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The High Sensitivity of Employment to Agency Costs: The Relevance of Wage Rigidity

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The High Sensitivity of Employment to Agency Costs: The Relevance of Wage Rigidity *

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Abstract

This paper studies the interaction of financing constraints and labor market imperfections on the labor market and economic activity. My analysis builds on the agency cost framework of Carlstrom and Fuerst [1998. Agency costs and business cycles. Economic Theory, 12(3):583-597]. The aim of this article is to show that financing constraints can substantially amplify and propagate total factor productivity shocks in cyclical labor market dynamics. I find that under the Nash bargaining solution financing constraints increase substantially the volatility of wages, and in turn, amplification for the labor variables falls short of the observed volatilities in the data. Atop of this, the comovement between output and labor share is counterfactual. However, there is substantial scope for any type of wage rigidity and financing constraints to reinforce each other, and to generate the observed volatilities in the labor market, moreover, to produce a wide range of comovements between output and labor share.

JEL: E24, E32, J64, G24

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1 Introduction

What role do financing constraints play for the cyclical behaviour of employment? This question has been always high in the agenda of both politicians and academicians as soon

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as the Great Depression. The idea that financing constraints, which may stem from moral hazard and/or adverse selection, could be relevant not only for corporate finance but also for macroeconomics has distilled in recent macroeconomic research.[1] Both the theoretical and empirical literature on financing constraints has focused on fixed capital investment decisions.[2] However, there are very few studies on the effects of financing constraints on the employment decisions of firms. Moreover these studies have dealt mainly with the influence of financing constraints on the level of employment.[3] The payment of wages makes hiring sensitive to the financial market imperfections that firms face. Missing to account for the effect of financial constraints on wages means missing to account for a powerful effect on hiring and on economic activity in general. Moreover the forward-looking nature of employment also makes firms sensitive to future expected financing constraints.

This paper studies the interaction between financing constraints and labor market imperfections in the business cycle context on the behaviour of labor markets and economic activity. The aim of this article is to show that financing constraints can substantially amplify and propagate total factor productivity shocks in cyclical labor market dynamics (hereafter referred to as TFP). I focus on TFP shocks as the driving force of business cycles mainly for comparability with much of the existing business cycle literature.[4] I find that (a) financing constraints are able to simultaneously generate both an effect of persistence and an effect of amplification on real economic activity. (b) However, under the assumption that the worker and firm bargain over the gains from trade, splitting the surplus according to the Nash bargaining solution (Nash, 1953), financing constraints increase substantially the volatility of wages. In turn, amplification for the labor variables falls short of the observed volatilities in the data. Moreover, the comovement between output and labor share is counterfactual. And (c) there is substantial scope for any type of wage rigidity and financing constraints to reinforce each other, and to generate the observed volatilities in the labor market, moreover, to produce a wide range of comovements between output and labor share.

I model financing constraints following the agency cost framework of Carlstrom and Fuerst (1998) (CF). Similar to them, I assume that informational problems may arise in

[1]Examples of papers making this type of early, significant contributions to the literature include Bernanke and Gertler (1989), Greenwald and Stiglitz (1990), Carlstrom and Fuerst (1997), Kiyotaki and Moore (1997) and Bernanke et al. (1999). Currently, the literature has burgeoned with a non-exhaustive list of examples such as Cúrdia and Woodford (2009), Gertler and Karadi (2009), Gertler and Kiyotaki (forthcoming) and Gilchrist et al. (2009).

[2]Hubbard (1998) provides a review of the literature.

[3]See, e.g., Acemoglu (2001) and Wasmer and Weil (2004).

[4]My treatment here follows broadly Pissarides (1985) and Mortensen and Pissarides (1994), the early analysis that integrates the labor search model into the real business cycle framework (Andolfatto, 1996; Merz, 1995), and recent analysis by Shimer (2010).

the production of aggregate output (hereafter, the 'output' model). The main insight in the CF model is that the asymmetric information between an entrepreneur (the borrower) and a financial intermediary (the lender) together with a costly state verification leads to a premium on the external finance. The premium arises because the lender monitors defaulting entrepreneurs and transfers this implicit cost onto the average cost of credit. In turn, the finance premium a firm pays to run a risky production manifests itself as an endogenous mark-up over the firm's total input costs: the firm demands a premium over operating cost. The appeal of the framework is that the financing constraints are endogenous over the business cycle.

I depart from CF in two main respects. First, to study employment (unemployment), contrary to total hours, I introduce labor search imperfections. There are two main reasons why departing from a Walrasian market are beneficial for the current analysis: (a) Labor search models provide an ideal laboratory for understanding employment and have been used extensively for this purpose. And (b) recent research suggests that search models have the potential to improve our understanding of business cycle fluctuations by delivering a framework for the analysis of alternative wage determination processes (Rogerson and Shimer, forthcoming). Second, following Faia and Monacelli (2007), I assume that the mean distribution of risky project outcomes across entrepreneurs is linked to the aggregate TFP in order for the 'output' model to better match the empirical evidence on the cyclical behavior of the external finance premium. The empirically observed finance premium is countercyclical, while the CF model predicts a counterfactual (procyclical) finance premium.[5] As a consequence, in the discussed model economy, financing constraints generate both an effect of amplification and persistence (i.e., more pronounced hump-shaped dynamics of output and employment, as in CF) in response to the TFP shocks.[6]

Financing constraints seem a promising avenue for answering the question of why employment is so volatile. First, as mentioned above, they amplify shocks. Second, in the current framework, they have a direct impact on employment. Namely, relaxing the financing constraints allows the firm to run bigger risky projects, thus loosely speaking spend more resources on the project and less on external financing costs. In turn, a bigger project translates into higher employment. However, following the conventional way wages are determined in the model and the way Nash bargaining is calibrated, wages respond strongly to changes in TFP shocks, stronger than in an environment lacking financing constraints, and

[5]The limitation of the CF framework to account for cyclical behavior of the external finance premium was first noted by Gomes et al. (2003).

[6]In contrast to CF, where trade-off exists between amplification and propagation.

the incentives for the firms to hire do not change very much over the business cycle. Despite the fact that financing constraints affect hiring directly, the Nash bargaining wage overshadows the model's ability to reproduce key labor market variables. This result is manifestation of the findings in Shimer (2005).

Hall (2005) and Shimer (2005) have argued that real wage rigidity is central to explaining the cyclical behavior of unemployment and vacancies. Essentially, wage rigidity is central for giving the financing constraints a role in labor dynamics in the 'output' model in their own right. The reason behind is that under any type of rigid wage the loosening of the financing constraints is channelled into hiring (and not into an increase of the wage). The amplification of labor market variables in the 'output' model is increased significantly. Moreover, the 'output' model can generate a wide range of comovements between output and labor share dependent on the wage rigidity. On the contrary, the model without agency costs has implications for the labor share that seem too extreme: the labor share under rigid wages becomes almost perfectly negatively correlated with output. It seems that the substantive contribution of search models with financing constraints relies on the presence of match-specific rents and the opportunity for a richer set of wage setting processes. This is where the contribution of the financing constraints lies: financial conditions lead to a much larger set of match-specific rents.

There are two studies most closely related to mine, both in terms of the question addressed - financing frictions may induce an amplified response of the labor market to aggregate TFP shocks - as well as methodology - build a business cycle framework in which the costly-state-verification problem is blended with search frictions a la Mortensen and Pissarides, Chugh (2009) and Petrosky-Nadeau (2009). I view my analysis as highly complementary to the two studies, despite the contrary conclusions we reach. The two papers state that conditional on a countercyclical external financing premium a financial accelerator mechanism amplifies labor market fluctuations. I agree with this conclusion, however conditional on a dose of wage rigidity. The first author presents some sophisticated arguments that induce some rigidity in the wage, similar to Hagedorn and Manovskii (2008).[7] The second author builds wage rigidity directly by assuming that only hiring costs are subject to working capital requirements. This modelling assumption changes the relative volatilities of the firms' total input production costs. It makes hiring costs more volatile relative to the wage bill costs.

[7] It is worth noting that the authors Hagedorn and Manovskii (2008) as well as Chugh (2009) do not view their paper as one with wage rigidities. They introduce an unemployment benefit term in the wage rule, worker's outside option, that is basically a constant. Also they calibrate the Nash bargaining parameter using information that wages move less than one-for-one with productivity, which gives them a small value for the workers' bargaining power.

The outline of the paper is as follows. In the next section I present the theoretical framework. Section 3 discusses calibration issues and long-run equilibrium properties of the model economies. Section 4 discusses the results. Section 5 concludes. Various technical details are relegated to appendices.

2 The model economy

The core framework is a closed economy CF model. The model has a representative household, firms and financial intermediaries. Each household consists of a continuum of infinitely-lived workers of measure one. Each firm is owned by an infinitely-lived entrepreneur (below I use 'entrepreneur' and 'firm' interchangeably). Firms undertake risky production activities and seek external resources in excess of their different and time-varying levels of internal funds. The household provides the resources that are channeled from financial intermediaries to firms using financial contracts. Financial frictions are a consequence of information asymmetries between lenders and borrowers. Because of the financial frictions and a limited supply of internal funds, firms are limited in borrowing by the premium associated with external finance.

The key modification of the model is the inclusion of labor search frictions. Each firm employs n_t workers in the current period. To hire workers firms must expend resources which are assumed to be linear in the number of vacancies. Workers do not face job-finding costs. The total number of unemployed workers searching for a job is $u_t \equiv 1 - n_{t-1}$.[8] Following convention, I assume that the aggregate number of new hires, m_t, is a Cobb-Douglas (CD) function of unemployed workers and vacancies, $m_t = \bar{l} u_t^{\psi} v_t^{1-\psi}$, where the parameter $\bar{l}$ reflects the efficiency of the matching process. The current probability that a firm fills a vacancy, $\mu(\theta_t)$, is given by $\mu(\theta_t) \equiv m_t/v_t = \bar{l}\theta^{-\psi}$ where $\theta_t \equiv v_t/u_t$ is labor market tightness, the ratio of vacancies, v_t, to searching unemployed workers, u_t. Similarly, the probability an unemployed worker finds a job, $l(\theta_t)$, is given by $l(\theta_t) \equiv m_t/u_t = \bar{l}\theta^{1-\psi}$. Both firms and workers take $\mu(\theta_t)$ and $l(\theta_t)$ as given. In a stationary environment, the above probabilities define the mean duration of unfilled vacancies and unemployment respectively. Finally, each firm exogenously separates from a fraction $0 < x < 1$ of existing workers each period, where $1 - x$ is the probability a worker survives with the firm until the next period.

I now proceed to describe the behavior of the different sectors of the economy, along with the key resource constraints.

[8] All workers unemployed at the beginning of the period, u_t, search for a job, that is, I abstract from labor force participation choices.

2.1 Production

This section provides an overview of the firm sector. Firms possess a production technology and hire workers and capital to produce goods. Firms are subject to an aggregate shock as well as idiosyncratic shocks. Timing of events in a given time period can be summarized as follows:

- Aggregate shock to productivity realizes.
- Firms borrow resources from the loan market signing a contract (which is described below).
- Firms rent capital from households and entrepreneurs and post vacancies to attract new workers.
- Matching outcomes from current period's recruiting are realized and firms bargain wages individually with the workers.
- Stock of workers, employed from the previous period, break up exogenously with the firms and become unemployed, at least till next period.
- After observing the idiosyncratic shocks, firms produce goods and sell them in the goods market.
- Firms either repay their loans or declare bankruptcy and are monitored.

Each firm i uses labor, n_{it}, and capital, k_{it}, to operate a CD production function:

$$y_{it} = \omega_{mt} \tau_t k_{it}^{\alpha} n_{it}^{1-\alpha} \tag{1}$$

where τ_t is an aggregate TFP shock that follows the following process: $\log \tau_t = \rho \log \tau_{t-1} + \varepsilon_t$, $\varepsilon_t \overset{\text{iid}}{\sim} N(0, \sigma_\tau^2)$. The idiosyncratic productivity shock ω_t, with mean ω_{mt}, is unknown at the time when the debt contract is signed and is independent and identically distributed across time. The shock variable has a continuous differentiable cumulative distribution function $F(\omega_t, \tau_t)$ and a density function $\phi(\omega_t, \tau_t)$. The riskiness of firm's i project is determined by the variance of the idiosyncratic shock, σ_ω^2. Notice that the average productivity of each entrepreneur is time-varying (e.g., Faia and Monacelli, 2007). I assume that each entrepreneur is on average more productive when total factor productivity τ_t increases. This feature is key in driving the cyclical properties of the cost of external finance.

In the CF model the firm commits to and pays for its capital rentals, wage bills and hiring after observing the aggregate shock, τ_t, but before observing the idiosyncratic shock, ω_{it} and thus before any output and revenue is realized.[9] Let w_t be the real wage rate, r_t the rental rate on capital and κ the per period cost of keeping a vacancy open. Respectively, hiring costs for an individual firm are given by $\omega_{mt}\tau_t\kappa v_{it}$, expressed in terms of the consumption goods.[10] Total input costs are given by $s_{it} = w_t n_{it} + r_t k_{it} + \omega_{mt}\tau_t\kappa v_{it}$. The firm uses the funds it receives from financial intermediaries as well as its net worth, a_{it}, to finance the firm's input bill. I suppose that $a_{it} < s_{it}$. The entrepreneur's internal funds consists of the beginning-of-period market value of its accumulated capital stock, z_{it}:

$$a_{it} = z_{it}\left[(1-\delta) + r_t\right], \text{[11]} \tag{2}$$

where $0 < \delta < 1$ is the depreciation rate of capital.

The entrepreneur's idiosyncratic shock is privately observed, and thus creates a moral hazard problem with external financing (as the entrepreneur may wish to underreport the true value of the shock). The financial intermediaries can not observe the outcome of a leveraged project. In case of bankruptcy financial intermediaries incur a cost to verify the outcome that is proportional to the size of the firm's input cost, χs_{it}. This costly state verification (CSV) ties the ability to obtain external finance to the net worth of an entrepreneur. Townsend (1979), Gale and Hellwig (1985), and Williamson (1987) show that in a world with CSV the optimal, incentive-compatible debt contract is a standard one period debt contract.[12] The contract is characterized by two values: project size s_{it} and a critical ω, denoted by $\bar{\omega}_{it}$. This critical or cut-off $\bar{\omega}_{it}$ is the realization that triggers bankruptcy: if $\omega_{it} < \bar{\omega}_{it}$ then bankruptcy occurs and the financial intermediaries seize all of the firm's output, while if $\omega_{it} \geq \bar{\omega}_{it}$, then the loan is re-paid and the firm keeps the excess output. At this stage, I can define the functions $g\left(\bar{\omega}_t, \tau_t\right)$ and $f\left(\bar{\omega}_t, \tau_t\right)$ that represent the sharing

[9] A relatively small proportion of goods in the real economy are 'made to order,' and even when they are, only a relatively small fraction of the payment is made by the purchaser up front.

[10] The motivation for indexing hiring costs to aggregate TFP, τ_t, (and to the idiosyncratic productivity, ω_{mt}, in the 'output' model, but not in the 'investment' model) similar to Blanchard and Galí (2008), is to avoid effects of productivity shocks on the cost of hiring relative to the cost of producing, an effect I believe is better left out of the model for the current analysis. Alternatively, Shimer (2010) assumes that employees are used either in the production of consumption goods or in hiring. Both specifications lead to the unemployment rate being invariant to TFP shocks in a model with search frictions without capital and financing constraints, and under particular assumptions on preferences (balanced growth and additive separability between consumption and non-work activity). The reason for this result is that income and substitution effects cancel, leading to no change in employment, and in unemployment.

[11] For completeness, notice that net worth have to consist of capital income share and an arbitrarily small noncapital income share. The latter one is intended to provide an opportunity to bankrupt entrepreneurs to initialize projects in the current period. Since this has no effect on dynamics, I ignore it for simplicity.

[12] A crucial assumption of the CSV models is that both the lender and borrower are risk-neutral. In the current framework, entrepreneurs discounts the future stronger than household. As for the financial intermediary, there is no aggregate risk as the contract is: first, intra-period and second, financial intermediaries pool contracts, and thus, diversify away idiosyncratic risk.

rule between financial intermediaries and firms-borrowers (where firms' subscripts have been dropped) on the income implied by the risky intra-period loan at each point in time:

$$g\left(\bar{\omega}_t,\tau_t\right)\equiv\int_0^{\bar{\omega}_t}\omega_t dF\left(\omega_t,\tau_t\right)-\chi F\left(\bar{\omega}_t,\tau_t\right)+\bar{\omega}_t\left(1-F\left(\bar{\omega}_t,\tau_t\right)\right), \tag{3}$$

$$f\left(\bar{\omega}_t,\tau_t\right)\equiv\int_{\bar{\omega}_t}^{\infty}\left(\omega_t-\bar{\omega}_t\right)dF\left(\omega_t,\tau_t\right)\equiv\int_{\bar{\omega}_t}^{\infty}\omega_t dF\left(\omega_t,\tau_t\right)-\bar{\omega}_t\left(1-F\left(\bar{\omega}_t,\tau_t\right)\right). \tag{4}$$

Notice that the sharing rule accounts for the dependence of the idiosyncratic mean on the realization of the aggregate shock, τ_t. The function $f\left(\bar{\omega}_t,\tau_t\right)$ integrates only over values of ω_t in excess of $\bar{\omega}_t$, while $g\left(\bar{\omega}_t,\tau_t\right)$ integrates over the lower part of the support. The two functions do not add to one: $f\left(\bar{\omega}_t,\tau_t\right)+g\left(\bar{\omega}_t,\tau_t\right)=1-\chi F\left(\bar{\omega}_t,\tau_t\right)$. This is due to the fact that there are costs of monitoring to be accounted for, $\chi F\left(\bar{\omega}_t,\tau_t\right)$. Since the firm's production function is constant returns to scale (CRS) these bankruptcy costs imply that the firm's output must sell at a mark-up, p_t. Because of this mark-up, the monitoring cost measured in terms of final output is $p_t\chi s_t$. In terms of final output, the firm's expected return on the financial contract is thus $p_t f\left(\bar{\omega}_t,\tau_t\right)s_t$, while that of financial intermediaries is $p_t g\left(\bar{\omega}_t,\tau_t\right)s_t$.

Debt contract

Due to financial intermediaries being perfectly competitive, p_t is taken as given in the maximization problem. The financial contract maximizes the expected firm's payoff

$$\max_{s_t,\bar{\omega}_t} p_t f\left(\bar{\omega}_t,\tau_t\right)s_t \tag{5}$$

subject to the zero profit condition on the financial intermediary:

$$p_t g\left(\bar{\omega}_t,\tau_t\right)s_t\geq s_t-a_t. \tag{6}$$

In equilibrium, any financial intermediary holds a pooled and perfectly safe portfolio. Therefore, the financial firm can obtain its funds at a riskless, intra-period opportunity cost to funds which equals unity. Perfect competition and free entry in the financial market imply that lenders' net cash flow must be zero in each period, i.e., the expected return from the lending activity would equal the opportunity cost of finance. It is easy to show that the solution to the problem above implies the following two first-order conditions:

$$p_t f\left(\bar{\omega}_{it},\tau_t\right)=\frac{f'\left(\bar{\omega}_{it},\tau_t\right)}{g'\left(\bar{\omega}_{it},\tau_t\right)}\left[p_t g\left(\bar{\omega}_{it},\tau_t\right)-1\right], \tag{7}$$

$$s_{it}=a_{it}\left[1/\left(1-p_t f\left(\bar{\omega}_{it},\tau_t\right)\right)\right]. \tag{8}$$

A few observations are in order. First, if there are no monitoring costs $\chi = 0$ then the mark-up disappears, $p_t = 1$. Hence, the agency costs are manifested by an endogenous mark-up over production costs. Notice also from Eq. (7) that $\bar{\omega}_{it}$ is a function only of p_t, and not of the level of net worth of the firm. That is, all firms receive the same basic terms on their debt contract. Eq. (8) shows that s_t/a_t is independent of the level of the entrepreneur's net worth. That is, the contracts differ only in size - a firm with larger net worth simply implements a larger project size s_t. Therefore, Eq. (8) allows immediate aggregation.[13]

Given CRS, the cut-off $\bar{\omega}_t$ determines the division of net revenues between borrower and lender, and satisfies: $\bar{\omega}_t \equiv r_t^L (s_t - a_t)/p_t s_t$, where r_t^L is the gross lending rate. From this definition, it is obvious that the gross lending rate and the external finance premium are independent of the firm's net worth. Thus, firms with any level of net worth, a_t, pay the the same external finance premium, $\varsigma_t \equiv r_t^L - 1 = \bar{\omega}_t / g(\bar{\omega}_t, \tau_t) - 1$. One can derive the expression for the external finance premium by combining the definition for the cut-off threshold, $\bar{\omega}_t$, together with Eq. (8). Notice that, in the case in which the mean ω_{mt} varies with aggregate TFP, the lender's income share $g(\bar{\omega}_t, \tau_t)$ also depends on aggregate productivity. The behavior of the income share $g(\bar{\omega}_t, \tau_t)$ relative to the threshold value $\bar{\omega}_t$ becomes critical in driving the cyclical properties of the finance premium.

Firm's maximization problem

Firm i controls its current workforce n_{it} by posting vacancies v_{it}. I assume that new matches at firm i at the beginning of period t are proportional to the ratio of its vacancies to total vacancies posted, v_{it}/v_t, so that $v_{it} m_t / v_t = v_{it}\mu(\theta_t)$ is hiring by firm i. Evolution of employment at firm i can then be written as

$$n_{it} = (1 - x) n_{it-1} + v_{it}\mu(\theta_t). \tag{9}$$

Period-t workforce is the sum of the number of last period's surviving workers, $(1-x)n_{it-1}$, and new hires, $v_{it}\mu(\theta_t)$.

Let $\beta\Lambda_{t,t+1}$ be the firm's stochastic discount factor between period t and $t+1$, where β is the household's subjective discount factor and $\Lambda_{t,t+1}$ is defined later below. The stochastic discount factor, capital rental prices and wages are taken as exogenous by the firm when choosing employment and capital.[14] Taking the debt contract outcome as given, the firm's

[13] This aggregation result is a natural implication of the CRS assumptions in the monitoring technology and the firm's production function. Since the description of firm's maximization problem and the Nash-wage bargaining follow below, I keep the firm-specific subscripts for now.

[14] Assuming that firms take wages as exogenous when choosing employment allows me to ignore an additional complexity. If Nash-bargained wages depend on the marginal product of labor, large firms, as in the current framework, would have an incentive to overhire. The reason behind is the motive to weaken incum-

problem can be written as:

$$J_{it} = \max_{k_{it}, v_{it}, n_{it}} \left\{ \omega_{mt}\tau_t k_{it}^{\alpha} n_{it}^{1-\alpha} - p_t \left(w_t n_{it} + r_t k_{it} + \omega_{mt}\tau_t \kappa v_{it} \right) + \mathbb{E}_t \beta \left\{ \Lambda_{t,t+1} J_{it+1} \right\} \right\} \tag{10}$$

subject to the employment constraint Eq. (9). The $\mathbb{E}_t$ symbol denotes the expectation operator conditional on information available at date t.

The first-order conditions for vacancies, employment, and capital are

$$r_t = \alpha \frac{y_{it}}{k_{it} p_t}, \tag{11}$$

$$J_{n,it} = \frac{p_t \omega_{mt} \tau_t \kappa}{\mu(\theta_t)}, \tag{12}$$

$$J_{n,it} = (1-\alpha) \frac{y_{it}}{n_{it}} - p_t w_t + \mathbb{E}_t \beta (1-x) \left\{ \Lambda_{t,t+1} J_{n,it+1} \right\}. \tag{13}$$

After the period t shock, τ_t, is realized, both households and entrepreneurs supply their stock of capital. Thus, total beginning-of-period t capital, k_t, is the sum of the two stocks of capital. Condition (11) for the firm's capital demand is equating the marginal product of capital to the rental rate. Notice that capital rental price will be below its marginal product, because of the agency cost mark-up.

The first-order condition with respect to vacancies is given by Eq. (12), while the discounted stream of expected future profits per worker, $J_{n,it}$, is given by Eq. (13). Combining (12) and (13) yields the job creation condition

$$\frac{p_t \omega_{mt} \tau_t \kappa}{\mu(\theta_t)} = (1-\alpha) \frac{y_{it}}{n_{it}} - p_t w_t + \mathbb{E}_t \beta (1-x) \left\{ \Lambda_{t,t+1} \frac{p_{t+1} \omega_{mt+1} \tau_{t+1} \kappa}{\mu(\theta_{t+1})} \right\}. \tag{14}$$

Condition (14) equates the marginal cost of hiring a worker with the marginal benefit. The latter is given on the right hand side, which consists of the net flow profit per worker $(1-\alpha)\, y_{it}/n_{it} - p_t w_t$ and a measure of the future value of the job $\mathbb{E}_t \beta (1-x) \left\{ \Lambda_{t,t+1} \frac{p_{t+1}\omega_{mt+1}\tau_{t+1}\kappa}{\mu(\theta_{t+1})} \right\}$.

Entrepreneur's capital accumulation

At the end of the period, after all other economic decisions have been made, all production input plus rental costs paid, the entrepreneur has $p_t s_{it} f(\bar{\omega}_{it}, \tau_t)$ units of output that he can either transfer back to the household, ζ_{it}, or accumulate as capital, z_{it+1}, for use as collateral

bent workers' bargaining power (where the term 'bargaining power' is used loosely in the sense that the Nash bargaining parameter is hold fixed). This would imply a wage w_t that at the margin is endogenous to the firms's level of employment. See Stole and Zwiebel (1996) for a general discussion. Krause and Lubik (2007) show that this additional effect has only small effects on the dynamic behaviour of labor search models.

in next period's contract. The entrepreneur maximizes the following utility function:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} (\beta\iota)^t \{\Lambda_{0,t}\zeta_{it}\}, \quad 0 < \iota < 1, \tag{15}$$

to the sequence of budget constraints:

$$\zeta_{it} + z_{it+1} \leq p_t s_{it} f(\bar{\omega}_{it}, \tau_t), \tag{16}$$

where $\Lambda_{0,t}$ is the time-t household's subjective discount factor. Note that the entrepreneur discounts utility at a higher rate, $\beta\iota$, than the household. This intertemporal problem renders the following Euler equation:

$$1 = \mathbb{E}_t \beta\iota \left\{ \{\Lambda_{t,t+1} [r_{t+1} + (1-\delta)]\} \left\{ \frac{p_{t+1} f(\bar{\omega}_{it+1}, \tau_{t+1})}{1 - p_{t+1} g(\bar{\omega}_{it+1}, \tau_{t+1})} \right\} \right\}. \tag{17}$$

The right-hand side of Eq. (17) is the expected discounted rate of return for an entrepreneur who is not bankrupt in period t. The term in the second curly brackets is the safe rate of return on capital (i.e., the one gained by the households). The term in the third curly brackets is the return on internal funds, which can be shown to strictly exceed unity for all t. That is, entrepreneurs earn a higher intertemporal rate of return on saving than do households. As a result, entrepreneurs with the same discount rate as households would save at a higher rate, eventually accumulating enough capital so that they have no need to borrow from financial markets. The assumption, $\iota < 1$ insures that the entrepreneurs never hold enough wealth to overcome the financing constraints.

2.2 Households

In the presence of unemployment risk, one may observe differences in consumption levels between employed and unemployed consumers. However, under the assumption of perfect insurance markets, consumption is equalized across consumers. This is equivalent to assuming the existence of a large representative household, as in Merz (1995). The household pools incomes and allocates consumption in period t, in order to maximize the sum of household utility, and so equalizes the marginal utility of consumption across individuals. With additive separability between consumption and leisure, this implies the household equalizes consumption across individuals. The lifetime utility of household j is given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log\left(c_{jt}\right) - \gamma n_{jt} \right\}, \quad 0 < \beta < 1, \tag{18}$$

where c_{jt} is consumption, $\gamma > 0$ is the relative disutility of work, and n_{jt} the number of employed workers. Notice that the household supplies inelastically workers to the market, i.e., the household effectively has an infinite Frisch elasticity of labor supply.

Each period, the household allocates its wealth to purchases of consumption goods and to accumulation of capital. It has the following sources of income: wage bills, capital rentals, interest income on deposit holdings, d_t, and transfers from the firms, ζ_{jt}. The household faces the period-by-period intertemporal budget constraint:

$$c_{jt} + k_{jt+1} \leq w_t n_{jt} + \left[r_t + (1-\delta)\right] k_{jt} + \left(r_t^D - 1\right) d_t + \zeta_{jt}. \tag{19}$$

As explained above, the financial intermediaries pay the household a zero rate of return $r_t^D - 1 = 0$ on deposits because the household has no alternative use of its funds over the short time span when firms requires financing.

Household's employment evolves according to the following law of motion:

$$n_{jt} = (1-x)\, n_{jt-1} + l\left(\theta_t\right)\left(1 - n_{jt-1}\right). \tag{20}$$

The household's welfare criterion from Eq. (18) can be rewritten as

$$H_{jt} = \max_{c_{jt}, k_{jt+1}, n_{jt}} \left\{ \log\left(c_{jt}\right) - \gamma n_{jt} + \mathbb{E}_t \beta \left\{ H_{jt+1} \right\} \right\}. \tag{21}$$

The household optimizes its life-time utility (21) by choosing consumption and capital to accumulate subject to the household budget constraint (19). Denote λ_{jt} the time-t Lagrange multiplier on the flow budget constraint. The following optimality conditions must hold:

$$\lambda_{jt} = \left(c_{jt}\right)^{-1}, \tag{22}$$

$$1 = \mathbb{E}_t \beta \left\{ \Lambda_{jt,t+1} \left[r_{t+1} + (1-\delta) \right] \right\}, \tag{23}$$

with the addition of (19) holding with equality. Denote $\beta \Lambda_{jt,t+1} = \beta \lambda_{jt+1} / \lambda_{jt}$ the household's pricing kernel between periods t and $t+1$. Eq. (22) defines the marginal utility of consumption at period t, λ_{jt}. Eq. (23) is the Euler condition for household's capital accumulation. It states that the household prefers expected marginal utility to be constant across time periods, unless the expected gross real return on capital, $\mathbb{E}_t\left[r_{t+1}+(1-\delta)\right]$, exceeding household's time preference induces it to lower its consumption today relative to the future.

Using the envelope condition for employment, I derive the marginal value to the household of having one member employed rather than unemployed, $H_{n,jt}$, which is a determinant of the bargaining problem:

$$H_{n,jt}=\lambda_{jt}w_t-\gamma+\mathbb{E}_t\beta\left(1-x-l\left(\theta_{t+1}\right)\right)\left\{H_{n,jt+1}\right\}. \tag{24}$$

The worker's contribution to the welfare of his household is given by the real wage (in utils), minus labor disutility, plus the future value of the job conditional on non-separation, minus the value this worker would contribute if he searched for another job.

2.3 Wage Bargaining

I assume, as in most of the labor search literature, that worker and firm bargain over wage at the individual level over the joint surplus of their match, $S_{n,t}=J_{n,t}+H_{n,t}$, according to the Nash bargaining solution. Given that in equilibrium all firms and workers behave similarly I can drop the i and j subscripts. The wage w_t maximizes the weighted geometric average of the gains from trade, $w_t=\arg\max_{w_t}\left(J_{n,t}\right)^{1-\eta}\left(H_{n,t}\right)^{\eta}$, where $0<\eta<1$ is the worker's bargaining power in the wage negotiation process. If there are no gains from trade, the worker becomes unemployed. The first-order condition of the Nash product is:

$$\eta\frac{J_{n,t}}{p_t}=(1-\eta)\frac{H_{n,t}}{\lambda_t}. \tag{25}$$

Substituting the expressions for $J_{n,t}$ and $H_{n,t}$ (Eq. (13) and Eq. (24)) in the sharing rule (25), and using Eq. (12), it is straightforward to show that the wage that solves the bargaining problem is given by

$$w_t=\eta\left((1-\alpha)\frac{y_t}{n_tp_t}+\kappa\mathbb{E}_t\beta\left\{\Lambda_{t,t+1}\omega_{mt+1}\tau_{t+1}\aleph_{t+1}\theta_{t+1}\right\}\right)+(1-\eta)\frac{\gamma}{\lambda_t}, \tag{26}$$

where $\aleph_{t+1}=\frac{1-x}{\mathbb{E}_t\{l(\theta_{t+1})\}}\left(\mathbb{E}_t\left\{\frac{p_{t+1}}{p_t}\right\}-1\right)+1$ is a composite term that depends on the current and the expected future mark-ups.

A few remarks concerning the wage rule condition are in order. Eq. (26) states that the bargained wage is a weighted average of two components, with the weight on the first component equal to worker's bargaining power. The first component is the marginal contribution to the match (MCM) (the marginal revenue product of labor (MRPL), i.e., the marginal product of labor divided by the mark-up, augmented with the discounted savings in future hiring costs that result from having to hire fewer workers the following period). The second component is the marginal cost of work activity (in consumption units), i.e., the marginal rate of substitution between consumption and leisure (MRS). The bargaining weight, dividing the joint surplus of the match, determines how close the wage is to either the MCM or to the MRS.

A second point concerns the influence of agency costs on the wage level. Similar to the capital rental rate, the price of labor is below its level in a setup that lacks financial frictions. Namely, the weighted average of the MCM and the MRS is lower because of the presence of the agency cost mark-up. Finally, it is obvious that the composite term, $\aleph_{t+1}$, captures the forward-looking aspect of employment. Namely, it takes into account how the difference between current and future financial conditions affects the cost of replacing a worker. Notice that in the absence of agency costs ($\chi = 0$ for all t), Eq. (26) reduces to a Nash-wage schedule in a model that lacks financing constraints.

2.4 Market Clearing

In a competitive equilibrium, all agents' optimality conditions are satisfied and all markets clear. I assume a symmetric equilibrium throughout, which entails identical choices for all variables. Defining aggregates as the averages of firm specific variables, equilibrium in the labor market requires that

$$n_t = n_{it} = \int_0^1 n_{it} di. \tag{27}$$

Aggregate capital, the sum of households' and entrepreneurs' capital, follows

$$k_{t+1} = (1 - \delta) k_t + i_t. \tag{28}$$

Furthermore, loans must be equal to deposits,

$$s_t - a_t = d_t. \tag{29}$$

Using the household budget contraint and definitions for firms' profits, the resulting aggregate income identity is:

$$y_t (1 - \chi F(\bar{\omega}_t, \tau_t)) = c_t + i_t + \omega_{mt} \tau_t \kappa v_t. \tag{30}$$

Equilibrium in the goods market requires that the production of goods be allocated to private consumption by households and investment. Final amount of consumption and investment is reduced due to the presence of costs that originate from monitoring and from hiring activities (i.e., the presence of both financing constraints and labor market imperfections endogenously distorts aggregate production).

3 Steady state

Before turning to the results in this section I briefly discuss: (a) how the parameter values are chosen and (b) the steps of determining the long-run equilibrium.

3.1 Calibration

I calibrate the model to the U.S. using data from 1951:q1 to 2010:q1. Data are taken from the Bureau of Labor Statistics, the Conference Board, Federal Reserve Bank of St. Louis' database FRED®II and National Income and Product Accounts Tables. Data is described in Appendix, Section B. I use the Hodrick-Prescott filter with a conventional filter weight of 1,600 to extract the business cycle component from the data in logs.

The time unit of the model is meant to be a month in order to properly capture the high rate of job finding in U.S. data. The calibrated parameter values and the targets are summarized in Table 1. Some implied steady state values in the 'output' economy are given in Table 2.

I set the subjective discount factor to $\beta = 1.04^{-\frac{1}{12}}$, yielding an annual real interest rate of 4 percent. In line with the evidence reported in Carlstrom and Fuerst (1997), I set χ equal to 0.25 and the average monthly bankruptcy rate $F(\bar{\omega}, 1)$ to 1.3%/3 (close to from the Dun and Bradstreet data set quarterly value, .974%). I target a long-run equilibrium annual external finance premium $\varsigma = 0.02$ (200 basis points), the risk premium spread on corporate bonds estimate in Longstaff et al. (2005). By imposing $\mathbb{E}\omega = 1$, I solve numerically for σ_ω equal to 0.749. ι is set to 0.996 in order to fix the targeted annual external finance premium. I assume that the mean of the idiosyncratic productivity is given by $\omega_{mt} = \Gamma(\tau_t) = \tau_t^{1+\upsilon}$, with spill-over parameter υ equal to 2, following Faia and Monacelli (2007).

Shimer (2005) infers time series for the job finding and separation rate from BLS data on unemployment and short term unemployment. The average monthly separation rate is $x = 0.034$ while the average monthly job finding rate is $l(\theta) = 0.45$. With the above two values I fix the average unemplyoment rate u to 0.07. I use the average value of the

Parameter	Value	Explanation; Target/Reference
Household sector		
β	$1.04^{-\frac{1}{12}}$	time-discount factor; matches annual real rate of 4 percent;
γ	0.824	scaling factor to disutility of work; imposed by model's steady state;
η	0.5	bargaining power of workers; conventional value;
Firm sector		
z	1	technological progress; normalization;
$F(\bar{\omega}, 1)$	1.3%/3	bankruptcy rate in a period; from the Dun and Bradstreet data set;
χ	0.25	percent of realized project's loss in bankruptcy; Carlstrom and Fuerst (1997)
ι	0.996	entrepreneur's time-discount factor; match finance premium of annual 200 b.p.;
σ_ω	0.749	idiosyncratic std. dev. of production; match finance premium of annual 200 b.p.;
ψ	0.5	elasticity of matches w.r.t. unemployment; Petrongolo and Pissarides (2001);
x	0.034	exogenous period rate of separation; Shimer (2005);
κ	0.626	hiring cost; imposed by model's steady state;
$\bar{l}$	0.613	efficiency of matching; match $\theta = 0.539$;
υ	2	spill-over parameter;
α	0.33	capital share; convention;
δ	0.006	capital depreciation rate; fixes capital-output ratio;
Correlation of Shocks and Size of Innovations		
ρ	$0.95^{\frac{1}{3}}$	autocorr. of TFP shock;
σ_z	0.0019	std. dev. of innovation to TFP shock; match 1.57% std. dev. of output;

Table 1: Parameters and their calibrated values. The Table reports calibrated parameter values. The model is calibrated to the U.S. using data from 1951:q1 to 2010:q1; see the main text for details.

Variable	Value	Description
y	5.390	output
u	0.070	unemployment rate
$\kappa\nu/y$	0.004	hiring costs to output ratio
c/y	0.782	consumption to output ratio
wn/y	0.663	labor share
k/y	3.000	annual capital to output ratio
a/s	0.074	annual net worth to assets ratio
ς	0.020	external premium to funding
$\mu(\theta)$	0.835	job filling rate
$\gamma cp/\varphi$	0.900	MRS to MRPL ratio

Table 2: Steady state for some variables in the 'output' economy implied by the calibration in Table 1.

vacancy/unemployment ratio, $\theta = 0.539$, reported in Hall (2005). This allows me to fix the efficiency of the matching function, $\bar{l}$, to 0.613. The bargaining power of the worker is set to a conventional value of $\eta = 0.5$, to impose symmetry in the bargaining problem. I set the elasticity of matches with respect to unemployment to $\psi = 0.5$, which is in the range of reasonable values discussed by Petrongolo and Pissarides (2001). This choice also guarantees that the Hosios (1990) condition for efficiency is satisfied. I fix $\alpha = 0.33$ to match the capital share of income in the National Income and Product Accounts. I set the monthly depreciation rate $\delta = 0.006$, which pins down the annual capital-output ratio, k/y, in the stochastic steady state to 3.

Finally, I turn to choosing $\epsilon = \gamma cp/\varphi$, perhaps the most controversial choice (see, e.g., Monacelli et al., 2010). I set $\epsilon = 0.9$ in the high side of the range of sensible values. Notice that the calibration strategy implies that larger values for ϵ, other things equal, correspond to smaller search frictions. With the above choice, I can fix the hiring cost parameter, κ, to 0.626 and the parameter governing the taste for leisure, γ to 0.824.

I set the autocorrelation of the shock to productivity $\rho = 0.95^{\frac{1}{3}}$. I choose a deviations of technology innovations of size $\sigma_z = 0.0019$ in order to match the standard deviation of U.S. GDP standard deviation of 1.57%.

3.2 The long-run equilibrium

Figure (1) shows the steps of determining the long-run equilibrium for a set of monitoring cost values ($\chi \in (0.001, 0.3)$) in a set of graphs in the 'output' model. The steps in pinning down analytically the long-run equilibrium are described also in Appendix A.2. The parameters correspond to those used in the calibration of the dynamic model. The upper-left graph translates the difference in the agency costs distortions into the increase in the output-capital ratio. The upper right, the middle-left and the middle-right graphs show the determination of the labor-capital and consumption-capital ratios, and of the wage respectively. Finally, the bottom-right graph calculates the increase in the net worth-assets ratio from the increase in the external finance premium.

How to interpret the graphs? For a given risk-free interest rate, increases in mark-up, p, imply larger agency costs (since the economy suffers a deadweight loss associated to the monitoring activity of the lender) and hence smaller acquired debt $s - a$, and in turn output project s. Larger agency costs values also imply higher consumption to output ratio, higher labor to capital ratio and lower wages.

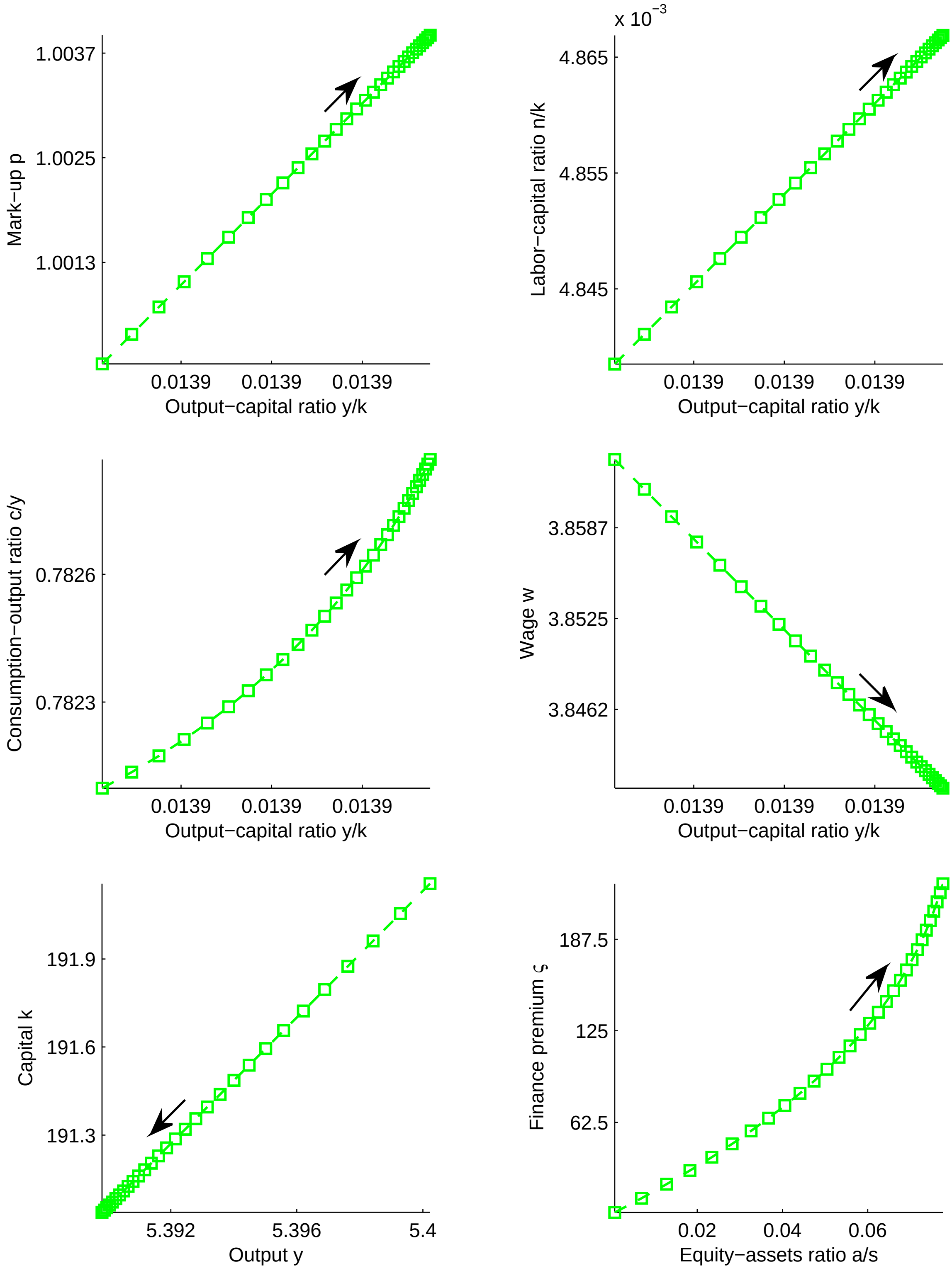

Figure 1: Long-run equilibrium as per-unit monitoring cost, χ, varies from 0.001 to 0.3. All other parameters held fixed at their benchmark values from Table 1. External finance premium reported in annual basis points; equity-assets ratio is in annual terms. The direction of arrows corresponds to direction of increase in χ.

4 Inspecting the mechanism

Financing constraints affect hiring through three distinct channels: (a) a total wage bill channel, (b) a hiring cost channel, and (c) a capital rental channel. This section builds intuition for how these channels operate.

The Nash bargaining solution, Eq. (26), can be inserted into the job creation condition, Eq. (14), to yield:

$$\frac{\omega_{mt}\tau_t\kappa}{\mu(\theta_t)} = (1-\eta)\left(\frac{\varphi_t}{p_t} - \frac{\gamma}{\lambda_t}\right) + \mathbb{E}_t\beta\left(1 - x - \eta\aleph_{t+1} l(\theta_{t+1})\frac{p_t}{p_{t+1}}\right)\left\{\Lambda_{t,t+1}\frac{p_{t+1}}{p_t}\frac{\omega_{mt+1}\tau_{t+1}\kappa}{\mu(\theta_{t+1})}\right\}, \quad (31)$$

where $\varphi_t = (1-\alpha)\, y_t/n_t$. I take a log-linear approximation of Eq. (31) and write

$$\widehat{\theta}_t = \left(\frac{1-\pi_1}{\psi}\right)\left(\frac{1}{1-\epsilon}\widehat{\varphi}_t - \frac{\epsilon}{1-\epsilon}\widehat{c}_t\right) + \frac{1+\upsilon}{\psi}\left(\pi_2\mathbb{E}_t\left\{\widehat{\tau}_{t+1}\right\} - \widehat{\tau}_t\right) - \frac{\pi_1}{\psi}\widehat{R}_t + \frac{\pi_2}{\psi}\mathbb{E}_t\left\{\widehat{\theta}_{t+1}\right\} \underbrace{- \left(\frac{1-\pi_1}{\psi}\right)\frac{1}{1-\epsilon}\widehat{p}_t}_{\text{wage bill channel}} + \underbrace{\beta\left(\frac{1-x}{\psi}\right)(1-\eta)\left(\mathbb{E}_t\left\{\widehat{p}_{t+1}\right\} - \widehat{p}_t\right)}_{\text{hiring costs channel}}, \quad (32)$$

where $\epsilon = \gamma p/\lambda\varphi$, $\pi_1 = 1 - x - \eta l(\theta)$ and $\pi_2 = (1-x)\psi - \eta l(\theta)$. A hat denotes the percentage deviation of a variable from its long-run equilibrium value. Long-run equilibrium values are given without subscript. In the equation above, $\widehat{R}_t = -\mathbb{E}_t\widehat{\Lambda}_{t,t+1}$ is the percentage deviation of the real interest rate.

Eq. (32) reveals how a persistent increase in the TFP above trend affects the joint surplus from the marginal match and, in turn, the hiring rate. But before describing how TFP shocks affect hiring consider first how the shocks affect the external finance premium. Since net worth in the agency cost model consists of previously accumulated capital, it is essentially fixed in the period of the shock, so that the project size rises by more than does net worth. Hence, the external finance premium, and in turn the mark-up p_t, must rise on impact. On the other hand, a positive feedback from aggregate TFP shock to the idiosyncratic firm productivity should cause a rise in the mean of the distribution of firm-level productivity, without changing its variance. Thus, the distribution of the idiosyncratic firm shock moves to the right. Holding constant the contractually-specified bankruptcy threshold $\bar{\omega}_t$, when the distribution $F(\omega_{it}, \tau_t)$ shifts to the right, increases the possibility for any firm of drawing idiosyncratic productivity $\bar{\omega}_{it} > \bar{\omega}_t$, i.e., the equilibrium probability of the average firm going bankrupt decreases. This must translate into a fall of the external finance premium, and in turn a fall of p_t. The two effects counteract each other with the latter prevailing, i.e., $\widehat{p}_t$ fall below trend under TFP shocks (under a wide range of calibration values for υ).

The increase in the TFP shocks is captured by the increase in the marginal product of labor, $\widehat{\varphi}_t$, the decrease of the average cost of capital and in turn the mark-up p_t, and the difference $(\pi_2 \mathbb{E}_t \{\widehat{\tau}_{t+1}\} - \widehat{\tau}_t)$ that accounts for the intertemporal change in the efficiency of hiring. The increase in the marginal product of labor raises current production and in turn consumption, $\widehat{c}_t$. Since households desire a smooth consumption, they start to save. This pushes down the interest rate below trend (raises $\mathbb{E}_t \widehat{\Lambda}_{t,t+1}$), which encourages firms to invest both in capital and in hiring workers. This leads to increased employment and respectively higher market tightness, $\mathbb{E}_t \widehat{\theta}_{t+1}$, in the following period. The increase in employment raises the marginal product of capital, which encourages more investment, and in turn, also enables firms to spend more on hiring. Workers experience a rise in wages on account of higher productivity, labor market tightness and disutility of work (MRS). This puts downward pressure on hiring. In the long-run, employment returns to its steady state.

The importance of the financing constraints on hiring stands out immediately upon inspecting Eq. (32). Relaxing of the financing constraints during a boom frees up resources that are channeled proportionally to any of the input production costs. Respectively, looser constraints reduce the opportunity cost of resources allocated to job creation, raising the elasticity of market tightness through (a) a wage bill channel, whereby the incentives to hire rise for a given wage bill; (b) a hiring cost channel, descreasing current to future hiring costs; and (c) a capital rental channel, whereby a higher expected future capital stock (due to the increase in current investment) implies a higher marginal product of labor. Notice also that the hiring cost channel is less important for the amplification since current and future mark-ups in general cancel each other: The difference between the current and future hiring costs is not big.

To anticipate the results from the simulations, I write the Nash wage log-linear equation, Eq. (26),

$$\widehat{w}_t = \frac{\eta\varphi}{pw}\widehat{\varphi}_t + \frac{(1-\eta)\gamma c}{w}\widehat{c}_t + \frac{\eta\beta\kappa\theta}{w}\mathbb{E}_t\left\{\widehat{\theta}_{t+1} + (1+\upsilon)\,\widehat{\tau}_{t+1} - \widehat{R}_t\right\}$$
$$-\frac{\eta\varphi}{pw}\widehat{p}_t - \frac{\eta\kappa\theta\beta(1-x)}{l(\theta)w}\left(\mathbb{E}_t\left\{\widehat{p}_{t+1}\right\} - \widehat{p}_t\right). \tag{33}$$

Although this is a general equilibrium environment, it is helpful to think of the equation as the partial equilibrium determinant of the wage in the 'output' model. The effect of a positive TFP shock on wage is amplified by the fall of the current mark-up, i.e., wage in the 'output' model increases by more than the wages in the 'RBCM' model, a model absent financing constraints ($p_t = 1$ for all t). The wage rise in the output model is slightly moderated by the fall of the future mark-up. Essentially, given the way wages are determined in the model and the way Nash bargaining is calibrated, wages in the 'output' model respond strongly to changes in TFP shocks so that the incentives for firms to hire do not change substantially over the business cycle compared to the 'RBCM' economy. Despite the fact that financing constraints affect hiring directly, the Nash bargaining wage overshadows the model's ability to reproduce key labor market variables.

5 Results

In this section I study the dynamic behavior of the two models, 'output' and 'RBCM' economies. I solve the models by log-linearizing the equations characterizing equilibrium around the deterministic steady state. All equilibrium equations in the 'output' economy are collected in the Appendix, subsection A.1. The resulting systems of linear rational expectations difference equations are solved using DYNARE.[15] The goal is to analyze how loosening of financing constraints impacts the observed business-cycle fluctuations in real activity in general and employment in particular in response to TFP shocks of a plausible magnitude. Analysis is carried out as follows: I first compare dynamic adjustment paths towards the steady state after a TFP disturbance. Secondly, I contrast their predictions for business cycle statistics based on simulated data.

5.1 Simulation and main findings: benchmark

In this section, I analyze the dynamics of the simulated benchmark models.

The impulse response function for the two model specifications are depicted in Figure 2. Three observations stand out immediately. First, the agency cost model is able to generate simultaneously both an effect of persistence and an effect of amplification. The fall in the finance premium in two periods after impact induces output, capital and employment to rise more in the model with agency costs than in the credit frictionless economy, 'RBCM' model. Moreover the sluggish response of net worth produces an effect of persistence in the same three variables. Employment reaches its peak respectively after 6 months upon impact in the 'output' model, while in the 'RBCM' model it reaches its peak only after three periods.

[15]Dynare is a pre-processor and a collection of MATLAB® and GNU Octave routines which solve models with forward looking variables. See http://www.dynare.org.

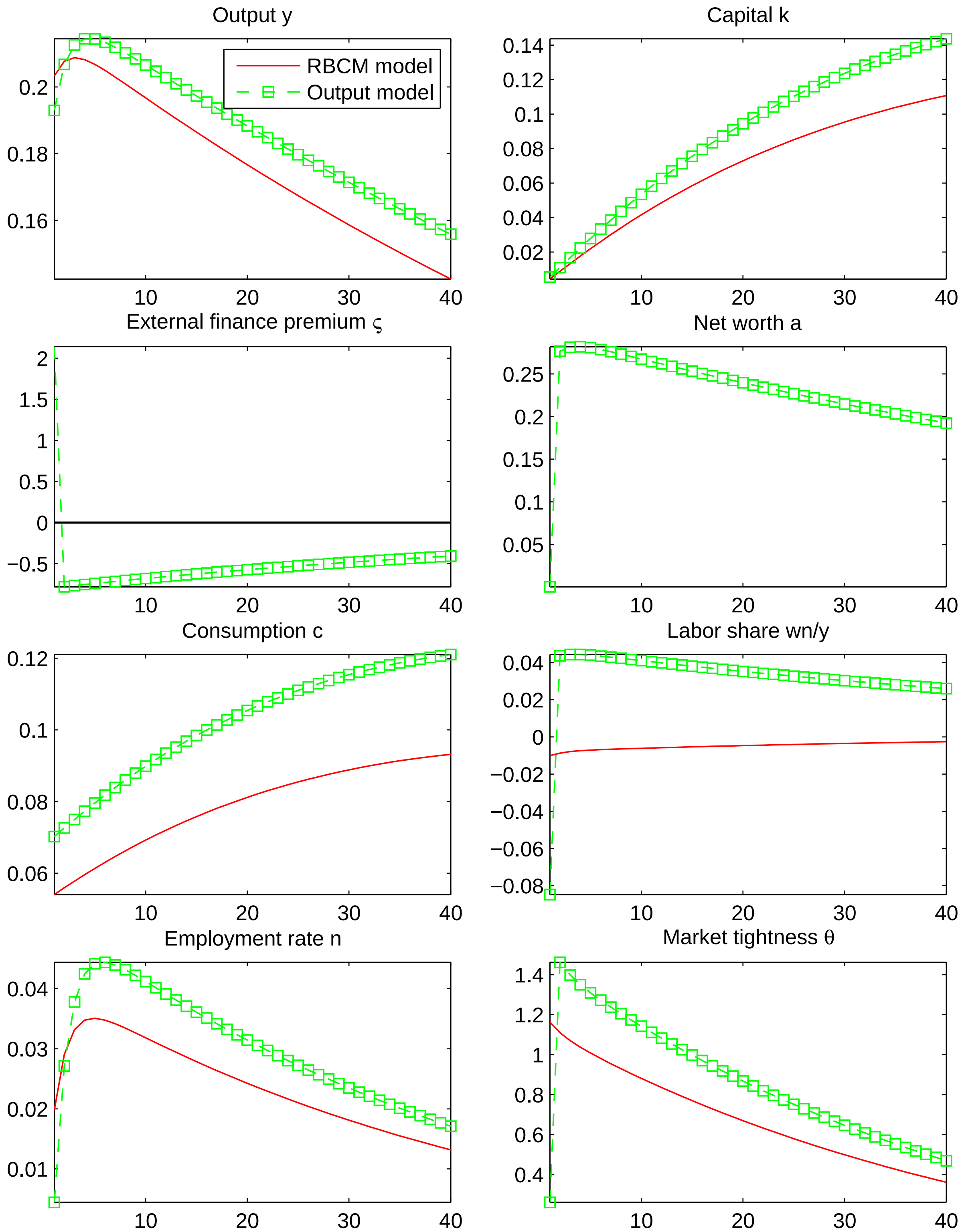

Figure 2: Response to a shock in TFP. The Figure displays percentage responses (1 in the plots corresponds to a 1% increase over the respective steady state value) of endogenous variables to a one percent shock in TFP. The time unit of the model is a month.

Second, and more importantly for my discussion, the responses of the labor share in the two specifications are remarkably different in terms of shape, size, and direction. To understand why first observe the behaviour of consumption. Consumption jumps up upon the impact of the shock in the two specifications. The direction of responses of consumption in the the 'output' and 'RBCM' are alike, besides the fact that in the 'output' model it jumps up more. On the other hand, the fall in the mark-up in the 'output' model is channelled into an increase of the wage, i.e., reduction of financing costs in boom are translated at large into wage increases. Together with the increase of consumption, wages in the 'output' model become highly procyclical and more volatile than wages in the 'RBCM' model.

Third, neither of the two models is able to replicate the volatility of employment and labor market tightness. This result is manifestation of the findings in Shimer (2005): The Nash wage absorbs most of the increases in productivity. On top of that, in the 'output' model, it absorbs the resources that are related to decreased monitoring costs (loosening of the financing constraints), thus eliminating the incentive for hiring. As a result, fluctuations in TFP shocks have little impact on the employment.

I also compare business cycles statistics computed from simulations of the two model specifications. I compare them to the business cycles statistics of their counterparts from the U.S. data. The results are reported in Table 3. The first two columns for model economies show statistics which are the theoretical, infinite sample moments of monthly variables. The last two columns for model economies show a measure more comparable to empirical estimates of these objects. They show statistics which are computed by simulating the models 1000 times for 697 monthly periods. The statistics are averages over the HP-filtered simulations. The statistics are conformation of the analysis above. To the extent that one hoped financing constraints would amplify TFP shocks on labor market variables, the results are disappointing.

5.2 Simulation and main findings: rigid wage

A lot of the new research has focused on wage determination. In a sense, the wage is indeterminant within a specified range in the models with Nash wage, i.e., there is a range of wages at which an employer and worker prefer to match rather than breakup. Loosely speaking, each will agree to any wage larger than the marginal rate of substitution between consumption and leisure but smaller than the marginal product of labor, if the alternative is breaking up. This insight has motivated many researchers, starting with Hall (2005) and Shimer (2005), to investigate the role of rigid wages in search models.

	U.S. economy	Theoretical RBCM	Theoretical Output	Finite Sample RBCM	Finite Sample Output
Relative s.d. y	1.570	1.410	1.570	1.482	1.660
θ	16.613	3.211	3.852	3.206	3.886
k	0.214	1.183	1.194	1.018	1.178
n	0.707	0.126	0.133	0.110	0.134
wn/y	0.493	0.035	0.172	0.023	0.172
w	0.634	0.913	1.064	0.902	1.063
c	0.581	0.747	0.881	0.749	0.873
ς	29.995	—	4.832	—	4.838
Correlations y,n	0.792	0.765	0.727	0.762	0.737
y,wn/y	-0.200	-0.521	0.922	-0.765	0.926
y,ς	-0.582	—	-0.856	—	-0.863
u,v	-0.905	-0.879	-0.905	-0.873	-0.908
Autocorrelations y	0.839	0.990	0.992	0.990	0.992
n	0.877	0.991	0.993	0.991	0.993
ς	0.706	—	0.819	—	0.828

Table 3: Business cycle properties of the U.S. economy and model economies. Statistics for the U.S. economy are computed using quarterly HP-filtered data from 1951:q1 to 2010:q1. The first two columns for model economies show statistics which are the theoretical, infinite sample moments of monthly variables. The last two columns for model economies show statistics which are computed by simulating the models 1000 times for 697 monthly periods under the baseline calibrated parameter values. The statistics are averages over the HP-filtered simulations. The standard deviations of all variables (except of output) are relative to output.

More formally, the Nash bargaining solution, Eq. (26), can be rewritten as a weighted average of the bargaining set limits, defined by the range of wage levels consistent with a non-negative surplus for both the worker and the firm respectively, $[\underline{w}_t, \overline{w}_t]$:

$$w_t = \eta \overline{w}_t + (1 - \eta)\underline{w}_t,$$

where

$$\underbrace{\overline{w}_t}_{\substack{\text{firm reservation}\\ \text{wage}}} = \underbrace{(1-\alpha)\frac{y_t}{n_t p_t}}_{\text{MRPL}} + \mathrm{E}_t \beta (1-x) \left\{ \Lambda_{t,t+1} \frac{J_{n,t+1}}{p_t} \right\},$$

$$\underbrace{\underline{w}_t}_{\substack{\text{worker reservation}\\ \text{wage}}} = \underbrace{\frac{\gamma}{\lambda_t}}_{\text{MRS}} - \mathrm{E}_t \beta (1 - x - l_{t+1}) \left\{ \Lambda_{t,t+1} \frac{H_{n,t+1}}{\lambda_{t+1}} \right\}.$$

Wage rigidity does not effect the efficient formation or retention of a match. But, it influences the firms' intensity of posting vacancies since it impacts on the firms' expected benefit from a worker. This arguement can be represented graphically with Figure 3.[16] A positive TFP shock generally affects the bargaining set in two ways: it tends to shift it toward higher wages (as both reservation wages, $\underline{w}_t$ and $\overline{w}_t$, generally increase) and it tends to increase its size (as the firms' reservation wage is more sensitive to the shock than the workers'). Wage rigid of any type, then, acts as a drag on the wage and generally limits its adjustment proportional to the change of the size of the bargaining set. Wage rigidity (illustrated by the vertical dashed line, in case the wage is perfectly rigid) amplifies the employment response to TFP shocks by allowing the firm to hold to a bigger portion of the match surplus.

The effect of the TFP shock on the bargaining set is amplified in the presence of financing constraints: the bargaining set moves to even higher wages and its size increases more compared to its response in the 'RBCM' economy. Thus, financing constraints and wage rigidity reinforce each other amplifying firms' hiring intensity by making the firm share of the surplus even more procyclical and volatile.

I extend the model to incorporate real wage rigidity. I do this through a simple wage adjustment rule. I distinguish between a target wage, w_t^T, which is determined by the Nash bargaining solution, and the actual wage, w_t, which is a weighted average of the target wage

[16] I borrow the the reasoning and the graph from Monacelli et al. (2010), extending analysis to a model economy with financing constraints.

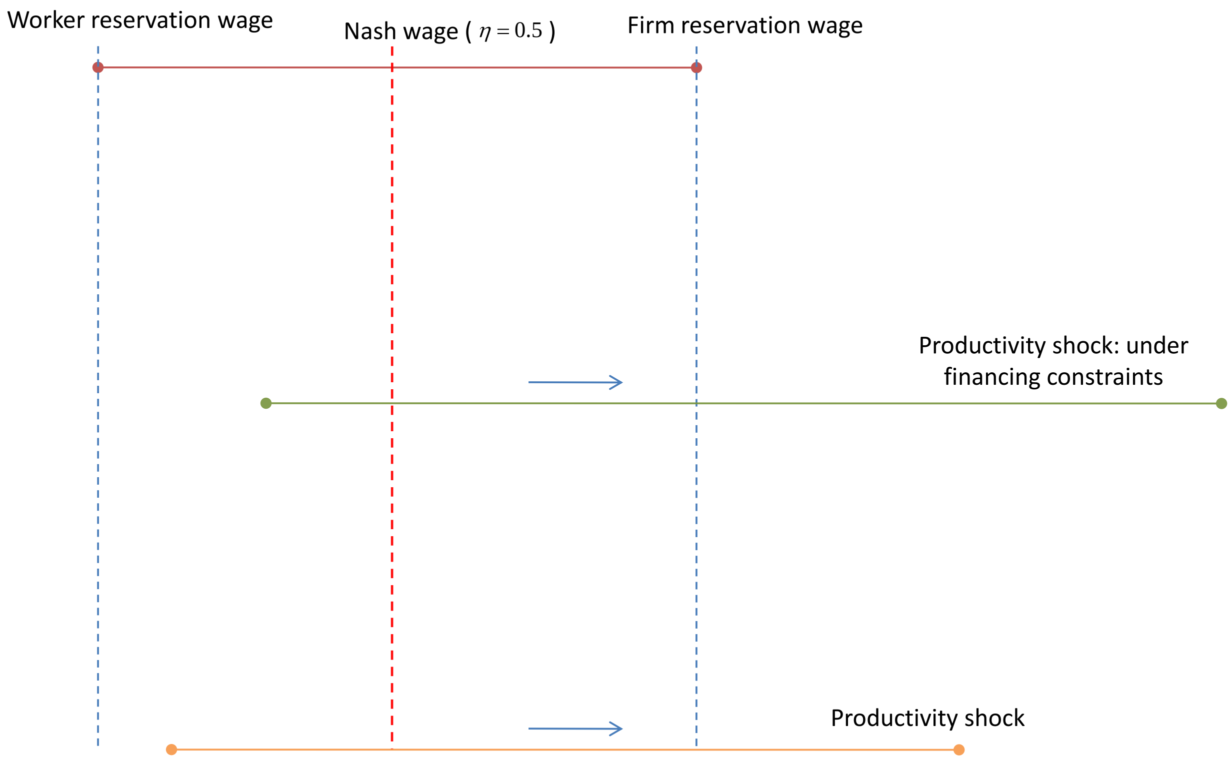

Figure 3: Response of the bargaining sets to a shock in TFP. The Figure displays responses of the wage bargaining set in a economy with financing constraints (green horizontal line) and in a economy without financing constraints (green horizontal line) to a shock in TFP.

and last period actual wage. The rule is given by

$$w_t = (1 - \sigma)\, w_t^T + \sigma w_{t-1}, \tag{34}$$

where σ is a partial adjustment parameter that reflects the degree of wage rigidity. When $\sigma = 0$, the actual wage corresponds to the Nash bargained wage and I recover the baseline case.

The effects of real wage rigidity on economic activity and labor market variables can be demonstrated by shutting down the wage adjustment almost entirely, i.e. by setting $\sigma = 0.95$. The impulse response functions to the TFP shocks for the two model specifications are depicted in Figure 4. The qualitative responses of the endogenous variables are very close to the baseline specification. The only big difference is the response of the labor share in the 'output' model. Logically, the labor share becomes less procyclical. This result can also be observed by comparing the business cycles statistics computed from simulations of the two model specifications to their counterparts from the U.S. data. The results are reported in Table 4. The rigid wage 'RBCM' model cannot replicate the observed patterns of the labor share and enough volatility of labor market tightness, jointly. The correlation between labor share and output and the relative standard deviation of the labor market tightness in the data are -0.200 and 16.613, respectively. By varying σ I find that a fairly high degree of rigidity is needed, $\sigma = 0.99$, to replicate volatility of labor market tightness in the data, whereas the model requires a high degree of flexibility, $\sigma = 0.2$, to explain the correlation between labor share and output. On the contrary, high levels of rigidity in the 'output' model, $\sigma = 0.99$, are consistent with both the labor market tightness (even overshooting it) and the negative comovement of labor share and output. The joint presence of wage rigidity and financing constraints is important for the dynamics of the labor market, as they reinforce each other to amplify the effect of TFP shocks on labor market quantities, while aligning the simulated comovement of labor share and output with its counterpart in the data.

6 Conclusion

I have studied a model in which shocks to aggregate TFP lead to large fluctuations in labor markets, and the amplification is mediated through financial conditions under some degree of wage rigidity. Financial constraints per se can not help to generate the empirical labor market statistics due to the Nash bargaining wage. I conclude that the main substantive contribution of search models with financing constraints relies on the presence of match-specific rents and the opportunity for a richer set of wage setting processes. This is where the contribution of the financing constraints in the current framework lies: financial conditions lead to a much larger set of match-specific rents. Allegedly, the joint presence of the two frictions can be helpful in explaining even complicated phenomenon as the Great Depression.

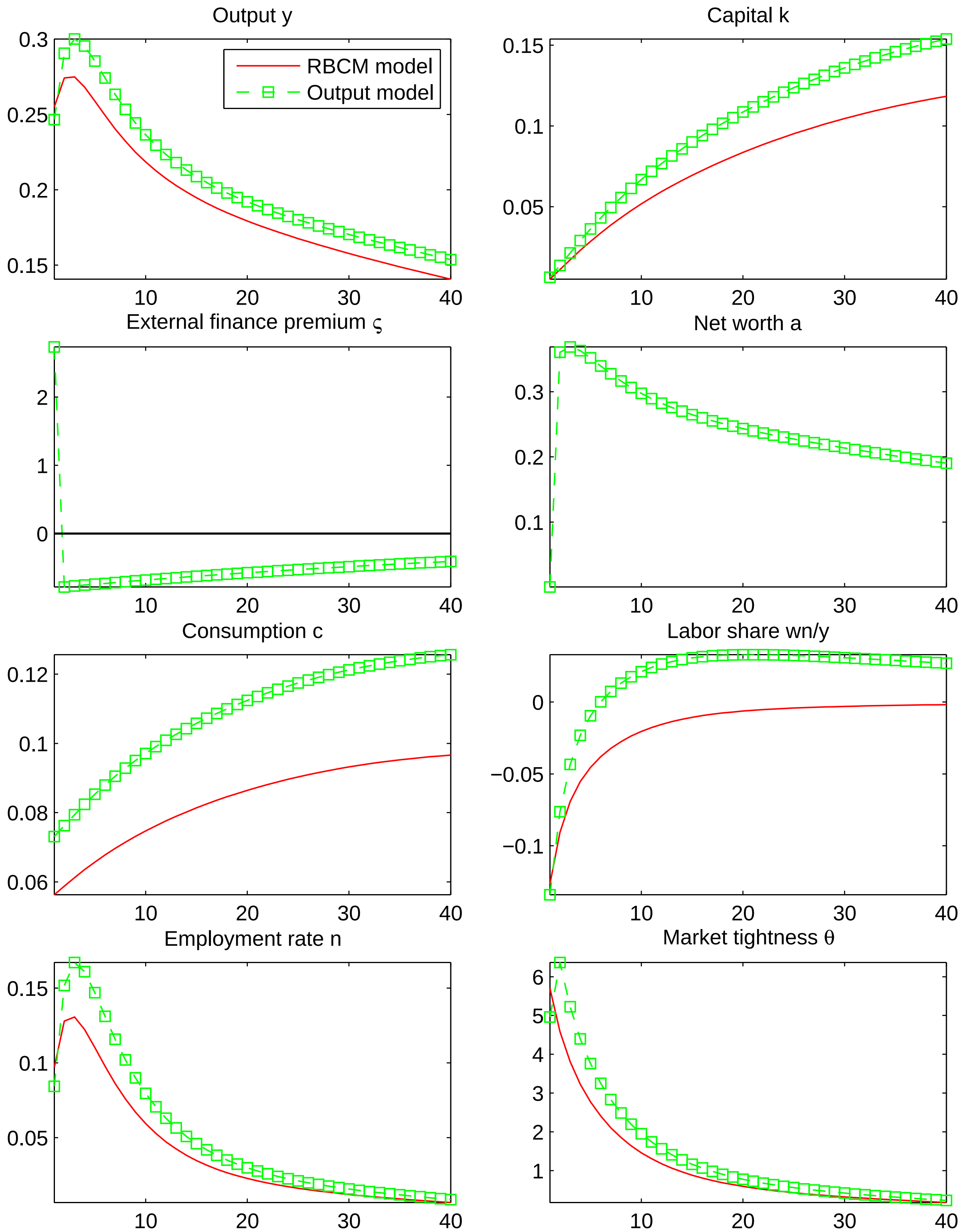

Figure 4: Response to a shock in TFP with rigid wages, $\sigma = 0.95$. The Figure displays percentage responses (1 in the plots corresponds to a 1% increase over the respective steady state value) of endogenous variables to a one percent shock in TFP. The time unit of the model is a month.

	U.S. economy	Theoretical RBCM	Theoretical Output	Finite Sample RBCM	Finite Sample Output
Relative s.d. y	1.570	1.628	1.806	1.644	1.849
θ	16.613	10.119	12.691	10.014	12.625
k	0.214	0.962	1.125	0.979	1.118
n	0.707	0.332	0.398	0.328	0.397
wn/y	0.493	0.144	0.148	0.142	0.147
w	0.634	0.793	0.928	0.798	0.929
c	0.581	0.695	0.816	0.706	0.812
ς	29.995	—	4.558	—	4.550
Correlations y,n	0.792	0.611	0.603	0.602	0.604
y,wn/y	-0.200	-0.635	0.418	-0.631	0.434
y,ς	-0.582	—	-0.807	—	-0.817
u,v	-0.905	-0.660	-0.708	-0.657	-0.717
Autocorrelations y	0.839	0.985	0.987	0.986	0.988
n	0.877	0.966	0.973	0.966	0.973
ς	0.706	—	0.718	—	0.733

Table 4: Business cycle properties of the U.S. economy and model economies with rigid wage ($\sigma = 0.95$). Statistics for the U.S. economy are computed using quarterly HP-filtered data from 1951:q1 to 2010:q1. The first two columns for model economies show statistics which are the theoretical, infinite sample moments of monthly variables. The last two columns for model economies show statistics which are computed by simulating the models 1000 times for 697 monthly periods under the baseline calibrated parameter values. The statistics are averages over the HP-filtered simulations. The standard deviations of all variables (except of output) are relative to output.

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Technical Appendix

A Analysis

A.1 Collecting equations: 'output' model

In equilibrium the household chooses plans to maximize its utility, the firm and the financial intermediary solve their maximization problems. The equations characterizing the equilibrium for the 'output' model are ("H": the first-order condition for the household; "F": the first-order conditions for the firm, the conditions for the debt contract, production function, evolution of net worth, evolution of entrepreneur's capital stock, respectively; "K": evolution of aggregate capital stock; "M": market clearing condition; "W": the wage bargaining rule; "L": evolution of aggregate employment, market tightness, job-filling rate, respectively; and "A": an auxiliary variable)

$$\text{H:}\quad 1 = \mathbb{E}_t\beta\left\{\frac{c_t}{c_{t+1}}\left[r_{t+1} + (1-\delta)\right]\right\},$$

$$\text{F:}\quad 1 = \mathbb{E}_t\beta\iota\left\{\left\{\frac{c_t}{c_{t+1}}\left[r_{t+1} + (1-\delta)\right]\right\}\left\{\frac{p_{t+1}f\left(\bar{\omega}_{t+1},\tau_{t+1}\right)}{1-p_{t+1}g\left(\bar{\omega}_{t+1},\tau_{t+1}\right)}\right\}\right\},$$

$$\text{F:}\quad \frac{\omega_{mt}\tau_t\kappa}{\mu\left(\theta_t\right)} = (1-\alpha)\frac{y_t}{n_t p_t} - w_t + \mathbb{E}_t\beta(1-x)\left\{\frac{c_t}{c_{t+1}}\frac{p_{t+1}}{p_t}\frac{\omega_{mt+1}\tau_{t+1}\kappa}{\mu\left(\theta_{t+1}\right)}\right\},$$

$$\text{F:}\quad p_t f\left(\bar{\omega}_t,\tau_t\right) = \frac{f'\left(\bar{\omega}_t,\tau_t\right)}{g'\left(\bar{\omega}_t,\tau_t\right)}\left[p_t g\left(\bar{\omega}_t,\tau_t\right) - 1\right],$$

$$\text{F:}\quad y_t = p_t a_t\left[1/\left(1-p_t f\left(\bar{\omega}_t,\tau_t\right)\right)\right],$$

$$\text{F:}\quad y_t = \omega_{mt}\tau_t k_t^{\alpha} n_t^{1-\alpha},$$

$$\text{F:}\quad a_t = z_t\left[(1-\delta) + r_t\right],$$

$$\text{F:}\quad z_{t+1} = y_t f\left(\bar{\omega}_t,\tau_t\right) - \zeta_t,$$

$$\text{K:}\quad k_{t+1} = (1-\delta)k_t + i_t,$$

$$\text{M:}\quad y_t(1-\chi F\left(\bar{\omega}_t,\tau_t\right)) = c_t + i_t + \omega_{mt}\tau_t\kappa v_t,$$

$$\text{W:}\quad w_t = \eta\left((1-\alpha)\frac{y_t}{n_t p_t} + \kappa\mathbb{E}_t\beta\left\{\frac{c_t}{c_{t+1}}\omega_{mt+1}\tau_{t+1}\aleph_{t+1}\theta_{t+1}\right\}\right) + (1-\eta)\gamma c_t,$$

$$\text{L:}\quad n_t = (1-x)\,n_{t-1} + \theta_t\mu\left(\theta_t\right)\left(1-n_{t-1}\right),$$

$$\text{L:}\quad \theta_t = \frac{v_t}{1-n_{t-1}},$$

$$\text{L:}\quad \mu\left(\theta_t\right) = \bar{l}\theta_t^{-\psi},$$

$$\text{A:}\quad \aleph_t = \frac{1-x}{\theta_t\mu\left(\theta_t\right)}\left(\frac{p_t}{p_{t-1}} - 1\right) + 1.$$

The above equations determine the evolution of quantities (c, y, θ, v, n, k, z, a, ζ), prices (p, r, w), the job-filling rate ($\mu(\theta)$), the default threshold ($\bar{\omega}$), and an auxiliary variable ($\aleph$). Note that there are 15 equations for 15 variables, plus the equation for the exogenous TFP process

$$\log \tau_t = \rho_\tau \log \tau_{t-1} + \varepsilon_t, \quad \varepsilon_t \overset{\text{iid}}{\sim} N\left(0, \sigma_\tau^2\right).$$

A.2 Long-run equilibrium

Some of the results in this subsection are generally useful for examining the impact of agency costs on the long-run equilibrium allocations. Below I shortly list derivation of some main long-run ratios for the 'output' model. The analysis of the 'investment' model is symmetric.

Given the household's preferences in Eq. (19), the risk-free return on capital is

$$R = 1/\beta,$$

thereby relating β to observations on R.

The log-normal pdf has two parameters, the variance of $\log\omega$ and the mean of ω. I fix the long-run mean to unity, $\mathrm{E}\omega = 1$, and then calibrate the steady state value of the variance so that, in the long-run equilibrium, $F(\bar{\omega}, 1)$ is equal to a specified calibrated value. By imposing $\mathrm{E}\omega = 1$, the idiosyncratic productivity disturbance ω_t has a log-normal distribution:

$$\log \omega_t \sim N\left(-0.5\sigma_\omega^2, \sigma_\omega^2\right).$$

In the long-run equilibrium, the firm's share of output is $f(\bar{\omega}, 1) \equiv \int_{\bar{\omega}}^{\infty} \omega dF(\omega, 1) - \bar{\omega}(1 - F(\bar{\omega}, 1))$. The financial intermediary's share of output is $g(\bar{\omega}, 1) \equiv \int_0^{\bar{\omega}} \omega dF(\omega, 1) - \chi F(\bar{\omega}, 1) + \bar{\omega}(1 - F(\bar{\omega}, 1))$. Then, the derivatives of the shares with respect to $\bar{\omega}$ are:

$$f^{\bar{\omega}}(\bar{\omega}, 1) = -(1 - F(\bar{\omega}, 1)),$$
$$g^{\bar{\omega}}(\bar{\omega}, 1) = -f^{\bar{\omega}}(\bar{\omega}, 1) - \chi\phi(\bar{\omega}, 1),$$

where the density function is $\phi(\bar{\omega}, 1) = F^{\bar{\omega}}(\bar{\omega}, 1)$. After imposing $\mathrm{E}\omega = 1$, I substitute the mark-up p, from Eq. (7),

$$pf(\bar{\omega}, 1) = \frac{f'(\bar{\omega}, 1)}{g'(\bar{\omega}, 1)}\left[pg(\bar{\omega}, 1) - 1\right]$$

into Eq. (17),

$$1 = \beta\iota \left\{ R \left\{ \frac{pf(\bar{\omega}, 1)}{1 - pg(\bar{\omega}, 1)} \right\} \right\},$$

and targeting a given long-run equilibrium annual external finance premium ς, I solve numerically for the variance of $\log \omega$.

The long-run value of the output-capital ratio, y/k, from combining Eq. (11) and Eq. (23), is given by

$$y/k = p(R - 1 + \delta)/\alpha,$$

which in turn implies the labor-capital ratio

$$n/k = (y/k)^{\frac{1}{1-\alpha}}.$$

From Eq. (20), the long-run employment rate satisfies

$$n = l(\theta)/(x + l(\theta)),$$

which in turn allows to pin down the long-run values of capital and output.

Next, I fix ϵ, and using Eq. (20) and Eq. (31), I find the hiring costs to output ratio

$$\frac{\kappa v}{y} = \frac{(1-\eta)(1-\alpha)(1-\epsilon)x}{1 - \beta\pi_1},$$

which, in turn from Eq. (30), pins down the consumption-output ratio

$$\frac{c}{y} = 1 - \chi F(\bar{\omega}, 1) - \delta\frac{k}{y} - \frac{\kappa v}{y}.$$

Finally, I can find the net worth and the wage from Eq. (8) and Eq. (26), respectively.

B Data

I discuss how I obtain the macroeconomic time series for the real economy, from 1951:q1 up to 2010:q1, each of which has a theoretical counterpart in the present paper. The data is identical to one used by Shimer (2010).

- Output y: I use a quantity-weighted measure of real Gross Domestic Product, National Income and Product Accounts Table 1.1.3, line 1. I express this in per capita terms, dividing by the population series from Prescott et al. (2009).

- Vacancy-unemployment ratio θ: I proxy the number of open vacancies v with the Conference Board help-wanted advertising index, available from the Conference Board. I divide this by the number of unemployed workers u, series LNS13000000 drawn from the Bureau of Labor Statistics.
- Consumption c: I use a quantity-weighted measure of real consumption of nondurables and services, National Income and Product Accounts Table 1.1.3, Rows 5 and 6. I express this in per capita terms, dividing by the population series from Prescott et al. (2009).
- Capital stock k: I measure the capital stock using the Bureau of Economic Analysis's Fixed Asset Table 1.1, line 1. This is an annual series, which I interpolate. I divide by the population series from Prescott et al. (2009).
- Labor share wn/y: I measure the labor share using National Income and Product Accounts Table 1.10. Labor income is taken from line 2. Capital income is consumption of fixed capital (line 23) plus net operating surplus of private enterprises (line 11) minus proprietors' income (line 15). Labor share is labor income divided by the sum of labor and capital income.
- Employment n: I use the measure of employment from Prescott et al. (2009), divided by population from the same paper.
- Labor compensation w: Real wages are measured by the labor share wn/y divided by employment n and multiplied by output y.
- The external finance premium ς: The premium is measured by the difference between Moody's BAA corporate bond yields and 3-Month Treasury Bill (TB3MS), available from Federal Reserve Bank of St. Louis' database FRED®II.

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