The cyclical volatility of labor markets under frictional financial markets

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Abstract

This paper shows the important role of financial imperfections in amplifying the volatility of labor markets. Our findings are the following :

i) Financial imperfections raise the calibrated elasticity of labor market tightness to productivity shocks by a factor M_f called the financial multiplier, which is an increasing function of total financial costs in the economy.

ii) Under a Hosios-Pissarides rule in the credit market —the bargaining power of firms vis-à-vis banks is equal, at the social optimum, to the elasticity of the finding rate of banks with respect to credit market tightness—, the total search costs in the credit market are minimized, and so is M_f.

iii) Relaxing that condition leads to larger financial accelerators, which can match or even overshoot the steady-state value of the elasticity of market tightness in the data.

iv) In particular, away from the Hosios rule, four situations generate a large or very large volatility. 1. When the matching function in the credit market is "balanced", e.g. a Cobb-Douglas with elasticity around half each for each segment of the market (banks and firms) and when firms have a very low bargaining power in the bargaining relation with the bank. 2. In the symmetrical case with balanced matching in the credit market but when firms have a very high bargaining power in the bargaining relation with the bank also generate large volatility of labor markets. 3. When instead the matching function is unbalanced, corresponding to a situation in which credit creation is limited by "ideas of entrepreneurs", that is an excess of liquidity ; 4. When the matching function is unbalanced on the other side, corresponding to situation in which credit creation is limited by "supply of liquidity" , that is a scarcity of liquidity.

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v) These results hold under endogenous or exogenous wages and in a static or dynamic setup : one can obtain any high elasticity of labor market volatility to productivity shocks in each of the four cases identified above.

1 Introduction

Cole and Rogerson (1999) and Shimer (2005) have investigated the cyclical properties of the search matching models following Pissarides (1985) and Mortensen and Pissarides (1994). The celebrated Shimer's puzzle is the demonstration of the inability of the conventional matching model to replicate the US statistics regarding the volatility of vacancy, unemployment and their ratio (called labor market tightness), in response to productivity shocks. His main finding is that the elasticity of labor market tightness to productivity shocks is around 20 in the data, and around 1 in a calibration of the Mortensen-Pissarides model. Several calibration improvements have been proposed, including raising the model value of non-employment utility (Hagedorn and Manovskii 2008), wage rigidity (Hall 2005), on-the-job search (Mortensen and Nagypàl 2007).

One line of research has so far been ignored but seems promising: the existence of credit market imperfections. In this note, we pursue this logic, following two previous papers by the authors. On the one hand, Nicolas Petrosky-Nadeau (2009) shows that introducing credit imperfections in a search model with in particular costly state verification leads to a large amplification of the volatility of labor market tightness. He shows that the standard deviation in his model of the vacancy unemployment ratio approaches 12.5, while it is 15.4 in US data and merely 3.7 in the standard search model. Credit market imperfections induce amplification by a factor of 3.5.

On the other hand, Wasmer and Weil (2004), who develop financial imperfections in a Mortensen-Pissarides economy with two matching functions (one in the labor market, one in the credit market), show that the steady-state volatility of labor market tightness to profit shocks is augmented by a factor 1.7 by the existence of moderate credit market imperfections. They call this a financial accelerator, in line with an earlier literature.

Despite recent papers attempting to bring together credit market imperfections and the search-matching approach, the macro-labor literature has indeed been slow to incorporate the well-known message of an earlier literature. Indeed, it has been known for a while that credit market imperfections generates additional volatility of the business cycle. Early papers such as Bernanke and Gertler (1989), Kiyotaki and Moore (1997) and subsequent papers (Bernanke and Gertler 1995, Bernanke Gertler and Gilchrist 1996) and several others, have emphasized the amplification role of credit markets and the existence of *financial accelerator*. Although part of this literature is centered on the role of credit shocks and the credit channel of monetary policy, the ingredients generating the amplification of credit shocks can very well be adapted to the amplification of business cycle shocks to labor markets.

Our results can be summarized as follows :

1. Consistently with Wasmer and Weil, financial imperfections raise the calibrated elasticity of labor market tightness to productivity shocks by a factor M_f called the financial multiplier. It increases in total financial costs in the economy.

2. A Hosios-Pissarides rule exists in the credit market : the bargaining power of firms vis-à-vis banks is equal, at the social optimum, to the elasticity of the finding rate of banks with respect to credit market tightness.

3. Under the Hosios rule, the search costs in the credit market are minimized, and so is M_f. Relaxing that condition leads to a larger financial accelerator, which can match or even overshoot the elasticity of market tightness in the data.

4. Away from the Hosios rule, four situations generate a large or very large volatility. 1. When the matching function in the credit market is "balanced", e.g. a Cobb-Douglas with elasticity around half each for each segment of the market (banks and firms) and when firms have a very low bargaining power in the bargaining relation with the bank. 2. In the symmetrical case with balanced matching in the credit market but when firms have a very high bargaining power in the bargaining relation with the bank also generate large volatility of labor markets. 3. When instead the matching function is unbalanced, corresponding to a situation in which credit creation is limited by "ideas of entrepreneurs", that is an excess of liquidity ; 4. When the matching function is unbalanced on the other side, corresponding to situation in which credit creation is limited by "supply of liquidity" , that is a scarcity of liquidity.

5. These results hold with endogenous or exogenous wages and in a static or dynamic setup : one can obtain any high elasticity of labor market volatility to productivity shocks in each of the four cases identified above.

Note that the recent crisis may have been an example of case 3, while the current post-crisis development with large injections of liquidity by Central Banks may resemble case 4.

The paper is organized as follows. In **Section 2**, we summarize the main equations in Wasmer and Weil (2004) and calculate the volatility of tightness to productivity shocks. In **Section 3**, we show how Hosios rule in the credit market affects the volatility. In **Section 4**, we proceed to the dynamic calibrations of the two variants of the model and show how changing the parameters of the model related to the matching technology substantially raise this elasticity. In **Section 5**, we extend the model to endogenous wages. In **Section 6** we conclude.

2 An economy with credit and labor market frictions

2.1 Wasmer and Weil (2004)

There are three types of agents: firms with no capital ; banks with no ability to produce ; workers with no capital and no ability to start a business. The timing of events of the firms is as follows : they initially need to find a "banker" in order to start a business. This search process costs c units of effort per unit of time. Search is successful with probability p. The firm then goes to the labor market. The bank finances the vacancy posting cost γ to attract workers (the so-called recruitment costs) for the firm. This search process succeeds with probability q. The firm is then able to produce and sell in the good market, which generates a flow profit $y - w - \varrho$ where y is the marginal product, w is the wage (assumed exogenous in this section, bargained in Section 5), r is the flow rate of discount, ϱ is the flow repayment to the bank (determined through bargaining). Jobs are subject to destruction shocks with Poisson parameter s. The steady-state asset values of the firms are denoted by E_j with $j = c, l$ or g the market in which the firm is searching, standing respectively for credit, labor and good markets. We also assume free entry at the first stage, that is $E_c \equiv 0$. We therefore have the following Bellman equations:

$$\begin{aligned} rE_c &= 0 = -c + pE_l & (1) \\ rE_l &= 0 + q(E_g - E_l) & (2) \\ rE_g &= y - w - \varrho + s(0 - E). & (3) \end{aligned}$$

In the last line, it was assumed that job destruction also leads the firm to destroy the lending relation with the bank.

Symmetrically, the bank's asset values are denoted by B_j, $j = c, l$ or g for each of the stages. We also assume free entry of the banking relationship : $B_c = 0$. We denote by k the screening cost per unit of time of banks in the first stage, and by $\widehat{p}$ the Poisson rate at which a bank finds a firm to be financed. We have:

$$\begin{aligned} rB_c &= 0 = -k + \widehat{p}B_l & (4) \\ rB_l &= -\gamma + q(B_g - B_l) & (5) \\ rB_g &= \varrho + s(0 - B_g). & (6) \end{aligned}$$

The matching rates p and $\widehat{p}$ are made mutually consistent by the existence of a matching function $M_c(\mathcal{B}, \mathcal{E})$ where $\mathcal{B}$ and $\mathcal{E}$ are respectively the number of bankers and of firms in stage c. This function is assumed to have constant returns to scale. Hence, denoting by ϕ the ratio $\mathcal{E}/\mathcal{B}$, which is a reflection of the tension in the credit market and that we shall call credit market tightness, we have

$$\begin{aligned} p &= \frac{M_c(\mathcal{B}, \mathcal{E})}{\mathcal{E}} = p(\phi) \text{ with } p'(\phi) < 0. \\ \widehat{p} &= \phi p(\phi) \text{ with } \widehat{p}'(\phi) > 0. \end{aligned}$$

After the contact, the bank and the firm engage in bargaining about ϱ which is such that

$$(1 - \beta)B_l = \beta E_l \tag{7}$$

where β is the bargaining power of the bank relative to the firm. With $\beta = 0$ the bank leaves all the surplus to the firm.

Combining (1), (4) and (7), we obtain the equilibrium value of ϕ denoted by ϕ^* with

$$\phi^* = \frac{k}{c}\frac{1-\beta}{\beta}.$$

Matching in the labor market is denoted by $M_l(\mathcal{V}, u)$ where u is the rate of unemployment and the total number of unemployed workers since the labor force is normalized to 1. $\mathcal{V}$ is the number of "vacancies", that is the number of firms in stage l. The function is also assumed to be constant return to scale, hence the rate at which firms fill vacancies is a function of the ratio $\mathcal{V}/u$, that is tightness of the labor market. We have

$$q(\theta) = \frac{M_l(\mathcal{V}, u)}{\mathcal{V}} \text{ with } q'(\theta) < 0.$$

Further using (5), (6) and (2), (3), we finally simultaneously solve for ρ and obtain the two main equations of the model :

$$\frac{\varrho}{r+s} = \beta\frac{y-w}{r+s} + (1-\beta)\frac{\gamma}{q(\theta)}$$

and

$$\text{(EE)} \quad : \quad \frac{c}{p(\phi)} = \frac{q(\theta)}{r+q(\theta)}\left(\frac{y-w}{r+s} - \frac{\gamma}{q(\theta)}\right)(1-\beta) \tag{8}$$

$$\text{(BB)} \quad : \quad \frac{\kappa}{\phi p(\phi)} = \frac{q(\theta)}{r+q(\theta)}\left(\frac{y-w}{r+s} - \frac{\gamma}{q(\theta)}\right)\beta \tag{9}$$

Each equation provides a link between θ and ϕ that is of opposite sign. There is therefore at most one equilibrium set of (θ^*, ϕ^*). Wasmer and Weil (2004) and Wasmer (2009) provide a condition for existence. Finally, summing up (EE) and (BB), one obtains a single market equation denoted by (CC) for θ^* :

$$\text{(CC):} \frac{c}{p(\phi^*)} + \frac{k}{\phi^* p(\phi^*)} = \frac{q(\theta)}{r+q(\theta)}\left(\frac{y-w}{r+s} - \frac{\gamma}{q(\theta)}\right) \tag{10}$$

where the left-hand side are a measure of the total amount of prospection costs in the financial markets denoted by K.

2.2 Steady-state volatility of θ to shocks

We now want to calculate the elasticity of θ to profit shocks, denoted by $\zeta_{\theta/\pi}$. Let $\pi = (y-w)/(r+s)$ be the present discounted value of profits. Let θ^P is the value of tightness solving for

$$\frac{y-w}{r+s} = \frac{\gamma}{q(\theta^P)} \tag{11}$$

The value of θ^P defined here is the credit frictionless world in Pissarides (1985). In using (EE), one has:

$$\frac{\gamma}{q(\theta^P)} - \frac{\gamma}{q(\theta^*)} = \frac{1}{1-\beta}\frac{c}{p(\phi^*)}\frac{r+q(\theta^*)}{q(\theta^*)} > 0$$

Hence, given that q' is downward sloping, we have that $\theta^* < \theta^P$ (Wasmer and Weil 2004), and the difference is precisely due to the existence of search costs in the credit market. Posing $r = 0$ to marginally simplify the analysis, we have

$$\pi - K = \frac{\gamma}{q(\theta^*)} \tag{12}$$

Taking logs and differentiating, we have

$$-\frac{q'(\theta^*)\theta^*}{q(\theta)^*}\frac{d\theta}{\theta^*} = \frac{d\pi}{\pi}\frac{\pi}{\pi - K}$$

or reusing (11) and (12) and where $\eta = -q'(\theta)\theta/q(\theta)$ is the (non-necessarily constant) elasticity of q to θ, we have

$$\zeta_{\theta/\pi} = \frac{d\ln\theta}{d\ln\pi} = \frac{1}{\eta}\frac{\frac{\gamma}{q(\theta^P)}}{\frac{\gamma}{q(\theta^*)}} = \frac{1}{\eta}\frac{q(\theta^*)}{q(\theta^P)}$$

Two remarks are in order. First, in the (credit) frictionless world in Pissarides, the elasticity is simply the inverse of the elasticity of q to θ, that is $1/\eta$. Second, the existence of credit market imperfections reduces θ^* relative to θ^P, hence raise the volatility $\zeta_{\theta/\pi}$ by a factor due to the financial accelerator identified in Wasmer and Weil (2004) : higher profits raise the entry of firms, hence banks make faster profits, which in turns benefits to firms, and so on. Denote by

$$M_f = \frac{q(\theta^*)}{q(\theta^P)}$$

the value of the financial accelerator, which can more generically be defined as the ratio of elasticity in a world with credit frictions and the elasticity in a world where credit frictions disappear. In their calibration, Wasmer and Weil (2004) find that $M_f = 1.74$. Hence the volatility of the economy to profit shocks is 1.74 larger than a Pissarides economy with perfect financial markets.

The response of this economy to productivity shocks on y is therefore :

$$\zeta_{\theta/y} = \frac{d\ln\theta}{d\ln y} = \frac{d\ln\theta}{d\ln\pi}\frac{d\ln\pi}{d\ln y} = \frac{1}{\eta}\frac{y}{y-w}M_f$$

The first one is the amplification due to the existence of search frictions. The second one is the gap between wages and marginal product - the smaller the gap, the more responsive job creations to productivity shocks ; and finally the third one is the financial accelerator.

With the parameters values in Wasmer and Weil (2004), $\eta = 0.5$, $y = 1$ and $w = 2/3$, hence

$$\zeta_{\theta/y} = 2 \times 3 \times 1.74 = 10.44.$$

This is a large factor compared to the conventional Pissarides elasticity in Shimer who found a much smaller number, namely 1.13.

The difference is due to three factors :

1. the choice of the matching elasticity on Shimer (1/0.28) ; assuming $\eta = 0.5$ instead raises the elasticity with respect to Shimer by a factor 2*0.72=1.44.

2. wage rigidity in our model (see Hall 2005): in the absence of rigidity in wages, the factor $\frac{y}{y-w} = 3$ would have to be replaced by a more complex term derived in Shimer. This is discussed later on in the part devoted to endogenous wages. In short, wage rigidity raise volatility by a factor 4 to 5.

3. The last part of the difference is due to the existence of a financial accelerator $M_f = 1.74$, consistently with the literature initiated by Bernanke and Gertler (1989).

The literature has attempted to raise the elasticity with either wage rigidities (Hall 2005) or by choosing higher values of z and lower values for the bargaining power of workers (Hagedorn and Manovskii 2008, which we call hereafter the "small surplus" assumption). While acknowledging the interest of these approaches, we pursue another root here and attempt to understand the determinants of M_f.

3 Entry costs and efficiency in the credit market

3.1 Hosios-Pissarides in the credit market

We start here in noting that frictions in the credit market may lead to a second best efficiency condition similar to that in Hosios (1990) and Pissarides (1990).

To see this, we can calculate the social welfare function as output net of all search costs. We have :

$$\Omega = y(1-u) + zu - \gamma\theta u - k\mathcal{B} - c\mathcal{E}$$

where $\theta u = \mathcal{V}$ is the number of firms prospecting in the labor market. To obtain a simpler expression for Ω, we can note that in a steady-state, we have $\mathcal{E}p(\phi) = q(\theta)\mathcal{V}$ which states that inflows into the financing stage are compensated by outflows out of that stage. It follows that

$$\mathcal{E} = \frac{q(\theta)\theta u}{p(\phi)} \text{ and } \mathcal{B} = \frac{\mathcal{E}}{\phi} = \frac{q(\theta)\theta u}{\phi p(\phi)}$$

Therefore, the social planner programs can be rewritten as

$$\begin{aligned}\max_{u,\theta,\phi}\Omega &= y(1-u)+zu-\gamma\theta u-\left(\frac{k}{\phi p(\phi)}+\frac{c}{p(\phi)}\right)q(\theta)\theta u \\ \text{s.t. } u &= s/(s+\theta q(\theta))\end{aligned}$$

Relative to the choice of the optimal ϕ denoted by ϕ^{opt}, the problem is simple and block-recursive in ϕ and then in u and θ. For the first block that we only consider here, the optimal choice of ϕ amounts to minimizing total search costs$K(\phi)=\frac{k}{\phi p(\phi)}+\frac{c}{p(\phi)}$:

$$\begin{aligned}\frac{\partial\Omega}{\partial\phi} &= q(\theta)\theta u\frac{\partial}{\partial\phi}K(\phi)=0 \\ &\Leftrightarrow \quad \phi^{opt}=\frac{1-\varepsilon}{\varepsilon}\frac{k}{c} \text{ where } \varepsilon=-\frac{\phi p'(\phi)}{p(\phi)}{}_1\end{aligned}$$

Hence, the socially optimal value of credit market tightness is the one that minimizes prospection costs. The Hosios-Pissarides rules applies here :

$$\begin{aligned}\phi^* &= \phi^{opt} \\ &\Leftrightarrow \quad \beta=\varepsilon : \text{Hosios condition in the credit market}\end{aligned}$$

This rule states that there is a value of the bargaining parameter over ρ that internalizes the matching externalities due to frictions.

3.2 Minimizing the financial costs and the gap between θ^* and θ^P

One may think that the Hosios condition is the one that minimizes entry costs in the credit market. One can check this formally. The left-hand side of equation (CC) is a function of β and ε denoted by $K(\beta,\varepsilon)$; the right-hand side is increasing in θ. It is therefore enough to show that $K(\beta,\varepsilon)$ is minimized in $\beta=\varepsilon$. Before doing so, we can use two intermediate steps. First, note that $K(\beta,\varepsilon)=\frac{\frac{c}{p(\phi^*)}}{1-\beta}$from equation (EE) divided by $(1-\beta)$. Second, we have $\frac{\partial\phi^*}{\partial\beta}=\frac{-1}{\beta^2}\frac{k}{c}$hence

$$\frac{\partial K}{\partial\beta}=\frac{\frac{-cp'}{p^2(\phi^*)}\frac{\partial\phi^*}{\partial\beta}}{1-\beta}+\frac{\frac{c}{p(\phi^*)}}{(1-\beta)^2}=0\Leftrightarrow\varepsilon=\beta^2 \tag{6}$$

Given that $\zeta_{\theta/\pi}$ is increasing in the gap between θ^* and θ^P, at any ϕ^*, the Hosios condition in the credit market is the one minimizing the volatility induced by financial imperfections. Away from this equation, one has necessarily a larger financial accelerator.

4 A dynamic extension and calibrations

In this Section, we study the model with departures from the above condition in the credit market, i.e. with $\beta \neq \varepsilon$. For that, and in order to provide the most general results, we relax $r = 0$ and further calibrate the dynamic evolution of the double-matching economy.

We make the following assumptions for convenience. First, time is discrete and labor productivity is assumed to follow a stationary AR(1) process $y_t = \rho_y y_{t-1} + \nu_t$, where $0 < \rho_y < 1$ and ν_t is white noise. Second, an entrepreneur meeting a banker begins the recruiting process within the period. A successful meeting between an entrepreneur and worker begins production the following period. Maintaining our assumption of free entry on both sides of the credit market and bargaining over ϱ, we find that the equilibrium value of ϕ is time invariant and of the same form as earlier.[3] Moreover, ϱ is assumed to be determined when a banker and an entrepreneur meet and is solved as

$$E_t\left[\rho_{t+1}\right] = \beta E_t\left[y_{t+1} - \overline{w}\right] + (1-\beta)E_t\left[\frac{(1+r)\gamma}{q(\theta_t)} - \frac{(1-s)\gamma}{q(\theta_{t+1})}\right] \tag{7}$$

where E_t is an expectations operator over productivity and $\overline{w}$ is a fixed wage.

From the constant values of being in the recruiting stage, $B_{l,t} = \frac{\kappa}{\phi p(\phi)}$ and $E_{l,t} = \frac{c}{p(\phi)}$, we can combine the (EE) and (BB) curves in this dynamic environment,

$$\begin{aligned}
\frac{c}{p(\phi)} &= \frac{q(\theta_t)}{1+r}E_t\left[E_{g,t+1}\right] + \frac{(1-q(\theta_t))}{1+r}\frac{c}{p(\phi)} \\
\frac{\kappa}{\phi p(\phi)} &= -\gamma + \frac{q(\theta_t)}{1+r}E_t\left[B_{g,t+1}\right] + \frac{(1-q(\theta_t))}{1+r}\frac{\kappa}{\phi p(\phi)}
\end{aligned}$$

to obtain a job creation condition in the presence of frictional credit markets

$$\frac{\Gamma_t}{q(\theta_t^*)} = \frac{1}{1+r}E_t\left[y_{t+1} - \overline{w} + (1-s)\frac{\Gamma_{t+1}}{q(\theta_{t+1}^*)}\right] \tag{8}$$

where $\Gamma_t \equiv \gamma + \Sigma\left(1 - \frac{1}{1+r}(1-q(\theta_t^*))\right)$ are vacancy costs augmented for frictional credit markets and $\Sigma = \frac{c}{p(\phi)} + \frac{\kappa}{\phi p(\phi)}$ the total prospection cost in the credit market.

Note two special cases. When $r = 0$, Γ_t is simply the sum of all prospection costs in credit and labor markets, unadjusted for discounting. When credit markets are perfect, Γ_t boils down to γ, and the job creation condition is reduced to

$$\frac{\gamma}{q(\theta_t^P)} = \frac{1}{1+r}E_t\left[y_{t+1} - \overline{w} + (1-s)\frac{\gamma}{q(\theta_{t+1}^P)}\right] \tag{9}$$

[3] Time invariance follows from the sharing rule $(1-\beta)B_{l,t} = \beta E_{l,t}$ which implies a constant ratio $\frac{E_{l,t}}{B_{l,t}} = \frac{1-\beta}{\beta}$.

4.1 Elasticity of θ_t to shocks

Define period profits $\Pi_t = y_t - \overline{w}$. Taking log-linear deviations around a steady state of equation (9), deviations in market tightness can be expressed as a discounted sum of deviations in future expected profits

$$\widehat{\theta}_t^P = \frac{q(\theta^P)}{\eta\gamma(1+r)} E_t \sum_{i=0}^{\infty} \left(\frac{1-s}{1+r}\right)^i \widehat{\Pi}_{t+1+i}$$

Given a fixed wage and the assumption on productivity, this is simply $\widehat{\theta}_t^P = \frac{q(\theta^P)}{\eta\gamma(1+r)} \sum_{i=0}^{\infty} \rho_y^{i+1} \nu_t$ such that the elasticity of market tightness to a productivity shock in the Pissarides world with a fixed wage is

$$\widehat{\theta}_t^P = \frac{q(\theta^P)\rho_y}{\eta\gamma\left[(1+r)-(1-s)\rho_y\right]}\nu_t \tag{10}$$

By the same steps, the elasticity in the presence of credit frictions is given by

$$\widehat{\theta}_t^* = \frac{q(\theta^*)\rho_y}{\eta\gamma^T\left[(1+r)-(1-s)\rho_y\right]}\nu_t \tag{11}$$

where $\gamma^T \equiv \left[\gamma + \Sigma\left(\frac{r}{1+r}\right)\right] > \gamma$ is a measure of total frictional costs in both credit and labor markets.

Denote the financial multiplier in this dynamic setting

$$M_f \equiv \frac{\partial\widehat{\theta}_t^*/\partial\nu_t}{\partial\widehat{\theta}_t^P/\partial\nu_t} = \frac{q(\theta^*)}{q(\theta^P)}\frac{\gamma}{\gamma^T}$$

4.2 Calibration and results

We follow an incremental strategy, building on a calibration of the Pissarides model to a set of steady state labor market outcomes. In order to achieve a wage consistent with the model of two thirds of labor productivity, we set the value of non-market activities z to 0.15 and the worker's bargaining weight to 0.2. We apply a labor Hosios condition and set the elasticity of the labor matching function equal to the worker's bargaining weight. The latter is assume to be a Cobb-Douglas $M_l(\mathcal{V}, u) = \chi\mathcal{V}^{1-\eta}u^{\eta}$ and, given a value for unit recruitment costs of γ =0.95, we adjust the level parameter χ to achieve a desired level of unemployment, approximately 13% in this calibration. Finally, the risk free rate is set 4%, corresponding to an 3-month treasury bill, and the persistence coefficient in the process for productivity is set to 0.95.

The calibration of the credit market requires choosing parameters of the credit matching function, assumed to be of the form $M_c(\mathcal{B}, \mathcal{E}) = \varsigma\mathcal{E}^{1-\epsilon}\mathcal{B}^{\epsilon}$, the costs of prospecting on credit markets and the bargaining weight β. The baseline calibration adopts equal bargaining between creditor and entrepreneur, $\beta = \epsilon = 0.5$, and symmetry in prospecting costs $\kappa = c = 0.05$. The remaining parameter, ς, is set such that the internal return on capital equal X%.

Table 1: Baseline results

	$q(\theta)$	Wage	Elasticity	Financial accelerator M_f
Pissarides				
- fixed wage	0.33	0.68	7.71	1
Credit friction - fixed wage				
$\beta = 0.5, \varepsilon = 0.5$	0.40	0.68	9.31	1.21
$\beta = 0.1, \varepsilon = 0.9$	0.94	0.68	21.83	2.83
$\beta = 0.9, \varepsilon = 0.1$	0.94	0.68	21.83	2.83

Table 1 presents the resulting steady state wage and job filling rate for several scenarios. The first three rows compare the Pissarides and credit friction worlds for a same wage rate. The elasticity of market tightness in the Pissarides model with rigid wage is 4.7s time greater than when wages are flexible (see Table 2), while frictional credit markets under the Hosios condition, increase this elasticity by an additional factor of 1.21. However, as we move away from this condition, as illustrated in Figure 1, the increased distortion caused by frictional credit markets amplify the effect of productivity shocks on labor market tightness.

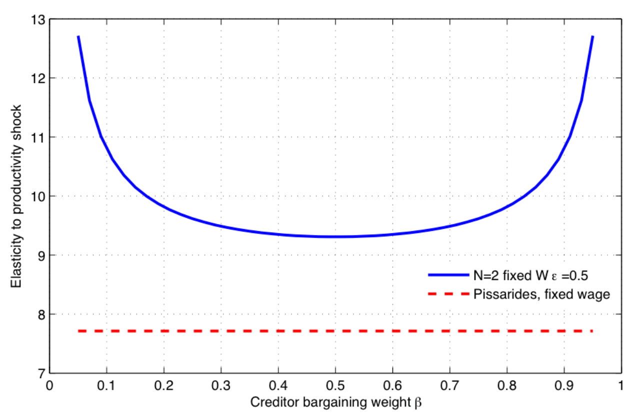

Figure 1: Elasticity of market labor market tightness to productivity shocks.

We explore this further with two cases in which there are large departures in the degree of matching externalities and creditor's bargaining weight. In

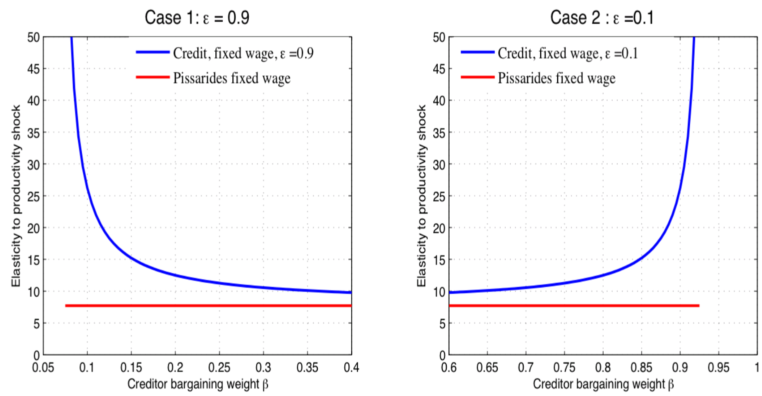

Figure 2: Two cases

both cases there is near linearity in the matching function, first in the supply of entrepreneurs, second in the supply of creditors, the results for which are shown, respectively, in the first ($\varepsilon = 0.9$) and second ($\varepsilon = 0.1$) panels of Figure 2. Case 1 shows that if matching is near linear in supply of entrepreneurs and we depart from the credit market Hosios condition, the elasticity of labor market tightness to productivity shocks becomes potentially very large and can overshoot the elasticity in the data. For example, when $\beta = 0.1$ the elasticity exceeds 20, corroborating the results in Petrosky-Nadeau (2009). A step further, at $\beta = 0.05$, the elasticity exceeds 50. The exact inverse is observed when the matching function is near linear in the supply of creditors, as can be seen in the second panel of Figure 2.

5 Robustness : endogenous wages

Endogenous wage seriously reduce the elasticity of labor market tightness to productivity shocks. This paper must therefore address the question and replicate the analysis of the previous section with endogenous wages. In this paper, we assume that the worker bargains the wage with the block firm+bank at the time of the meeting. There are two related reasons for this choice.

The first one is that the natural alternative, bargaining between the bank and the firm, leads to complex strategic interactions illustrated in Wasmer and Weil (2004, Section IV-A) : the firm and bank wish to raise the debt of the firm above what is needed in order to reduce the size of total surplus to be shared between the firm and the worker later on. Hence, wages are driven down, to the reservation wage of workers. This leads to the second reason, which is that we want our endogenous wage extension to be as comparable as the classical wage solution in the literature in order to compare the volatility in the model to other elasticities found in the literature.

We therefore verify the robustness of our results to allowing wages to adjust to changes in productivity. Defining the values of employment and unemployment in a discrete time dynamic setting as

$$\begin{aligned} U_t &= z + f(\theta_t)\beta E_t W_{t+1} + (1 - f(\theta_t))\beta E_t U_{t+1} \\ W_t &= w_t + \beta E_t \left[(1-s)W_{t+1} + sU_{t+1}\right] \end{aligned}$$

the Pissarides wage is $w_t^P = \alpha \left(y_t + \gamma \theta_t^P \right) + (1-\alpha)z$ where α is the bargaining power of workers vis-à-vis the firm. Taking log-deviations, movement in market tightness to future productivity are

$$\widehat{\theta}_t^P = \frac{q(\theta^P)(1-\alpha)}{\eta\gamma(1+r)} E_t \sum_{i=0}^{\infty} \Psi^i \widehat{y}_{t+1+i}$$

where the second term in $\Psi = \left(\frac{1-s}{1+r}\right) - \frac{\alpha\theta^P q(\theta^P)}{\eta(1+r)}$ reflects the share of the change in productivity accruing to the worker through the wage. The latter strongly reduces the elasticity of labor market tightness to productivity shocks which, with our specification, is

$$\widehat{\theta}_t^P = \frac{q(\theta^P)(1-\alpha)\rho_y}{\eta\gamma(1+r) - \gamma\left[\eta(1-s) - \alpha f(\theta^P)\right]\rho_y} \nu_t \tag{12}$$

In our baseline calibration we find an elasticity of 1.6 when wages are endogenous.[4]

As discussed earlier, we assume that the wage negotiated in a worker-firm pair in the presence of credit market frictions satisfies $\alpha F_{g,t} = (1-\alpha)(W_t - U_t)$ where $F_{g,t} = E_{g,t} + B_{g,t}$ is the joint value of the firm to the entrenpreneur-banker pair. Under this assumption the wage is

$$w_t = \alpha \left[y_t + \Gamma_t \theta_t\right] + (1-\alpha)z$$

and differs from the Pissarides wage by the coefficient Γ_t on market tightness. To the extent the this term is negatively correlation with productivity, credit market frictions induce a certain degree of wage rigidity by limiting the effect of a rise in market tightness. To see why this is the case, recall that $\Gamma_t \equiv \gamma + \Sigma\left(1 - \frac{1}{1+r}(1 - q(\theta_t^*))\right)$ are vacancy costs augmented for frictional credit markets. Since q is decreasing in market tightness, so is Γ.

The elasticity of market tightness in the presence of friction credit market and endogenous wage we derive is,

$$\widehat{\theta}_t = \frac{q(\theta)(1-\alpha)\rho_y}{\eta\gamma^T(1+r) - \left[\eta\gamma^T(1-\delta) - \alpha f(\theta)(\gamma^T + (1-\eta)\widetilde{\kappa})\right]\rho_y} \nu_t \tag{13}$$

[4] To check the result, note that is $\rho_y = 1$ this is the elasticity obtained when comparing steady states, or to a permanent productivity shock, as in Shimer (2005), i.e. $\epsilon_{\theta,y} = \frac{(1-\alpha)}{\gamma\left[\frac{\eta(r+s)}{q(\theta^P)} + \alpha\theta^P\right]}$.

where $\widetilde{\kappa} \equiv \Sigma \frac{q(\theta)}{1+r}$.

Table 2 present the results when wages are endogenous. We focus on two sets of results: 1) when we depart from the credit market Hosios condition and 2) when the we calibrate to a small labor surplus. But first, note that when the credit matching function is equally weighted and we are at the credit Hosios condition, frictional credit markets with endogenous wages provied a significant financial accelarator. The elasticity of market tightness increases from 1.6 in the Pissarides model to 7.06 in ours, a factor of 4.4. When the credit matching function is near linear in the number of bankers and the latter bargaining weight equal 0.1, frictional credit markets increase the elasticity to 9.13, above the elasticity obtained for the Pissarides model with a fixed wage.

We next looking into the proposition that has appeared in the literature of calibrating to a small labor surplus in the last rows of Table 2. Such a strategy

yields an elasticity of market tightness for the Pissarides model of 9.12. When we perform the same exercise by applying the Hosios condition on credit markets and an equal bargaining weight, the elasticity reaches 20.31. The elasticity rises to 27.5 by reducing β to 0.1, and the model largely over shoots the data if in addition we set ϵ to 0.9 by implying an elasticity of 45.46.

Table 2: Robustness to endogenous wages

	$q(\theta)$	Wage	U	Elasticity	Financial accelerator M_f
Pissarides					
- flexible wage	0.10	0.69	0.126	1.60	1
Credit friction - flexible wage					
$\beta = 0.5, \varepsilon = 0.5$	0.26	0.69	0.128	7.06	4.41
$\beta = 0.1, \varepsilon = 0.9$	0.32	0.62	0.22	9.13	5.70
$\beta = 0.9, \varepsilon = 0.1$	0.32	0.62	0.22	9.13	5.70
Small labor surplus					
- Pissarides	0.51	0.95	0.13	9.12	5.70
- Credit friction					
$\beta = 0.5, \varepsilon = 0.5$	0.52	0.96	0.14	20.31	12.7
$\beta = 0.1, \varepsilon = 0.5$	0.68	0.97	0.15	27.50	17.2

6 Conclusion

Financial imperfections raise the calibrated elasticity of tightness to productivity shocks by a factor M_f called the financial multiplier.

With exogenous wages, it is easy to generate a plausible large elasticity of labor market tightness to productivity shocks, if one relaxes the Hosios-Pissarides rule in the credit market. Under the assumption of a large enough difference between the bargaining power of banks vis-à-vis firms (β) with the elasticity of the finding rate of banks with respect to credit market tightness (ε), one gets a elasticity around 20 or even larger.

With endogenous wages with bargaining power α of workers relative to the entity (bank+firm), all elasticities are divided by a factor 4 to 5, as was established by Shimer (2005) and Hall (2005). Hence, the model requires more extreme values of β or ε, (e.g. 0.95 or 0.05). Alternatively, with the same values of β and ε as in the exogenous wage case, the model can generate large volatility with less stringent assumptions on α or z (value of leisure of the unemployed) as compared to the 'small surplus assumptions' in Hagedorn and Manovskii (2008).

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