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Résumé

Nous étudions l'effet de chocs financiers sur la dynamique du marché du travail. Nous développons un modèle avec deux types de travailleurs et deux types de capital, ainsi que des frictions financières et sur le marché du travail. Nous constatons que les chocs financiers, modélisés comme des perturbations exogènes de la contrainte d'endettement des entreprises, peuvent générer des mouvements réalistes de l'emploi agrégé et reproduire la volatilité et contracyclicité du rapport entre l'emploi qualifié et non qualifié, observés dans les données. Le resserrement des conditions financières affecte l'emploi par trois canaux : i) la baisse de la productivité marginale du travail, en raison d'une réduction du capital total ii) l'augmentation du coût implicite de la main d'œuvre en termes de financement externe et iii) une rigidité endogène des salaires, provoquée par une augmentation à court terme de la consommation des ménages et de leur valeur marginale du temps. La volatilité de l'emploi relatif s'explique par cette rigidité endogène des salaires ainsi que le calibrage du modèle, qui impliquent une plus forte probabilité de ré-embauche et des coûts de recrutement plus faibles pour les travailleurs non qualifiés.

Mots-clés: Chocs financiers, Cycles économiques, Volatilité de l'emploi, Search

Classification JEL: E24, E32, E44

Abstract

We study the effect of financial shocks in labor market dynamics. We build a model with two types of labor, two types of capital and both search and financial frictions. We find that financial shocks, modeled as exogenous disturbances to the borrowing constraint of firms, can generate realistic movements in aggregate employment and reproduce the volatile and countercyclical ratio of skilled to unskilled employment observed in the data. Tighter financial conditions impact employment through three channels: i) a fall in the marginal product of labor as a result of a reduction in aggregate capital, ii) an increase in the shadow cost of labor in terms of external financing and iii) an endogenous wage rigidity caused by a short-lived increase in households' consumption and in their marginal value of time. This endogenous wage rigidity together with the model's calibration implying a higher re-hiring probability and lower recruitment costs for unskilled workers, explains the volatility of relative employment.

Keywords: Financial Shocks, Business Cycles, Employment Volatility, Search

JEL Codes: E24, E32, E44

Non-technical summary

The last financial and economic crisis in the US has brought renewed interest in models of financial frictions and their impact on economic fluctuations. Whereas most of the literature prior to the great recession had focused on the role of the financial sector in propagating real shocks, new research has began to explore the importance of financial shocks, that is, shocks originating directly in the financial sector. In this paper we try to shed light on this issue by studying the role of financial shocks in the business cycle dynamics of labor markets. In particular, we ask whether financial shocks can help to improve the performance of the standard search model in terms of aggregate and skill-specific employment volatilities relative to the case in which the only source of uncertainty comes from productivity shocks.

To address this question, we build a model with two types of labor, two types of capital and both search and financial frictions. We begin by analyzing the behavior of our benchmark model when hit by a negative shock to aggregate productivity and find that the results in Shimer (2005, 2010) carry over to our model with financial frictions. TFP shocks cannot on their own produce enough volatility of employment because wage dynamics offset any changes in labor productivity. The same can be said about relative employment.

Financial shocks have a very different impact. Modeled as a tightening of the borrowing constraint, a financial shock generates a big drop in employment in this economy as well as a fairly volatile and countercyclical ratio of skilled to unskilled employment. The high volatility of employment in the model generated by financial shocks can be explained as follows. On the production side, a tighter borrowing constraint forces entrepreneurs to reduce their debt and scale down their operation. It also gives them incentives to reallocate resources towards the pledgable asset at the expense of investment in the non-collateralized one, so as to offset the tighter borrowing constraint. The overall effect is a decline in aggregate capital that reduces the marginal product of labor and thus the incentives to hire workers. On the cost side, the financial shock introduces an endogenous wage rigidity in the model, as a result of a short-lived increase in households' consumption and in the marginal rate of substitution between consumption and leisure of workers that occurs at the time of the shock, which prevents wages from falling as otherwise. Additionally, as a result of the need for working capital, the tightening of the borrowing constraint generates an increase in the shadow cost of financing labor, providing further incentives for firms to cut back employment.

We also find that financial shocks trigger a larger drop in unskilled employment relative to the skilled. The reason for this is twofold. First, entrepreneurs internalize that future re-hiring is easier in the unskilled market given the larger pool of unemployed and the lower cost of recruitment. This asymmetry results from our calibration, which is consistent with higher steady state unemployment of unskilled workers, but does not rely on a larger replacement ratio for this type. Moreover, the endogenous wage rigidity generated by the financial shock reinforces this effect. This follows from the full risk sharing assumption, which implies that the outside option of both types of workers

exhibit the same dynamics. Thus, wages of the unskilled do not fall as much, giving additional incentives for firms to cut hiring in the unskilled labor market.

Finally, we feed into the model times series for productivity and financial shocks estimated from US data, and find that financial shocks are capable of replicating the behavior of employment during the whole sample period (1976.II-2012.II.), including the sharp drops during all four recessions: 1980s, 1990-1991, 2001 and 2008-2009. In particular, for the last recession the financial shock generates a drop in employment almost of the same magnitude as observed in the data. The model with financial shocks is also able to capture the dynamics of relative employment between skilled and unskilled workers, and can account for all of its increase during the last crisis. When feeding the model with the time series of productivity shocks, we find that it fails to produce enough movements in either aggregate or skill-specific employment, consistent with the literature and our previous results.

1 Introduction

The last financial and economic crisis in the US has brought renewed interest in models of financial frictions and their impact on economic fluctuations[1]. Whereas most of the literature prior to the great recession had focused on the role of the financial sector in propagating real shocks, new research has began to explore the importance of financial shocks, that is, shocks originating directly in the financial sector[2]. In this paper we try to shed light on this issue by studying the role of financial shocks in the business cycle dynamics of labor markets. In particular, we ask whether financial shocks can help to improve the performance of the standard search model in terms of aggregate and skill-specific employment volatilities relative to the case in which the only source of uncertainty comes from productivity shocks[3].

We construct a model with labor search frictions and financial frictions, in the form of a collateral constraint. Our economy is populated by relative impatient entrepreneurs and a representative household with two types of workers: skilled and unskilled, calibrated to capture differences in labor shares, wages, job exit rates and costs of recruitment. Households supply labor in exchange for labor income and provide funds to finance the entrepreneurs' productive activity. Entrepreneurs use the skilled and unskilled labor input to run a constant returns to scale production function with two types of capital: structures and equipment. Because of limited enforceability of contracts, entrepreneurs can only borrow up to a fraction of the value of their stock of capital structures[4]. Entrepreneurs cannot use capital equipment as collateral and need working capital , which introduces a labor wedge in our economy.

We find that a financial shock, modeled as a tightening of the borrowing constraint, generates a big drop in employment in this economy as well as a fairly volatile and countercyclical ratio of skilled to unskilled employment. When feeding into the model productivity and financial shocks estimated from the data, we find that financial shocks are capable of replicating the behavior of employment during the whole sample period, including the sharp drops during all four recessions: 1980s, 1990-1991, 2001 and 2008-2009. For the last recession the financial shock generates a drop in employment almost of the same magnitude as observed in the data. The model with financial shocks is also able to capture the dynamics of relative employment between skilled and unskilled workers, and can account for all of its increase during the last crisis. At the same time, we find that productivity shocks fail to produce enough movements in either aggregate or skill-specific

[1] Quadrini (2011) has a recent survey on the literature.

[2] See, for example, Christiano, Motto and Rostagno (2010), Jermann and Quadrini (2012), Kiyotaki and Moore (2012), Gilchrist and Zakrajsek (2012) and Khan and Thomas (2013), for models with financial shocks.

[3] Since the seminal work of Merz (1995), Andolfato (1996) and the influential paper by Shimer (2005), there has been a lot of work devoted to study the quantitative performance of the search and matching Mortensen and Pissarides (1994) model with productivity shocks and flexible wages. Hornstein, Krusell and Violante (2005) and Shimer (2010) present a summary of this literature.

[4] The introduction of collateralized debt as a way of modeling procyclical credit supply follows Kiyotaki and Moore (1997).

employment, consistent with the literature.

The high volatility of employment in the model generated by financial shocks can be explained as follows. On the production side, a tighter borrowing constraint forces entrepreneurs to reduce their debt and scale down their operation. It also gives them incentives to reallocate resources towards the pledgable asset at the expense of investment in the non-collateralized one, so as to offset the tighter borrowing constraint. The overall effect is a decline in aggregate capital that reduces the marginal product of labor and thus the incentives to hire workers. On the cost side, the financial shock introduces an endogeneous wage rigidity in the model, as a result of a short-lived increase in households' consumption and in the marginal rate of substitution between consumption and leisure of workers that occurs at the time of the shock, which prevents wages from falling as otherwise. Additionally, as a result of the need for working capital, the tightening of the borrowing constraint generates an increase in the shadow cost of financing labor, providing further incentives for firms to cut back employment. Overall, the dynamics of labor costs cannot offset the fall in marginal product, causing a significant decrease in employment.

We also find that financial shocks trigger a larger drop in unskilled employment relative to the skilled. The reason for this is twofold. First, entrepreneurs internalize that future re-hiring is easier in the unskilled market given the larger pool of unemployed and the lower cost of recruitment. This asymmetry results from our calibration, which is consistent with higher steady state unemployment of unskilled workers, but does not rely on a larger replacement ratio for this type[5]. Moreover, the endogenous wage rigidity generated by the financial shock reinforces this effect. This follows from the full risk sharing assumption, which implies that the outside option of both types of workers exhibit the same dynamics. Thus, wages of the unskilled do not fall as much, giving additional incentives for firms to cut hiring in the unskilled labor market.

With respect to TFP shocks, the results in Shimer (2005, 2010) carry over to our model with financial frictions. TFP shocks cannot on their own produce enough volatility of employment because wage dynamics offset any changes in labor productivity. The same can be said about relative employment. Even when we introduce capital-skill complementarity in the model, movements in relative employment resulting from a TFP shock are of several orders of magnitude smaller than in the data and than in the specification with financial shocks.

We perform sensitivity analysis to assess how much of the model's employment volatility depends on our specific modeling assumptions and find thathaving only one pledgeable asset and assuming that entrepreneurs need working capital are quantitatively important for our results. In a model in which both types of capitals can be used as collateral, or equivalently there is only one type of capital, a tightening of the borrowing constraint leads to a higher stock of capital in the economy, and with it an increase in the marginal product of labor. In this setup a financial shock cannot

[5]Hagedorn and Manovskii (2008) show that a calibration that implies a high replacement ratio, defined as the flow of utility of being unemployed relative to the worker's productivity, translates into high employment volatility.

explain a large decline in employment, and for some parameterizations can result in an expansion of output rather than in a contraction, depending on the strength of the accumulation motive of the collateral asset.

We also find the calibration of the inter-temporal elasticity of substitution (risk aversion) of consumers and the difference in discount rates between households and entrepreneurs, which determines the amount of borrowing in steady state, to be quantitatively important for the endogenous wage rigidity caused by financial shocks. If households are risk linear, the marginal rate of substitution between consumption and leisure is constant. Thus, changes in consumption have no effect on wages, which will only respond to variations in the marginal product of labor. Alternatively, if households' utility exhibits more curvature, changes in consumption have a stronger effect on wages, bringing higher employment volatility. The same is true if the model is calibrated to sustain higher borrowing and lending in steady-state. If a large fraction of the household's income is derived from lending, consumption falls less during unemployment spells. This raises the reservation wage of workers and increases the volatility of employment implied by the model.

Our model is in line with recent work by Wasmer and Weil (2004), Caggese and Perez (2013) and Petrosky-Nadeau and Wasmer (2013), that incorporates both search and financial frictions. It differs however in that we consider shocks directly affecting the financing conditions in the economy. These shocks resemble the financial shocks studied in Jermann and Quadrini (2012), in which the financial sector acts too as a source of business cycles. Moreover, we follow their procedure regarding the construction of financial shocks based on the model's enforcement constraint. Different to their work, we focus on the interaction between financial and labor market frictions rather than on the interaction between financial frictions and the firm's equity and debt flows. Monacelli, Quadrini and Trigaru (2011) also study how labor markets respond to shocks on financing conditions. Our paper differs from theirs in that in our model the financial shock is transmitted through the standard credit channel (higher cost of financing employment), while in theirs financing costs are constant over time. In addition, in their environment a reduction in borrowing put firms in a less favorable bargaining position with workers, which explains why after a contraction in credit their model predicts high wages and depresses job creation. Other papers that study financial shocks but in the context of models with heterogenous agents include Lorenzoni and Guerrieri (2012), Khan and Thomas (2013), Buera and Moll (2012) and Gilchrist, Sim and Zakrajsek (2013).

Finally, our paper is related to the literature that studies skill-specific labor market dynamics. A recent paper by Cajner and Cairo (2013) analyzes the importance of on-the-job training in explaining the level and dynamics of skilled and unskilled employment, but does so in a standard search model, abstracting from financial frictions. Regarding the skill wage premium, we find several papers that study the effects of skill-biased technological change on its dynamics, such as Greenwood et al. (1997), Krusell et al (2000), Lindquist (2004) and Baller and Van Rens (2013). However, none of these consider models with labor market frictions or financial frictions.

The rest of the paper is organized as follows. In the next section we present the model and equilibrium conditions. Section 3 discusses the effect of leverage on steady state employment while the main quantitative results are presented in section 4, where we analyze the dynamics of the model induced by shocks estimated from the data, and compute the impulse response functions of the model as well as the standard business cycle statistics. In section 5 we perform sensitivity analyses to assess the impact that changes in key elements of the model have on our results. Finally, we conclude.

2 Model Description

2.1 Households

There is a representative household composed by a unit measure of infinitely lived individuals with the same preferences over consumption and disutility of working. There are two types of family members, skilled and unskilled, with measure s and u respectively, where $u = 1-s$. In every period, each member of the household can be either employed or unemployed. The disutility of working of the two types is represented by $\hat{\gamma}_S$ and $\hat{\gamma}_U$ for skilled and unskilled members, respectively. Each type searches for employment in a separate labor market, but there is only one level of consumption within the household, as if markets were complete. Wages of the two types of workers are determined in separate markets and in equilibrium there is a fraction n_s and n_u of family members of the skilled and unskilled type, respectively, that are employed.

The representative household supplies funds to entrepreneurs in the form of non-contingent one-period bonds, D_t. There is a household-level budget constraint, which states that the consumption of all family members, c_t, and the amount of funds supplied to the firm should be equal to the total labor income of the household plus the return on the previous period bond holdings.

The optimization problem of the representative household can be written as:

$$max_{c_t,D_{t+1}} E_0 \sum_{t=0}^{\infty} \beta^t \left[log\left(c_t\right) - \hat{\gamma}_S n_{S,t} - \hat{\gamma}_U n_{U,t}\right]$$

subject to the budget constraint

$$c_t + D_{t+1} = n_{s,t}W_{S,t} + n_{u,t}W_{U,t} + \left(1+r_t\right)D_t$$

and laws of motion of the fraction of skilled and unskilled employed workers given by:

$$n_{S,t+1} = \left(1-x_S\right)n_{S,t} + f_{S,t}\left(\theta_{S,t}\right)\left(s-n_{S,t}\right)$$

$$n_{U,t+1} = \left(1-x_U\right)n_{U,t} + f_{U,t}\left(\theta_{U,t}\right)\left(u-n_{U,t}\right)$$

where $W_{S,t}$ and $W_{U,t}$ are wages of skilled and unskilled workers respectively, r_t is the interest rate on loans determined in the bond market, $f_{S,t}$ and $f_{U,t}$ are the job finding rates of skilled and unskilled, respectively, which depend on the market tightness of each labor market, $\theta_{S,t}$ and $\theta_{U,t}$. Finally, x_S and x_U are exogenous death shocks, specific to each match type[6]. The laws of motion indicate that skilled and unskilled employment in the next period will be determined by this period's surviving matches plus the new matches formed in each market. The first-order optimal conditions for the household problem are summarized in the following Euler equation:

$$\tfrac{1}{c_t} = \beta E_t \left[\tfrac{1}{c_{t+1}} \left(1 + r_{t+1}\right) \right]$$

2.2 Entrepreneurs

Entrepreneurs own capital and produce final goods using capital structures $K_{S,t}$, capital equipment $K_{E,t}$, skilled labor $L_{S,t}$ and unskilled labor $L_{U,t}$. The production technology exhibits constant returns to scale and is given by:

$$F(K_{S,t}, K_{E,t}, L_{S,t}, L_{U,t}) = Y_t = Z_t K_{S,t}^{\alpha_{K_S}} K_{E,t}^{\alpha_{K_E}} L_{S,t}^{\alpha_{L_S}} L_{U,t}^{1-\alpha_{K_S}-\alpha_{K_E}-\alpha_{L_S}}$$

where α_{K_S}, α_{K_E}, α_{L_S} are the income shares of structures, equipment and skilled labor and Z_t is an aggregate productivity shock.

Firms use some of their labor input to recruit new workers[7]. For this purpose the firm divides workers of each type between two tasks: production ($L_{S,t}$, $L_{U,t}$) and recruiting ($V_{S,t}, V_{U,t}$)[8]. Total labor demand for each type can be written as:

$$n_{S,t} = L_{S,t} + V_{S,t}$$

$$n_{U,t} = L_{U,t} + V_{U,t}$$

and their laws of motion given by:

$$n_{S,t+1} = (1 - x_S)\, n_{S,t} + \omega\left(\theta_{S,t}\right) V_{S,t}$$

$$n_{U,t+1} = (1 - x_U)\, n_{U,t} + \omega\left(\theta_{U,t}\right) V_{U,t}$$

[6]In the next section we discuss the calibration of the parameters governing the dynamics of each labor market. Given that in the data most of the employment fluctuations for both skilled and unskilled workers are driven by changes in the job finding rate, we don't find the assumption of an exogenous separation rate restrictive.

[7]This specification follows Shimer (2010) and is consistent with the view that recruiting is a time-intensive activity. Our results are robust to the alternative specification in which recruiting costs are denominated in units of the final good (as in Mortensen and Pissarides)

[8]In the sensitivity analysis section we modify this assumption and make recruiting an activity exclusive of the skilled type

where $\omega(\theta_{S,t})$ and $\omega(\theta_{U,t})$, are functions of the market tightness of each labor market and represent the number of workers that a skilled and an unskilled recruiter can hire, respectively. From the entrepreneurs's point of view, next-period employment will be a function of the surviving matches this period and the amount of new workers that current recruiters are able to hire

Entrepreneurs maximize their expected discounted flow of consumption C_t^E, by choosing how much to invest in physical capital, structures and equipment, how two divide workers of each type between production and recruiting activities and how much to borrow from households B_{t+1}. The optimization problem of the entrepreneur is thus summarized by:

$$max_{C_t^E, K_{S,t+1}, K_{E,t+1}, V_{S,t}, V_{U,t}, B_{t+1}} E_0 \sum_{t=0}^{\infty} \gamma^t \frac{(C_t^E)^{1-\sigma_E}}{1-\sigma_E}$$

subject to the following budget constraint:

$$C_t^E + (1+r_t)B_t + (K_{S,t+1} - (1-\delta_S)K_{S,t}) + (K_{E,t+1} - (1-\delta_E)K_{E,t}) + W_{U,t}n_{U,t} + W_{S,t}n_{S,t} = F(K_t, L_{S,t}, L_{U,t}) + B_{t+1}$$

where δ_S and δ_E are depreciation rates of capital structures and equipment respectively. The entrepreneurs are assumed to be less patient and less risk adverse than households, thus, their discount factor satisfies $\gamma < \beta$ and their coefficient of risk aversion $\sigma_E < 1$. In fact, in order to insure that entrepreneurs are financially constrained, we set their risk aversion coefficient such that they are very close to being risk neutral[9]. Finally, entrepreneurs cannot commit to repaying their loans, and thus face the following borrowing constraint:

$$B_{t+1}(1+r_{t+1}) \leq \chi_t K_{S,t+1} - (W_{U,t}n_{U,t} + W_{S,t}n_{S,t})$$

This constraint implies that entrepreneurs are able to borrow up to the point where the repayment equals a fraction χ_t of the total value of their capital structures minus the wage bill. This means that even in the event of default in which the entrepreneur appropriates $1-\chi_t$ of the collateral and liquidates the firm, there is enough pledgable asset to pay the workers. The fraction of collateralized capital χ_t, sometimes referred to as the "hair-cut", evolves stochastically in this economy and reflects shocks to the terms of loans or current financial conditions. For example, a negative shock to χ_t implies that creditors are willing to lend less to the entrepreneur, relative to the same level of collateral. The timing of the constraint implies the following sequence of events: At the beginning of every period entrepreneurs repay their debt, $B_t(1+r_t)$, and ask for a new loan, B_{t+1} to finance production. Then they produce, invest in physical capital, pay workers, and consume. In equilibrium there is no default and entrepreneurs maximize their external financing, so the borrowing constraint always holds with equality.

Let $\mu_t(c_t^E)^{-\sigma}$ be the multiplier associated to the borrowing constraint. The Euler equation for capital structures is described by:

[9]The risk aversion coefficient is set to be very small, but not zero, to insure that the consumption of the entrepreneurs does not become negative in any of the simulations

$$1 - \mu_t \chi_t = \gamma \left(\frac{c_{t+1}^E}{c_t^E} \right)^{-\sigma} E_t \left[r_{S,t+1} + (1 - \delta_S) \right]$$

where $r_{S,t+1}$ is the return on physical capital in terms of the final good defined by the standard capital-output ratio: $r_{S,t+1} = \alpha_{K_S} \frac{Y_{t+1}}{K_{S,t+1}}$. The multiplier associated to the borrowing constraint μ_t affects the optimal decisions regarding capital structures directly. In particular, whenever the borrowing constraint binds, it provides incentives for entrepreneurs to increase investment in capital structures, so as to relax their financial constraint. The Euler equation of capital equipment is completely standard:

$$1 = \gamma \left(\frac{c_{t+1}^E}{c_t^E} \right)^{-\sigma} E_t \left[r_{E,t+1} + (1 - \delta_E) \right]$$

where $r_{E,t+1}$ is the return of equipment, defined as: $r_{E,t+1} = \alpha_{K_E} \frac{Y_{t+1}}{K_{E,t+1}}$. The Euler equation for debt can be expressed as:

$$\mu_t = \frac{1}{(1+r_{t+1})} - \gamma E_t \left(\frac{c_{t+1}^E}{c_t^E} \right)^{-\sigma}$$

Given the differences in discount factors between the representative household and the entrepreneur, the multiplier μ_t is positive in steady-state, which implies that in steady-state the borrowing constraint is satisfied with equality. In addition, a low value of the risk-aversion coefficient for the entrepreneur ensures that the borrowing constraint remains binding in the stochastic approximation around the steady-state.

Regarding the decision of assigning workers between productive labor and recruiting, the following Euler equations describe the trade-off faced by the entrepreneur in each market:

$$\frac{MPL_{S,t}}{\omega(\theta_{S,t})} = \gamma \left(\frac{c_{t+1}^E}{c_t^E} \right)^{-\sigma} E_t \left[MPL_{S,t+1} \left(1 + \frac{1-x_S}{\omega(\theta_{S,t+1})} \right) - W_{S,t+1} \left(1 + \mu_{t+1} \right) \right]$$

$$\frac{MPL_{U,t}}{\omega(\theta_{U,t})} = \gamma \left(\frac{c_{t+1}^E}{c_t^E} \right)^{-\sigma} E_t \left[MPL_{U,t+1} \left(1 + \frac{1-x_U}{\omega(\theta_{U,t+1})} \right) - W_{U,t+1} \left(1 + \mu_{t+1} \right) \right]$$

In each of these two equations the left-hand side indicates the opportunity cost of hiring one extra worker, which implies increasing the number of recruiters today, at the expense of productive labor. As we indicated before, the functions $\omega(\theta_{S,t})$ and $\omega(\theta_{U,t})$ indicate the number of workers that a skilled and unskilled recruiter can hire respectively, so their inverses,$1/\omega(\theta_{S,t})$ and $1/\omega(\theta_{U,t})$ represent the number of recruiters needed to hire one worker. Thus, the left-hand side of each euler equation is equal to the value of foregone production associated with increasing the number of recruiters, so as to increase the number of productive workers by one. The right-hand side of both equations is the expected discounted value of increasing the size of the firm by one worker. The first term is given by the benefit in terms of marginal product of hiring a new worker plus the saving (also in terms of marginal product) associated to the need of less recruiters in t+1 to keep the number of workers constant. The second term is the cost of increasing the firm's payroll which includes the wage of the newly hired worker plus the shadow cost in terms of external funds. In all these expressions $MPL_{S,t}$ and $MPL_{U,t}$ stands for the marginal product of skilled and unskilled labor in terms of the final good: $MPL_{S,t} = \alpha_{L_S} \frac{Y_t}{L_{S,t}}$ and $MPL_{U,t} = \alpha_{L_U} \frac{Y_t}{L_{S,t}}$.

2.3 Wage Determination

Following most of the literature, we assume Nash Bargaining in the wage determination for both the skilled and unskilled markets[10]. Each type of worker bargains with the entrepreneur, separately, over the surplus created in the match. The wage conditions for skilled and unskilled workers are given by the following two equations (see the Appendix for the full derivation).

$$W_S = \frac{\beta\phi}{\phi\beta+(1-\phi)\gamma} \frac{MPL_S}{(1+\mu)} \left(1 + \theta_S + \frac{\gamma-\beta}{\gamma\beta} \frac{1}{\omega(\theta_S)}\right) + \frac{\gamma(1-\phi)}{\phi\beta+(1-\phi)\gamma} \hat{\gamma}_S \cdot c$$

$$W_U = \frac{\beta\phi}{\phi\beta+(1-\phi)\gamma} \frac{MPL_U}{(1+\mu)} \left(1 + \theta_U + \frac{\gamma-\beta}{\gamma\beta} \frac{1}{\omega(\theta_U)}\right) + \frac{\gamma(1-\phi)}{\phi\beta+(1-\phi)\gamma} \hat{\gamma}_U \cdot c$$

As in the standard search model, equilibrium wages in each market are determined as a weigthed average of two terms, the marginal product of labor and the marginal rate of substitution between leisure and consumption. In our setup however, the wedge between the discount factors of household and firms and the shadow cost of financing labor that results from the working capital assumption give rise to some differences relative to the standard specification. In particular, in our equilibrium wages the marginal product of labor is adjusted by the financing cost of labor, and the weights used are a function not only of the bargaining power of workers (ϕ), but of β and γ as well. Note that if these two parameters were equal, then the weights would only be function of the bargaining power of workers, as in the standard model. In addition, the difference in impatience between households and entrepreneurs introduces a new term, multiplying the marginal product of labor, which modifies the value of the surplus of a match relative to the standard model. Increasing the size of the firm by one worker, frees up resources by an amount equivalent to the cost of recruiting in terms of units of the final good: $\frac{MPL_S}{(1+\mu)} \frac{1}{\omega(\theta_S)}$. The present value associated to these savings is valued differently by households and entrepreneurs, as the two agents discount the future at different rates. If there was no wedge between β and γ, then this additional term would disappear, as happens in the standard model.

[10] As in Shimer (2010), we assume that firms don't internalize that investment and hiring decisions affect wages through changes in the marginal product of labor. We study the quantitative implications of departing from this assumption in an online appendix. In order to solve for the equilibrium wages assuming intra-firm bargaining, we follow Cahuec and Wasmer (2007). We find that after re-calibrating the steady-state of the model, this specification delivers business cycle statistics for aggregate variables almost identical to our benchmark. This result is in line with the findings by Krause and Lubik (2007).

2.4 Equilibrium

An equilibrium in this economy consists of sequences of prices $\{r_t, W_{S,t}, W_{U,t}\}_{t=0}^{\infty}$ and allocations for the households and entrepreneurs such that, given prices, initial conditions, the borrowing constraint of the entrepreneur and the stochastic processes, these allocations are optimal, as defined by the first-order conditions mentioned before, and labor and debt markets clear:

$$f_{S,t}\left(\theta_{S,t}\right)\left(s - n_{S,t}\right) = \omega\left(\theta_{S,t}\right) V_{S,t}$$

$$f_{U,t}\left(\theta_{U,t}\right)\left(u - n_{U,t}\right) = \omega\left(\theta_{U,t}\right) V_{U,t}$$

$$D_{t+1} = B_{t+1}$$

Finally, we assume a constant returns to scale matching function in which the elasticity with respect to the market tightness is the same as the bargaining power of workers, meeting the Hosios (1990) condition:

$$m_{i,t} = \bar{\omega}_i u_{i,t}^{\phi} V_{i,t}^{1-\phi}$$

where m_i is the number of matches and u_i is the number of unemployed workers in each labor market for $i = S, U$. Under this assumption the recruiting cost function can be expressed as:

$$\omega\left(\theta_i\right) = \bar{\omega}_i \theta_i^{-\phi}$$

and the market-tightness for unskilled and skilled labor market is defined by:

$$\theta_U = \frac{V_U}{1-s-n_U} \text{ and } \theta_S = \frac{V_S}{s-n_S}$$

3 Leverage, Financial Shocks and Elasticity of Employment

Before solving the model numerically we explore the response of employment to financial shocks around the steady state. We find that as a result of the assumptions that guarantee a balanced-growth, aggregate productivity plays no role in steady state. On the contrary, the fraction χ has a first-order effect on market tightness and all other endogenous variables.

To simplify the analysis, we focus on a parameterization of the model in which there are no differences between skilled and unskilled workers. We begin by solving for the wage from the steady state Euler equation for employment as a function of the marginal product of labor:

$$W = \frac{MPL}{(1+\mu)}\left(1 + \frac{[1-x-1/\gamma]}{\omega(\theta)}\right)$$

Also, from the Nash Bargaining equation:

$$W = \lambda \frac{MPL}{(1+\mu)}\left(1 + \theta + \frac{\gamma-\beta}{\gamma\beta}\frac{1}{\omega(\theta)}\right) + (1-\lambda)\,\hat{\gamma}\cdot c$$

where $\lambda = \frac{\beta\phi}{\phi\beta+(1-\phi)\gamma}$. In the steady state allocation, in which bond asset holdings are constant, the budget constraint of the household, combined with the borrowing constraint of entrepreneurs, allows us to express consumption as follows:

$$c = \beta W n + (1-\beta)\chi K_s$$

Combining the steady state Euler equation with the Nash-Bargaining equation and substituting for consumption we get the following labor market clearing expression:

$$\frac{MPL}{(1+\mu)}\left(1+\frac{[1-x-1/\gamma]}{\omega(\Theta)}\right) = \lambda\frac{MPL}{(1+\mu)}\left(1+\theta+\frac{\gamma-\beta}{\gamma\beta}\frac{1}{\omega(\theta)}\right)+(1-\lambda)\,\hat{\gamma}\left(\beta W n+(1-\beta)\chi K_s\right)$$

From the Euler-equation we get the capital structures-output ratio:

$$\frac{K_s}{Y} = \frac{\gamma\alpha_{K_S}}{1-\mu\chi-\gamma(1-\delta_S)}$$

Finally, using the fact that $MPL = \alpha_L \frac{Y}{L}$, $L = n - V = \frac{f-\theta x}{f+x}$ and $\omega(\theta) = \frac{f(\theta)}{\theta}$, we can rewrite the labor market clearing expression (after diving both sides by Y and simplyfing) as:

$$\left(\frac{f(\theta)+x}{f(\theta)-\theta x}\right)\left[1+\frac{\theta}{f(\theta)}(1-x-1/\gamma)-\lambda\left(1+\theta+\frac{\gamma-\beta}{\gamma\beta}\frac{\theta}{f(\theta)}\right)\right] =$$
$$(1-\lambda)\,\hat{\gamma}\beta\left(\frac{f(\theta)}{f(\theta)-\theta x}\right)\left[1+\frac{\theta}{f(\theta)}(1-x-1/\gamma)\right]+(1-\lambda)\,\hat{\gamma}(1-\beta)\frac{(1+\mu)\gamma(\alpha_{K_S}/\alpha_L)}{1-\mu\chi-\gamma(1-\delta_S)}\chi$$

Solving for the labor market equilibrium implies solving for the market tightness θ. The last equation defines market tightness as a function only of parameters and χ. Productivity shocks do not appear in this equation, which means that in the steady state the ratio of recruiters to unemployed workers is independent of productivity[11]. The high non-linearity of this equation prevents us from getting a closed form solution for θ as a function of χ, but using total derivatives we can show that there is a negative relationship between the two. The numerical simulation allows us to verify this relationship, by changing the steady state level of χ and comparing the results.

The intuition behind this is the following. A higher χ implies that higher debt can be sustained in equilibrium. This in turn implies that a higher fraction of household income is unrelated to the employment status of its members. Hence, as more borrowing and lending can be sustained, the marginal rate of substitution between leisure and consumption increases as consumption falls less during unemployment spells. In addition, as entrepreneurs become less constrained they can borrow more, they produce more, thus using more labor which reduces its marginal product. Overall, the outside option of workers and wages increase and the marginal product of labor falls, reducing the total surplus of a match in the steady state. In the sensitivity analysis section we quantitatively assess the effect of changes in the steady state value of χ on the volatilty of aggregate variables.

[11] Shimer (2010) shows that this neutrality result for the steady state also carries through to the stochastic simulation of a model with no capital, one type of labor and no financial frictions

Regarding its effect on employment volatility, a calibration with high steady state leverage can be compared to that in Hagedorn and Manovskii (2008) with high unemployment benefits (a high replacement ratio)[12].

4 Quantitative Analysis

4.1 Calibration

Following most of the literature on search models, we calibrate the model on a monthly basis. Table 1 presents the complete list of parameter values used in our numerical simulation. Using BLS data for civilian labor force and employment by educational attainment we calculate the average labor force participation rate and the unemployment rate for skilled and unskilled workers[13]. Based on these numbers we set the fraction of skilled workers in the labor force to 0.31. We use the disutility parameters γ_s and γ_u to match the long-run average unemployment rate for skilled and unskilled workers of 2.8% and 5.2%, respectively. The discount factor of the representative household, β, is set to 0.996, implying a real annual interest rate of 5%. The income share of capital structures and equipment, α_{K_S} and α_{K_E} are set equal to 0.13 and 0.17, following estimates by Greenwood, Hercowitz, and Krusell, (1997), used also in Krusell et al (2000) and Lindquist (2004). The depreciation rates of capital structures and of capital equipment, δ_S and δ_E, are set equal to 0.01 and 0.05 respectively, to match the ratio of investment in capital structures and capital equipment to output, as observed in the National Income and Product Accounts data. The income share of skilled workers is consistent with a wage premium of 60%, as suggested by the estimations of Acemoglu (1998) and Krusell et al (2000).

The entrepreneur's discount factor, γ, is set equal to 0.85, so as to match, together with the mean value of the share of collateralized capital, $\bar{\chi}$, a steady state ratio of debt to quarterly GDP of 0.63 (1.89 in our monthly calibration). This is the average ratio over the period 1976.II-2012.III for the nonfinancial business sector based on data from the Flow of Funds (for debt) and National Income and Product Accounts (for GDP). The mean value of the share of collateralized capital is computed by assuming that the borrowing constraint is always binding. We first compute χ_t as a residual using empirical series for end of period debt (Flow of Funds), capital structures (NIPA and own calculations) and wage bill (also from NIPA), all relative to GDP and transformed into monthly frequency. Then, $\bar{\chi}$ is determined as the average of this residual over the sample period.

[12] An alternative way to see this effect is by looking at the steady-state replacement ratio of workers defined as $\frac{\gamma C(1+\mu)}{MPL}$. The higher the value of the multiplier μ, which is given in steady-state by the difference between β and γ, the higher the replacement ratio in the model.

[13] Series: LNS11027659, LNS12027659, LNS11027660 for less than High School Diploma, LNS11027660, LNS12027660 for High School Graduates, LNS11027689, LNS12027689 For less than Bachelor's Degree and LNS11027662, LNS12027662 for College Graduates. Monthly data from January 1992 to July 2012. We also complete this data we time series for job finding and destruction rates from Elsby et al (2010).

The intertemporal elasticity of substitution of the entrepreneur, σ_E, which is also the risk aversion parameter, is set to 0.08, so that the entrepreneur is close to being a risk neutral agent but always exhibits non-negative consumption. Regarding the workers' bargaining power we follow the literature, in particular the paramaterization of Shimer (2010), and set ϕ equal to 0.5. The separation rates for both skilled and unskilled are set to 0.0113 and 0.0268, respectively, to match their empirical counterpart as reported by Elsby et al (2010). The parameters governing the matching efficiency for both skilled and unskilled are chosen to match the recruitment costs in hours of each type as reported by the Employment Opportunity Pilot Project (EOPP) 1982 survey and reported by Cajner and Cairo (2012). In our robustness section we change the configuration of the recruiting technology so that only skilled workers can be used to recruit new workers.

Table 1. Parameter Values

Parameter	**Source / Target**	**Symbol**	**Value**
Skilled Labor Force Fraction	BLS Data	s	0.31
Household's discount factor	5% Annual Interest Rate	β	0.996
Skilled workers' disutility of work	Unempl. Rate 2.8%, Replacement Ratio 0.71,	$\hat{\gamma}_S$	1.328
Unskilled workers' disutility of work	Unempl. Rate 5.2%, Replacement Ratio 0.71,	$\hat{\gamma}_U$	0.842
Entrepreneur's discount factor	Quarterly Debt-to-GDP of 0.63	γ	0.85
Entrepreneur's risk aversion	Risk Neutral Entrepreneur	σ_E	0.08
Unconditional mean of financial shock	Quarterly Debt-to-GDP of 0.63	$\bar{\chi}$	0.85
Depreciation of capital structures	Investment-to-GDP of 4.1% NIPA	δ_S	0.01
Depreciation of capital equipment	Investment-to-GDP of 7.3%NIPA	δ_E	0.05
Income share of capital structures	Greenwood, Hercowitz, and Krusell (1997)	α_{K_S}	0.13
Income share of capital equipment	Greenwood, Hercowitz, and Krusell (1997)	α_{K_E}	0.17
Income share of the skilled	Skill Premium of 60%	α_{L_S}	0.3
Workers' bargaining power and Elasticity	Shimer (2005)	ϕ	0.5
Exogenous separation rate for skilled	Elsby et al (2010)	x_s	0.0113
Exogenous separation rate for unskilled	Elsby et al (2010)	x_u	0.0268
Matching function efficiency for skilled	Recruitment costs in hours (EOPP)	$\overline{\omega}_s$	1.91
Matching function efficiency for unskilled	Recruitment costs in hours (EOPP)	$\overline{\omega}_u$	2.75

4.2 Stochastic Processes

The economy is subject to both aggregate productivity shocks z_t and financial shocks, that is, shocks to the share of collateralized capital χ_t . To recover z_t from the data, we use the standard solow residual approach. From the production function we get:

$$\hat{z}_t = \hat{y}_t - \alpha_{K_S}\hat{k}_{S,t} - \alpha_{K_E}\hat{k}_{E,t} - \alpha_{L_S}\hat{l}_{S,t} - (1 - \alpha_{K_S} - \alpha_{K_E} - \alpha_{L_S})\hat{l}_{U,t}$$

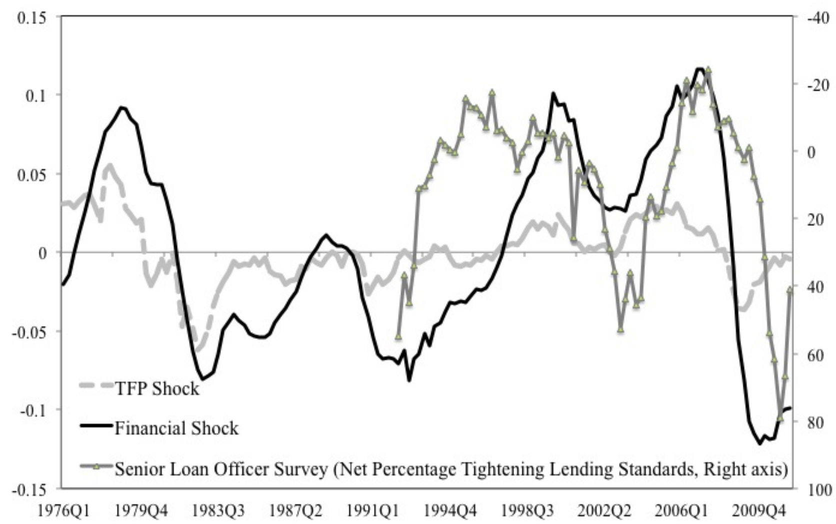
where hat variables are percentage deviations from trend. Given the values for the parameters α_{KS}, α_{KE} and $\alpha_{LS}$and empirical series for $\hat{y}_t$, $\hat{k}_{S,t}$, $\hat{k}_{E,t}$, $\hat{l}_{S,t}$ and $\hat{l}_{U,t}$ we can construct the $\hat{z}_t$ series.

To construct the series for the financial shock, we assume that the borrowing constraint holds and write all the variables relative to output:

$$\frac{B_{t+1}(1+r_{t+1})}{Y_t} + \frac{W_{U,t}n_{U,t}+W_{S,t}n_{S,t}}{Y_t} = \chi_t \frac{K_{S,t+1}}{Y_t}$$

Each term in this equation has a clear counterpart in the data.The first term is the leverage of the private sector, which can be computed using the Flow of Funds data. The second term is the labor-share of the economy which can be measured using the NIPA accounts. The right-hand side term is the capital structures-output ratio which can also be computed using data from the NIPA accounts. We can thus compute the series for χ_t as a residual[14]. Figure 1 plots the series for both shocks over the period 1976.II-2012.II.

Figure 1. TFP and Financial Series



Finally, we estimate the autoregressive system:

$$\begin{pmatrix} \hat{z}_{t+1} \\ \hat{\chi}_{t+1} \end{pmatrix} = \begin{pmatrix} \rho_{zz} & \rho_{z\chi} \\ \rho_{\chi z} & \rho_{\chi\chi} \end{pmatrix} \begin{pmatrix} \hat{z}_t \\ \hat{\chi}_t \end{pmatrix} + \begin{pmatrix} \epsilon_{z,t+1} \\ \epsilon_{\chi,t+1} \end{pmatrix}$$

where $\epsilon_{z,t+1}$ and $\epsilon_{\chi,t+1}$ are iid shocks with standard deviations σ_z and σ_χ respectively[15]. The results are presented in Table 2.

[14]As in Jermann and Quadrini (2002), the validity of this procedure depends on the validity of the assumption that the borrowing constraint is always binding. We check this condition ex-post by feeding the constructed series into the model and checking whether the constraint is always binding.

[15]Please see appendix 8.1 for details on how we obtain our monthly estimates from quarterly data

Table 2. Stochastic Properties of Shocks

Standard deviation productivity shock	σ_z	0.0044
Standard deviation financial shock	σ_χ	0.0057
Covariance parameter innovations	$\sigma_{z\chi}$	0.0008
	$\sigma_{\chi z}$	0.0008
Autoregressive parameter for productivity shock	ρ_{zz}	0.9824
Autoregressive parameter for financial shock	$\rho_{\chi\chi}$	0.9738
Spill-over from financial shock to productivity	$\rho_{z\chi}$	-0.0032
Spill-over from productivity to financial shocks	$\rho_{\chi z}$	0.1072

4.3 Impulse-Responses

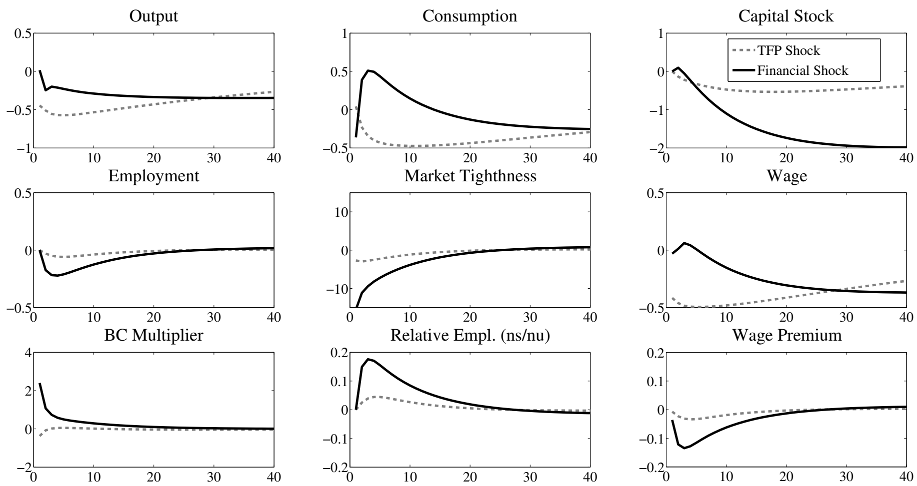
We begin by analyzing the behavior of our benchmark model when hit by a one standard deviation negative shock to aggregate productivity and to the parameter governing the fraction of collateralized asset. Figures 2 shows the impulse response functions.

We first look at the effects of a TFP shock. This shock impacts output directly, and is capable of generating a larger fall in output and consumption relative to a financial shock. However, the response of labor market variables and the aggregate capital stock over a long horizon to a TFP shock is relatively weak. The small decline in employment and other labor market variables is not surprising in light of two results. First, Shimer's (2005, 2010) neutrality result, that predicts, as discussed earlier, low volatility of employment when changes in productivity affect in a similar way both consumption and the marginal product of labor, leaving the surplus of a match unchanged. As seen from the impulse response functions, TFP shocks produce a fall in wages of a similar magnitude as the drop in the marginal product of labor. Second, as shown in Olivella and Roldan (2012), in models with reproducible capital general equilibrium effects dampen the response of real variables to productivity shocks, even in the presence of financial frictions.

Regarding relative variables, a TFP shock has little effect on relative employment of skilled to unskilled workers and also a negligible effect on the composition of capital. Changes in TFP affect all production inputs uniformly and have little reallocation effects between the two types of workers and the two types of capital.

Figure 2. Impulse-Responses Full Model: TFP and Financial Shock

(% deviation of steady state)



Financial shocks have a very different impact on all variables. They produce a larger drop in employment and in the stock of debt, while generating a much higher increase in the multiplier of the borrowing constraint, where they have a first order effect.

The high volatility of employment in the model generated by financial shocks can be explained as follows. On the production side, a tighter borrowing constraint forces entrepreneurs to reduce their debt and scale down their operation. It also gives them incentives to reallocate resources towards the pledgable asset K_S at the expense of investment in the non-collateralized capital K_E, so as to offset the tighter borrowing constraint[16]. The decrease in K_E is such that aggregate capital also falls, reducing the marginal product of labor and thus the incentives to hire workers. On the cost side, the financial shock introduces an endogeneous wage rigidity in the model, as a result of a short-lived increase in households' consumption that occurs in the periods immediately following the shock, and thus in the marginal value of time of workers[17]. At the time of the shock, output remains constant as capital and employment are fixed. Given that firms demand less funds, households' consumption goes up, which translates into a decrease in its marginal utility. As a result, the marginal rate of substitution between leisure and consumption increases, which prevents wages from falling as otherwise[18]. Additionally, as a result of the need for working capital, the tightening of the borrowing constraint generates an increase in the shadow cost of financing labor, providing further incentives for firms to cut back employment. This appears in the model as labor

[16]We find evidence for this in the data

[17]This short-lived increase in consumption is also present in models with volatility shocks, see Bloom et al. (2011)

[18]Kennan (2010) and Menzio (2005) also have models with search frictions and endogenous wage rigidites. However, in their work rigidities arise from asymmetric information on productivity and not from short-lived

wedge. Overall, the cost of labor falls by less than its marginal product, reducing the value of a match surplus and causing a significant decrease in employment[19].

With respect to the responses of skilled and unskilled employment to a financial shock, we observe that what holds for the aggregate also holds for each type. In particular, a financial shock generates larger movements in both skilled and unskilled employment relative to those generated by a TFP shock. The same is true of the market tightness for both types of labor.

A financial shock also causes the ratio of skilled to unskilled employment (ns/nu) to move in favor of skilled workers, much more than what a TFP shock does. Although the TFP shock also generates a counter-cyclical ratio of skilled to unskilled workers, it is unable to reproduce almost any of the volatility of this ratio observed in the data. In general, as we discuss in the sensitivity analysis, various specifications of the model can generate a counter-cyclical employment ratio. This countercyclicality is a result of our calibration, which is consistent with higher steady state unemployment of unskilled workers, but does not rely on a larger replacement ratio for this type. Entrepreneurs internalize that future re-hiring is easier in the unskilled market given the larger pool of unemployed and the lower cost of recruitment, and facing the decision to scale down production, find it optimal to hire proportionally less unskilled workers than skilled, as attracting unskilled workers in the future is much easier than re-hiring skilled ones. However, it is the endogenous wage rigidity generated by the financial shock that reinforces this effect. This follows from the full risk sharing assumption, which determines that the marginal rate of substitution between leisure and consumption of both types of workers exhibit the same dynamics. Thus, wages of the unskilled do not fall as much, giving additional incentives for firms to cut hiring in the unskilled labor market.

In the next subsection we present the basic RBC statistics of the model with both shocks as well as with one shock at the time.

4.4 Business Cycle Statistics

Table 3 presents the standard Real Business Cycle statistics for the data, for our benchmark model with financial and TFP shocks and for model specifications that only include one shock at the time. The volatility of the data is computed as the standard deviation of the cyclical component of the detrended quarterly series[20]. To compute volatilites implied by the model we follow the same procedure but adjust the HP filter to control for the fact that the model is calibrated at a monthly

[19]Note that our financial shock is different from an investment price shock, mainly in that the latter results in a significant increase in investment and capital, causing the marginal product of labor to increase. At the same time consumption decreases, lowering the marginal rate of substitution between leisure and consumption of workers. This, together with the fact that the shadow cost of financing labor remains relatively unchanged, results in employment moving significantly less than when a financial shock hits.

[20]The sample period is the same use for estimating the stochastic processes: 1976.II-2012.II. We use data from NIPA accounts and report statistics using the Hodrick-Prescott (HP) filter with the standard smoothing parameter $\lambda = 1,600$ for quarterly data. The volatility for θ is taken from Shimer (2010). The correlation between wages and output is from Gertler and Trigari (2009)

frequency[21].

The statistics for the benchmark model and the two alternative specifications with only one shock confirm what we discussed earlier when analyzing the IRF of the model. In particular, the model with a TFP shock delivers a volatility of output and consumption similar to the data but fails to reproduce the volatility of employment variables. Moreover, they confirm that the introduction of borrowing constraints has no effect on the typical successes and failures of the standard search model. All in all, the numbers reported for this exercise are very similar to the ones in Shimer (2010).

Table 3. Second Moments of the Simulated Model

	Data	**Full Model**		
		Both Shocks	TFP Shocks	Financial Shocks
		Volatility (stdv, %)		
σ_Y	1.46	1.74	1.30	0.60
		Volatility Relative to Output		
σ_C	0.77	0.75	0.82	2.09
σ_N	0.66	0.38	0.10	0.81
$\sigma_{K/Y}$	1.38	1.99	0.68	4.17
σ_{n_U}	0.77	0.47	0.12	0.99
σ_{n_S}	0.62	0.20	0.05	0.40
σ_θ	15.30	17.41	4.63	39.25
σ_{θ_U}	-	18.07	4.81	41.04
σ_{θ_S}	-	15.21	4.02	33.49
σ_{n_S/n_U}	0.84	0.28	0.07	0.61
σ_{w_S/w_U}	0.46	0.22	0.06	0.46
		Correlations with Output		
$corr(C,Y)$	0.87	0.38	0.87	-0.35
$corr(N,Y)$	0.79	0.79	0.81	0.55
$corr(K,Y)$	0.38	0.49	0.74	0.72
$corr(W,Y)$	0.56	0.92	0.99	0.58
$corr_{(n_S/n_U,Y)}$	-0.57	-0.77	-0.81	-0.52

The financial shock however, produces statistics that are significantly different. Output has a lower standard deviation, but consumption, aggregate capital stock relative to output, employment

[21] The statistics for the model are the theoretical moments using an smoothing parameter of 10^5 as in Shimer (2011)

(of both skilled and unskilled workers) and the market tightness for both labor markets are more volatile than their counterpart with TFP shocks. The volatilities of most labor market variables in this specification are higher than what is observed in the data. For example, the volatility of employment relative to output is 0.81, higher than the 0.66 reported in the data. The same is true for the volatility of unskilled employment (0.99 in the model vs 0.77 in the data) and the aggregate market tightness (39 in the model vs 15 in the data). As we discussed earlier, the financial shock has a first order effect on employment as it affects the shadow cost of hiring as well as the reservation wages through the movement in consumption. In fact, the financial shock predicts a counterfactual negative correlation between consumption and output, given that, as shown before, during the first few months after the shock, consumption is above steady-state levels while output is falling. This explains the lower correlation of aggregate wages to output in the presence of financial shocks (0.58), relative to case with TFP shocks (0.99), in which wages follow very closely output dynamics.

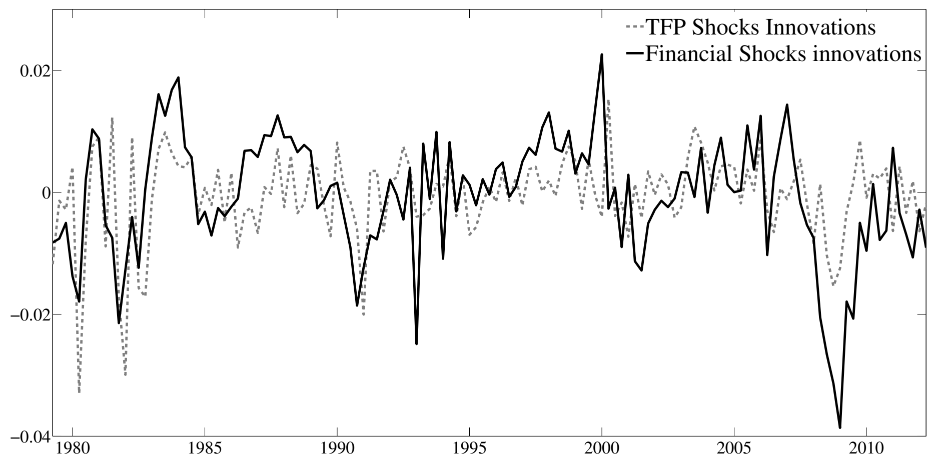
The model that includes both shocks (with properties as estimated in section 4.2) is able to deliver statistics closer to the data. The model explains almost 58% of the volatility in employment relative to output (0.38 in the model vs 0.66 in the data), and 69% of the absolute volatility of employment (0.66 in the model and 0.96 in the data). The volatility of theta relative to output is 17.41 in the model with both shocks, close to the 15.3 of the data and almost 4 times bigger than the volatility delivered by the standard search model with TFP shocks. The benchmark model also delivers the correct correlation among aggregate variables, although the correlation of consumption and output is lower than in the data and than in the standard search model with TFP shocks.

Finally, in the three specifications the ratio of employment of skilled to unskilled is countercyclical. However, for the TFP shock this ratio has a very low volatility, in line with our findings from the IRF analysis.

4.5 Dynamics Induced by Shocks

To study the dynamics of the model induced by the constructed series of shocks, we conduct the following simulation. Starting with initial values of $\hat{z}_{1976.II}$ and $\hat{\chi}_{1976.II}$ we compute the quarterly innovations (recall that we use quarterly data to construct the series of shocks) for the period going up to 2012.II. These are shown in Figure 3. It is important to point out how the decline in $\hat{\chi}$ during the last crisis is the largest in all of our sample period, and it is in this sense that the recent crisis is characterized by the most severe financial conditions experienced in the US economy for decades.

Figure 3. TFP and Financial Innovations

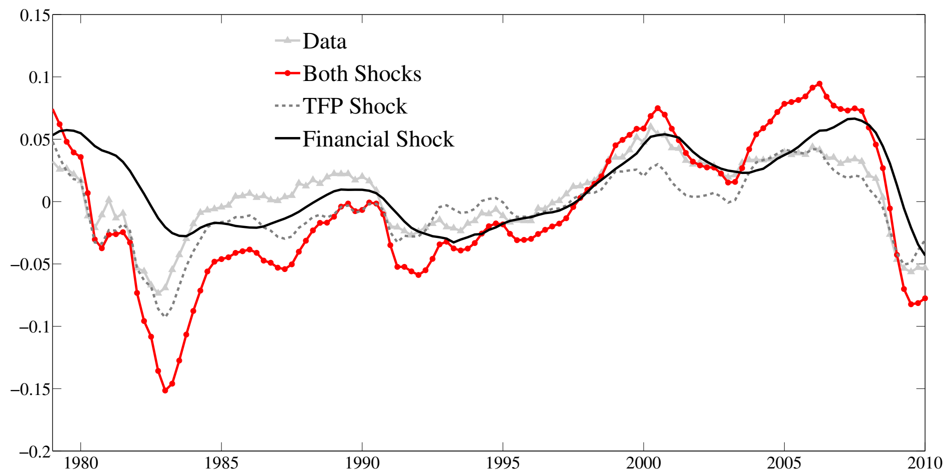


Once we have the quarterly innovations, we transform them into monthly, which we feed into the model and compute the responses for output, employment and relative employment. We do this for three different specifications of the model, one in which we only have productivity shocks ($\hat{\chi}$ is kept constant at its unconditional mean value $\bar{\chi}$), one with financial shocks only and one with both. Note that although we use the actual sequence of shocks, the agents do not perfectly anticipate them, they forecast their future values using the autoregressive system described earlier. Finally, we verify that the multiplier of the borrowing constraint remains positive during the whole simulation period, implying that the constraint is always binding.

Figure 4 to 6 plot the response of output, employment and relative employment, respectively, under the three different specifications together with the corresponding data. (GDP and employment are in logs deviations from trend over the period 1976.II-2012.II, relative employment is also linearly detrended during the same period but not logged).

Figure 4. Output Simulation With Estimated Shocks

(% deviations from trend)

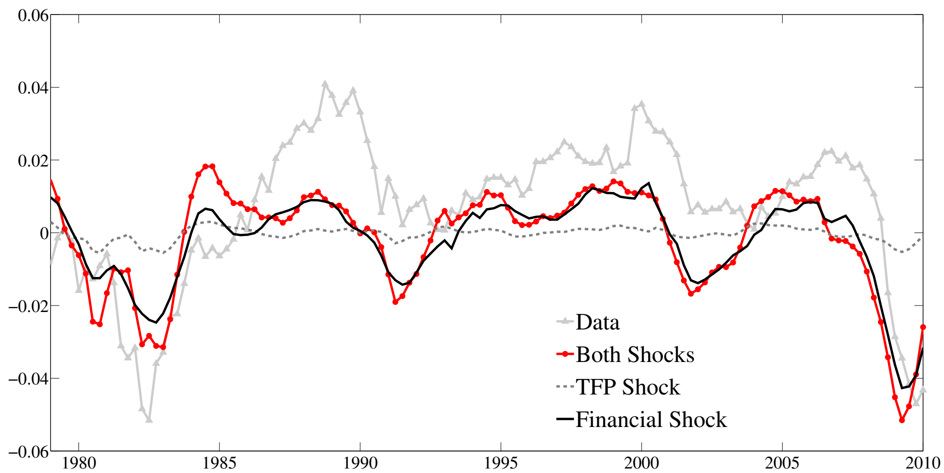


Regarding output, TFP shocks capture most of its dynamics. However, financial shocks appear to perform better during the second half of the sample, in particular during the great recession when TFP shocks predict a smaller decline and a much faster recovery in production. Financial shocks do not generate enough output fluctuations during the first years of the sample though, as a result of smaller innovations during the 1980s as shown in figure 2. The specification with both shock tracks output fluctuations well but over estimates its volatility.

With respect to employment, TFP shocks alone do not capture any of the movements observed in the data, as they fail to generate enough volatility. Moreover, the drop in employment captured by TFP shocks during the last recession is barely noticeable relative to the fall observed in the data. On the contrary, the specification with financial shocks is capable of replicating the behavior of employment during the whole sample period. In particular, financial shocks generate sharp drops in employment during all four recessions: 1980s, 1990-1991, 2001 and 2008-2009. The drop in employment generated by financial shocks in the last recession is almost of the same magnitude as that observed in the data.

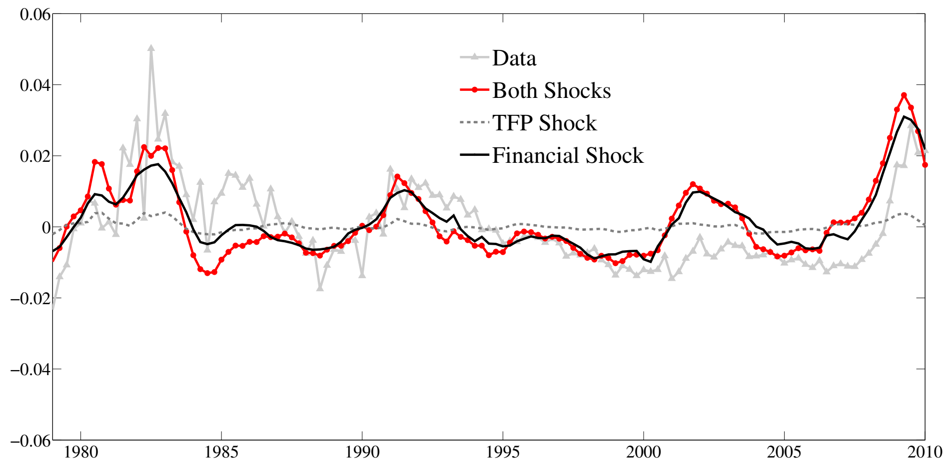
Figure 5. Employment Simulation With Estimated Shocks

(% deviations from trend)



Something similar holds for relative employment of skilled to unskilled workers. While the model with TFP shocks can account for almost none of the volatility in relative employment, the model with financial shocks captures the dynamics of the variable quite well, and in particular is able to explain all of the increase in relative employment during the last crisis. Finally, for employment and relative employment the performance of the model with both shocks is very similar to that of the model with financial shocks only.

Figure 6. Relative Employment Simulation With Estimated Shocks
(% deviations from trend)



5 Sensitivity Analysis

In this section we analyse the importance of some of our main assumptions for our results. In particular, we consider different specifications of the model and study the impact of financial and TFP shocks on the volatility of key employment variables. We change the model along 4 dimensions: 1) we change some of the features on the production side, 2) we depart from balance growth preferences introducing more or less curvature in the utility function regarding consumption, 3) we recalibrate the model to have lower or higher leverage in equilibrium and 4) we recalibrate the model so as to get a high flow utility of leisure like the one suggested by Hagedorn and Manovski (2008). Table 4 reports these results.

Table 4: Sensitivity Analysis

	Financial Shocks								TFP Shocks	
	Production				Household		Leverage			
	One Capital	No Wage Bill	KS	Skill Recruit	Neutral	Averse	Low	High	HM	KS
	Volatility (stdv, %)									
σ_Y	1.19	0.61	0.56	0.53	0.71	0.49	0.71	0.57	1.66	1.23
	Volatility Relative to Output									
σ_N	0.37	0.54	0.87	0.65	0.52	1.24	0.43	1.00	0.37	0.09
σ_{n_U}	0.44	0.66	1.10	0.75	0.64	1.53	0.52	1.24	0.38	0.11
σ_{n_S}	0.20	0.27	0.37	0.44	0.26	0.61	0.22	0.49	0.35	0.07
$\sigma_{\frac{n_S}{n_U}}$	0.25	0.40	0.74	0.32	0.39	0.92	0.30	0.76	0.04	0.06
$\sigma_{\frac{W_S}{W_U}}$	0.14	0.28	0.52	0.27	0.30	0.70	0.17	0.62	0.02	0.19
	Correlations with Output									
$\frac{n_S}{n_U}$	-0.05	-0.34	-0.47	-0.39	-0.62	-0.59	-0.22	-0.73	-0.83	-0.28
$\frac{W_S}{W_U}$	0.08	0.32	0.58	0.29	0.59	0.54	0.26	0.69	0.64	0.97

Regarding the modifications on the production side, we first consider the case in which the two types of capital can be used as collateral (which is equivalent to having only one type of capital in the economy). As can be seen from the first column of Table 4, under this model specification a financial shock generates smaller changes in employment. The reason for this is that when the entrepreneur has only one type of capital, the substitution effect between the pledgeable and non pledgeable asset that was present in the benchmark model no longer exists, and thus the only way for entrepreneurs to counteract the tightening of the borrowing constraint is by accumulating aggregate capital, which in turn increases the marginal product of labor. This partially offsets the endogenous wage rigidity generated by the financial shock and results in a smaller decrease in employment.

The second exercise is related to the presence of the wage bill in the borrowing constraint. If labor costs are not part of the latter, hiring decisions are not directly affected by the financial situation of the firm (they will still be affected indirectly, through capital and borrowing decisions). In this case the model exhibits around 65% of the volatility of employment observed in the benchmark model (column 2). That is, roughly one third of the volatility generated by the financial shock is coming from the direct effect of the tightening of the borrowing constraint on the shadow cost of labor in terms of financing.

We consider two more variations of the model on the production side. Column 4 reports the results of the model with only one recruiter of the skilled type. This model exhibits lower volatility but sufficiently high to show that this particular feature is not key for the results of the benchmark model. One important difference between this specification and the benchmark model is the volatility of unskilled workers, which falls to 0.75 from 0.99. When only skilled workers can recruit, the opportunity cost of hiring unskilled is determined by skilled wages, and hence the differences between the two types of labor narrow. Finally, column 3 presents the results of our capital-skill complementarity specification, which we discuss in more detail later in this section.

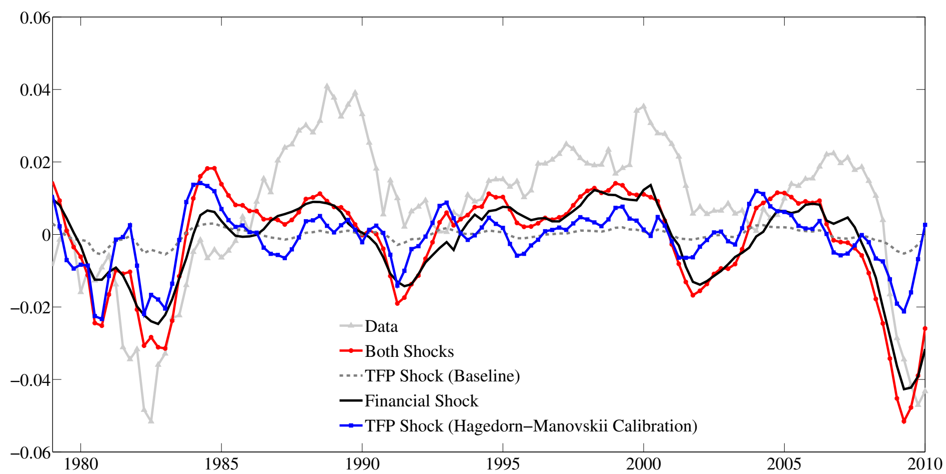
A second dimension we explore is that of household's preferences. Column 5 and 6 present the results of a model recalibrated to have the same steady state as the benchmark but in which the risk aversion coefficient (the intertemporal substitution parameter), is different from one. In the first of these two columns we report the results for the case in which households are very close to having linear utility in consumption and in the second we present the case in which the risk aversion coefficient is 2. Given that the two specifications have the same steady state as in the benchmark model, this allows us to isolate the effect of a financial shock on wages, and hence on the overall elasticity of employment, that comes solely from consumption dynamics. When agents are risk-neutral, the relative volatility of employment to output is 64% of the one observed in the benchmark, falling to 0.52 from 0.81. This drop in volatility occurs for both skilled and unskilled employment, as well as for the relative employment ratio. This result suggests that in the benchmark model, about one-third of the volatility of employment generated by financial shocks is explained by the general equilibrium effect of consumption on wages and employment. Alternatively, if households' utility exhibits more curvature, changes in consumption have a stronger effect on wages, bringing higher employment volatility, as shown in column 6.

We then consider a model that is calibrated to have lower or higher leverage in equilibrium, and show that the elasticity of employment resulting from financial shocks is directly related to the level of leverage in the economy. For the benchmark calibration we chose parameter values of χ and γ consistent with a debt-to-gdp ratio of 0.63 at quarterly basis. In the last two columns we present a calibration of the model that favors lower and higher leverage respectively. For the first case we re-calibrate γ to be consistent with a steady state debt-to-gdp ratio of 0.2 at quarterly basis. For the high leverage case we target a ratio of 1. The economy with higher leverage shows higher volatilities across all labor market variables, as suggested in our earlier discussion on leverage and employment.

Regarding the ability of the model to generate movements in labor variables with productivity shocks, we conduct two robustness exercises. First, we follow a calibration in which we maximize the flow utility derived from unemployment in line with the work by Hagedorn and Manovksi (2008). For this case we set the bargaining power parameter (ϕ) close to zero and choose the leisure utility parameters, $\hat{\gamma}_s$ and $\hat{\gamma}_u$, so as to match the unemployment level of skilled and unskilled workers. Table 4 shows that, when hit by a TFP shock, this specification (under the label HM) exhibits a larger volatility of employment relative to output than in the basic model, just as in the setup of Hagedorn and Manovksi (2008). However, the overall employment volatility is lower than in our benchmark model with both TFP and financial shocks and also lower than in the model with financial shocks only. Moreover, Figure 7 shows that this model specification, calibrated to have higher leisure utility, does a poor job in replicating the observed pattern of employment fluctuations when fed with the actual realizations of the aggregate productivity series.

Figure 7. Employment Simulation HM Calibration

(% deviations from trend)



In terms of relative employment, the HM specification delivers a low volatility of the $\frac{n_S}{n_U}$ ratio. That is, while TFP shocks create incentives for firms to re-scale their production, they don't generate any strong reallocation incentives among production inputs. Moreover, if we were to change the calibration to generate higher movements in the relative ratio of employment, we would have to set a higher bargaining power for unskilled workers. This, however, would in turn reduce the volatility of aggregate employment, because of the lower $\hat{\gamma}_u$ needed to keep the steady-state unemployment level of unskilled workers unchanged. Additionally, it would be at odds with the conjecture that skill workers should have, if any different, a higher bargaining power than the unskilled.

In our second exercise we test whether departing from a Cobb-Douglas production function could help to generate realistic employment fluctuations under TFP shocks. In order assess this we consider a production function and parameter values such that there is capital-skill complementarity as in the work by Greenwood et al. (1997) and Krusell et al (2000).

Under this specification the production technology is given by:

$$F(K_{S,t}, K_{E,t}, L_{S,t}, L_{U,t}) = Z_t K_{S,t}^{\theta} \left[\alpha L_{U,t}^{\nu} + (1-\alpha) \left[\lambda K_{E,t}^{\varphi} + (1-\lambda) L_{S,t}^{\varphi} \right]^{\frac{\nu}{\varphi}} \right]^{\frac{1-\theta}{\nu}}$$

where $\theta, \alpha, \lambda \in (0,1)$; $\nu, \varphi \in (-\infty, 1)$ and $\nu, \varphi \neq 0$. This production function has been applied both to study long-term dynamics of the wage skill premium (such as Krusell et al, 2000), as well as business cycle dynamics under TFP shocks as well as shocks to the relative price of investment on equipment (Lindquist, 2004). More recently, Baller and Van Rens (2013) have challenged the view that there is any evidence of capital-skill complementarity at the business cycle frequency and suggest an alternative parameterization in which capital and skill are mildly substitutable .

Parameters ν and φ are the two key substitution parameters. $1/(1-\varphi)$ defines the elasticity of substitution between capital equipment and skilled labor, while the elasticity of substitution between capital equipment and unskilled labor and between skilled and unskilled labor are both given by $1/(1-\nu)$. If $\nu > \varphi$, the production function is said to exhibit capital-skill complementarity.

Income share of capital structures is given by θ,while α and λ determine the income shares of skilled and unskilled labor and of capital equipment. We set the substitution parameters, $\nu = 0.401$ and $\varphi = -0.495$, as in Krusell et al. (2000), and choose the other parameters in order to match the same moments as in our benchmark model.

We report the main statistics of employment-related variables for this exercise in Table 4 under the label "KS". Both aggregate and relative employment fluctuations are similar for the specification with capital-skill complementarity and the benchmark Cobb-Douglas calibration for both TFP and financial shocks respectively. That is, the capital-skill complementarity specification does not appear to contribute much regarding employment volatilities, and the same results that hold in our benchmark scenario carry over.

6 Conclusions

In this paper we study the effect of exogenous shocks to financing conditions on labor market outcomes. We find that financial shocks, unlike aggregate productivity shocks, can replicate the large fluctuations in aggregate and skill-specific employment as observed in the data. This suggests that understanding cyclical changes in credit is important to help us understand economic fluctuations and labor market dynamics. Given that we assume here a representative entrepreneur, understanding how financial shocks reallocate resources from different labor markets between heterogeneous producers or sectors is beyond the scope of this paper but is a promising area for research. Recent papers by Khan and Thomas (2013) and Buera, Fattal-Jaef and Shin (2013) discuss financial shocks in the context of heterogeneous firms but with homogenous labor markets. Allowing for heterogeneity in labor markets could be important for understanding the differences in employment levels as well as the persistence of unemployment across skill types observed during and after the crisis.

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8 Appendix

8.1 Estimation of Stochastic Processes

We use quarterly data to construct our series of TFP and the credit shock, but in our model the stochastic processes have a monthly frequency. Hence, we need to transform our quarterly estimates into monthly numbers. In order to do so, we solve the non-linear system of equations associated to the problem of temporal aggregation as follows. [22]:

The monthly auto-regressive process can be represented as: $\hat{X}t^M = A\hat{X}^M_{t-1} + B\xi^M_t$, where $\hat{X}^M_t = \begin{bmatrix} \hat{z}^M_t \\ \hat{\chi^M}_t \end{bmatrix}$, $A = \begin{bmatrix} \rho^M_{\hat{z}\hat{z}} & \rho^M_{\hat{z}\hat{\chi}} \\ \rho^M_{\hat{z}\hat{\chi}} & \rho^M_{\hat{\chi}\hat{\chi}} \end{bmatrix}$, $B = \begin{bmatrix} \sigma^M_{\hat{z}\hat{z}} & \sigma^M_{\hat{z}\hat{\chi}} \\ \sigma^M_{\hat{z}\hat{\chi}} & \sigma^M_{\hat{\chi}\hat{\chi}} \end{bmatrix}$ and $\xi^M_t \sim N(0, \sum_{z,\chi^M} = I_2)$. We can re-write it as $\hat{X}t^M = A^3\hat{X}^M_{t-3} + B\xi^M_t + AB\xi^M_{t-1} + A^2B\xi^M_{t-2}$, and then, re-stated in quarterly terms $\hat{X}t^Q = C\hat{X}^Q_{t-1} + D\epsilon_t$, where $\hat{X}^Q_t = \begin{bmatrix} \hat{z}^Q_t \\ \hat{\chi^Q}_t \end{bmatrix}$, $C = \begin{bmatrix} \rho^Q_{\hat{z}\hat{z}} & \rho^Q_{\hat{z}\hat{\chi}} \\ \rho^Q_{\hat{z}\hat{\chi}} & \rho^Q_{\hat{\chi}\hat{\chi}} \end{bmatrix}$, $B = \begin{bmatrix} \sigma^Q_{\hat{z}\hat{z}} & \sigma^Q_{\hat{z}\hat{\chi}} \\ \sigma^Q_{\hat{z}\hat{\chi}} & \sigma^Q_{\hat{\chi}\hat{\chi}} \end{bmatrix}$, $A^3\hat{X}^M_{t-3} = C\hat{X}^Q_{t-1}$ and $D\epsilon_t = B\xi^M_t + AB\xi^M_{t-1} + A^2B\xi^M_{t-2}$, with $\epsilon_t \sim N\left(0, \sum_{z,\chi^Q} = I_2\right)$. From our quarterly estimates we get matrices C and D. The matrix A, governing the persistence of the monthly process can be calculated using $A = C^{\frac{1}{3}}$. We can recover the B matrix, by solving the following non-linear system: $DD' = BB' + ABB'A' + A^2BB'A'^2$.

8.2 Wage Determination

We present here the characterization of the bargaining problem for the skilled worker, but there is an analogous condition for the unskilled. The Nash Bargaining solution to this negotiation protocol is given by the wage that maximizes the following Nash product:

$$W_S = argmax\left(\tilde{V}_{n_S}\right)^{\phi}\left(\tilde{J}_{n_S}\right)^{1-\phi}$$

where $\tilde{V}_{n_S}$ is the marginal value for a household of having a skilled worker employed at wage W_s and $\tilde{J}_{n_S}$ is the marginal value of this worker for the firm. The bargaining power of workers is represented by ϕ (same for skilled and unskilled workers).

Using a recursive representation for the household's preferences we obtain the following expression:

$$\frac{\partial \tilde{V}_{n_S}}{\partial W_S} = \tilde{V}'_{n_S} = \frac{1}{c}$$

Taking logs to the Nash product and deriving with respect to the equilibrium wage, we can express the first term as:

[22]For a discussion on this topic see Marcellino (1999)

$$\phi \frac{\tilde{V}'_{n_S}\left(\bar{W_S}\right)}{\tilde{V}_{n_S}\left(\bar{W_S}\right)} = \phi \frac{(1/c)}{V_{n_S}} = \phi \frac{[1-\beta(1-x_S-f(\theta_S))]}{W_s - c \cdot \hat{\gamma}_S}$$

For the firm side, we can compute the marginal value of a worker employed at a wage W_S for one period, instead of the equilibrium wage $\bar{W_S}$:

$$\tilde{J}_{n_S}\left(K_E, K_S, B, n_S, n_U, W_S\right) = \left(W_S - \bar{W_S}\right)(1+\mu) + J_{n_S}$$

Taking logs and the derivative with respect to the wage, we have:

$$(1-\phi)\frac{\tilde{J'}_{n_S}}{\tilde{J}_{n_S}} = \frac{-(1-\phi)(1+\mu)}{J_{n_S}} = \frac{(1+\mu)(1-\phi)\gamma\omega(\theta_S)}{MPL_S}$$

Putting together the expressions from the household and firm side:

$$\phi \frac{\tilde{V}'_{n_S}\left(\bar{W_S}\right)}{\tilde{V}_{n_S}\left(\bar{W_S}\right)} + (1-\phi)\frac{\tilde{J'}_{n_S}}{\tilde{J}_{n_S}} = \phi \frac{(1-\beta(1-x_S-f(\theta_S)))}{W_s - c \cdot \hat{\gamma}_S} = \frac{(1-\phi)\gamma\omega(\theta_S)(1+\mu)}{MPL_S}$$

and simplifying and solving for the equilibrium wage, we get:

$$W_S = \frac{\beta\phi}{\phi\beta + (1-\phi)\gamma}\frac{MPL_S}{(1+\mu)}\left(1 + \theta_S + \frac{\gamma-\beta}{\gamma\beta}\frac{1}{\omega(\theta_S)}\right) + \frac{\gamma(1-\phi)}{\phi\beta + (1-\phi)\gamma}\hat{\gamma}_S \cdot c$$

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