# Credit imperfections, labor market frictions and unemployment: a DSGE approach

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# Credit Imperfections, Labor Market Frictions and Unemployment: a DSGE approach

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**Abstract**

This paper investigates the impact of credit market imperfections on unemployment, vacancy posting and wages. We develop and simulate a new-Keynesian DSGE model, integrating sticky prices in goods market and frictions in labor and credit markets. A search and matching process in the labor market and a costly state verification framework in the credit market are introduced. Capital spending, vacancies costs and wage bill need to be paid in advance of production and thus require external financing in a frictional credit market. The theoretical model demonstrates how the procyclicality of the risk premium impacts the vacancy posting decisions, the wage and unemployment levels in the economy. Higher credit market frictions are the source of lower posting vacancies and higher unemployment level. Asymmetric information in the signing of a loan pushes up wholesale firms' marginal costs, as well as hiring costs by a financial mark-up charged by financial intermediaries. This financial mark-up is then transmitted by these firms on prices. Thus, it affects their hiring behavior, the wage and employment levels, as well as inflation in the economy. Then, the theoretical model is simulated by using quarterly United-States (US) data for the sample period 1960:Q1 to 2007:Q4. We find that employment rates and vacancy posting increase following positive credit, net worth and uncertainty shocks. Different channels of propagation from the financial sphere of the economy to the labor market are investigated and the results appear to be consistent with our theoretical model.

*JEL classification*: E12, E24, E32, E44

*Keywords*: new-Keynesian model, labor and credit market frictions, vacancies and unemployment dynamics, intensive and extensive margins, credit shocks

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# 1 Introduction

Credit market imperfections are suspected of playing a key role in the worsening of the situation on the labor market. In recent years, especially following the Great Recession, there has been an increasing interest in analyzing the interaction between credit and labor markets. Questions have been raised about the fact that higher credit imperfections may be the cause of a slowdown of the economy, and not its consequence. By themselves, financial frictions could destabilize the whole economy. The research to date has tend to focus either on the impact of financial frictions on overall macroeconomic performances (Bernanke and Gertler (3), Bernanke and Gertler (4), Carlstrom and Fuerst (10), Kiyotaki and Moore (26), Bernanke et al. (5), Carlstrom and Fuerst (11), Gertler et al. (22) and Fiore and Tristani (18)), either on the impact of labor market frictions (Merz (33), Andolfatto (2), Walsh (47), Krause et al. (28), Gertler and Trigari (24), Thomas and Zanetti (44), Trigari (46), Christoffel et al. (15), Lechthaler et al. (31), Blanchard and Galí (6), Galí et al. (20), Campolmi and Faia (9), Christiano et al. (13)). However, far too little attention has been paid to the impact of financial frictions on labor markets, being themselves imperfect (Thomas and Zanetti (44), Christiano et al. (14), Zanetti and Mumtaz (50) and Petrosky-Nadeau (38)).

Figures 1 and 2 shed light on the possible causal relationships that we propose to study and highlight in this paper. The evolution of unemployment rate, Baa-Aaa spread and default rate between 1970-Q1 and 2007-Q4 for the United-States (US) is represented in figure 1. The unemployment rate is the ratio of civilian unemployed persons to the civilian labor force. The default rate is the default rate for Moody's rated US speculative-grade corporate bonds. The Baa-Aaa spread is the Moody's seasoned Baa-Aaa corporate bond yield. A correlation is observed among these variables, especially for the unemployment rate and the Baa-Aaa spread (0.76). The higher the unemployment rate is, the higher the Baa-Aaa spread is and conversely. For the default rate, the correlation is less explicit, due to plausible structural forces between 1971 and 1982, linked to the monetary policy. However, some periods of correlation exist: 1979-Q1 until 1985-Q4 (0.6) and from 1990 (0.32). Then, the negative correlation between the labor market tightness and the Baa-Aaa spread is shown on figure 2. The negative correlation among 1970.Q1 and 2007.Q4 is quite huge ($-0.84$). It induces that the higher are vacancy posting relative to unemployment, the lower is the Baa-Aaa spread and conversely. Based on these basic empirical correlations, we construct and simulate a new-Keynesien model integrating credit and labor market frictions, so as to figure out possible causal links among this kind of variables.

The model is a monetary new-Keynesian model with asymmetric information in the credit market à la Bernanke et al. (5) and a search and matching process in the labor market à la Mortensen and Pissarides (35). Capital spending, wage bill and vacancies costs are assumed to be paid partially by external funds (Petrosky-

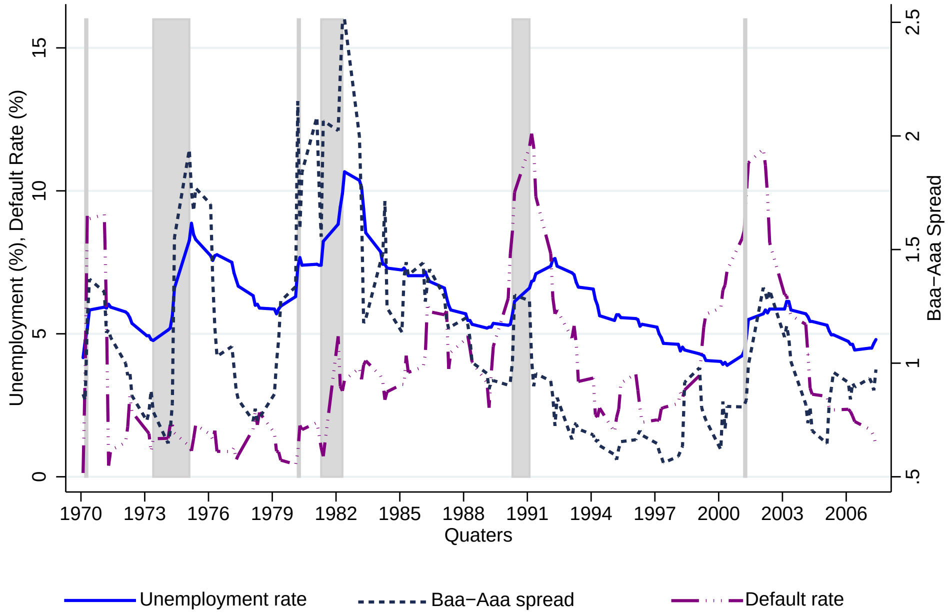



**Figure 1:** Unemployment, Baa-Aaa Spread and Default Rate between 1970-Q1 and 2007-Q4 for the United-States

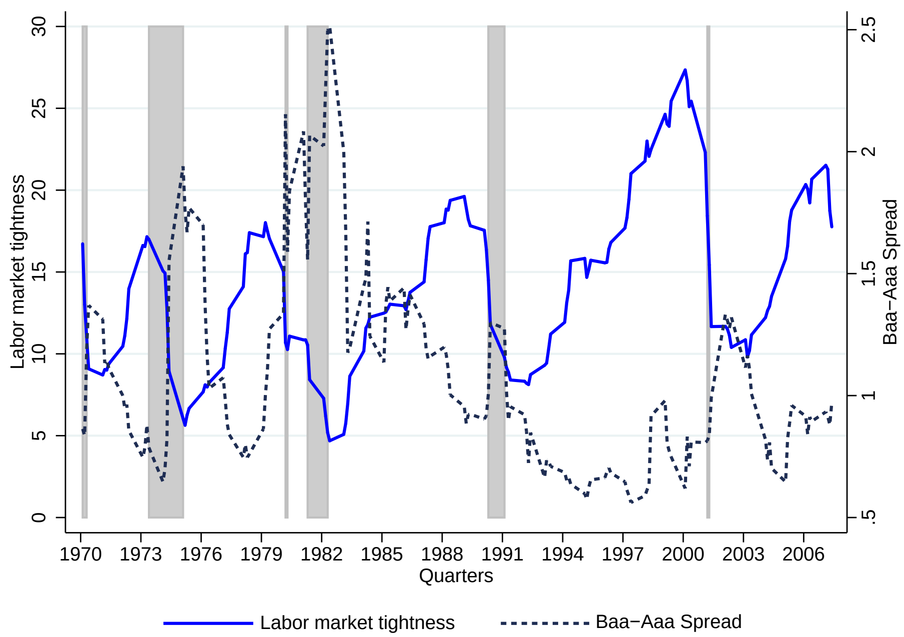



**Figure 2:** Labor-market tightness and Baa-Aaa Spread between 1970-Q1 and 2007-Q4 for the United-States

Nadeau (38) consider that only vacancies costs are paid in advance). The costly state verification (CSV) approach (Townsend (45)) is used because of its tractability and the facility that it offers to embed informational frictions in a general equilibrium analysis. Moreover, this approach was chosen because it generates a wedge between the cost of internal and external finance, with a financial accelerator mechanism. The propagation and amplification mechanism come from the fluctuation of entrepreneurs' net worth, while in collateral constraints framework (Kiyotaki and Moore (26)), it comes from fluctuations in asset prices.

Our model, based on these features, provides an explanation of cyclical fluctuations in key labor market variables (unemployment, vacancies, hours worked per employee and wages) and in credit market central variables (risk premium and default rate). We find that the procyclicality of the risk premium (the cost of external over internal funds) impacts vacancy posting decisions, the wage bill and unemployment levels in the economy, as well as the level of inflation. In period of downturns, the risk premium increases and the net worth of entrepreneurs decreases. It increases their dependence on external funds, making job posting more expensive. So, less vacancies are posted and a higher equilibrium unemployment is obtained. More precisely, asymmetric information in the credit market pushes up marginal costs and prices, as well as hiring costs by a financial mark-up, depending on the levels of monitoring cost and idiosyncratic shock threshold. This financial mark-up is made to overcome the agency problem between financial intermediaries and entrepreneurs. But it will be charged in return by wholesale firms on prices and will affect their hiring behavior, as well as wage, employment and inflation levels in the economy.

A simulation exercise, based on parameters calibration, is then chosen to investigate the impact of a net worth shock, a credit shock and an uncertainty shock on macroeconomic variables, such as vacancies, unemployment rate, real wages, intensive and extensive margins. Quarterly US data for the sample period 1960:Q1 to 2007:Q4 are used. The most striking result to emerge from the simulation is that employment rates and vacancies posting increase well following positive credit, net worth and uncertainty shocks. Different channels of propagation from the financial sphere of the economy to the labor market are investigated and appear to be consistent with our theoretical model. The key mechanism behind this result is that following positive shocks on the credit market, the financial mark-up decreases, leading to lower real marginal costs paid by wholesale firms, that is pass through prices in the economy, and inducing firms to post more vacancies. The unemployment as a consequence decreases. Furthermore, after a positive net worth shock, a substitution effect appears between hours worked per employee and the number of employees, either between the intensive and the extensive margins. This element is verified in the data, in the sense that the extensive margin is always more reactive that the intensive one. This substitution effect does not appear following a positive credit shock, or a positive uncertainty shock, resulting in a higher positive impact on the whole economy.

Section 2 consists of a related literature review. The theoretical model is developed in Section 3. In Section 4, we outline the simulation exercise and present the consequent results. Section 5 summarizes and concludes.

## 2 Related literature

As explained in the previous section, the paper is at the intersection of different lines of research. Firstly, a number of research papers introduce search and matching frictions on labor markets in real business cycle (RBC) models or in new-Keynesian (NK) models. Other articles highlight the role of financial frictions for macroeconomic dynamics, without taking into account search and matching frictions on labor markets. Finally, more recent studies embody simultaneously frictions in labor and credit markets in partial equilibrium models or in dynamic stochastic general equilibrium (DSGE) models, to study interactions and implications of these two types of frictions.

The assumption of Walrasien labor markets is considered as a weakness of standard RBC and NK models. Indeed, these models do not take into account variations in the number of unemployed, the extensive margin that never changes. They allow only to study variations in hours worked per employee, the intensive margin. This may seem annoying to the extent that unemployment is an important indicator of performances of the economy in its use of resources and it is a major policy issue. Furthermore, this kind of models is ineffective to explain the effect of various shocks on unemployment dynamics. As a consequence, many articles have introduced search and matching frictions in labor markets, based on Mortensen and Pissarides (35) framework, in RBC models or in NK models (Merz (33), Andolfatto (2), Walsh (47), Krause et al. (28), Gertler and Trigari (24), Thomas and Zanetti (44), Trigari (46), Christoffel et al. (15), Lechthaler et al. (31), Blanchard and Galí (6), Galí et al. (20), Campolmi and Faia (9), Christiano et al. (13)).

Papers, as those of Merz (33) and Andolfatto (2), study implications of search and matching frictions for economic fluctuations in a standard RBC model. Both model show that labor market frictions are a mechanism of amplification and persistence for technology shocks. These frictions improve the empirical performance of RBC models, compared to a standard one, even if they do not predict enough cyclical movements in vacancies and output compared to data. Moreover, Andolfatto (2), by introducing extensive and intensive margins, finds that most of the variability of total hours worked is due to changes in unemployment level rather than hours worked per employee.

Then, several papers in the same spirit (Walsh (47), Trigari (46), Thomas and Zanetti (44), Lechthaler et al. (31) and Campolmi and Faia (9)) examine the role of matching frictions in new-Keynesian models. For example, Walsh (47) develops a new-Keynesien DSGE model with labor market frictions and with different potential sources of persistence (habit persistence, price stickiness and policy inertia). He founds through a calibration exercise that his model amplifies for US data the output response and decreases the inflation response to a monetary policy shock, as well as it generates persistence in output and inflation as observed in data and as

standard NK models do not succeed to generate. In the same idea, Trigari (46) considers cyclical fluctuations of output, inflation and labor market variables following a monetary shock. She studies the possibility of endogenous separation between firms and workers, as well as extensive and intensive margins. Her estimated model is able to replicate well for US data the observed responses of output, inflation and labor market data to a monetary policy shock. Using a VAR, she finds as observed in data that in a model with labor market frictions, the response of inflation is less volatile and response of output more persistent after a monetary policy shock than in a standard NK model.
However, these Mortensen-Pissarides search and matching models of unemployment remaines unable to match important stylized facts observed in data. In particular, these types of models are not performing well to explain high volatility and persistence of unemployment and vacancies, as well as the relative smooth behavior of real wages found in data. The framework of wage Nash bargaining appears to lead to an exaggerated procyclical movements in wages after a positive productivity shock for example, that dampens the firm's incentives to hire. Wages absorb much of the change in the expected benefit to a new worker induced by fluctuations in labor productivity. As a consequence, several papers try to tackle this issue by introducing wage rigidity mechanisms (Shimer (41), Gertler and Trigari (24) and Christiano et al. (13)) or hiring and firing costs. Firstly, Blanchard and Galí (6) find that while search and matching frictions modify the level of unemployment but the unemployment rate stays invariant to productivity shocks. Thus, they study alternative wage-setting (Nash bargaining wage and more rigid real wages) and show that rigid wages enable to have inefficient fluctuations in unemployment after a productivity shock. Lechthaler et al. (31) introduce in a new-Keynesian model labor market frictions, through hiring and firing costs but no wage rigidity. They find trough a calibration on a given European country, more persistence in output and unemployment in response to real and monetary policy shocks and in inflation in response to real shocks, as well as a strong amplification effect of these shocks on unemployment and on the job finding rate. Gertler and Trigari (24) reproduce by calibration, in a standard Mortensen-Pissarides search and matching framework with a staggered multiperiod Nash wage, the relative volatile behavior of unemployment and the relative smooth behavior of real wages over the business cycle as observed in data.

On the other hand, frictions have been also studied on the credit market side (Bernanke and Gertler (3), Bernanke and Gertler (4), Carlstrom and Fuerst (10), Kiyotaki and Moore (26), Bernanke et al. (5), Carlstrom and Fuerst (11), Gertler et al. (22) and Fiore and Tristani (18)). They have been devoted to understand the relationship between financial markets and overall macroeconomic performances. Financial factors are indeed suspected to amplify and increase persistence of macroeconomic variables responses to aggregate shocks. The idea behind is that deteriorating credit conditions could be the source of poor economic activity and not the consequence of a declining real economy.

Bernanke and Gertler (3), **?** ), Kiyotaki and Moore (26) and Bernanke et al. (5) develop the concept of a financial accelerator in DSGE models integrating money and price stickiness. Without credit frictions, an entrepreneur can resort to external financing to raise capital at a risk-free interest rate. With credit market frictions, information asymmetry appears in the form of moral hazard between the lender and the borrower. Borrower will indeed be induced to report to the lender a lower real output produced than their true level. As a consequence, this type of asymmetric information can lead first to borrowing restrictions for borrowers on the amount of external financing available, based on the existence of collateral constraints to cover their potential inability to reimburse loans as in Kiyotaki and Moore (26). In this framework, agents face endogenous credit limits determined by the value of collateralized assets. Collateral constraints always bind but default never occur at the equilibrium. Then, asymmetric information between a lender and a borrower can lead to a second type of financial frictions (Bernanke and Gertler (3), **?** ), Bernanke et al. (5)), namely a higher cost of external financing compared to internal financing opportunity cost (the risk-free interest rate), that to say an external finance premium or a risk premium, paid by entrepreneurs. Agency costs are here endogenous over the business cycle and default emerges as an equilibrium phenomenon. The canonical RBC model of **?** ) introduce informational asymmetry between lenders and borrowers and show that it leads the economy to return more slowly to the steady-state after being hit by a shock (propagation mechanism). The mark-up distorts factor markets, so wages and capital rental rates are below their corresponding productivity. Thus, an increase in the net worth of a firm reduces agency costs and hence the mark-up. Debt arises as the optimal financial contract between firms and banks, and firms must borrow at a premium over the risk-free rate. The financial contract is designed to minimize the expected agency costs. It specifies returns when bankruptcy or success occurs and a monitoring threshold as developed in our model. The threshold is a decreasing function of borrower's net worth and an increasing function of the deposit risk free-rate (opportunity cost).

Fiore and Tristani (18) show also, by adopting the costly state verification set-up, that financial market conditions are important to explain macroeconomic outcomes because its affects firms' marginal costs. Higher credit spreads increase lending rates and marginal cost of credit for firms, which leads to increase prices and as a consequence, it affects output.

All these previous papers assume standard Walrasien labor markets. Only few papers consider both credit and labor markets frictions, as the ones of Christiano et al. (14), Zanetti and Mumtaz (50) and Petrosky-Nadeau (38). Labor market frictions imply that it is costly to hire new workers. The functioning of frictional labor markets prevents the competitive allocation of labor resources, and thus it will interact with financial frictions to impact production, unemployment, investment and capital accumulation. Those models enhance the Bernanke et al. (5) framework with a more realistic labor market. Christiano et al. (14) show in a new-Keynesian model that financial and employment frictions are able to change the model dynamics in an open economy setting, and improve the forecasting properties of the model for Swedish data, in particular for inflation. Zanetti and Mumtaz (50) demonstrate through a Bayesian estimation that labor and financial frictions are supported by the data and that they play together to amplify or reduce the variables' reaction to various shocks. Firms have in their model to paid only capital in advance. Petrosky-Nadeau (38) considers that firms finance only their vacancies costs with external financing on frictional credit markets. He finds that the easing of financing constraints during an expansion (a productivity shock) reduces the opportunity cost for resources allocated to job creation (cost channel), because firms are able to accumulate net worth. Credit market frictions generate persistence in the dynamics of labor-market tightness and have a moderate effect on amplification.

The research to date has tended to focus on technological or monetary policy shocks. No paper tries to investigate direct shocks from the financial sphere, such as credit, net worth or uncertainty shocks. Furthermore, no paper takes into account that production costs, as well as vacancies costs are paid in advance in a DSGE framework. Our paper tries to bring the gap. Besides, note that our framework is different from the one of Acemoglu (1) or Wasmer and Weil (48), Petrosky-Nadeau and Wasmer (39), who assume search frictions on both labor and credit markets. Search frictions and agency costs are both credit market imperfections but we decide to focus on agency costs by a costly-state verification framework. Note also that our work is included in the spirit of researches about the impact of credit market imperfections on investment flows but on our side, we decide to focus on their impact on employment and vacancies flows, hours worked and wages.

# 3 The model

## 3.1 Model overview and timing summary

The model is populated by seven types of agents: households, wholesale-good firms managed by entrepreneurs, retailers, final-good firms, banks and a government that conducts monetary and fiscal policies.

The household sector is represented by a continuum of identical households of length unity. Each household is constituted of members who are either working or unemployed. All members are supposed to be risk-averse. They supply labor, consume, rent capital and save through money holding and through their deposits in a financial intermediary.

Entrepreneurs are risk-neutral and have finite lifetime. Following Bernanke et al. (5), each entrepreneur is assumed to have a given probability to survive to the next period. They manage wholesale firms, that produce wholesale goods using a constant return-to-scale technology using labor and capital as inputs. Surviving entrepreneurs carry their profits as a part of their net worth. Dying entrepreneurs consume everything. After deciding on the number of new workers they need, entrepreneurs, based on their net worth amount and their expected production and returns, borrow funds from banks to post vacancies (and recruit workers), to pay capital spending and the wage bill in advance. However, wholesale-good production is subject to an idiosyncratic shock, privately observed by entrepreneurs, while banks need to pay a monitoring cost to check the real output produced, as well as the efficiency of the recruitment process. This agency problem will alter the marginal cost of production and the real recruitment costs of wholesale firms.

As soon as funds are obtained, entrepreneurs enter the labor market, match with their potential employees and bargain on wages. Whenever it happens, the match is assumed to keep going on until it is exogenously costlessly destroyed.

Finally, the production sector has three different layers in the spirit of Bernanke et al. (5). At the first layer, where agency problem and search and matching frictions occur, a continuum of perfectly competitive wholesale firms produce homogeneous goods using capital and labor. At the second layer, where price stickiness arises, wholesale goods are differentiated costlessly by a continuum of monopolistic firms. The realized profits are rebated lump-sum to households. The final good is then homogeneous and can be used for consumption, capital accumulation and government spending.

The seven agents are thus interacting in seven different markets (labor market, capital market, credit market, liquidity market, wholesale-good market, intermediate and final-good markets), where the timing is given by the following sequence of events.

Firstly, monetary policy and aggregate shocks are realized. The liquidity market opens. Then, a given fraction of entrepreneurs are born so as to ensure a constant fraction of entrepreneurs at each period. An exogenous endowment is given to all entrepreneurs, to be sure that they remain entrepreneurs. Given all expected prices and revenues in the economy, households decide on their level of consumption, deposits, money holding, investment and on the capital rate of utilization.

The credit market opens. Banks accumulate the deposited amounts by households at the end of period $t-1$ in order to grant them as loans at the beginning of the current period $t$. The credit market clears when the amount of deposits and money injected in the economy equals the amount of granted loans.

Entrepreneurs own and manage the wholesale production sector. They enter period $t$ with a net worth, either composed by the exogenous endowment and the accumulated net worth at the end of period $t-1$ for the last period not dying solvent entrepreneurs. Or they enter the period $t$ with a net worth given by the exogenous endowment for the entrepreneurs who died or went bankrupt last period. They all borrow from banks using a nominal financial contract, in order to cover their expected production bill (labor and capital costs) and vacancies costs. Indeed, these elements are assumed to be paid in advance.

After, the labor market opens. Entrepreneurs post vacancies at a real unit cost and recruit a given number of workers. The wage is established after a Nash bargaining process and new hired employees start working immediately. The Nash bargained wage and the vacancies costs have to be paid immediately by entrepreneurs, using their loans.

The capital market opens, where households are assumed to own the capital stock of the economy. They rent effective capital to entrepreneurs at a perfectly competitive price. They accumulate capital at the end of the period $t-1$ to lend it during the current period $t$ to entrepreneurs. The capital market clears when the amount of effective capital supplied by households is equal to the amount demanded by entrepreneurs. Entrepreneurs have to pay immediately their capital costs to households, using their loans.

The three production markets can now opened. First, wholesale goods are produced by wholesale-good firms thanks to labor and capital. Entrepreneurs sell it to retailers and declare either being solvent or bankrupt, after having observed privately their own idiosyncratic shocks. Solvent entrepreneurs, characterized by a sufficiently high idiosyncratic shock, pay back their loan and keep the remaining amount to use it at the end of the period $t$ (to consume and/or to accumulate net worth). For bankrupt entrepreneurs, the bank spends a monitoring cost, proportional to the realized firm's value, in order to check the output they produced and confiscates the proceeds of production left by these entrepreneurs. These later can neither consume nor carry over net worth to the coming period. Then, banks reimburse households' deposits. The role of the financial intermediary is well defined: it allows to mitigate the monitoring cost and to avoid its duplication.

Retailers, that are a set of monopolistically competitive firms owned by households, buy the wholesale good and differentiate it costlessly. However, only a given fraction of retailers are able to fully re-optimize their prices. All the realized profits are transferred to households at the end of the period $t$.

Final goods are then sold to households (to consume and to accumulate capital), to the government (government spending) and to solvent dying entrepreneurs (to consume), at a consumer's price index.

Finally, households consume, invest, make their deposits and their money holding. Solvent entrepreneurs decide either on their consumption or on their net worth, depending on their probability of death in the current period $t$: those exiting the economy at the end of the period $t$ consume all their net worth just before death, and those keeping in the economy will accumulate totally their net worth thanks to money.

To make it more understandable, the figure 3 represents the previous timing of events in a synthetic way. Then, the figure 4 reports the flow of funds between agents in the economy characterized by the previous timing.

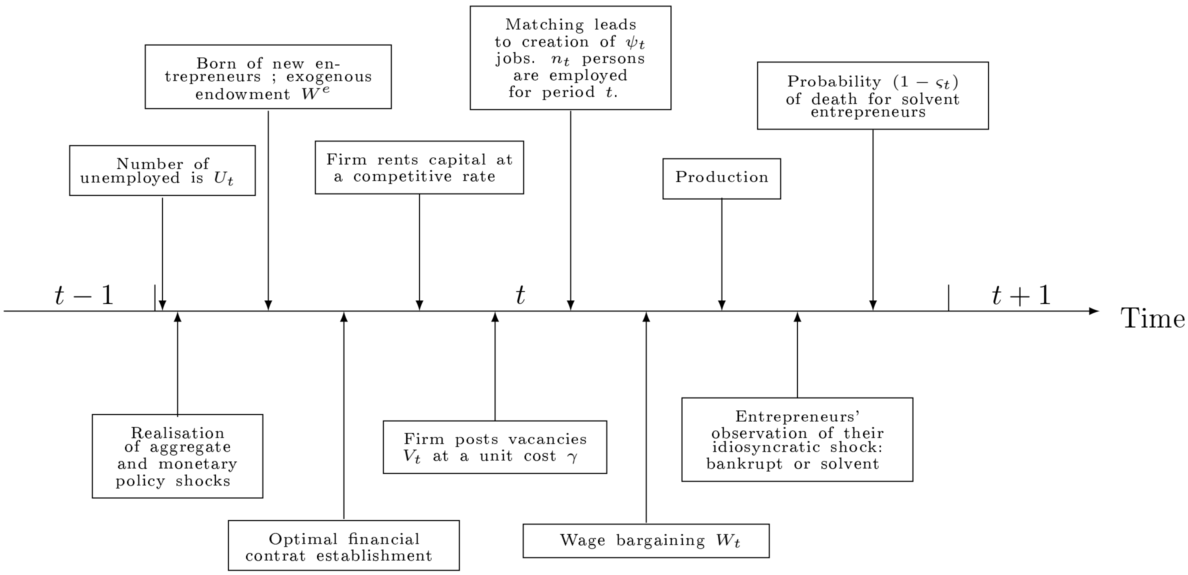



**Figure 3:** Timing of events

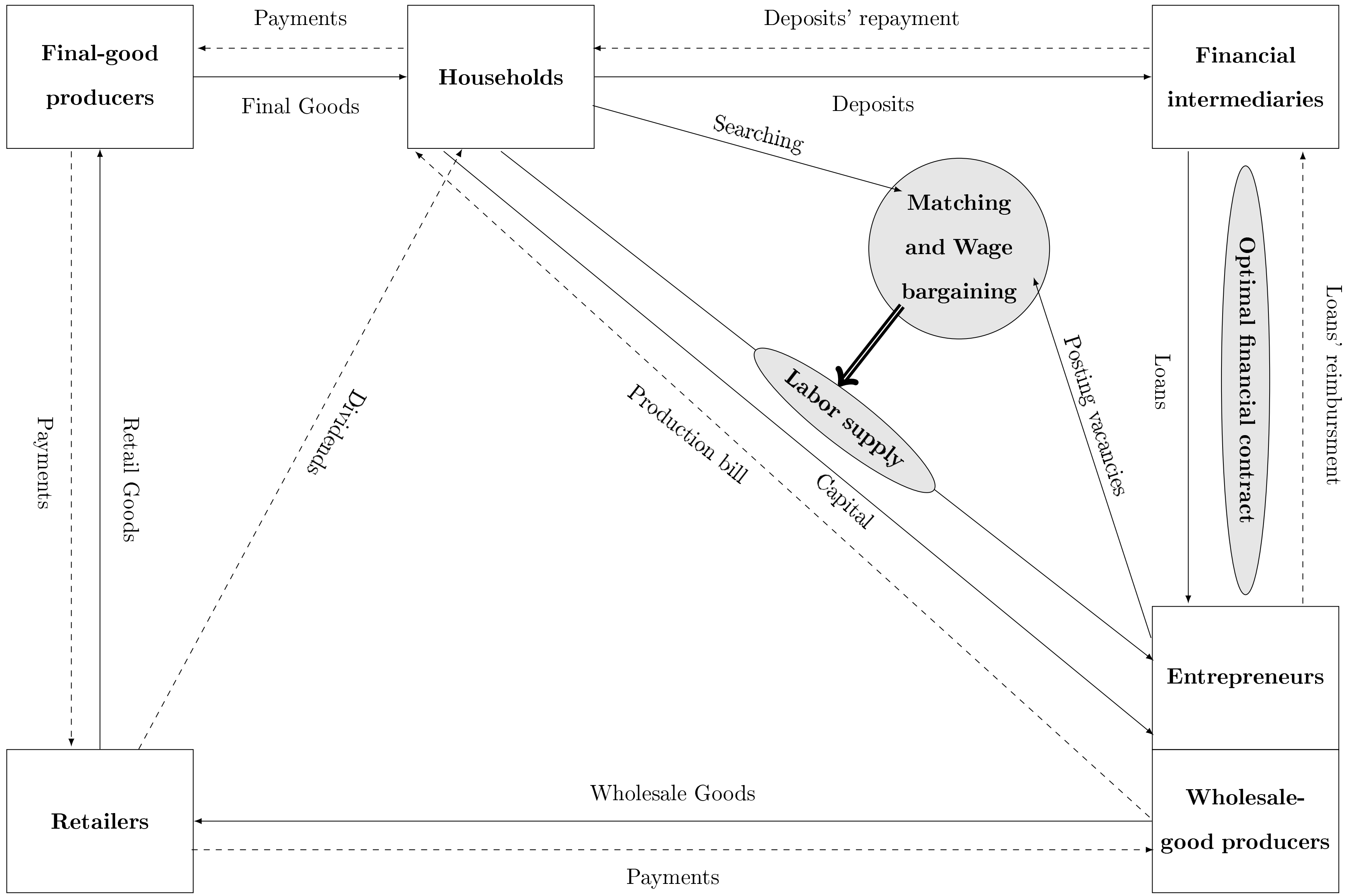



**Figure 4:** Model overview and flows of funds

## 3.2 Households

Households consume, save through deposits, hold money, invest in capital and supply passively labor to entrepreneurs. At the beginning of the period $t$, given all expected prices and revenues in the economy, households decide how much they want to consume, to save through deposits and money and how much they want to invest final goods to accumulate capital. This capital will be rented at the next period $t + 1$ to entrepreneurs on a perfectly competitive capital market. Households decide also the capital utilization rate for the current period $t$, which will determine the effective capital submitted for rent in this period $t$.

To make their decisions, households expect as resources, wages earned after the matching process of the period $t$ by workers, and unemployment benefits earned by unemployed at the end of period $t$. They earn also incomes from the rental of capital and profits from retailers, as they own them. Finally, they receive from banks, after loans reimbursement by wholesale-good firms, the last period risk-free interest rate, multiplied by the amount of deposits decided last period. This revenue is sure because financial intermediation is assumed to be realized through a large number of atomistic risk-neutral banks, holding enough large and diversified portfolios to ensure perfect risk pooling for their main creditors, the households.

Then, when the labor market opens, unemployed households members supply passively labor to entrepreneurs. A fraction of them is matched with entrepreneurs and begins to work immediately. The other fraction is not matched and stays unemployed. Newly matched workers and workers who have been matched without exogenous destruction in the period $t - 1$ receive their wages immediately after the wage bargaining. The unemployed have to wait the end of the period to receive unemployment benefits.

At the end of the period, after the production of final goods, households have to pay lump-sum taxes to the government, that will finance unemployment benefits and government spending. Finally, households consume effectively, invest final goods to accumulate capital, hold money and make their deposits to banks.

**Employed and unemployed members**

After obtaining a loan from a bank, a wholesale firm $i$ posts actively $V_{it}$ job vacancies at a real unit cost, $\gamma$, to attract unemployed workers, $U_t$, who are searching passively for a job.

***Assumption 1.*** Only the unemployed workers can search passively for a job and can be hired. Current employed workers are not allowed to look for another job. Job-to-job transition is not considered.

Job creation occurs when an entrepreneur and an unemployed worker meet on the labor market after a search and matching process à la Mortensen and Pissarides (35), and when they agree on a Nash bargaining wage. At the end of this process, a wholesale firm $i$ employs $n_{it}$ workers at a real hourly wage $W_{it}$. As there exists a continuum of wholesale firms represented by the unit interval, the total number of vacancies during the matching process of period $t$, and the total number of employed workers after the matching process of period $t$, are:

$$V_t = \int_0^1 V_{it}\, di$$
$$n_t = \int_0^1 n_{it}\, di$$

As the labor force is normalized to one, the number of unemployed searching for a job during the matching of the period $t$ corresponds to:

$$U_t = 1 - (1-\delta)n_{t-1} \tag{1}$$

where $\delta$ is the exogenous job destruction rate.

***Assumption 2.*** A job is assumed to be destroyed at an exogenous rate, $\delta$. According to our timing, the exogenous destruction of a match can occur only between the end of the matching process of period $t$ and the end of the period $t$.

***Assumption 3.*** There is a full participation of workers. They are either employed or unemployed workers looking for a job. The transition between in and out the labor force is ignored.

Formally, total vacancies, $V_t$, will be filled by unemployed workers, $U_t$, via an aggregate constant return to scale matching function, $m(U_t, V_t)$, specified by[1]:

$$m(U_t, V_t) = U_t^{\rho} V_t^{1-\rho} \tag{2}$$

where $\rho \in (0,1)$ is the elasticity of matches to unemployment. Moreover, as standard in the literature, the matching technology is assumed to be concave and increasing in both arguments. It represents the aggregate flows of hires in period $t$.

***Assumption 4.*** As soon as the matching happens, new hired workers start working immediately[2]. Employed

[1] Gertler et al. (23) use the same specification. The Cobb-Douglas matching function is used in almost all macroeconomic models with search and matching frictions. Furthermore, the constant returns to scale assumption (homogeneity of degree one) seems to be supported empirically according to Petrongolo and Pissarides (37).

[2] Following Krause and Lubik (29), Gertler et al. (23), Thomas and Zanetti (44) and Blanchard and Galí (6), workers are assumed

workers for whom the matching ends exogenously during period $t$ are allowed to search for a new job in the same period[3]. But a new matching is only possible after financial contracts and loans are decided and obtained, so only at the opening of the labor market at the next period.

The ratio of total vacancies to unemployed workers, $\theta_t$, defines the labor market tightness during the matching process of the period $t$ from the firm point of view, so that:

$$\theta_t \equiv \frac{V_t}{U_t}$$

The probability for a firm to fill a vacancy job during the matching process of the period $t$, $p_t$, is given by:

$$p_t = \frac{m(U_t, V_t)}{V_t} = m(\theta_t^{-1}, 1) \tag{3}$$

And the probability for an unemployed worker to find a job during the matching process of the period $t$, $q_t$, is given by:

$$q_t = \frac{m(U_t, V_t)}{U_t} = m(1, \theta_t) \tag{4}$$

Therefore, the number of hired workers during the matching of the period $t$, $\psi_t$, is given by:

$$\psi_t = p_t V_t = m(U_t, V_t) \tag{5}$$

Note that $q_t = \theta_t p_t$ and $\partial p_t / \partial \theta_t < 0$, $\partial q_t / \partial \theta_t > 0$. The higher vacancies on unemployment (or the higher the labor market tightness from the firm point of view), the higher the probability for an unemployed worker to find a job and the lower the probability for a firm to fill a job. Both unemployed workers and firms are assumed to take $q_t$ and $p_t$ as given.

Finally, the total number of employed workers after the matching process of the period $t$, $n_t$, is defined as the sum of the surviving workers from the exogenous separation at the end of period $t-1$, $(1-\delta)n_{t-1}$, and the new hires from the matching of the period $t$, $\psi_t$:

$$n_t = (1-\delta)n_{t-1} + \psi_t \tag{6}$$

to be immediately productive after being hired.

[3] Many papers on searching and matching literature are considering the same assumption. See Blanchard and Galí (6) for example.

So the level of unemployment in the economy after the matching process of period $t$ is $1 - n_t$, as the labor force is normalized to one. Then, since workers who discontinue their match during the period $t$ are assumed to be allowed to search passively for a new job in the same period, the number of unemployed searching workers at the end of the period $t$ is $1-(1-\delta)n_t$, which will be used as the definition of unemployment for the next period $t+1$.

**Household behavior**

Households are seen as a large representative family represented by the unit interval, consisting of a continuum of members, either employed or unemployed. As in Merz (33) and Andolfatto (2), there is a full risk sharing of consumption in order to avoid distributional issues due to heterogeneity in incomes among family members. So, the family pools its income such that a perfect consumption is fully insured for all members. The same notation is then used for the consumption of the representative household and for the consumption of each member[4].

After a search and matching process à la Mortensen and Pissarides (35) on the labor market, the number of employed family members is $n_t \in (0,1)$, whereas the remaining members, $1-n_t$, are unemployed. Each employed worker supplies labor at a real Nash bargaining wage, $W_t$. Entrepreneurs set unilaterally effective hours of work, $H_t$, at the time of the financial contract establishment. Therefore, the total number of hours worked by a representative household, $N_t$, is given by:

$$N_t = n_t H_t$$

In addition to the real wage income, $W_t N_t$, earned by employed workers and real unemployment benefits, $b$[5], received by unemployed workers, the representative family has a diversified ownership stake in monopolistic retailers, paying out a nominal lump-sum profit, $\Pi_t$. The family receives also from banks the last period risk-free interest rate, $R_{t-1}$, multiplied by the amount of deposits decided last period, $D_{t-1}$. Then, households hold an amount $M_{t-1}$ of money carried from the previous period. As the household owns the capital stock of the economy, he rents effective capital, $K_t$, to wholesale firms at a real interest rate, $r_t^K$. He has also to make a nominal lump-sum transfer for a nominal amount $T_t$ to the government.

Finally, this total income is used to consume a real amount $C_t$ of final goods, to invest a real amount $I_t$, to save a nominal amount $D_t$ of bank deposits remunerated at a risk free rate, $R_t$, and to accumulate a nominal amount

[4] The family optimally allocates the same consumption for each member, regardless their respective individual income.

[5] $b$ can be interpreted as home production or as unemployment benefits, as we do, provided by the government and financed by lump-sum taxes.

of money $M_t$. Thus, the representative household budget constraint is given by:

$$\begin{aligned} W_t n_t H_t + (1-n_t)b + \frac{R_{t-1}D_{t-1}}{P_t} + \left[r_t^K \nu_t - \Upsilon(\nu_t)\right] K_{t-1}^p + \frac{\Pi_t}{P_t} + \frac{T_t}{P_t} \\ = \frac{M_t - M_{t-1}}{P_t} + C_t + I_t + \frac{D_t}{P_t} \end{aligned} \tag{7}$$

where $P_t$ is the nominal aggregate price level.

Households are assumed to own the economy's stock of physical capital, $K_{t-1}^p$, and so, they choose the capital utilization rate, $\nu_t$, which transforms physical capital into effective capital, $K_t$. The amount of effective capital that households rent to wholesale firms in period $t$ is given by:

$$K_t = \nu_t K_{t-1}^p \tag{8}$$

$\Upsilon(\nu_t)$ is the real cost of capital utilization per unit of physical capital[6]. We assume that, at the steady state, the following conditions hold: $\nu_t = 1$ and $\dfrac{\Upsilon''(1)}{\Upsilon'(1)} = \sigma_a$.

By investing $I_t$ units of final goods in period $t$, the representative household increases the physical capital stock, $K_t^p$, available during period $t+1$ according to:

$$K_t^p = (1-\delta_K)K_{t-1}^p + \left[1 - \Lambda\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{9}$$

where $\delta_K$ is the capital depreciation rate and $\Lambda(.)$ is the real cost of investment adjustment. $\Lambda(.)$ is an increasing and convex function[7]. Since the aggregate productivity shock is then assumed to be stationary, $\Lambda(.)$ satisfies the following conditions at the steady state: $\Lambda(.) = \Lambda'(.) = 0$ and $\Lambda''(.) = \kappa > 0$.

Conditional on $\{H_t, n_t\}_{t=0}^{\infty}$ and taking as given the set of prices $\{P_t, W_t, R_t, r_t^K\}_{t=0}^{\infty}$, the household chooses the streams of consumption of final goods $\{C_t\}_{t=0}^{\infty}$, nominal money balances $\{M_t\}_{t=0}^{\infty}$, deposits $\{D_t\}_{t=0}^{\infty}$, investment $\{I_t\}_{t=0}^{\infty}$, capital utilization rate $\{\nu_t\}_{t=0}^{\infty}$ and physical capital $\{K_t^p\}_{t=0}^{\infty}$, maximizing the following discounted utility

[6] $\Upsilon(\nu_t)$ is specified as follow:

$$\Upsilon(\nu_t) = \frac{\bar{r}^K}{\sigma_a}\left[\exp\left(\sigma_a(\nu_t - 1)\right) - 1\right],$$

where $\bar{r}^K$ is the steady state value of the renting capital interest rate and $\sigma_a$is defined as the capital adjustment cost elasticity.

[7] The following specification is used for $\Lambda(x_t)$:

$$\Lambda(x_t) = \frac{1}{2}\left[\exp[\sqrt{\kappa}(x_t - 1)] + \exp\left(-\sqrt{\kappa}(x_t - 1)\right) - 2\right], \text{where } x_t = \frac{I_t}{I_{t-1}}$$

.

function[8] subject to the budget constraint (7) and the physical capital law of motion (9):

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \log(C_t - hC_{t-1}) + \xi \log\left(\frac{M_t}{P_t}\right) - \frac{H_t^{1+\tau} n_t}{1+\tau} \right] \tag{10}$$

where $0 < \beta < 1$ is the intertemporal discount factor, $h$ is a habit persistence parameter, $\xi$ is a money preference parameter and $\tau$ denotes the inverse of the Frisch elasticity of labor supply. When $h > 0$, the model allows for habit persistence in consumption preferences to take into account the necessary empirical persistence in the consumption process.

The first-order conditions of the representative household's problem are given by:

$$(C_t) \qquad \lambda_t = \frac{1}{C_t - hC_{t-1}} - \beta h E_t \frac{1}{C_{t+1} - hC_t} \tag{11}$$

$$(D_t) \qquad 1 = \beta E_t \left[ \frac{\lambda_{t+1}}{\lambda_t} \frac{R_t}{\pi_{t+1}} \right] \tag{12}$$

$$(\nu_t) \qquad r_t^K = \Upsilon'(\nu_t) \tag{13}$$

$$(I_t) \qquad Q_t \left[ 1 - \Lambda\left(\frac{I_t}{I_{t-1}}\right) \right] = 1 + Q_t \frac{I_t}{I_{t-1}} \Lambda'\left(\frac{I_t}{I_{t-1}}\right) - \beta E_t \frac{\lambda_{t+1}}{\lambda_t} Q_{t+1} \left(\frac{I_{t+1}}{I_t}\right)^2 \Lambda'\left(\frac{I_{t+1}}{I_t}\right) \tag{14}$$

$$(K_t^p) \qquad Q_t = \beta E_t \left[ \frac{\lambda_{t+1}}{\lambda_t} \left( (1 - \delta_K) Q_{t+1} + r_{t+1}^K \nu_{t+1} - \Upsilon(\nu_{t+1}) \right) \right] \tag{15}$$

$$(M_t) \qquad \frac{M_t}{P_t} = \xi \left[ \lambda_t - \beta E_t \left( \frac{\lambda_{t+1}}{\pi_{t+1}} \right) \right]^{-1} \tag{16}$$

where $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is the inflation rate, $\lambda_t$ is the Lagrange multiplier associated to the household's budget constraint and $Q_t$ is the value of an additional unit of physical capital in terms of final goods units. $Q_t$ represents more precisely the ratio between the Lagrange multiplier associated to the capital evolution law (9) and $\lambda_t$.

Equation 11 defines the marginal utility of consumption when there is habit formation. It states that the Lagrange multiplier equals the marginal utility of consumption. Equations 12, 13, 14 and 15 correspond to the household choice in terms of deposits, rate of capital utilization, investment and physical capital. Equation 16 denotes the household's demand for real balances.

[8] The form of the utility function is based on the ones used by (5) and (23).

### 3.3 Wholesale-good firms

Wholesale-good firms, indexed by $i \in (0,1)$, need labor and capital to produce. $Y_{it}^{ws}$ is the quantity of wholesale goods produced by a firm $i$ using $N_{it}$ total hours of labor and $K_{it}$ units of effective capital, according to the following production function:

$$Y_{it}^{ws} = A_t K_{it}^{\alpha} N_{it}^{1-\alpha} \tag{17}$$

where $\alpha$ is the capital share in production and $A_t$ is the aggregate technology shock, realized at the beginning of each period, source of systematic risk. This shock is assumed to be stationary and evolves according to:

$$\log(A_t) = \rho_A \log(A_{t-1}) + u_t^A, \qquad \rho_A \in (0,1) \text{ where } u_t^A \overset{iid}{\sim} N(0, \sigma_A^2)$$

Effective capital, $K_{it}$, is rented from households at a competitive price, $r_t^K$. Total hours worked, $N_{it}$, are paid to employed workers through the wage, $W_{it}$. Needed new hires, $\psi_{it}$, are obtained through a matching process on the labor market, implying vacancy posting costs, $\gamma V_{it}$. The expected production bill, $W_t N_{it} + r_t K_{it}$, and vacancy posting costs, $\gamma V_{it}$, are assumed to be paid prior to production.

Each wholesale firm is managed by a finite lived risk-neutral entrepreneur, who may die at each period with a probability $(1-\varsigma_t)$. This assumption is made to be sure that entrepreneurs will not accumulate net worth and that they will borrow from banks at each period[9]. Intra-period entry into and exit out of wholesale firms at each period are ruled out. Entrepreneurs have a net worth, composed by a real exogenous entrepreneurial wage, $W^e$, and for the one solvent and not exiting the economy last period, by the net worth accumulated from the previous period. But this net worth will not be sufficient to cover the total production bill, as well as the vacancy posting costs. Entrepreneurs have to borrow from banks. Thus, a financial intermediation is realized through a large number of atomistic risk-neutral banks. They receive deposits from households at the end of period $t-1$, that they use to lend to entrepreneurs in period $t$. Furthermore, entrepreneurs are subject to idiosyncratic shocks, privately observed by them, but not observed by banks. So banks have to monitor wholesale firms, which declare themselves bankrupt after the production occurs. The monitoring is costly and has to be integrated in the financial contract. An optimal financial contract is thus determined between banks and entrepreneurs, maximizing the entrepreneur's expected returns, subject to the bank's participation constraint.

[9] The same assumption is made by Bernanke et al. (5) and Paustian (36). Carlstrom and Fuerst (10) make the different assumption, that consumers and entrepreneurs have different time-discount factors, with entrepreneurs less impatient than consumers.

### 3.3.1 Hiring decision

Before the financial contract conclusion, based on the firm's expected net returns, the number of needed new hires, $\psi_{it}$, is determined by the human resources department of each firm. Indeed, wholesale firms are assumed to be composed by different departments. In particular, there are a human resources department, which is in charge with the recruitment process, and a management department, directed by the entrepreneur, which is in charge with the borrowing process. The human resources department decides on the labor needs of the firm in order to maximize its discounted value of future profits. To do so, this department determines the price of a new worker, or to be more precise, the expected net value of this new worker for the firm. Each new worker is thus evaluated through this value. It enables then the management department to go to negotiate to the bank, based on this implicit worker price. At the end, the net recruitment cost or the replacement cost of a new worker, integrating financial costs, will be obtained.

To sum up, just before the financial contract establishment, wholesale firms set up their hiring decision, based on the workers' expected net returns. They determine the number of new workers, $\psi_{it}$, they have to take on, knowing the given probability for a firm to fill a vacancy job, $p_t$. Then, the hiring section of the firm post vacancies, $V_{it}$, on the labor market at the real unit cost, $\gamma$, partially externally financed. The level of $Z_t$, the net recruitment cost of a new worker, is finally derived.

Precisely, the hiring decision of a wholesale firm $i$ is the optimal solution to the following bellman equation:

$$\begin{aligned} \Psi_{it} = \max_{\psi_{it}} \quad & \frac{P_t^{ws}}{P_t} Y_{it}^{ws} - W_{it} N_{it} - \frac{Z_t}{P_t}\psi_{it} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \Psi_{it+1} \\ \text{subject to} \quad & n_{it} = (1-\delta) n_{it-1} + \psi_{it} \\ & N_{it} = n_{it} H_{it} \end{aligned} \tag{18}$$

where $P_t^{ws}$ is the wholesale-good price and $\beta \frac{\lambda_{t+1}}{\lambda_t}$ is the firm's discount factor[10].

Conditional on $\{H_{it}\}_{t=0}^{\infty}$ and taking as given the set of prices $\{P_t, W_{it}, Z_t, P_t^{ws}\}_{t=0}^{\infty}$, the human resources department of a wholesale firm chooses first the number of hirings, $\psi_{it}$, and consequently the number of employees sought, $n_{it}$, so as to maximize the firm's discounted value of future profits. An univariate optimization problem can be obtained in $n_{it}$ by embedding both constraints into the problem, since by choosing $n_{it}$, the human resources department determines implicitly $\psi_{it}$. So that the following first-order condition can be derived:

$$\frac{Z_t}{P_t} = \frac{P_t^{ws}}{P_t} \frac{(1-\alpha) Y_{it}^{ws}}{n_{it}} - W_{it} H_{it} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \Psi_{n_{it}, it+1} \tag{19}$$

[10]Since all firms are owned by households in this economy, profits are evaluated in terms of utility brought to them.

Using the envelop theorem, one obtains:

$$\Psi_{n_{it-1},it} = (1-\delta)\frac{Z_t}{P_t} \tag{20}$$

By taking equation (20) one period forward and plugging it in equation (19), the following Euler equation is derived:

$$\frac{Z_t}{P_t} = \frac{P_t^{ws}}{P_t}\frac{(1-\alpha)Y_{it}^{ws}}{n_{it}} - W_{it}H_{it} + (1-\delta)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{Z_{t+1}}{P_{t+1}} \tag{21}$$

The expected real total cost of hiring a new worker, $Z_t$, is equal to the real expected net value of a match. The real marginal value of a new hire is the sum of the net real return of a worker, which corresponds to its real marginal productivity net of the real marginal labor cost that is defined as the hourly wage, plus the real value of the continued relationship with the same worker, realized with the probability $(1-\delta)$. Therefore, the hiring decision of wholesale firms is such that the expected profit from maintaining a match with an existing worker is equal to the expected real total cost of hiring a new worker. This expected cost will be now determined explicitly trough the financial contract establishment.

### 3.3.2 Optimal financial contract

A financial contract is established between a financial intermediary and an entrepreneur, who needs to pay in advance its production bill and vacancies posting costs. The financial intermediation is realized through a large number of atomistic risk-neutral banks. Banks are assumed to hold enough large and diversified portfolios to ensure perfect risk pooling for their main creditors, the households, carrying deposits to banks.[11].

Although we use the same costly state verification framework (CSV) used in Carlstrom and Fuerst (10), Bernanke et al. (5) and others, asymmetric information is introduced between wholesale-good producers, called entrepreneurs, and banks. Financial intermediaries and banks are used interchangeably in the model. They are operating in a competitive market, so that only the behavior of a representative bank will be considered below. Then, by difference to Carlstrom and Fuerst (10), credit contracts are here nominal. These contracts stipulate one-period loans, established after the aggregate shock, $A_t$, has occurred. Indeed, in order to eliminate aggregate uncertainty from the lender-borrower relationship, the aggregate technology shock, $A_t$, is assumed to be observed by all agents in the economy and it is realized before any loan contract is established. On the

[11]Infinitely-lived households are risk averse, but they become risk neutral for the financial contract. Carlstrom and Fuerst (10) explain this fact by the absence of uncertainty about the term of the one-period contract since the aggregate uncertainty is realized before the contract establishment. Furthermore, by the law of large numbers as banks are financing a continuum of different entrepreneurs, households know they will receive the expected return of the idiosyncratic shock.

other hand, an idiosyncratic shock, $\omega_{it}$, is privately observed by the entrepreneur $i$ after the production takes place and it can be verified by the lender only at a monitoring cost, $\mu_t$, proportional to the realized value of the firm. Thus, this private information creates a moral hazard problem as the entrepreneur may be encouraged to under-report the true value of its production at the time of loan's repayment.

Finally, under a costly state verification framework, the perfectly competitive financial intermediaries' setting ensures that each firm-bank pair writes the borrowing contract that maximizes the expected return of the borrower, the entrepreneur, under the constraint that the expected return to the lender, the bank, exceeds its opportunity cost, namely the risk free interest rate, $R_t$. So the optimal incentive-compatible financial arrangement is just a standard risky debt contract, whose terms are the optimal solution to a standard principle-agent problem between entrepreneurs and banks[12].

After the wholesale-good production takes place, each entrepreneur observes its idiosyncratic shock, $\omega_{it}$, defined as a productivity and management efficiency shock, reflecting its management skills, recruitment efficiency, hires' quality and input utilization skills. This idiosyncratic shock is the source of wholesale firms' heterogeneity. $\omega_{it}$ is i.i.d. with a continuous distribution function, $\Phi(.)$, and a density function, $\phi(.)$. $\omega_{it}$ is defined over a non-negative support, has a mean of unity and $\Phi(0) = 0$. Moreover, its variance, reflecting the shock's volatility and the entrepreneurs' riskiness, is time-varying and its standard deviation, $\sigma_{\omega,t}$, follows a first-order auto-regressive process given by:

$$\log(\sigma_{\omega,t}) = (1-\rho_\sigma)\log(\bar{\sigma}_\omega) + \rho_\sigma \log(\sigma_{\omega,t-1}) + u_t^\sigma, \quad \rho_\sigma \in (0,1) \text{ where } u_t^\sigma \overset{iid}{\sim} N(0,\sigma_\sigma^2)$$

$\bar{\sigma}_\omega$ is the steady-state value of the standard deviation, $\sigma_{\omega,t}$. A shock on this standard deviation is called in our simulation exercise an uncertainty shock, representative of a variation in the degree of uncertainty concerning the idiosyncratic efficiency of entrepreneurs.

To justify the recourse to external funding, entrepreneurs are assumed to pay their real production bill, $r_t^K K_{it} + W_{it}N_{it}$, as well as the real vacancy posting costs, $\gamma V_{it}$, prior to production[13]. But due to idiosyncratic shocks, firms face a default risk on their debt. For low values of $\omega_{it}$, some entrepreneurs may not be able to reimburse their credit. Let $B_{it}$ be the total expected real amount of the production bill, including vacancy posting costs, for a firm $i$, so that:

$$B_{it} = W_{it}N_{it} + r_t^K K_{it} + \gamma V_{it}$$

[12]See Townsend (45) and Gale and Hellwig (19).

[13]Recall that entrepreneurs have a probability to die at each period, $1-\varsigma_t$, that ensures that they do not accumulate net worth and have to borrow from banks at each period.

The entrepreneur of each firm borrows a nominal amount of $P_t(B_{it} - X_{it})$ from the bank at an implicit interest rate, $R_t^l$, where $X_{it}$ is its real net worth. The entrepreneur and a representative bank agree on a financial contract specifying a break-even entrepreneur-specific productivity level, $\bar{\omega}_{it}$, satisfying $R_t^l P_t(B_{it} - X_{it}) = \bar{\omega}_{it}(P_t^{ws} Y_{it}^{ws} + Z_t \psi_{it})$.

Indeed, if $\omega_{it} \geq \bar{\omega}_{it}$, the entrepreneur pays back the value $\bar{\omega}_{it}(P_t^{ws} Y_{it}^{ws} + Z_t \psi_{it})$, either the loan amount augmented with interest, $R_t^l P_t(B_{it} - X_{it})$.

If $\omega_{it} < \bar{\omega}_{it}$, the firm is insolvent and the bank confiscates the proceeds of the production. The bank can observe this state of nature at a monitoring cost $\mu_t \in (0,1)$, proportional to the realized value of the firm. After the realization of shocks and production occurrence, this firm's value is given by $\omega_{it}(P_t^{ws} Y_{it}^{ws} + Z_t \psi_{it})$. The monitoring is non-stochastic and the lender actions are pre-committed.

Formally, the expected return earned by the wholesale firm $i$, $E_{it}^f$, is given by:

$$E_{it}^f = (P_t^{ws} Y_{it}^{ws} + Z_t \psi_{it}) \int_{\omega > \bar{\omega}_{it}} (\omega - \bar{\omega}_{it}) \phi(\omega, \sigma_\omega) d\omega \tag{22}$$

Using the statistic properties of the random idiosyncratic shock, equation (22) can be developed to see that the expected return of the wholesale firm is a fraction of its realized value:

$$E_{it}^f = (P_t^{ws} Y_{it}^{ws} + Z_t \psi_{it}) f(\bar{\omega}_{it}, \sigma_{\omega,t}) \tag{23}$$

where $f(\bar{\omega}_{it}, \sigma_{\omega,t}) = \int_{\omega > \bar{\omega}_{it}} \omega \phi(\omega, \sigma_\omega) d\omega - \bar{\omega}_{it}[1 - \Phi(\bar{\omega}_{it}, \sigma_{\omega,t})]$. Note that $f(\bar{\omega}_{it}, \sigma_{\omega,t}) \in (0,1)$[14] and $f'(\bar{\omega}_{it}, \sigma_{\omega,t}) = \Phi(\bar{\omega}_{it}, \sigma_{\omega,t}) - 1 \leq 0$. The wholesale firm's expected return is a decreasing function of $\bar{\omega}_{it}$. This result is quite intuitive since an increase of the default rate, $\Phi(\bar{\omega}_{it}, \sigma_{\omega,t})$, reduces the gross share of return going to the firm.

Similarly, the expected return earned by the bank, $E_{it}^b$, is given by:

$$E_{it}^b = (P_t^{ws} Y_{it}^{ws} + Z_t \psi_{it}) \Big[ \int_{\omega > \bar{\omega}_{it}} \bar{\omega}_{it} \phi(\omega, \sigma_\omega) d\omega + (1 - \mu_t) \int_{\omega < \bar{\omega}_{it}} \omega \phi(\omega, \sigma_\omega) d\omega \Big] \tag{24}$$

It is straightforward to show that lender's expected return is also a fraction $g(\bar{\omega}_{it}, \sigma_{\omega,t}) \in (0,1)$, of the total

[14] $f'(\bar{\omega}, \sigma_\omega) \leq 0, \forall \bar{\omega} \in [0, \infty)$. In addition, $\lim_{\bar{\omega} \to 0} f(\bar{\omega}, \sigma_\omega) = 1$ and $\lim_{\bar{\omega} \to \infty} f(\bar{\omega}, \sigma_\omega) = 0$. Then, $f(\bar{\omega}, \sigma_\omega) \in (0,1)$.

realized value of the wholesale firm[15]. Then,

$$E_{it}^{b} = (P_t^{ws} Y_{it}^{ws} + Z_t \psi_{it}) g(\bar{\omega}_{it}, \sigma_{\omega,t}) \tag{25}$$

where $g(\bar{\omega}_{it}, \sigma_{\omega,t}) = 1 - f(\bar{\omega}_{it}, \sigma_{\omega,t}) - \mu_t \Gamma(\bar{\omega}_{it}, \sigma_{\omega,t})$ and $\Gamma(\bar{\omega}_{it}, \sigma_{\omega,t}) = \int_{\omega<\bar{\omega}_{it}} \omega \phi(\omega, \sigma_\omega) d\omega$. So, an amount of the realized firm's value is lost due to monitoring in cases of declaring bankruptcy by the borrower. In this context, the monitoring cost spending is a synonym of bankruptcy and it is spent in terms of currency so that bankruptcy has no impact on the real output. The proportion of the total amount recovered by the bank in case of bankruptcy is finally $(1 - \mu_t)\Gamma(\bar{\omega}_{it}, \sigma_{\omega,t})$. $(1 - \mu_t)$ is thus interpreted as the recovery rate. Following Livdan et al. (32) and Petrosky-Nadeau (38), this recovery rate is assumed to be time-varying and to have the following specification:

$$1 - \mu_t = s_{0,t} \exp s_1(\omega_{it} - 1) \tag{26}$$

$s_1$ is the elasticity of the recovery rate to the entrepreneurial productivity level and $s_{0,t}$ is interpreted as a credit shock, following a first-order auto-regressive process:

$$\log s_{0,t} = (1 - \rho_{s0}) \log \bar{s}_0 + \rho_{s0} \log s_{0,t-1} + u_t^{s0}, \quad \rho_{s0} \in (0,1) \text{ where } u_t^{s0} \overset{iid}{\sim} N(0, \sigma_{s0}^2)$$

$\bar{s}_0$ is the steady-state value of the credit shock, $s_{0,t}$.

Finally, the optimal debt contract is a solution to a maximization problem, where the entrepreneur maximizes its expected return subject to the bank's participation constraint (Paustian (36)), knowing the level of $n_{it}$ decided by the human resources department in the previous step. The bank is willing to lend funds only and only if the contract yields an expected return greater or equal to the riskless rate of return, $R_t$:

$$\begin{aligned} \max_{K_{it}, H_{it}, V_{it}, \bar{\omega}_{it}} \quad & [P_t^{ws} Y_{it}^{ws} + Z_t \psi_{it}] f(\bar{\omega}_{it}, \sigma_{\omega,t}) \\ \text{subject to} \quad & [P_t^{ws} Y_{it}^{ws} + Z_t \psi_{it}] g(\bar{\omega}_{it}, \sigma_{\omega,t}) \geq R_t P_t (W_{it} N_{it} + \gamma V_{it} + r_t^K K_{it} - X_{it}) \\ & \psi_{it} = p_t V_{it} \\ & N_{it} = n_{it} H_{it} \end{aligned} \tag{27}$$

[15]Since $1 - f(\bar{\omega}, \sigma_\omega) \in (0,1)$ and by definition, we have $\int_{\omega<\bar{\omega}_{it}} \omega \phi(\omega, \sigma_\omega) d\omega \in (0,1)$ and $\int_{\omega>\bar{\omega}_{it}} \bar{\omega}_{it} \phi(\omega, \sigma_\omega) d\omega + \int_{\omega<\bar{\omega}_{it}} \omega \phi(\omega, \sigma_\omega) d\omega \in (0,1)$, then $g(\bar{\omega}, \sigma_\omega) \in (0,1)$, $\lim_{\bar{\omega}\to 0} g(\bar{\omega}, \sigma_\omega) = 0$ and $\lim_{\bar{\omega}\to\infty} g(\bar{\omega}, \sigma_\omega) = 1 - \mu$.

The first-order conditions for the wholesale firm's problem are summarized by the three following equations:

$$Y_K^{ws}(K_{it}, H_{it} \mid n_{it}) = \frac{P_t}{P_t^{ws}} r_t^K R_t S_{it} \tag{28}$$

$$Y_H^{ws}(K_{it}, H_{it} \mid n_{it}) = \frac{P_t}{P_t^{ws}} n_{it} W_{it} R_t S_{it} \tag{29}$$

$$\frac{Z_t}{P_t} = \frac{\gamma}{p_t} R_t S_{it} \tag{30}$$

where $S_{it} = \{1 - \mu_t[\Gamma(\bar{\omega}_{it}, \sigma_{\omega,t}) + \bar{\omega}_{it} h(\bar{\omega}_{it}, \sigma_{\omega,t}) f(\bar{\omega}_{it}, \sigma_{\omega,t})]\}^{-1}$, with $h(\bar{\omega}_{it}, \sigma_{\omega,t})$ the hazard rate[16] defined by $h(\bar{\omega}_{it}, \sigma_{\omega,t}) = \dfrac{\phi(\bar{\omega}_{it}, \sigma_{\omega,t})}{1 - \Phi(\bar{\omega}_{it}, \sigma_{\omega,t})}$.

In order to keep the representative-firm context, we assume that the threshold value of the entrepreneurial productivity, $\bar{\omega}_{it}$, is the same for all wholesale firms. This assumption guarantees a constant capital-labor ratio across firms. At the equilibrium, this is an important assumption since all firms will have the same financial mark-up, $S_{it}$, and they will bargain the same wage, $W_{it}$. Consequently, according to our assumption, the subscript $i$ is dropped in what follows.

From first-order conditions, asymmetric information in the credit market generates inefficiencies in both markets, the wholesale-good market and the labor market. On the one hand, the marginal productivity of labor (and capital) is higher than its corresponding marginal cost without financial frictions. Then, the final real price of the wholesale good is augmented by a financial mark-up, $S_t > 1$[17], used to overcome the agency problem between entrepreneurs and banks. As a consequence, credit market conditions matter because they affect firms' marginal costs and are transmitted to the rest of the economy through the selling price's mark-up. Banks have a margin behavior, that will pass trough the rest of the economy by the wholesale-good price. This framework breaks down the Modigliani-Miller theorem and makes the firms' external borrowing costs higher than internal funds opportunity costs. Indeed, firms must borrow at a premium over the risk-free rate.

Aggregating over entrepreneurs and embedding equations (28)-(30) in the lender's break even constraint, the firms' leverage ratio, $\mathcal{L}_t$, is given by:

$$\mathcal{L}_t \equiv \frac{B_t}{X_t} = \frac{1}{1 - S_t(\bar{\omega}_t, \sigma_{\omega,t}) g(\bar{\omega}_t, \sigma_{\omega,t})} \tag{31}$$

[16] We assume that $\bar{\omega} h(\bar{\omega}, \sigma_\omega)$ is increasing in $\bar{\omega}$ in order to ensure the concavity of the lender's net share of return, $g(\bar{\omega}, \sigma_\omega)$, and avoid any credit rationing at the equilibrium. This regularity condition is without loss of generality and it is satisfied by most of the continuous probability distributions. See Bernanke et al. (5) for details.

[17] See appendix A for the proof.

with $\mathcal{L}_{\bar{\omega}} > 0$. For a given level of net worth $X_t$, a higher leverage ratio is associated with a higher default rate. Indeed, the probability of default increases as the loan amount raises (Stiglitz and Weiss (43)).

It is straightforward to show that, at the optimum, the constraint (27) is binding. Using this result with the condition on $\bar{\omega}_t$, the risk premium, $\Delta_t$, defined as the ratio of the lending rate to the risk free rate, $R_t^l/R_t$, is given by:

$$\Delta_t = \frac{\bar{\omega}_t}{g(\bar{\omega}_t, \sigma_{\omega,t})} \quad (32)$$

Figure 5 shows the evolution of the risk premium as a convex increasing function of the entrepreneurial productivity threshold, $\bar{\omega}$. This result is quite familiar in the financial accelerator literature. A higher default probability of firms induces a higher cost of lending for banks and consequently, a higher loan spread.

On the other hand, from equation 30, the cost of a new hire, $Z_t$, depends also on the financial contract conditions. Besides the unit cost stemming from hiring, $\gamma$, and the average duration of vacancies, $1/p_t$, the total cost of recruitment is augmented by the same financial mark-up, $S_t$. Financial contract conditions affect the labor market efficiency through the total vacancies posting cost, that becomes here an endogenous variable. This relation is represented by figure 6, where the real job posting cost is also an increasing and convex function of $\bar{\omega}$ and its slope raises with monitoring costs, $\mu$. For a higher default likelihood (higher $\bar{\omega}$), banks charge a higher risk premium, $\Delta$, so that entrepreneurs obtain their credit at a higher lending rate, $R^l$. External financing becomes more expensive, as well as the cost of a new hire and it reduces their willingness to open vacancies.

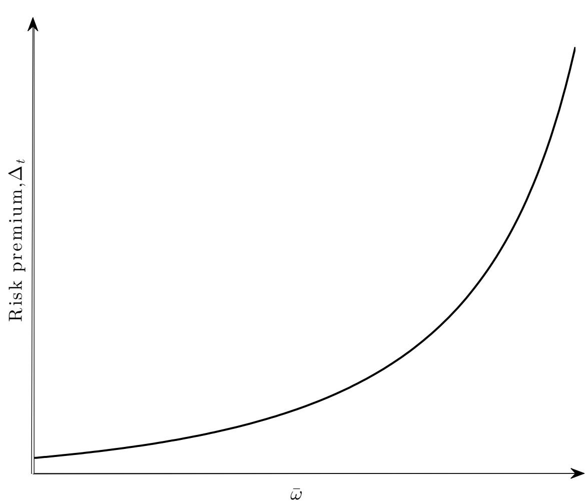



**Figure 5:** The risk premium as a function of $\bar{\omega}$

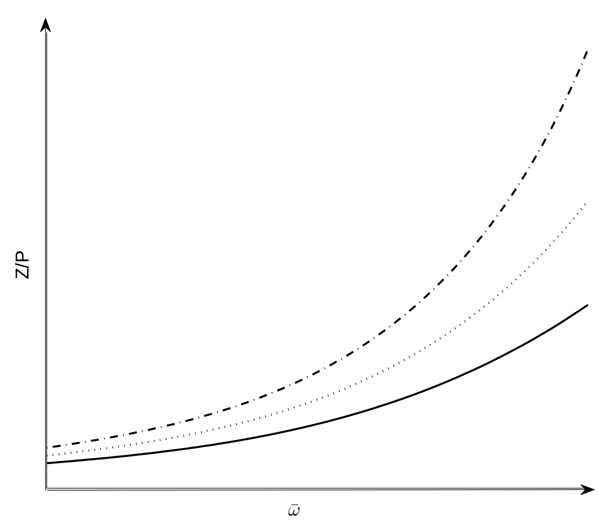



**Figure 6:** Real vacancy posting cost as a function of $\bar{\omega}$ for different values of monitoring costs: $\mu = 0.15$ (solid line), $\mu = 0.2$ (dotted line) and $\mu = 0.25$ (dashed line)

Then, an increase of $\mu$ shifts the real vacancies posting cost upward. For a fixed level of $\bar{\omega}$, the real cost of a new hire raises with monitoring costs. As these costs are expressed in terms of currency, and not in terms of physical goods, they do not generate a loss of resources through a destruction of goods, which could have been used for consumption. However, they generate an additional cost taken into account by banks when agreeing on an appropriate interest rate on loans. Fluctuations in monitoring costs and bankruptcy rates have an impact on welfare only indirectly, through their implications on the mark-up pricing.

Now, by making use of the optimal financial contract conditions derived below and the hiring condition given by equation (21), the job creation condition under financial frictions in the credit market is obtained:

$$\frac{\gamma}{p_t} R_t S_t = W_t H_t [R_t S_t - 1] + (1 - \delta_t) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\gamma}{p_{t+1}} R_{t+1} S_{t+1} \tag{33}$$

For any positive monitoring cost, financial frictions increase as expected the average cost of filling a vacancy. The evolution of credit market conditions changes the opportunity cost for resources used to create new jobs. Thus, it alters the dynamics of job vacancies. Credit spreads are a key element to understand the cyclical behavior of job creation and the general dynamics of labor markets. Thus, agency problems on credit markets affect the performance of labor markets.

### 3.3.3 Wage bargaining

Once entrepreneurs decided the number of new workers they need and once they obtained a loan covering their production bill, as well as vacancies costs, they enter the labor market to post vacancies, match with unemployed workers and bargain on wages. The real hourly wage, $W_t$, is assumed to be determined on a period-by-period basis and through a Nash bargaining between a representative entrepreneur and a representative household.

#### Bellman equations

The Nash real hourly wage splits by definition the joint surplus of the employment relationship between a representative entrepreneur and a representative household, depending on their respective bargaining power, $\eta$. The discounted value of employment for a worker in terms of current consumption is given by:

$$\mathcal{W}_t^n = W_t H_t - \frac{H_t^{1+\tau}}{(1+\tau)\lambda_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \Big[ \big(1 - \delta(1 - q_{t+1})\big) \mathcal{W}_{t+1}^n + \delta(1 - q_{t+1}) \mathcal{W}_{t+1}^U \Big] \tag{34}$$

The discounted value of a job for a worker in terms of current consumption is the sum of the total real wage earned, reduced for the marginal disutility of working and the expected discounted gain from being either employed or unemployed during the subsequent period. A worker will be again employed at the period $t+1$ if the match has not been destroyed, with a probability $(1-\delta)$, after the matching of the period $t$ ; or if the match has been destroyed with the probability $\delta$ after the matching of the period $t$, but that another matching occurs at the period $t+1$ with the probability $q_{t+1}$. And a worker will become unemployed at the period $t+1$ if the match is destroyed after the matching of the period $t$ and if he or she does not find a job at the period $t+1$, that to say with the probability $\delta(1-q_{t+1})$.

The discounted value of unemployment for a worker in terms of current consumption is given by:

$$\mathcal{W}_t^U = b + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[q_{t+1}\mathcal{W}_{t+1}^n + (1-q_{t+1})\mathcal{W}_{t+1}^U\right] \tag{35}$$

In the same spirit, the discounted value to be unemployed for a worker in terms of current consumption is the sum of real unemployment benefits and the expected discounted gain from being either employed (with probability $q_{t+1}$) or unemployed (with probability $1-q_{t+1}$) after the matching of the period $t+1$.
Therefore, the worker's surplus of an employment relationship is given by:

$$\mathcal{W}_t^n - \mathcal{W}_t^U = W_t H_t - \frac{H_t^{1+\tau}}{(1+\tau)\lambda_t} - b + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[(1-\delta)(1-q_{t+1})(\mathcal{W}_{t+1}^n - \mathcal{W}_{t+1}^U)\right] \tag{36}$$

For a firm, the discounted value of an employed worker in terms of current consumption is defined as:

$$J_t^n = \frac{P_t^{ws}}{P_t}\frac{(1-\alpha)Y_t^{ws}}{n_t} - W_t H_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-\delta)J_{t+1}^n \tag{37}$$

This discounted value is equal to the current profits from an employed worker, plus the expected discounted continuation value. The job is still provided at the period $t+1$ if the match has not been destroyed with a probability $(1-\delta)$ after the matching of the period $t$. And if the job is not provided at the period $t+1$, the continuation value will be equal to zero.

Then, the discounted value of an open vacant job for a firm in terms of current consumption is given by:

$$J_t^V = -\frac{Z_t}{P_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[p_{t+1}J_{t+1}^n + (1-p_{t+1})J_{t+1}^V\right] \tag{38}$$

The discounted value of an open vacancy job for a firm in terms of current consumption is equal to the real total hiring costs of the vacancy job, plus the expected discounted gain to fill or not the vacant job during the following period. The vacancy job is filled at the period $t+1$ with a probability $p_{t+1}$, if a match occurs during the matching of the period. Otherwise, with a probability $(1-p_{t+1})$, the job remains vacant in $t+1$.

**Nash bargaining and wage setting**

The Nash wage bargaining consists of maximizing the net surplus of the employment relationship for a representative firm, $(J_t^n - J_t^V)$, and a representative household, $(\mathcal{W}_t^n - \mathcal{W}_t^U)$, depending on the households' bargaining power, $\eta$. As a consequence, the chosen real hourly wage is the one that maximizes[18]:

$$\max_{W_t} \quad (\mathcal{W}_t^n - \mathcal{W}_t^U)^{\eta}(J_t^n - J_t^V)^{(1-\eta)}$$

Since there is a free-entry condition on the labor market, at the equilibrium, $J_t^V = 0$ is satisfied. Indeed, if $J_t^V > 0$, a firm has an incentive to post vacancies as the value of a vacant job is positive. As the number of vacancies increases relative to the number of unemployed workers, the probability to fill a vacancy job, $p_t$, decreases. Indeed, the labor market tightness, $\theta_t$, increases and $p_t$ decreases since $\partial p_t / \partial \theta_t < 0$. That reduces the incentive to post vacancies and diminishes the value of $J_t^V$, until it equals zero. Therefore, the first-order necessary condition for the Nash bargaining solution is given by:

$$\eta J_t^n = (1-\eta)(\mathcal{W}_t^n - \mathcal{W}_t^U) \tag{39}$$

The following Nash real hourly wage is then obtained:

$$W_t H_t = \eta \left[ \frac{P_t^{ws}}{P_t} \frac{(1-\alpha)Y_t^{ws}}{n_t} + (1-\delta)\frac{Z_t}{P_t} E_t(\theta_{t+1}) \right] + (1-\eta)\left[ b + \frac{H_t^{1+\tau}}{(1+\tau)\lambda_t} \right] \tag{40}$$

The real wage shares costs and benefits from the match between households and entrepreneurs according to the parameter $\eta$. Workers are compensated for a fraction $(1-\eta)$ for the disutility they suffer from supplying hours of work and for the foregone unemployment benefits. And they obtain a fraction $\eta$ of the firm's revenues, as well as a fraction $\eta$ of the firm's saving of total hiring costs, depending on the probability that the match will not be destroyed exogenously until the end of the period $t$ and the expected labor market tightness of period $t+1$. If the matching is broken, entrepreneurs have to look for another partner in the next period, which is costly. This cost is thus incorporated in the wage.

[18]Recall that by assuming an identical threshold value of entrepreneurial productivity for all wholesale firms, we keep a representative-firm context.

The wholesale-good production takes place, once capital and labor inputs are obtained. The production process is then split into two different sectors, in the spirit of what it is standard in medium scale DSGE models, a competitive final goods sector and a monopolistically competitive intermediate-good sector, that use wholesale goods as inputs.

### 3.4 Intermediate and final-good production

Final-good firms proceed in a perfectly competitive market and are owned by households. They purchase a continuum of differentiated intermediate goods indexed by $j \in (0,1)$ and aggregate theses varieties to produce $Y_t$ units of final good. They have no other cost, except the one to buy to intermediate-good firms the different varieties.

Final goods are produced using a standard constant return to scale technology given by:

$$Y_t = \left[ \int_0^1 Y_{j,t}^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \tag{41}$$

where $\epsilon > 1$ is a parameter governing the degree of monopolistic competition in the intermediate good sector (or the elasticity of substitution between intermediate goods).

Each competitive final-good firms choose their own input demand functions for each variety of intermediate goods, $Y_{j,t}$, so as to maximize their nominal profit, $\Pi_t$, defined as:

$$\Pi_t = P_t Y_t - \int_0^1 P_{j,t} Y_{j,t} dj$$

where $P_t$ is the bundler's technology price-index that corresponds to the nominal aggregate consumer's price index. The solution to the maximization problem[19] yields the following demand function for the intermediate good of variety $j$:

$$Y_{j,t} = \left[ \frac{P_{j,t}}{P_t} \right]^{-\epsilon} Y_t \tag{42}$$

So, the demand for each variety of intermediate good is a downward sloping demand curve, which will give to the intermediate-good firms some pricing power.

[19]Final-good firms maximize their expected stream of profits, which is equivalent to maximizing their profit period-by-period since they purchase intermediate goods at the same frequency.

Then, as we are in a competitive setting, the zero-profit condition applies at the equilibrium for final-good firms and it yields:

$$P_t Y_t = \int_{j=0}^{1} P_{j,t} Y_{j,t} dj$$

From this condition, the nominal output price or the consumer's price index can be easily derived by plugging the demand function into the zero-profit condition:

$$P_t Y_t = \int_{j=0}^{1} P_{j,t} \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} Y_t dj$$

which gives:

$$P_t = \left[\int_{j=0}^{1} P_{j,t}^{(1-\epsilon)} dj\right]^{\frac{1}{1-\epsilon}} \tag{43}$$

Looking now to the intermediate-good sector, there is a continuum of monopolistically competitive retailers. These retailers are owned by households. They buy from entrepreneurs homogeneous wholesale goods at the price $P_t^{ws}$. They differentiate costessly each unit of these goods into a unit of retail goods, $Y_{j,t}$. These firms are assumed to have no other inputs or costs than the homogeneous good. Following Yun (49), Christiano et al. (12) and Trigari (46), a price stickiness for these firms is formulated in the spirit of Calvo (8). Every period, only a random fraction $(1-\varrho) \in (0,1)$ of firms is able to fully re-optimize their nominal prices knowing the aggregate shock, $A_t$. The hazard rate, $\varrho$, is constant across firms and time. And prices are thus fixed on average for $\frac{1}{1-\varrho}$ periods. The remaining fraction of firms does not re-optimize their prices and following Christiano et al. (13), they keep their prices unchanged. So the price set by a retailer $j$, $P_{j,t}$, corresponds to:

$$P_{j,t} = \begin{cases} P_{j,t-1} \text{ with probability } \varrho \\ P_t^* \text{ with probability } 1-\varrho \end{cases} \tag{44}$$

where $P_t^*$ is the optimal price set by the fraction $\varrho$ of retailers who are able to re-optimize their prices at time $t$. Note that $P_t^*$ does not depend on $j$ because all firms that can re-optimize their prices at time $t$ choose the same price as they are assumed to be symmetric. Then, for firms not able to re-optimize their prices, there is no price indexation to replicate the observation that many prices can remain unchanged over time (**(author?)** (Eichenbaum and Rebelo) and **(author?)** (Klenow and Malin)). So, the price index, $P_t$, is thus given by:

$$P_t = \Big[\int_0^1 P_{j,t}^{1-\epsilon} dj\Big]^{\frac{1}{1-\epsilon}} = \Big[(1-\varrho)\big(P_t^*\big)^{1-\epsilon} + \varrho\big(P_{t-1}\big)^{1-\epsilon}\Big]^{\frac{1}{1-\epsilon}} \tag{45}$$

The price index is a CES aggregate of all retail goods' prices in the economy at period $t$. The sum in equation (45) can then be transformed into a convex combination of two prices because firms of each type are assumed to be respectively symmetric. A costless price regulation mechanism is assumed, which guarantees that a consumer pays the same price whatever the firm at which she or he realizes his purchases[20]. So, the price index corresponds to a weighted average price of the fraction $\varrho$ of firms who can re-optimize their prices after the aggregate shock, $A_t$, and the fraction $(1-\varrho)$ of firms who can not.

Firms that can re-optimize their price, maximize the expected discounted value of their profits given the demand for the good they produce, since firms expect to keep this price for more than the current period. They take into account that the price may be fixed for many periods. If the expected probability of price stickiness is high, firms able to re-optimize their price at the period $t$ will be relatively more concerned about the future when they make their current pricing decisions.

Thus, these firms face the following problem, subject to the total demand (42) it faces:

$$\max_{P_{j,t}} \quad E_t \sum_{s=0}^{\infty} (\varrho\beta)^s \frac{\lambda_{t+s}}{\lambda_t} \left[ \left( \frac{P_{j,t}}{P_{t+s}} \right)^{1-\epsilon} Y_{t+s} - \left( \frac{P_{j,t}}{P_{t+s}} \right)^{-\epsilon} \left( \frac{P^{ws}_{t+s}}{P_{t+s}} \right) Y_{t+s} \right]$$

Note that $\varrho$ is integrated in the discount rate because there is a probability $\varrho^s$ that the price chosen is still applied in $s$ periods time.

The first-order condition of the problem is given by:

$$E_t \sum_{s=0}^{\infty} (\varrho\beta)^s \frac{\lambda_{t+s}}{\lambda_t} P_{t+s}^{(\epsilon-1)} Y_{t+s} \left( \epsilon P^{ws}_{t+s} P^{*(-\epsilon-1)} + (1-\epsilon) P_t^{*(-\epsilon)} \right) = 0$$

The optimal price, $P_t^*$ , sets by firms who are able to re-optimize their prices is thus given by:

$$P_t^* = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{s=0}^{\infty} (\varrho\beta)^s \frac{\lambda_{t+s}}{\lambda_t} P^{ws}_{t+s} P^{\epsilon}_{t+s} Y_{t+s}}{E_t \sum_{s=0}^{\infty} (\varrho\beta)^s \frac{\lambda_{t+s}}{\lambda_t} P^{\epsilon-1}_{t+s} Y_{t+s}} \tag{46}$$

These firms set their price such that it equals the present discounted value of marginal costs. The optimal price is a mark-up over a weighted average of future marginal costs. The size of the mark-up depends negatively on the degree of monopolistic competition in the intermediate good sector, $\epsilon$. If there is no price-stickiness, $\varrho = 0$,

[20] The matching of consumers and firms is ignored.

the monopoly standard mark-up formula is derived:

$$P_t^* = \frac{\epsilon}{\epsilon - 1} P_{t+s}^{ws}, \qquad \text{where} \ \frac{\epsilon}{\epsilon - 1} > 1 \tag{47}$$

The final-good market clearing condition implies that final goods, $Y_t$, may be consumed by households, $C_t$, and entrepreneurs, $C_t^e$, or be used as investment, $I_t$, as government expenditures, $G_t$, or as capital utilization costs, $\Upsilon(\nu_t)K_{t-1}^p$. The following aggregate resource constraint is thus obtained:

$$Y_t = C_t + C_t^e + I_t + G_t + \Upsilon(\nu_t)K_{t-1}^p \tag{48}$$

### 3.5 Entrepreneurs

Entrepreneurs own wholesale-good firms. At the beginning of period $t$, they borrow from banks to cover hiring costs, wage bill and renting capital because they have to pay them prior to the production. Then, after receiving the amount borrowed from the bank, they rent and pay immediately capital from households on a perfectly competitive capital market. At the same time, vacancies are posted and matches take place with workers. Entrepreneurs pay also immediately vacancies costs and wages of workers hired and of workers already hired in previous periods. Finally, after the wholesale-good sale, some entrepreneurs will be declared solvent or bankrupt, depending on their production and idiosyncratic shock levels. Entrepreneurs declared bankrupt are not able to reimburse their entire loan. The bank will confiscate the proceeds of the production. As a consequence, bankrupted entrepreneurs will not consume, nor accumulate net-worth. But at the beginning of the next period $t + 1$, entrepreneurs are assumed to receive an exogenous endowment, $W^e$, which will be used as collateral or net worth to borrow from banks at the beginning of the next period, in order to be sure that this kind of agents, specialized in managing production, will be able to continue their activities. Entrepreneurs declared solvent reimburse their entire loan to banks. Then, they have to wait the production of the final good to consume or accumulate a net worth. To ensure that entrepreneurs do not accumulate net worth, such that they could be able to self-finance their production at the next period, we assume that each entrepreneur has a constant probability, $1 - \varsigma_t$, to die at the end of the period. It will limit the size of aggregate net worth in an infinite horizon set up. Indeed, since the rate of return on internal funds is higher than the one of external funds, due to asymmetric information on credit markets, risk neutral entrepreneurs may be willing to postpone consumption and would only accumulate funds.

So solvent entrepreneurs who exit the economy at the end of the period will consume all their net worth. Thus, the aggregate entrepreneurial consumption, $C_t^e$, is given by:

$$C_t^e = (1 - \varsigma_t)\frac{P_t^{ws}}{P_t} Y_t^{ws} f(\bar{\omega}_t) \tag{49}$$

To be sure however to have a constant fraction of entrepreneurs in the economy in every period, we assume that the birth of rate of entrepreneurs at the beginning of each period ensures this constant fraction.

Solvent entrepreneurs who do not exit the economy at the end of the period will keep accumulating net worth using their realized returns. Consequently, the evolution of the aggregate entrepreneurial real net worth is:

$$X_{t+1} = W^e + \varsigma_t \frac{P_t^{ws}}{P_t} Y_t^{ws} f(\bar{\omega}_t) \tag{50}$$

$\varsigma_t$ is interpreted as a shock to entrepreneurs' net worth. It evolves according to:

$$\varsigma_t = \bar{\varsigma}\epsilon_t^{\varsigma} \tag{51}$$

$$\log(\epsilon_t^{\varsigma}) = \rho_{\varsigma} \log(\epsilon_{t-1}^{\varsigma}) + u_t^{\varsigma}, \quad \rho_\delta \in (0,1) \;\text{ where }\; u_t^{\varsigma} \overset{iid}{\sim} N(0, \sigma_{\varsigma}^2)$$

where $\bar{\varsigma}$ is the steady state value of the shock to entrepreneurs' net worth, $\varsigma_t$.

## 3.6 Monetary and fiscal policy

### Monetary policy

The monetary policy is decided and carried out by the central bank following an interest rate Taylor-type rule[21]. The nominal interest rate of each period will be set depending on deviations in output, inflation and nominal interest rate from their steady-state levels:

$$\frac{R_{t+1}}{\bar{R}} = \left(\frac{R_t}{R}\right)^{\rho_r} \left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\rho_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\rho_Y}\right]^{1-\rho_r} \tag{52}$$

where $\rho_R$ is the degree of interest rate smoothing, $\rho_Y$ and $\rho_\pi$ are the response coefficients to output and inflation variables and variables without a time subscript are steady state values. $R_{t+1}$ is the interest rate decided today by the government, that will pay off in period $t+1$. So this interest rate is known at time $t$. Then, knowing

[21] The same kind of Taylor rule is used by (21), Krause et al. (28) and Trigari (46).

this nominal interest rate, the government adjusts the money supply so as to achieve the equilibrium in the money market.

**Fiscal policy**

The fiscal policy is decided and carried out by the government at the end of the period $t$. After the final-good production, households pay nominal lump-sum taxes, $T_t$, to the government. Then, we assume that the government earns mainly revenue through printing of real money. Basically, the central bank returns this revenue back to the fiscal authority. With these taxes and seignoriage revenue, $\frac{M_{t+1}-M_t}{P_t}$, the government finance the real exogenous government spending, $G_t$, and the amount of real unemployment benefits, $(1-n_t)b$, for unemployed workers. The level of the unemployed is known by the government at the end of the matching process on the labor market.
So the government budget constraint is the following:

$$G_t + (1-n_t)b = \frac{T_t}{P_t} + \frac{M_{t+1}-M_t}{P_t} \tag{53}$$

where $G_t$ is the exogenous government spending.

# 4 Model simulation

This section demonstrates how both financial and labor market frictions affect the response of unemployment and vacancies to shocks originating in the credit market.
First a positive shock on the net worth of entrepreneurs is considered. We next represent a positive shock on credit conditions, through an increase in monitoring costs. Finally, we consider a positive uncertainty shock on the idiosyncratic efficiency's standard deviation of wholesale firms, inducing that it is more risky for banks to lend to wholesale firms.

## 4.1 Data

Quarterly US data are used for the sample period 1960:Q1 through 2007:Q4. Output is defined as the real gross domestic product; consumption as the real personal consumption expenditures; the nominal interest rate is defined as quarterly averages of Federal Funds rate; inflation is defined as the growth rate of the GDP deflator; unemployment and employment are defined as the civilian unemployment and employment rate (as a percentage of the civilian labor force); real wages are defined as the nonfarm business sector real compensation per hour and hours worked per employee are nonfarm business sector average weekly hours worked per employee. Investment is defined as the real private fixed investment. Vacancy job data are obtained from the Help Wanted OnLine (HWOL) dataset provided by the Conference Board (TCB). They are used by Sahin et al. (40). This data covers online advertised vacancies posted on internet job board in newspapers online editions. More precisely, it is the number of new, first-time online jobs and jobs reposted from the previous month for over 16,000 Internet job boards, corporate boards and smaller job sites. This data set is constructed to avoid double-counting (a same ad can appear on multiple job boards), by using an unduplication algorithm that identifies unique advertised vacancies on the basis of a combination of company name, job title, city or state [22]. Finally, government expenditures are defined as the real government consumption expenditures and gross investment[23].

The data are demeaned, seasonally adjusted when necessary and the output, consumption, investment and government expenditures series are expressed in per capita terms, in the sense of the labor force as in Smets and Wouters (42).

Our simulation period ends in 2007:Q4 as justified by Galí et al. (20) in order to prevent our simulation from being disturbed by nonlinearities induced by the lower bound on the Federal Funds rate and binding downward nominal wage rigidity during the Great Recession.

### 4.2 Calibration

Parameter values are chosen to be consistent with those standard in literature and especially with estimated new-Keynesian models. The household discount factor, $\beta$, is set to 0.99 implying an annual real interest rate of 4 %. The capital depreciation rate, $\delta_K$, is fixed to 0.025 corresponding to an average annual depreciation rate of 10 per cent. For the wholesale-good sector, the capital share in output, $\alpha$, is standard at 0.36. This value is based on calculation of Kydland and Prescott (30) using US time series data.

The elasticity of matches to unemployment, $\rho$, is set to 0.72 as in Shimer (41) and Petrosky-Nadeau (38). This value is almost within the range of values of 0.5 to 0.7 reported by Petrongolo and Pissarides (37) in their survey of the literature on the estimation of matching function[24]. The conventional value, 0.5, is given to the

[22] Like The Conference Board's long-running Help Wanted Advertising Index of print ads (which was published for over 55 years and discontinued in July 2008), the HWOL series measures help wanted advertising, i.e. labor demand. The HWOL data series began in May 2005. It replaces the Help-Wanted Advertising Index of print advertising maintained by the TCB (the Conference Board surveys help-wanted print advertising volume in 51 major newspapers across the country every month, until 2008). Since the online ads are a direct indication of hiring intent by employers, the ads serve as a measure of labor demand. For more detailed information and comments on survey coverage, concepts, definitions and methodology, see the Technical Notes at https://www.conference-board.org/data/helpwantedonline.cfm.

[23] More details about data used are available in Appendix 5.

[24] Others values are used such as 0.4 in Blanchard and Diamond (7), Merz (33), Andolfatto (2) and Mortensen and Nagypal (34) or 0.5 in Gertler et al. (23).

bargaining power, $\eta$, as in (23). The vacancy posting cost, $\gamma$, is set to 0.14, and the destruction rate parameter, $\delta$, is set to 0.08. It is compatible with those used in the literature which range from 0.07 in Merz (33) to 0.15 in Andolfatto (2). The unemployment benefits, $b$, is equal to 0.71 also as in Petrosky-Nadeau (38).

The inverse of the elasticity of worked hours to real hourly wage (or the Frish elasticity), $\tau$, is equal to 10 as in Trigari (46), who has extensive and intensive margin in her paper. The external habit persistence parameter, $h$, is fixed to 0.5 as in Gertler et al. (23).

For the intermediate-good sector, the monopolistic mark-up or the elasticity of substitution across inputs, $\epsilon$, is fixed to 11 to have a conventional price-mark-up on marginal costs at 10 % as in Walsh (47) and Trigari (46). The Calvo stickiness of prices, $\varrho$, is set to 0.66 as in Gertler et al. (23). The steady state entrepreneurial survival rate, $\bar{\varsigma}$, is equal to 0.9728 in line with Bernanke and Gertler (4) and Zanetti and Mumtaz (50). The gross external finance premium, $s_1$, is set to 4.97307139522323, and the steady state value of credit shock, $\bar{s_0}$, is set to 7.3678.

For the Taylor rule, conventional value are also taken. The interest rate smoothing coefficient, $\rho_R$, is set to 0.75. Coefficients for the responses of interest rate to inflation, $\rho_\pi$ and to the output gap are fixed respectively to 1.7 and 0.125 as in Gertler et al. (23).

**Table 1:** Baseline calibration

| Parameter | Value | Description |
|---|---|---|
| Preferences | | |
| $\beta$ | 0.99 | Households discount factor |
| Technology | | |
| $\alpha$ | 0.36 | Capital share in production |
| $\delta_K$ | 0.025 | Capital depreciation rate |
| $\sigma_A$ | 0.05 | Cost of capital utilization |
| $\kappa$ | 4 | Investment adjustment cost |
| Preferences | | |
| $\tau$ | 10 | Inverse of the elasticity of worked hours to real wage |
| $h$ | 0.5 | External habit persistence |
| Job market | | |
| $\rho$ | 0.72 | Elasticity of matches to unemployment |
| $\gamma$ | 0.14 | Unit cost of job vacancies |
| $b$ | 0.71 | Unemployment benefits |
| $\eta$ | 0.5 | Bargaining power parameter |
| $\delta$ | 0.08 | Job destruction rate |
| Entrepreneurs and financial market | | |
| $s_1$ | 4.97307139522323 | Gross external finance premium |
| $\bar{s_0}$ | 7.3678 | Steady-state value of credit shock |
| $\bar{\varsigma}$ | 0.9728 | Steady-state value of net worth shock |
| $W^e$ | 0.01 | Entrepreneurial endowment |
| Intermediate-good market | | |
| $\varrho$ | 0.66 | Calvo stickiness of prices |
| $\epsilon$ | 11 | Monopolistic mark-up |
| Monetary policy | | |
| $\rho_R$ | 0.75 | Interest rate smoothing coefficient |
| $\rho_\pi$ | 1.7 | Response to inflation |
| $\rho_Y$ | 0.125 | Response to output |
| Shocks | | |
| $\rho_{s0}$ | 0.95 | Credit shock persistence |
| $\rho_\omega$ | 0.97 | Uncertainty shock persistence |
| $\rho_\varsigma$ | 0.5 | Net worth shock persistence |
| $\sigma_{s0}$ | 0.15 | Standard deviation of credit shock |
| $\sigma_\omega$ | 0.15 | Standard deviation of uncertainty shock |
| $\sigma_\varsigma$ | 0.15 | Standard deviation of net worth shock |

### 4.3 Results

Our simulation exercise is a Taylor approximation around the steady state of order one.

#### 4.3.1 Net worth shock

Let us assume that there is an expansionary shock to the entrepreneurs net worth. According to our model, it means a positive increase in $\varsigma_t$. The aggregate real net worth is increasing as the probability of dying for each entrepreneur is decreasing. A positive net worth shock induces that all entrepreneurs will carry on to the next period $t+1$ a higher real amount of net worth. Recall that in our model, surviving solvent entrepreneurs carry their profits as a part of their net worth. And entrepreneurs, based on their net worth amount and their expected production and returns, borrow funds from banks to post vacancies, to pay capital spending and the wage bill in advance. So the net worth is a mean for entrepreneurs to lower their use of external financing.

Figure 7 shows impulse responses to a positive net worth shock. According to our simulation exercise, firstly, an increase in the aggregate real net worth has a positive effect on the financial sphere. By a positive effect, we mean that it decreases the financial mark-up, highlighting a financial accelerator mechanism. The higher is the level of the aggregate real net worth, the lower is the financial markup charged by banks to entrepreneurs, as found by Zanetti and Mumtaz (50). As a consequence of the real aggregate net worth increase and of the financial mark-up decrease, the default rate is also decreasing. This decrease induces an increase in the gross share of returns going to the firm according to our model.

These results on the financial sphere will impact the real sphere of the economy, especially the labor market. An increase in the aggregate real net worth of entrepreneurs leads to a decrease in the unemployment rate, following a negative hump-shaped, thanks to an easing in their financing costs. Indeed, entrepreneurs are now able to finance by themselves a higher part of their production and vacancies costs, and for the part financed by loans, the financial mark-up charged by banks is reduced. So the aggregate real wholesale firm's marginal costs are reduced according to our model. This reduction induces entrepreneurs to post more vacancies, and the unemployment rate decreases as a consequence, as found in the estimation of Zanetti and Mumtaz (50). The job finding rate for workers increases as expected and the labor market tightness from the firm point of view decreases.

More precisely, a substitution effect between hours worked per employee and the amount of employed workers appears for the labor market in our simulation, as in the estimation of Christiano et al. (14). This phenomenon highlights the interaction between intensive and extensive margins on labor markets. As a consequence of the easing of financing costs, entrepreneurs are willing to hire more workers, but they decrease their demand for hours worked per employee. This fact is also observed in data in the sense that extensive margin is more reactive than the intensive margins when the economy is hit by a shock.

Furthermore, the link from the financial market to the labor market goes through wages. An easing in financial

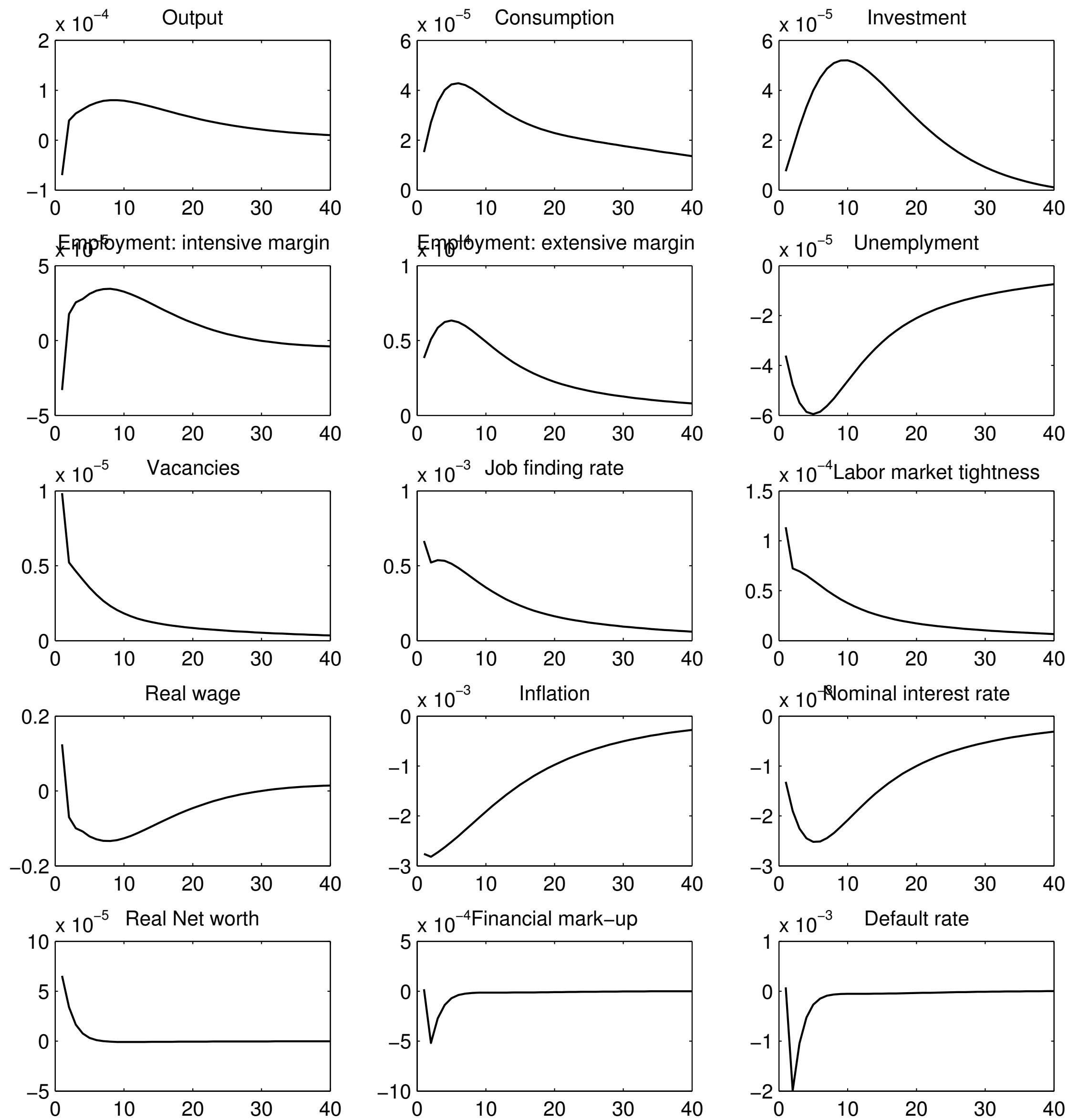



**Figure 7:** IRF to a positive networth shock

constraints increases the labor market tightness from the firm point of view. And the reduction in aggregate real marginal costs is pass through prices according to our model, leading to a lower inflation rate as observed in the simulation exercise. These two facts contribute to an increase of the real wage in the economy. However, these results are not found in the estimation of Zanetti and Mumtaz (50). It could be linked to the fact they integrate only the capital stock as the production cost to be paid in advance.

Obviously, the previous results on the financial sphere have also an impact on goods market. An increase in the net worth of entrepreneurs generates a positive hump-shaped in consumption, through according to our model, the higher wages, more vacancies posted and less unemployment. The net worth positive shock induces also a positive hump-shaped, larger than the one for consumption, in investment. This increase in investment can be explained by our model as the consequence of more employed workers and higher wages for households that are able to invest more, and through a higher demand for capital expressed by entrepreneurs, as net worth and financial mark-up decrease (Zanetti and Mumtaz (50)). The conjunction of higher consumption and higher investment leads to an increase of output, after a first decrease, possibly due to the existence of investment adjustment costs and higher wages.

So the economy is better off, at least in terms of consumption and employment, when all firms are able at the aggregate level to self-finance a higher part of their production and vacancies costs. Financial frictions are indeed less at stake as a consequence, through a decrease in the amount of loans demanded by firms and a decrease in the level of marginal costs, realized by a lower financial mark-up. The most important impact appears to be on the labor market, where vacancies increase and unemployment rate decreases, as expected by our model.

#### 4.3.2 Credit shock

A positive credit shock is realized in the economy through a decrease in the monitoring costs, $\mu_t$. More precisely, the recovery rate defined in our model following Livdan et al. (32) and Petrosky-Nadeau and Wasmer (39) increases (so the monitoring cost decreases), by an increase of $s_{0,t}$, interpreted as a credit shock. Recall that in our model monitoring costs appear because wholesale-good production is subject to an idiosyncratic shock, observed privately by entrepreneurs. Thus, banks have to pay a monitoring cost for bankrupt entrepreneurs to check the real output produced and the efficiency of the recruitment process. This monitoring cost is assumed to be proportional to the realized firm's value. Furthermore, it is spent in terms of currency.

Figure 8 shows impulse responses to a positive credit shock. As for the net worth shock, a positive credit shock has an impact on the financial sphere. A decrease of the monitoring cost leads to a reduction of the default rate. It was strongly expected as in our model, the monitoring cost spending is a direct synonym of bankruptcy. The lower are the monitoring costs, the lower is the default rate according to our framework. Then, the positive credit shock leads to a reduction of the financial mark-up charged by banks to entrepreneurs. It could be easily explained through our model by the expression of the financial mark-up, $S_t$, that depends negatively on the recovery rate. A positive credit shock means that the recovery rate for banks increases. The proportion of the real amount recovered by banks is higher. So banks do not need to charged, everything else equal, the same amount of financial mark-up to entrepreneurs.

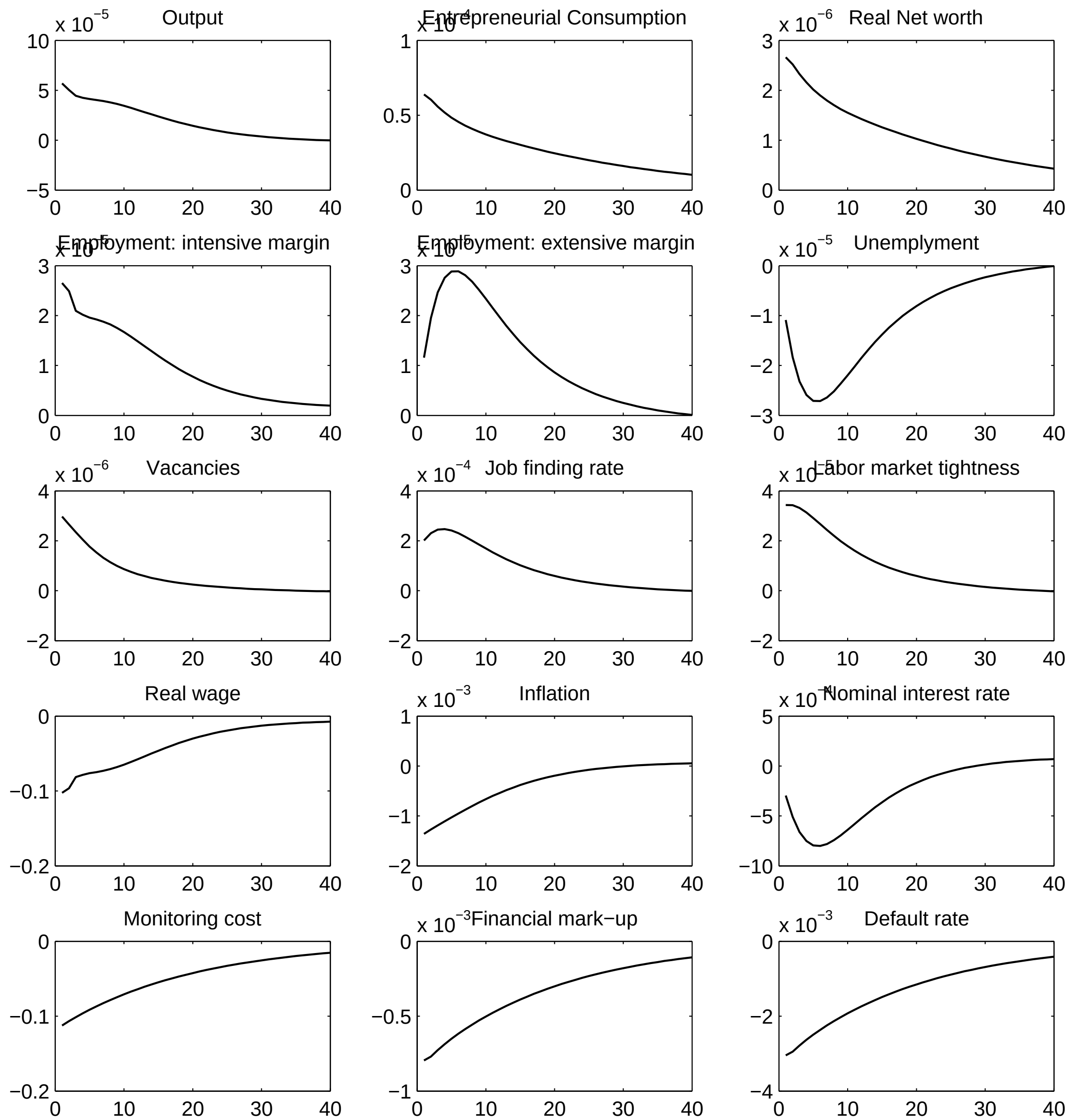



**Figure 8:** IRF to a positive credit shock

For the real part of the economy, following our model, the agency problem between banks and entrepreneurs alter the real recruitment cost and the marginal cost of production for wholesale firms. We observe in our simulation exercise that it is the case: a positive credit shock induces an increase of vacancies and a decrease of unemployment, following a negative hump-shaped with a peak at one year and half. Petrosky-Nadeau (38) finds in the same spirit following a negative credit shock a positive hump-shaped for unemployment with a peak just over a year after the shock, that is considered as comparable to the research of Jermann and Quadrini (25), but with a specific insight into the labor market. Eckstein et al. (16) identify also this impact, through a called flow profit and vacancy cost channels. So, lower marginal costs, thanks to lower financial mark up, induce firms to recruit more, to post more vacancies. The labor market tightness from the firm point of view increases, and the job finding rate for households increases as a consequence, as in Petrosky-Nadeau (38). In our model, we find as well that the slope of the real posting cost raises with the monitoring costs. The real cost of a new hire raises with monitoring costs, everything else equal.

The substitution effect between hours worked per employee and number of employed workers does not appear here after a positive credit shock. On the contrary, a complementary effect is observed: employed workers are more, and each of them are working more. That is a first reason why we could observe a positive impact on the output compared to the previous case.

Concerning the output, in the model, we assume that the monitoring cost spending, synonym of bankruptcy is spent in terms of currency, and not in terms of physical goods. Bankruptcy has no direct impact on the real output. However, the simulation shows a clear indirect impact on output. Indeed, monitoring costs are additional costs taken into account by banks when agreeing on an appropriate interest rate on loans. A reduction in monitoring costs and bankruptcy rates has an impact on welfare indirectly, through their implications on the mark-up pricing. The simulation illustrates this phenomenon: the decrease in monitoring costs reduce real marginal costs of firms, reducing the level of inflation in the economy, as well as the level of nominal interest rate. It generates an increase in consumption and investment that in turns increase the output level. Then, a slow decrease in the level of the real wages can be observed probably as the consequence of the inflation rate decrease.

Finally, the entrepreneurial consumption and the aggregate real net worth increase as a consequence of the reduction of the monitoring cost, and of marginal costs. Solvent dying and not dying entrepreneurs have indeed a larger share of the net output to consume and to save to the next period.

Thus, a positive credit shock pushes down marginal costs and prices, as well as hiring costs by a financial mark-up, depending on the level of monitoring cost. A reduction of monitoring costs in an economy has a strong impact on the vacancies and employment levels, as expected in our model.

### 4.3.3 Uncertainty shock

An uncertainty shock is defined as a variation in the variance of the idiosyncratic shock concerning entrepreneur's efficiency. According to our model, this variance reflects the degree of entrepreneurs' riskiness for banks. As a consequence, banks are facing a higher risk when they decide to lend to entrepreneurs. Recall that in our model, banks do not observe firm's idiosyncratic shocks, but they only know the cumulative and density functions of these idiosyncratic shocks.

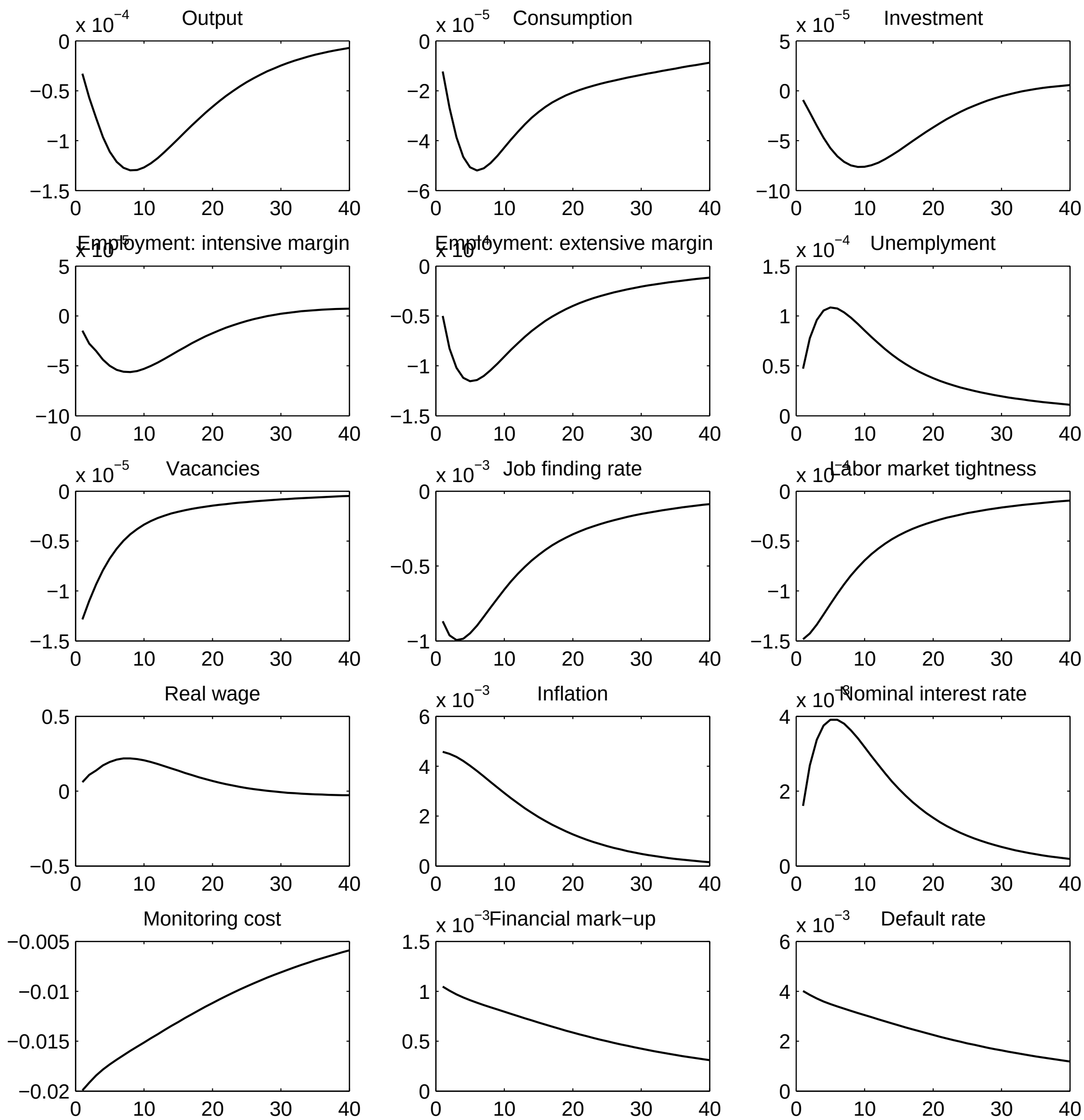



**Figure 9:** IRF to a positive uncertainty shock

Figure 9 shows impulse responses to a positive uncertainty shock. As expected, after an increase in the level of uncertainty for banks about the idiosyncratic shock of firms, banks charge a higher financial mark-up to protect them against the asymmetric information. The default rate increases in quite huge proportion, due to the increase of uncertainty in the economy, and due to the increase in the financial mark-up that increases firm's real marginal costs. On the real side, a higher uncertainty decreases employment, output, consumption and investment. As a consequence, labor market tightness from the workers' point of view increases. Indeed, firms are posting fewer vacancies. The reason is linked to the increase of the financial mark-up. After an increase in the level of uncertainty, according to our model, the increase of the financial mark-up is passing through real marginal costs and prices in the economy. Firms are induced to post fewer vacancies, to hire fewer workers because of this increase in financing costs. Furthermore, inflation increases, as well as the nominal interest rate. Intensive and extensive margins appear here to move in the same direction. Hours worked per employee decrease also. So, fewer workers are employed in the economy and each employed workers are working less. According to our model, it could explain why consumption and investment are going down. Households have a less amount of resources to invest and the demand for capital by firms decreases, due to the increase of the financial mark-up. Thus, the economy reaches a negative position after an increase in the uncertainty concerning the idiosyncratic shock of wholesale firms. Facing higher risks, banks need, to overcome the agency problem they face with entrepreneurs, to increase the financial mark-up that they charge to them. The real marginal financing costs of entrepreneurs increase. It reduces as a consequence the value of a new hire, and leads to lower vacancies. The unemployment goes down. Furthermore, the higher marginal costs are passed through prices to the rest of the economy, leading to higher inflation, less consumption, and less output.

By moving three dimensions involving different degrees of financial frictions, we observe through our simulation exercise a clear impact from the financial market to the labor market. Increasing asymmetric information in financial markets (through higher monitoring costs, higher uncertainty or lower entrepreneurial net worth) leads clearly to higher unemployment in the economy, through different channels. These channels converge all to the role of the financial mark-up that is charged by banks to overcome agency problems. This financial mark-up is pass through the rest of the economy by higher marginal costs, and higher inflation. That in turn reduces the levels of vacancies posting, employment, wages and consumption, and finally, the level of output. The evolution of credit market conditions changes the opportunity cost for resources used to create new jobs. Thus, it alters the dynamics of job vacancies and unemployment. For our three shocks, the unemployment jumps up or goes down to its highest level in the first period and then slowly converges back to its steady state level.

## 5 Conclusion

We construct a new-Keynesien DSGE model integrating sticky prices, financial frictions on the credit market and asymmetric information on the labor market. We find that credit market frictions may be the source of lower posting vacancies and higher unemployment level. Asymmetric information pushes up wholesale firms' marginal costs, as well as hiring costs by a financial mark-up charged by financial intermediaries. This financial mark-up is then transmitted by these firms on prices. Thus, it affects their hiring behavior, as well as wage and employment levels in the economy. Then, we simulate the model by using quarterly US data for the sample period 1960:Q1 to 2007:Q4. We consider three shocks: a net worth shock, a credit shock and an uncertainty shocks. We find that employment rates and vacancies posting increase following positive credit, net worth and uncertainty shocks. Different channels of propagation from the financial sphere of the economy to the labor market are investigated and appear to be consistent with our theoretical model. All these channels appear to converge to the key role of what we called, a financial mark-up charged by banks to overcome agency problems.

# Appendices

## Appendix A

In this appendix, we prove that $S_t > 1, \ \forall\, \bar{\omega} \in [0, \infty)$, where $S_t = \{1 - \mu_t[\Gamma(\bar{\omega}_t) + \bar{\omega}_t h(\bar{\omega}_t) f(\bar{\omega}_t)]\}^{-1}$.

Using the assumption that $\bar{\omega}_t h(\bar{\omega}_t)$ is increasing in $\bar{\omega}_t$ and taking derivatives, we obtain

$$S_t' = \frac{\mu_t}{1 - \Phi(\bar{\omega}_t)} \frac{d(\bar{\omega}_t h(\bar{\omega}_t))}{d\bar{\omega}_t} \frac{1}{S_t^2} > 0.$$

Given this result, $S_t$ is an increasing function of $\bar{\omega}_t$.

Now taking limits of $\Gamma(\bar{\omega}_t)$ and $\bar{\omega}_t h(\bar{\omega}_t) f(\bar{\omega}_t)$ at the lower bound of $\bar{\omega}$, we get

$$\lim_{\bar{\omega} \to 0} \Gamma(\bar{\omega}_t) = 0, \qquad \lim_{\bar{\omega} \to 0} \bar{\omega}_\mathrm{t} \mathrm{h}(\bar{\omega}_\mathrm{t}) \mathrm{f}(\bar{\omega}_\mathrm{t}) = 0$$

Thus, $\lim_{\bar{\omega} \to 0} S_t = 1$.

Combining the previous results, $S_t \geq 1, \ \forall\, \bar{\omega} \in [0, \infty)$.

## Appendix B: Log-normal distribution and financial contract

### Financial contract: Technical issues

The idiosyncratic shock $\omega_t$ has a log-normal distribution with mean 1 and standard error $\sigma_{\omega,t}$. In order to resolve the model numerically, some simplifications and analytic expressions regarding $f(\bar{\omega}_t, \sigma_{\omega,t})$, $g(\bar{\omega}_t, \sigma_{\omega,t})$ and $S(\bar{\omega}_t, \sigma_{\omega,t})$ are needed. Since $E(\omega_t) = 1$ and $V(\omega_t) = \sigma^2_{\omega,t}$, then the parameters of the log-normal distribution are given by $\Big(-0.5 \ln(1 + \sigma^2_{\omega,t}), \ln(1 + \sigma^2_{\omega,t})\Big)$. So that the density function $\phi(\omega_t, \sigma_{\omega,t})$ can be expressed by:

$$\phi(\omega_t, \sigma_{\omega,t}) = \frac{1}{\omega_t \sqrt{2\pi} \sqrt{\ln(1 + \sigma^2_{\omega,t})}} \exp\Big[-\frac{\Big(\ln(\omega_t) + 0.5 \ln(1 + \sigma^2_{\omega,t})\Big)^2}{2 \ln(1 + \sigma^2_{\omega,t})}\Big] \tag{54}$$

- **Finding $\Phi(\omega_t, \sigma_{\omega,t})$ and $\Gamma(\omega_t, \sigma_{\omega,t})$** . We know that:

$$\Phi(\bar{\omega}_t, \sigma_{\omega,t}) = \int_0^{\bar{\omega}_t} \phi(\omega, \sigma_{\omega,t}) \mathrm{d}\omega$$

By making the change of variables, we get $x_{1,t}$ and $x_{2,t}$ defined by:

$$\begin{aligned} x_{1,t} &= \frac{\ln(\omega_t) + 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}} \qquad \text{then} \qquad \omega_t = \exp\Big[\sqrt{\ln(1+\sigma^2_{\omega,t})}x_{1,t} - 0.5\ln(1+\sigma^2_{\omega,t})\Big] \\ x_{2,t} &= \frac{\ln(\omega_t) - 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}} \qquad \text{then} \qquad \omega_t = \exp\Big[\sqrt{\ln(1+\sigma^2_{\omega,t})}x_{2,t} + 0.5\ln(1+\sigma^2_{\omega,t})\Big] \end{aligned}$$

with

$$\mathrm{d}x_1 = \mathrm{d}x_2 = \frac{1}{\omega\sqrt{\ln(1+\sigma^2_{\omega})}}\mathrm{d}\omega$$

and

$$\lim_{\omega_t \to 0} x_{1,t} = -\infty, \quad \lim_{\omega \to \bar{\omega}_t} x_{1,t} = \frac{\ln(\bar{\omega}_t) + 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}.$$

$$\lim_{\omega_t \to 0} x_{2,t} = -\infty, \quad \lim_{\omega \to \bar{\omega}_t} x_{2,t} = \frac{\ln(\bar{\omega}_t) - 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}.$$

Substituting $\omega_t$ by $x_{1,t}$ and applying the substitution rule in integration, we get:

$$\Phi(\bar{\omega}_t, \sigma_{\omega,t}) = \int_{-\infty}^{\frac{\ln(\bar{\omega}_t)+0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}} \frac{1}{\sqrt{2\pi}}\exp\Big[-\frac{x_1^2}{2}\Big]\mathrm{d}x_1 = F\Big[\frac{\ln(\bar{\omega}_t) + 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}\Big] \tag{55}$$

where F(.) is the cumulative distribution function of a standard Normal distribution.

Similarly,we know that:

$$\Gamma(\bar{\omega}_t, \sigma_{\omega,t}) = \int_0^{\bar{\omega}_t} \omega\phi(\omega, \sigma_{\omega,t})\mathrm{d}\omega$$

Substituting $\omega_t$ by $x_{2,t}$ and applying the substitution rule in integration, we get:

$$\begin{aligned} \Gamma(\bar{\omega}_t, \sigma_{\omega,t}) &= \int_{-\infty}^{\frac{\ln(\bar{\omega}_t)-0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}} \frac{1}{\sqrt{2\pi}}\exp\Big[-\frac{\Big(x_2 + \sqrt{\ln(1+\sigma^2_{\omega,t})}\Big)^2}{2}\Big]\omega\mathrm{d}x_2 \\ &= \int_{-\infty}^{\frac{\ln(\bar{\omega}_t)-0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}} \frac{1}{\sqrt{2\pi}}\exp\Big[-\frac{x_1^2}{2}\Big]\mathrm{d}x_2 \\ &= \int_{-\infty}^{\frac{\ln(\bar{\omega}_t)-0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}} \frac{1}{\sqrt{2\pi}}\exp\Big[-\frac{x_1^2}{2}\Big]\mathrm{d}x_1 \\ &= F\Big[\frac{\ln(\bar{\omega}_t) - 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}\Big] \end{aligned}$$

Given the obtained results, we get the following:

$$
\begin{aligned}
f(\bar{\omega}_t, \sigma_{\omega,t}) &= 1 - F\Big[\frac{\ln(\bar{\omega}_t) - 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}\Big] - \bar{\omega}_t\Big(1 - F\Big[\frac{\ln(\bar{\omega}_t) + 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}\Big]\Big) \\
g(\bar{\omega}_t, \sigma_{\omega,t}) &= (1-\mu_t)F\Big[\frac{\ln(\bar{\omega}_t) - 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}\Big] + \bar{\omega}_t\Big(1 - F\Big[\frac{\ln(\bar{\omega}_t) + 0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}\Big]\Big) \\
h(\bar{\omega}_t, \sigma_{\omega,t}) &= \frac{1}{\bar{\omega}_t\sqrt{2\pi\ln(1+\sigma^2_{\omega,t})}} \frac{\exp\Big[-\frac{\Big(\ln(\bar{\omega}_t)+0.5\ln(1+\sigma^2_{\omega,t})\Big)^2}{2\ln(1+\sigma^2_{\omega,t})}\Big]}{1 - F\Big[\frac{\ln(\bar{\omega}_t)+0.5\ln(1+\sigma^2_{\omega,t})}{\sqrt{\ln(1+\sigma^2_{\omega,t})}}\Big]} \\
S(\bar{\omega}_t, \sigma_{\omega,t}) &= \Big[1 - \mu_t\Big(\Gamma(\bar{\omega}_t, \sigma_{\omega,t}) + \bar{\omega}_t h(\bar{\omega}_t, \sigma_{\omega,t}) f(\bar{\omega}_t, \sigma_{\omega,t})\Big)\Big]^{-1}
\end{aligned}
$$

- **Derivatives computation**

$$
\begin{aligned}
\bar{f}_\omega &= \Phi(\bar{\omega}, \bar{\sigma}_\omega) - 1 \\
\bar{f}_{\sigma_\omega} &= \bar{\omega} f_{\sigma_\omega}(\bar{\omega}, \bar{\sigma}_\omega) - \Gamma_{\sigma_\omega}(\bar{\omega}, \bar{\sigma}_\omega) \\
\bar{g}_\omega &= 1 - \Phi(\bar{\omega}, \bar{\sigma}_\omega) - \bar{\mu}\bar{\omega}\phi(\bar{\omega}, \bar{\sigma}_\omega) \\
\bar{g}_{\sigma_\omega} &= -f_{\sigma_\omega}(\bar{\omega}, \bar{\sigma}_\omega) - \bar{\mu}\Gamma_{\sigma_\omega}(\bar{\omega}, \bar{\sigma}_\omega)
\end{aligned}
$$

# Appendix C: Data

## .1 Data documentation

**Data documentation: United-States from 1960:Q1 to 2007:Q4**

$$
\begin{aligned}
\text{Real output per capita} &= LN(GDPC1/CLF16OV\text{index})*100 \\
\text{Real consumption per capita} &= LN((PCEC/GDPDEF)/CLF16OV\text{index})*100 \\
\text{Real investment per capita} &= LN((PFI/GDPDEF)/CLF16OV\text{index})*100 \\
\text{Inflation} &= LN(GDPDEF/GDPDEF(-1))*100 \\
\text{Nominal interest rate} &= FEDFUNDS/4 \\
\text{Average weekly hours worked per employee} &= LN((PRS85006023/CE16OV\text{index})/CLF16OV index)*100 \\
\text{Unemployment rate} &= UNRATE \\
\text{Vacancy rate} &= \text{Conference Board Help Wanted OnLine data series} \\
\text{Real wage per hour} &= LN(COMPRNFB)*100 \\
\text{Total hours worked} &= LN(PRS85006023)*100 \\
\text{Real government expenditure per capita} &= LN(GCEC1/CLF16OV\text{index})*100 \\
\text{Baa-Aaa Spread} &= \text{Moody's yield on seasoned Baa-Aaa corporate bond}
\end{aligned}
$$

**Sources and explanation**

- GDPC1: Real gross domestic product. Billions of chained 2009 dollars. Seasonally adjusted annual rate.
  Source: U.S. Department of Commerce, Bureau of Economic Analysis.
- PCEC: Personal consumption expenditures. Billions of dollars. Seasonally adjusted annual rate.
  Source: U.S. Department of Commerce, Bureau of Economic Analysis.
- PFI: Private fixed investment. Billions of dollars. Seasonally adjusted annual rate.
  Source: U.S. Department of Commerce, Bureau of Economic Analysis.
- GDPDEF: Gross domestic product: implicit price deflator. Index 2009 = 100. Seasonally adjusted.
  Source: U.S. Department of Commerce, Bureau of Economic Analysis.
- FEDFUNDS: Effective Federal Funds rate. Averages of daily figures. Percent.
  Source: Board of Governors of the Federal Reserve System.
- CLF16OV: Civilian labor force: Sixteen years and over. Thousands of persons. Seasonally adjusted.
  Source: U.S. Department of Labor: Bureau of Labor Statistics.

- CLF16OV index: CLF160V(1991:3)=1
- CE16OV: Civilian employment: Sixteen years and over. Thousands of persons. Seasonally adjusted.

  Source: U.S. Department of Labor: Bureau of Labor Statistics.
- UNRATE: Civilian unemployment rate. Percent. Seasonally adjusted.

  Source: U.S. Department of Labor: Bureau of Labor Statistics.
- Vacancy rate:

  Source: Conference Board Help Wanted Online Data Series
- COMPRNFB: Nonfarm business sector: real compensation per hour. Index 2009 = 100. Seasonally adjusted.

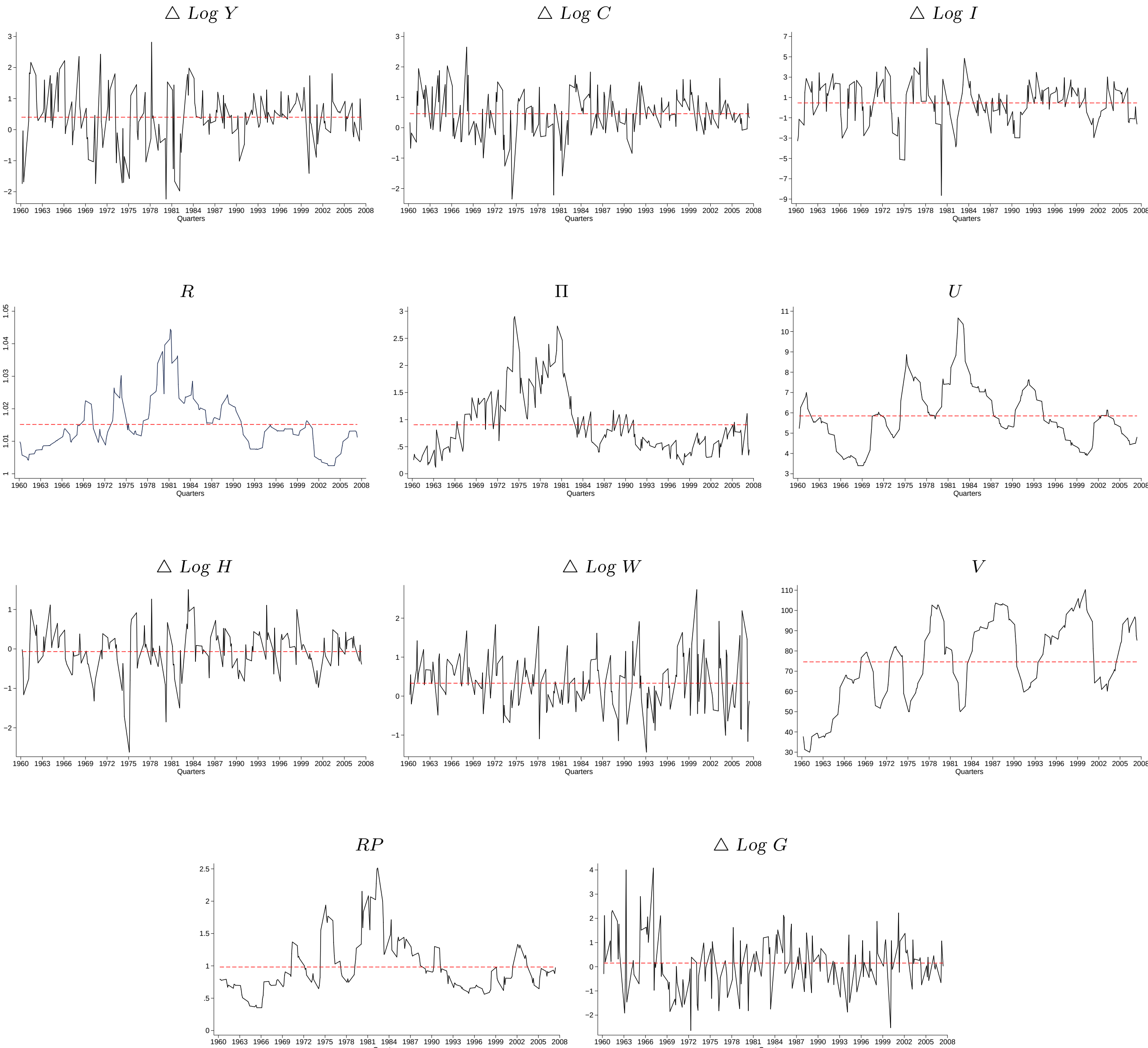
  Source: U.S. Department of Labor: Bureau of Labor Statistics.
- PRS85006023: Nonfarm business sector: average weekly hours. Index 2009 = 100. Seasonally adjusted.

  Source: U.S. Department of Labor: Bureau of Labor Statistics.
- GCEC1: Real government consumption expenditures and gross investment. Billions of Chained 2009 Dollars. Seasonally adjusted annual rate.

  Source: U.S. Department of Commerce, Bureau of Economic Analysis.
- Baa-Aaa Spread: Moody's seasoned Baa-Aaa corporate bond yield. Percent.

  Source: Federal Reserve Bank of St. Louis.

## .2 Data description



## References

[1] Acemoglu, D. (2001). Credit market imperfections and persistent unemployment. *European Economic Review*, 45(4):665–679.

[2] Andolfatto, D. (1996). Business cycles and labor-market search. *American Economic Review*, 86(1):112–32.

[3] Bernanke, B. and Gertler, M. (1989). Agency costs, net worth, and business fluctuations. *American Economic Review*, 79(1):14–31.

[4] Bernanke, B. S. and Gertler, M. (1995). Inside the black box: The credit channel of monetary policy. *The Journal of Economic Perspectives*, 9(4):27–48.

[5] Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. *Handbook of macroeconomics*, 1:1341–1393.

[6] Blanchard, O. and Galí, J. (2010). Labor markets and monetary policy: A new keynesian model with unemployment. *American Economic Journal: Macroeconomics*, 2(2):1–30.

[7] Blanchard, O. J. and Diamond, P. (1989). The Beveridge Curve. *Brookings Papers on Economic Activity*, 20(1):1–76.

[8] Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, 12(3):383–398.

[9] Campolmi, A. and Faia, E. (2011). Labor market institutions and inflation volatility in the euro area. *Journal of Economic Dynamics and Control*, 35(5):793–812.

[10] Carlstrom, C. T. and Fuerst, T. S. (1998). Agency costs and business cycles. *Economic Theory*, 12(3):583–597.

[11] Carlstrom, C. T. and Fuerst, T. S. (2001). Monetary shocks, agency costs, and business cycles. volume 54, pages 1–27.

[12] Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45.

[13] Christiano, L. J., Eichenbaum, M., and Trabandt, M. (2013). Unemployment and business cycles. *NBER Working Paper*, (w19265).

[14] Christiano, L. J., Trabandt, M., and Walentin, K. (2011). Introducing financial frictions and unemployment into a small open economy model. *Journal of Economic Dynamics and Control*, 35(12):1999–2041.

[15] Christoffel, K., Kuester, K., and Linzert, T. (2009). The role of labor markets for euro area monetary policy. *European Economic Review*, 53(8):908–936.

[16] Eckstein, Z., Setty, O., and Weiss, D. (2015). Financial Risk and Unemployment. (10596).

[Eichenbaum and Rebelo] Eichenbaum, Martin, N. J. and Rebelo, S. Reference prices, costs, and nominal rigidities.

[18] Fiore, F. D. and Tristani, O. (2013). Optimal monetary policy in a model of the credit channel. *The Economic Journal*, 123(571):906–931.

[19] Gale, D. and Hellwig, M. (1985). Incentive-compatible debt contracts: The one-period problem. *The Review of Economic Studies*, 52(4):647–663.

[20] Galí, J., Smets, F., and Wouters, R. (2011). Unemployment in an estimated new-keynesian model. *NBER Working Paper*, (w17084).

[21] Gertler, M., Gali, J., and Clarida, R. (1999). The science of monetary policy: A new-Keynesian perspective. *Journal of Economic Literature*, 37(4):1661–1707.

[22] Gertler, M., Kiyotaki, N., et al. (2010). Financial intermediation and credit policy in business cycle analysis. *Handbook of monetary economics*, 3(3):547–599.

[23] Gertler, M., Sala, L., and Trigari, A. (2008). An estimated monetary DSGE model with unemployment and staggered nominal wage bargaining. *Journal of Money, Credit and Banking*, 40(8):1713–1764.

[24] Gertler, M. and Trigari, A. (2009). Unemployment fluctuations with staggered nash wage bargaining. *Journal of political economy*, 117(1):38–86.

[25] Jermann, U. and Quadrini, V. (2012). Macroeconomic effects of financial shocks. *The American Economic Review*, 102(2):1186–1186.

[26] Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2):211–48.

[Klenow and Malin] Klenow, P. J. and Malin, B. A. Microeconomic evidence on price-setting.

[28] Krause, M. U., Lopez-Salido, D., and Lubik, T. A. (2008). Inflation dynamics with search frictions: A structural econometric analysis. *Journal of Monetary Economics*, 55(5):892–916.

[29] Krause, M. U. and Lubik, T. A. (2007). The (ir)relevance of real wage rigidity in the new-Keynesian model with search frictions. *Journal of Monetary Economics*, 54(3):706–727.

[30] Kydland, F. E. and Prescott, E. C. (1982). Time to build and aggregate fluctuations. *Econometrica*, 50(6):1345–70.

[31] Lechthaler, W., Merkl, C., and Snower, D. J. (2010). Monetary persistence and the labor market: A new perspective. *Journal of Economic Dynamics and Control*, 34(5):968–983.

[32] Livdan, D., Sapriza, H., and Zhang, L. (2009). Financially constrained stock returns. *The Journal of Finance*, 64(4):1827–1862.

[33] Merz, M. (1995). Search in the labor market and the real business cycle. *Journal of Monetary Economics*, 36(2):269–300.

[34] Mortensen, D. and Nagypal, E. (2007). More on Unemployment and Vacancy Fluctuations. *Review of Economic Dynamics*, 10(3):327–347.

[35] Mortensen, D. T. and Pissarides, C. A. (1994). Job creation and job destruction in the theory of unemployment. *The Review of Economic Studies*, 61(3):397–415.

[36] Paustian, M. (2004). Welfare effects of monetary policy rules in a model with nominal rigidities and credit market frictions. (597).

[37] Petrongolo, B. and Pissarides, C. A. (2001). Looking into the black box: A survey of the matching function. *Journal of Economic literature*, pages 390–431.

[38] Petrosky-Nadeau, N. (2014). Credit, vacancies and unemployment fluctuations. *Review of Economic Dynamics*, 17(2):191–205.

[39] Petrosky-Nadeau, N. and Wasmer, E. (2014). Macroeconomic dynamics in a model of goods, labor and credit market frictions. *Labor and Credit Market Frictions (February 12, 2014)*.

[40] Sahin, A., Song, J., Topa, G., and Violante, G. L. (2014). Mismatch unemployment. *American Economic Review*, 104(11):3529–64.

[41] Shimer, R. (2004). The consequences of rigid wages in search models. *Journal of the European Economic Association*, 2(2-3):469–479.

[42] Smets, F. and Wouters, R. (2003). An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association*, 1(5):1123–1175.

[43] Stiglitz, J. E. and Weiss, A. (1981). Credit rationing in markets with imperfect information. *The American economic review*, pages 393–410.

[44] Thomas, C. and Zanetti, F. (2009). Labor market reform and price stability: An application to the euro area. *Journal of Monetary Economics*, 56(6):885–899.

[45] Townsend, R. M. (1979). Optimal contracts and competitive markets with costly state verification. *Journal of Economic theory*, 21(2):265–293.

[46] Trigari, A. (2009). Equilibrium unemployment, job flows, and inflation dynamics. *Journal of Money, Credit and Banking*, 41(1):1–33.

[47] Walsh, C. E. (2005). Labor market search, sticky prices, and interest rate policies. *Review of economic Dynamics*, 8(4):829–849.

[48] Wasmer, E. and Weil, P. (2004). The macroeconomics of labor and credit market imperfections. *American Economic Review*, pages 944–963.

[49] Yun, T. (1996). Nominal price rigidity, money supply endogeneity, and business cycles. *Journal of Monetary Economics*, 37(2-3):345–370.

[50] Zanetti, F. and Mumtaz, H. (2011). The effect of labor and financial frictions on aggregate fluctuations. *Macroeconomic Dynamics*, pages 1–29.