c_{t+1};\Omega_{t+1}\right)$$

In the case of default both firms and lenders start negotiations. If an agreement is reached, firms agree to pay lenders a quantity ν_t the continuation value of the firm in case of a successful negotiation, $v^{f,s}$, can be expressed as

$$v^{f,s} = \mathrm{E}_t\,\Lambda^c_{t|t+1}J_{t+1}\left(\omega^c_{t+1};\Omega_{t+1}\right) + l_t - \nu_t$$

From Assumption 3, it follows that the value for the firm of an unsuccessful negotiation, $v^{f,u}$, is

$$v^{f,u} = l_t$$

Consequently, from the perspective of the firm the net value of an agreement, $v^{f,net}$

$$\begin{aligned} v^{f,net} &= v^{f,u} - v^{f,s} \\ &= \mathrm{E}_t\,\Lambda^c_{t|t+1}J_{t+1}\left(\omega^c_{t+1};\Omega_{t+1}\right) - \nu_t \end{aligned}$$

The value of the lender of a successful negotiation for the lender, $v^{l,s}$, is, on the other hand,

$$v^{l,s} = \nu_t + \frac{b_{t+1}}{R_t}$$

If the agreement is not reached from assumptions 2 and 4, the value of unsuccessful negotiations, $v^{f,u}$ is

$$v^{l,u} = \eta_t q_{k,t} k_t$$

Therefore, I can define the net value of renegotiation from the lender's perspective, $v^{l,net}$, as

$$\begin{aligned} v^{l,net} &= v^{l,u} - v^{l,s} \\ &= \nu_t + \frac{b_{t+1}}{R_t} - \eta_t q_{k,t} k_t \end{aligned}$$

The joint surplus of renegotiation, $V\left(\omega^c_{t+1};\Omega_{t+1}\right)$ will be, hence, the sum of the net value of renegotiation for both parties. Formally,

$$\begin{aligned} V\left(\omega^c_{t+1};\Omega_{t+1}\right) &= v^{f,net} + v^{l,net} \\ &= E_t \Lambda^c_{t|t+1} J_{t+1}\left(\omega^c_{t+1};\Omega_{t+1}\right) + \frac{b_{t+1}}{R_t} - \eta_t q_{k,t} k_t \end{aligned}$$

From assumption 4, in case of default the firm gets its liquidity plus the joint surplus of renegotiating the debt. The value of default, $v^{f,d}$, is then

$$\begin{aligned} v^{f,d} &= l_t + V\left(\omega^c_{t+1};\Omega_{t+1}\right) \\ &= E_t \Lambda^c_{t|t+1} J_{t+1}\left(\omega^c_{t+1};\Omega_{t+1}\right) + l_t + \frac{b_{t+1}}{R_t} - \eta_t q_{k,t} k_t \end{aligned}$$

In order to rule out default it is needed that the value of not defaulting is at least as large as the value of defaulting,

$$\begin{aligned} v^{f,n} &\geq v^{f,d} \\ \mathrm{E}_t\, \Lambda^c_{t|t+1} J_{t+1}\left(\omega^c_{t+1};\Omega_{t+1}\right) &\geq E_t \Lambda^c_{t|t+1} J_{t+1}\left(\omega^c_{t+1};\Omega_{t+1}\right) + l_t + \frac{b_{t+1}}{R_t} - \eta_t q_{k,t} k_t \end{aligned}$$

After arranging terms equation (3) in the test is obtained:

$$l_t + \frac{b_{t+1}}{R_t} \leq \eta_t q_{k,t} k_t$$

C Borrowing Constraint

From the household's first first order conditions with respect to the one-period bond we have that

$$\frac{1}{R_t} = \beta_h \frac{\mu_{h,t+1}}{\mu_{h,t}} \tag{32}$$

Similarly, for entrepreneurs

$$\frac{1}{R_t} = \mathbb{E}_t \Lambda^c_{t|t+1} \frac{\mu_{c,t+1}}{\mu_{c,t}} + \mathbb{E}_t \Lambda^c_{t|t+1} \frac{\mu_{b,t+1}}{\mu_{c,t}} \tag{33}$$

Combining (32) and (33) and denoting as $\bar{\mu}_b$ the steady state value of μ_b, we have that in the steady state

$$\frac{\beta_h - \beta_c}{\beta_c} = \frac{\bar{\mu}_b}{\mu_c} \tag{34}$$

Since $\mu_c > 0$, the borrowing constraint will be binding in steady state ($\bar{\mu}_b > 0$) as long as households are more patient than entrepreneurs, i.e. $\beta_h > \beta_c$.

D Solution Method

Given the size of the state space, I solve the model by relying on local methods. Specifically, I make use of the perturbation method and, in order to capture some of the nonlinearities present in the model, I perform a second-order approximation around the deterministic steady-state. For this purpose, I follow the method proposed by Schmitt-Grohe and Uribe (2004) and perform a second order Taylor approximation around the natural logarithm of the equilibrium conditions that were described in the paper. Formally, the approximation is taken around the equilibrium conditions given by

$$\mathbb{E}_t \left[f_i \left(\mathbf{y}_{t+1}, \mathbf{y}_t, \mathbf{x}_{t+1}, \mathbf{x}_t \right) \right] = 0$$

where f_i are the optimality conditions for $i = 1, 2, \cdots, n$; $\mathbf{x}_t$ and $\mathbf{y}_t$ are, respectively a vector $n_x \times 1$ and $n_y \times 1$ of state and jump variables with $n_x + n_y = 1$.

The policy function for the model give the equilibrium, $\mathbf{y}_t = g(\mathbf{x}_t, \sigma)$ and $\mathbf{x}_{t+1} = h(\mathbf{x}_t; \sigma) + \varsigma \sigma \epsilon_{t+1}$ with $\sigma \geq 0$ and ς being a $n_\epsilon \times n_\epsilon$ matrix with known parameters and ϵ contains the innovations.

E Data Description and Sources

I use data extracted from NIPA tables from the BEA, in order to construct measures for output and y_t and investment, i_t. Output is Gross Domestic Product (Series A191RC1) divided by the respective deflator (Series B191RG3). Investment in turn is defined as Personal Consumption Expenditures in durable goods (Series DDURRC1) divided by its deflator (Series DDURRG3) plus Gross Private Domestic Investment in Equipment and Software (Series B010RC1) divided by its deflator (Series B010RG3).

The measures of credit market tightness used to construct panel 1a, are the Net Percentage of Domestic Respondents Tightening Standards for Commercial and Industrial Loans for Small and Large Firms obtained from the Senior Loan Officer Opinion Survey on Bank Lending Practices from the Federal Reserve Board. Panel 1b is a quarterly average of monthly data of the proportion of respondents that, conditional on seeking credit in the past three months, reported more difficulty in obtaining credit less the proportion that reported more ease, obtained from the National Federation of Independent Business.

Vacancies in this paper are constructed using the method proposed by Barnichon (2010). The method combines job openings from the JOLTS data set (Series JTS00000000JOL), the Help-Wanted Online Advertisment Index published by the Conference Board (Series HWOL), and the Help-Wanted Print Adverstising Index that was discontinued in October 2008 and it was also constructed by the Conference Board.

Unemployment is the quarterly average of the monthly seasonal adjusted unemployment rate reported by the BLS (Series LNU04000000).