Credit, Vacancies and Unemployment Fluctuations*

(preliminary)

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Abstract

This paper investigates the implications of agency problems on credit markets when vacancy costs require some external financing for the propagation properties of an otherwise standard labor search model. The countercyclical premium on external finance greatly increases the elasticity of vacancies to exogenous innovations such that the model can match the volatility of aggregate unemployment, vacancies and labor market tension. The model is extended to allow for endogenous job separation as there is evidence that employment contractions are more pronounced at financially constrained firms. This improves the ability of the model to match key labor market statistics while preserving a Beveridge curve between unemployment and vacancies.

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1 Introduction

The standard Mortensen and Pissarides (1994) search and matching model has been argued in many places to be inconsistent with key business cycle facts (e.g. Shimer, 2005). In particular it cannot explain the high volatilities of unemployment and vacancies, nor the strong procyclicality of the rate at which workers find a job. Subsequent research has focused on whether the lack of internal propagation stems from the structure of the model itself (e.g., Shimer 2004) or whether it is a question of setting an appropriate calibration (e.g., Hagedorn and Manovskii, 2007).

This paper explores the implications of agency costs when external finance must be called upon to fund part of a firm's vacancies in an otherwise standard DSGE labor search framework (e.g. Merz, 1996, or Andolfatto, 1997). Firms write standard debt contracts to fund vacancies over net worth in a set similar to Carlstrom and Fuerst (1997). As the premium on external funds varies inversely with the business cycle, so do the costs of vacancies. Combined with the persistent relaxation of financing constraints as net worth is accumulated during an expansion, this generates a powerful financial accelerator that greatly increases the response of vacancies to an exogenous shock.

The model's quantitative results, detailed in section 3, are set against a comparable framework without credit frictions. The results show that the propagation potential is significant generating a labor market tension that matches the volatility relative to output observed in the data. As a result, the relative volatility of unemployment in the presence of credit frictions rises to 4.50, compared to 1.46 in the standard model and 6.82 in the data. The second significant implication is a sluggish response of vacancies and the job finding hazard to a technological innovation. Such a response, characteristic of the empirical observations that a standard model cannot replicate, stems from the progressive relaxation of financing constraints through the accumulation of net worth. These results are robust to various parameterizations of the credit and labor market frictions.

The model is then extended to allow for endogenous labor separation. Introducing endogenous separation to meet interest payments on debt contracts is motivated by the observation that employment contractions are more pronounced at financially constrained firms.¹ The impact of countercyclical separation is twofold. On the one hand, the response of output is amplified as the separation rate directly impacts employment entering production. As a consequence, the relative

¹This observation is drawn from data for all publicly listed firms in the U.S. having filed for bankruptcy since 1980 contained in the Bankruptcy Research Database along with firm level observations contained in Compustat.

volatility of unemployment increases, closer yet to the empirical observation. On the other hand, the drop in separation during an upturn, by rapidly increasing employment, puts downward pressure on the value of an additional vacancy. While the model with credit frictions and exogenous labor separation generates too much volatility in vacancies, the extension to endogenous job separation results in less volatile job vacancies which are in line, almost exactly, with their empirical counterpart.

The model, is motivated by the large body of evidence, suggesting that credit market frictions play an important role for firm behavior. Empirically, panel data studies find that small firms with more difficult access to credit pay fewer dividends, take on more debt, and have investment rates that are more sensitive to cash flows even after controlling for future profitability.² More to the present concern, Rendon (2001?) finds that job creation is restricted by limited access to credit. Theoretically, numerous papers show how optimizing models of the firm with incomplete contract enforcement and asymmetric information in the lending process can rationalize the observed correlation of firm size and age with mean growth (negative) and survival rates (positive).³ While the macroeconomic consequences of credit market imperfections have generally focused on their consequences for capital investment, e.g. models of financial intermediation and agency costs by Bernanke and Gertler (1989) or Kiyotaki and Moore (1997), their implications for labor markets have been largely overlooked.⁴

The macroeconomic literatures concerned with the dynamic effects of credit and labor market imperfections have overlooked the potential propagating properties of conditioning hiring of the availability of external funding and, furthermore, that separations be affected by financial constraints. One notable exception is the analysis of Wasmer and Weil (2004), which is close in spirit to this paper and who first identify the financial accelerator at play in this paper. In their setting, to some degree, the credit friction is extreme in that vacancies require a firm to first locate a creditor. Thus a job is a tripartite arrangement between an entrepreneur, a creditor and a worker. Such a framework applies more to market entry and doesn't accommodate the notion of multi-worker firms nor the accumulation of net worth, the friction being independent of size. Moreover, their paper is concerned with steady state implications, not the dynamic propagation of shocks. This paper

²See Hubbard (1998) and Stein (2000) for surveys.

³See Cooley and Quadrini (2001) or Clementi and Hopenhayn (2002).

⁴Notable exceptions include Acemoglu (2001) and Wasmer and Weil (2004) who examine the impact of credit frictions for equilibrium unemployment.

also contributes to the growing body of research of the dynamic properties of labor search models. Various authors have presented alternative wage determining mechanisms as a way to increase the internal propagation. Ramey conducts an extensive analyses of the importance of modelling the separation margin. XXXX

2 Model

The model is populated by two types of agents: firms that produce using labor and households who decide on optimal consumption and purchases of risk free bonds. The allocation of labor from households to firms involves a costly and time consuming matching process in a representative household framework, as Merz (1996) or Andolfatto (1997).⁵ Firms must seek external funds over their net worth to finance current vacancies, and the lending relationship is subject to a credit market friction of the costly state verification type initiated by Townsend (1979), resulting in a debt contract characterized by a monitoring threshold and optimal vacancy postings.

2.1 Labor markets and households

The set up of the labor market is quite standard now in the labor search literature. Firms post job vacancies V_t at a unit cost of γ . Jobs are filled via a constant returns to scale matching function taking vacancies and unemployed workers $M(U_t, V_t)$. Define $\theta_t = \frac{V_t}{U_t}$ as the labor market tightness from the point of view of the firm. The matching probabilities are $\frac{M(U_t, V_t)}{V_t} = p(\theta_t)$ and $\frac{M(U_t, V_t)}{U_t} = q(\theta_t)$ for firms and workers respectively, with $\partial p(\theta_t)/\partial \theta_t < 0$ and $\partial q(\theta_t)/\partial \theta_t > 0$. Note that $q(\theta_t) = \theta_t p(\theta_t)$. Jobs are destroyed at the exogenous rate δ . Thus employment N_t and unemployment U_t evolve according to

$$N_{t+1} = (1 - \delta)N_t + p(\theta_t)V_t \quad (1)$$

$$U_{t+1} = (1 - q(\theta_t))U_t + \delta N_t \quad (2)$$

⁵For a formal treatment of the set-up, see Mortensen and Pissarides (1994). The introduction of labor search to quantitative business cycle research is owed to the contributions of Merz (1995) and Andolfatto (1996). Labor force participation choices are not considered here, individuals are either employed or unemployed. See Wasmer and Garibaldi (2005) or Haefke and Reite (2006) for models of labor market participation.

The representative household, given existing employment and unemployment, choose optimal consumption and purchases of risk free bonds, which pay a rate r the following period, in order to maximize the value function:⁶

$$V(N_t, U_t) = \max_{C_t, B_t} [U(C_t) + \beta E_t V(N_t, U_t)],$$

subject to the budget constraint $W_t N_t + b U_t + (1 + r_{t-1}) B_{t-1} + \Pi_t = C_t + B_t + T_t$, and the laws of motion for matched labor (1) and unemployment (2). The government raises T_t in taxes to fund unemployment benefits $U_t b$. Π_t are firm profits rebated lump sum at the end of the period. Denoting the multiplier on the budget constraint by λ , the first order conditions are

$$(C_t) \quad : \quad U_C(C_t) = \lambda_t \tag{3}$$

$$(B_t) \quad : \quad \lambda_t = \beta E_t \lambda_{t+1} (1 + r_t) \tag{4}$$

2.2 Financial contract and vacancy decisions

The informational assumptions are chosen to generate standard one period debt contracts, in the tradition of Gale and Hellwig (1985) and Williamson (1987), set in a quantitative macroeconomic framework as in Carlstrom and Fuerst (1997) or Bernanke et al. (1999).⁷ The contracts are written in a competitive capital market (in the sense that there is a large number of insignificant lenders and firms) and lenders are assumed to hold sufficiently large and diversified portfolios to ensure perfect risk pooling, with the result that investors behave as if they were risk neutral. Repayment of the debt is assumed to occur within the period such that there is a unit opportunity cost to funds. The competitive pressure ensures that each lender-firm pair will write a contract which maximizes the expected utility of the firm subject to the constraint that the expected return to the lender covers the opportunity cost of funds.⁸

Define period net revenues as $x(X - W)N$, where W is the wage rate, x is a random variable with positive support, cdf $F(x)$ and pdf $f(x)$, and X is the aggregate level of technology. The crucial assumption is that agents have asymmetric information over the realization of the random

⁶As in Andolfatto (1997), each worker is a member of a household that offers perfect insurance against labor market outcomes, and is involved in a passive search process.

⁷The contract specific notation will be similar to Bernanke et al. (1999).

⁸If the expected utility of the firm is not maximized subject to this constraint, some other investor can offer a contract which is more attractive to the firm and still make a profit, see Gale and Hellwing (1985).

variable x . This state can only be observed by lenders at some cost proportional to realized net revenues, $0 < \mu < 1$.

The timing of events in each period is as follows. Assume that vacancy costs γV must be paid before production occurs. All agents observe the aggregate state X and, given initial assets A , firms borrow $(\gamma V - A)$ from financial markets to pay for period vacancy postings. Lenders and borrowers agree on a contract that specifies a cutoff productivity $\bar{x}$ such that if $x > \bar{x}$, the borrower pays $\bar{x}(X - W)N$ and keeps the equity $(x - \bar{x})(X - W)N$. If $x < \bar{x}$, the borrower receives nothing and the lender claims the residual net of monitoring costs.

Before writing the optimal contract, define the expected gross share of returns going to the lender as:

$$\Gamma(\bar{x}) = \int_0^{\bar{x}} x dF(x) + \int_{\bar{x}}^{\infty} \bar{x} dF(x)$$

noting that $\Gamma'(\bar{x}) = 1 - F(\bar{x}) > 0$ and $\Gamma''(\bar{x}) = -f(\bar{x}) < 0$, and expected monitoring costs as

$$\mu G(\bar{x}) = \mu \int_0^{\bar{x}} x dF(x)$$

with $\mu G'(\bar{x}) = \mu \bar{x} f(\bar{x})$. Express the expected share of returns going to the borrower as

$$\Upsilon(\bar{x}) = \int_{\bar{x}}^{\infty} (x - \bar{x}) dF(x)$$

and note that $\Gamma(\bar{x}) + \Upsilon(\bar{x}) = 1$. It is easy to see that the expected gross share to the lender will always be positive.⁹ We can now express the lender's participation constraint as $[\Gamma(\bar{x}) - \mu G(\bar{x})](X - W)N = (\gamma V - A)$.

Given the assumptions on the functional forms, notably the constant returns to scale in production and a linear monitoring technology, the loan amount will be proportional to net worth and each firm will face the same interest rate (see Carlstrom and Fuerst, 1997). The result is a straightforward aggregation that permits to work in a representative firm framework. Aggregate assets will evolve according to $A_{t+1} = \varsigma [1 - \Gamma(\bar{x}_t)](X_t - W_t)N_t$, where $0 < \varsigma < 1$ is needed for avoid self-financing,¹⁰ which by rearranging as

$$A_{t+1} = \varsigma \left[(X_t - W_t)N_t - \left(1 + \frac{\mu G(\bar{x}_t)(X_t - W_t)N_t}{\gamma V_t - A_t} \right) (\gamma V_t - A_t) \right]$$

⁹To do so, take the limits $\lim_{\bar{x} \rightarrow \infty} \Gamma(\bar{x}) = \int_0^{\infty} x dF(x) = 1 > 0$; $\lim_{\bar{x} \rightarrow 0} \Gamma(\bar{x}) = \int_0^{\infty} \bar{x} dF(x) = 0$, and recall that $\Gamma(\bar{x})$ is strictly increasing and concave in $\bar{x}$.

¹⁰The assumption of some depletion in the stock of assets is needed to rule out eventual self-financing. Carlstrom and Fuerst (1997) and Bernanke, Gertler and Gilchrist (1998) assume that a fraction of the entrepreneurial population exits every period consuming their assets on the way out.

focuses on the premium associated with external funds: $\frac{\mu G(\bar{x}_t)(X_t - W_t)N_t}{\gamma V_t - A_t}$.

We can now write the optimal incentive compatible contracting problem with non-stochastic monitoring and repayment within the period. Vacancy postings and the threshold $\bar{x}$ are chosen to maximize the expected gross return to the firm subject to the lender's participation constraint and the law of motion for employment:

$$\begin{aligned} J(N_t) &= \max_{V_t, \bar{x}_t} [1 - \Gamma(\bar{x}_t)] (X_t - W_t) N_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J(N_{t+1}) \\ &\text{subject to } [\Gamma(\bar{x}_t) - \mu G(\bar{x}_t)] (X_t - W_t) N_t = (\gamma V_t - A_t) \\ &\text{and } N_{t+1} = (1 - \delta)N_t + V_t p(\theta_t) \end{aligned}$$

Denoting the multiplier on the lender's participation constraint by ϕ , the first order conditions are

$$\begin{aligned} (V_t) &: -\gamma \phi_t + p(\theta_t) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_n(N_{t+1}) = 0 \\ (\bar{x}_t) &: -\Gamma'(\bar{x}_t) + \phi_t [\Gamma'(\bar{x}_t) - \mu G'(\bar{x}_t)] = 0 \\ (\phi_t) &: [\Gamma(\bar{x}_t) - \mu G(\bar{x}_t)] (X_t - W_t) N_t - (\gamma V_t - A_t) = 0 \end{aligned}$$

The first of these defines a job creation condition equating the average cost of a vacancy to the expected marginal value of an additional employed worker $\frac{\gamma \phi_t}{p(\theta_t)} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_n(N_{t+1})$. In order to derive the marginal value of a worker to the firm, $J_n(N_t)$, differentiate the firm's value function with respect to N :

$$J_n(N_t) = [1 - \Gamma(\bar{x}_t)] (X_t - W_t) + \phi_t [\Gamma(\bar{x}_t) - \mu G(\bar{x}_t)] (X_t - W_t) + (1 - \delta) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_n(N_{t+1}).$$

The first term express the net return on an employee accruing to the firm, the second captures the value an additional worker brings in terms of relaxing the financing constraint, and the final terms captures the value of the continued relationship. For the sake of simplifying the notation, call $\Omega(\bar{x}_t) = \phi_t [\Gamma(\bar{x}_t) - \mu G(\bar{x}_t)] - \Gamma(\bar{x}_t)$. Combining the value of a marginal worker with the optimality condition for vacancies, and making use of the household bond Euler equation (4), yields the intertemporal condition for vacancy postings

$$\frac{\gamma \phi_t}{p(\theta_t)} = \frac{1}{1 + r_t} E_t \left[[1 + \Omega(\bar{x}_{t+1})] (X_{t+1} - W_{t+1}) + (1 - \delta) \frac{\gamma \phi_{t+1}}{p(\theta_{t+1})} \right] \quad (5)$$

At this stage it is useful to show how this setting with credit frictions compares with a standard search model. First, consider the limit of the credit constraint multiplier ϕ_t . From the first order

condition for the cutoff productivity, the multiplier may be expressed as

$$\phi_t = \frac{\Gamma'(\bar{x}_t)}{[\Gamma'(\bar{x}_t) - \mu G'(\bar{x}_t)]} \quad (6)$$

In the absence of monitoring costs the threshold $\bar{x}$ tends to the lower bound of its support. It is straightforward to show that $\partial\phi_t/\partial\bar{x}_t > 0$, and that in the limit $\lim_{\bar{x}_t \rightarrow 0} \phi_t = 1$ and $\lim_{\bar{x}_t \rightarrow 0} \Omega(\bar{x}_t) = 0$. As a result the first order condition (5) collapses to the standard, job creation condition in a stochastic discrete time setting:

$$\frac{\gamma}{p(\theta_t)} = \frac{1}{1+r_t} E_t \left[X_{t+1} - W_{t+1} + (1-\delta) \frac{\gamma}{p(\theta_{t+1})} \right] \quad (7)$$

2.3 Workers and wages

Before setting the wage rule, the values of a job (V_n) and unemployment (V_u) to a worker are defined by differentiating the household's value function with respect to N and U :

$$\begin{aligned} V_n(N_t, U_t) &= \lambda_t W_t + \beta E_t [(1-\delta)V_n(N_{t+1}, U_{t+1}) + \delta V_u(N_{t+1}, U_{t+1})] \\ V_u(N_t, U_t) &= \lambda_t b + \beta E_t [(1-q(\theta_t))V_u(N_{t+1}, U_{t+1}) + q(\theta_t)V_n(N_{t+1}, U_{t+1})] \end{aligned}$$

The current value of a job corresponds to the wage measured in utils and the discounted expected values of next period's state, which with probability $(1-\delta)$ remains employment. The value of unemployment is derived from the value of non-market activities, $\lambda_t b$, and the discounted expected value of next period's state, which with probability $q(\theta_t)$ is employment.

Splitting the surplus of a worker-firm match, defined as $S(t) = J_n(t) + \frac{V_n(t) - V_u(t)}{\lambda_t}$, under Nash bargaining yields the wage rule (see appendix)

$$W_t = \eta \omega_t [(1 + \Omega(\bar{x}_t)) X_t + \gamma \theta_t \phi_t] + (1 - \eta) \omega_t b \quad (8)$$

where $\omega_t = 1/[1 + \eta \Omega(\bar{x}_t)]$. As with the job creation condition, consider the wage rule (8) as $\bar{x}_t$ tends to 0,

$$W_t = \eta [X_t + \gamma \theta_t] + (1 - \eta) b \quad (9)$$

This is simply the usual the wage without credit frictions. We will discuss in the next section the steady state and dynamic implications for labor markets.

2.4 Closing the model

From the household's budget constraint it is straightforward to derive an aggregate resource constraint

$$Y_t [1 - \mu G(\bar{x}_t)] = C_t + \gamma V_t.$$

where $Y_t = X_t N_t$, $\mu G(\bar{x}_t)$ are resources consumed in monitoring and γV_t are vacancy costs.

The equilibrium of the model is then defined by equations (3) and (4) from household optimization, a job creation condition (5), optimality condition for the threshold $\bar{x}_t$ in (6), the financiers' participation constraint, a wage rule (8), the aggregate resource constraint and laws of motion for asset accumulation, aggregate employment and unemployment.

3 Propagation properties of financial and labor market frictions

Before discussing some of the steady state labor market implications of credit market frictions in this setting, the assumptions on functional forms and calibration are presented in detail. The model is then solved by computing the unique rational expectations solution for a linearization around the deterministic steady state, and the dynamics effects are evaluated with a series of unconditional second moments and impulse response functions. The performance of the model is assessed by simulating a standard labor search model and performing a series a sensitivity analyses to key parameters and aspects of the calibration.

3.1 Functional forms and calibration

Following much of the real business cycle literature, aggregate technology is assumed stationary and to evolve according to

$$\log X_t = \rho_X \log X_{t-1} + \varepsilon_t^X,$$

with $\varepsilon_t^X \sim (0, \sigma_X^2)$ and $0 < \rho_X < 1$.

For household preferences, period utility is defined as $u(C) = \log C$. The idiosyncratic shock x is assumed to follow a log-normal distribution with mean $E(x) = 1$; i.e. $\log(x) \sim N(-\frac{\sigma_{\log(x)}^2}{2}, \sigma_{\log(x)}^2)$. Finally, following much of the labor literature, the matching technology is a Cobb-Douglas $M(U, V) = \chi U^\epsilon V^{1-\epsilon}$, with $0 < \epsilon < 1$.

The model is calibrated to quarterly data. For the parameters that are common with the RBC literature the calibration is standard. The discount factor $\beta = 0.992$ is set so as to match an average annual real yield on a risk less 3-month treasury bill of 3.3%. The parameters of the exogenous process are $\rho_X = 0.975$ and $\sigma_X = 0.0072$. The quarterly default rate is set to 2.5%, larger than the value of 1% in Carlstrom and Fuerst (1997) and slightly smaller than the value of 3% used in Bernanke et al. (1999). The resource cost of monitoring is set to $\mu = 0.075$. This value is much lower than Carlstrom and Fuerst (1997) who use a value of 0.25 and the value of 0.12 in Bernanke et al. (1999). The value of ς is chosen to match a ratio of liquidity to vacancy costs of one third. Together, these last two elements ensure a steady state premium on external finance of 134 basis points. The standard deviation of the idiosyncratic productivity σ_x is 0.30.

Much recent work has been done in the business cycle literature to incorporate search frictions labor markets into DSGE frameworks in order to quantify the ability of the model to match key labor market statistics.¹¹ In deciding on the rate of unemployment to target, several authors have argued that it should include more than the rate of workers counted as unemployed as the model does not account for non-participation. Krause and Lubik (2005), for example, choose an unemployment rate of 12%, above the average rate observed for the United States, while Gertler and Trigari (2006) set the rate at 7%. The benchmark calibration here will aim for a steady state unemployment rate of 10%. The cost of job vacancies is set to $\gamma = 0.125$.¹² The elasticity in the labor matching function, ϵ , is set to 0.6, which below the value of 0.72 used in Shimer (2005) but well within the range of values identified by Petrongolo and Pissarides(2001) in their survey of the matching function. The bargaining weight of the household in the wage negotiation, η , is set to 0.5. This mid-point is chosen to strike a balance between the extremes advocated in Hagedorn and Manovskii (2005) and Shimer (2005).¹³ The quarterly rate of job separation is set to 6%, in line with the evidence presented in Davis, Faberman and Haltiwanger (2006).

The benchmark calibration results in an average job finding rate of 0.54 and a replacement rate b/w of 0.81. It is well known that the properties of labor search models change dramatically as this ratio tends to unity, and setting a high value as advocated by Hagedorn and Manovskii (2005) has the unappealing implication that worker gain little utility from accepting a job (see

¹¹See Ramey (2008) for an extensive and detailed review of the model and its most common extensions xxxx.

¹²See Baron (1997) and Baron (1985) cited Ramey (2008).

¹³Reasons put forward by each author xxxx.

Mortensen and Nagypal, 2007).¹⁴ While there is no definitive value for the replacement rate, the present calibration tries to stay clear of such issues by straying closer to the value used in Elsby and Michaels (2007).

3.2 Steady state implications

As in Acemoglu (2001) and Wasmer and Weil (2004), the presence of credit frictions results in greater equilibrium unemployment. To see this, the two labor market equilibrium conditions (7) and (9) at a steady state, normalizing aggregate technology to 1, represented in Figure 1 in (W, θ) space, combined pin down as the equilibrium market tightness θ as

$$\gamma \left(\frac{r + \delta}{\chi} \theta^\epsilon + \eta \theta \right) = (1 - \eta) [1 - b].$$

In the presence of credit market imperfections, the labour market equilibrium is determined by the wage rule (8) and job creation condition (5), represented by the dashed lines in Figure 1. Combining these two condition the labor market tension is pinned down as¹⁵

$$\gamma \left(\frac{\phi(r + \delta) \tilde{\theta}^\epsilon}{\chi(1 + \Omega(\bar{x}))\omega} + \eta \tilde{\theta} \phi \right) = (1 - \eta) [1 - b]$$

While the effect on the equilibrium wage is ambiguous, equilibrium market tension is unambiguously lower in the presence of credit frictions.

3.3 Dynamic results

Several authors have noted the failure of the Mortensen-Pissarides framework to generate sufficient internal propagation of exogenous shocks to match key labor market statistics. Table 1 reports the Hodrick-Prescott filtered standard deviation relative to aggregate output of variables central

¹⁴Hagerdorn and Manovskii (2005) reconcile the standard search model with key labor market statistics by employing an elevated value of the replacement rate of 0.96. Rotemberg (2006) chooses a value of 0.9, while Elsby and Michaels (2007) set the rate at a lower 0.86.

¹⁵Note that the calibration here is based on identical parameter values as opposed to aiming for a target value of the unemployment rate, as is the case for the dynamic evaluation. proceeds by choosing the same parameters, implying different steady state v-u ratios. In other words, we instead calibrate on an observed unemployment rate letting the value of non-market activities, b , adjust accordingly.

Figure 1: Equilibrium wages and labor market tension.

to the labor market, along with their contemporaneous correlation with the cyclical component of aggregate output. The first columns set the performance of the standard labor search model against moments from U.S. data and highlight its shortcomings. The relative volatility of vacancies generated by the standard model is only 40% of that in the data. The performance in terms of unemployment or employment is hardly any better: the model generates a relative standard deviation for unemployment of 1.46 against a relative standard deviation of 6.82 in the data, or just 20% of the relative volatility observed in the data. The dismal performance of the model extends to the measure of labor market tension, which has a relative volatility of 15.41 in the data and 4.61 for the standard model.

Table 1: Unconditional 2nd moments

1977:1-2005:4	U.S. data		Labor search		Labor search credit friction	
Variable:	a	b	a	b	a	b
V	8.82	0.89	3.78	0.93	9.89	0.97
θ	15.41	0.89	4.61	0.99	13.35	0.97
U	6.82	-0.84	1.46	-0.74	4.50	-0.79
N	0.48	0.82	0.16	0.74	0.50	0.79
$\sigma(y)$	1.59		1.05		1.38	
$corr(\Delta y, \Delta y_{-1})$	0.264		0.11		0.25	
$corr(\Delta y, \Delta y_{-2})$	0.227		0.04		0.28	
$corr(\Delta y, \Delta y_{-3})$	0.057		0.01		0.20	

a: Standard deviation relative to output; b: contemporaneous correlation with output.

All moments, but output growth, are Hodrick-Prescott filtered; Data sources: BLS, BEA.

3.3.1 Vacancies and labor market tension

We begin by examining, in Figure (2), the dynamic response of vacancies and the job finding rate to a persistent expansionary innovation a standard model (dashed line) and the proposed model with credit frictions (solid line). The introduction of credit frictions yields two improvements on the standard model: first, the response is largely amplified, second, the response is persistent, or the adjustment to the exogenous innovation is "sluggish". As can be observed in both panels of Figure (2) the response of vacancies in the proposed mode is large, hump shaped. Whereas the initial response is similar for both models, vacancies peak several quarters after the shock in the model with credit frictions, and the same observation holds for the job finding rate. The unconditional second moments for the proposed model, presented in the last columns of Table 1, show that in fact the relative volatility of vacancies is now perhaps slightly too large, at 9.89 versus 8.82 in the data. We will return to this point in an extension to the model. The labor market tension generated, is also remarkably close to its empirical counterpart with a relative volatility of 13.35, compared to 15.41 in the data.

Figure 2: IRFs to an expansionary technological innovation.

The source of both the amplification and the sluggish response of vacancies and the job finding rate lay in the accumulation of liquidity, relaxing the external financing constraint progressively. Figure (3) plots first the response of the multiplier on the credit constraint, then the response of the wage for both models to a positive technology shock. While the constraints is relaxed on impact, the slow accumulation of net worth pushes the constraint to its lowest several periods after the shock. The effect on the job creation condition to post vacancies is strongest therefore several periods after the shock. On the other hand, the wage does not respond as strongly as in the standard model on impact, increasing progressively. This has two effects: first, the limited initial response increases the incentive to post vacancies; second, the progressive increase counters some of the relaxing in the financing constraint for job creation.

Figure 3: IRFs to an expansionary technological innovation.

The large propagation potential of financial frictions results is a standard deviation of output

of 1.38, whereas the volatility of output in the standard model extends barely beyond the impulse provided by the exogenous process. Through the accumulation of liquidity and its effect on external financing constraints, the model is also characterized by a high degree of persistence in output growth. As can be seen in Figure 4, the initial response of output is similar in both models (by construction) the peak in output takes more time to reach and is greater in the model with financial frictions. The last rows of Table 1 report the autocorrelation of output growth observed in the data and generated by both models. While the standard model can generate some positive autocorrelation in output growth a one quarter lag, it falls short of the persistence at the second and third lags seen in the data. The model with credit frictions greatly improves the performance at the first and second lags, but generates too much persistence at the third lag.

Figure 4: IRFs to an expansionary technological innovation.

3.3.2 Beveridge curve and cross-correlations

The second aspect of labor market properties concerns the contemporaneous cross-correlations of key variables, the results for which are presented in Table 2. One concern for extensions to the standard framework is the violation of a robust empirical observation of a strong negative correlation between unemployment and vacancies, or the Beveridge curve. In this respects the proposed model is again an improvement on the standard models, with a correlation of -0.68, half way in between the correlation in the data, -0.89, and the correlation generated by the standard model, -0.45.

The data are also characterized by a very strong negative correlation between the unemployment rate and the measure of labor market tension with a contemporaneous correlation of -0.97. The standard model generates a somewhat weak correlation -0.68. The presence of credit friction

improves along this dimension as well, bringing the correlation closer to the data at -0.84. By extension, the proposed model also improves on the correlation between the unemployment and job finding rates.

Another significant improvement of the proposed model is to reduce the correlation between unemployment and labor productivity, almost perfectly replicating a correlation of -0.42 in the data. This correlation is too strong in the standard labor search model, which generates a correlation of -0.65. Both models fall short, however, of being consistent with the correlations between labor productivity and vacancies or the measure of labor market tension. These have a mild positive correlation in the data, around 0.4, whereas both models generate very high positive correlations.

Table 2: Labor market cross-correlations

U.S. data			Labor search			Labor search - Credit friction			Labor search - Credit friction and endogenous separation		
U	V	θ	$q(\theta)$	Y/N	U	V	θ	$q(\theta)$	Y/N	U	V
U	1.00	-0.89	-0.97	-0.95	-0.41	1.00	-0.45	-0.68	-0.68	-0.84	-0.84
V	-	1	0.98	0.90	0.36	-	1	0.96	0.97	0.97	0.91
θ	-	-	1	0.95	0.40	-	-	1	0.99	1	0.85
$q(\theta)$	-	-	-	1	0.40	-	-	-	1	0.85	-
Y/N	-	-	-	-	1	-	-	-	1	-	-

All moments, but output growth, are Hodrick-Prescott filtered; Data sources: BLS, BEA.

Table 3: Robustness - baseline model with credit friction and exogenous labor separations

	Premium						$\frac{A}{\gamma V}$			γ			ϵ			U		
	0.5%		2%		2/3		0.2		0.1		0.25		0.5		0.75		0.07	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
U	3.17	-0.70	5.04	-0.83	2.95	-0.66	5.23	-0.86	5.99	-0.88	3.55	-0.75	5.36	-0.83	3.03	-0.71	5.30	-0.77
V	6.95	0.99	11.21	0.93	6.39	0.98	11.76	0.93	13.18	0.92	7.80	0.97	8.76	0.89	12.05	0.99	10.04	0.97
θ	9.39	0.97	4.62	0.99	8.70	0.95	15.65	0.98	17.78	0.98	10.53	0.96	12.72	0.96	14.45	0.97	14.48	0.95
$\sigma(y)$	1.18		1.51		1.14		1.61		1.81		1.22		1.55		1.17		1.27	

a. Standard deviation relative to output; b. contemporaneous correlation with output.

All moments, but output growth, are Hodrick-Prescott filtered; Data sources: BLS, BEA.

3.4 Sensitivity analysis

This section examines the sensitivity of the main results along the dimensions of credit and labor market imperfections. With results presented in Table 3, we look at the effects of calibrating on a different external finance premium and liquidity to vacancy costs ratio first, then look at the impact of variations in the unit cost of vacancies, the elasticity of the matching function with respect to unemployment and to different steady state unemployment rates.

Calibrating to a lower premium on external finance, as the first column of Table 3 shows, markedly reduces the volatility of vacancy postings, and thus the volatility of employment and aggregate output. The inverse is observed when the premium on external finance is raised. Changing the liquid assets to vacancy cost ratio has a similar impact, although it operates mainly by changing the elasticity of liquidity to aggregate shocks, thereby playing on the external financing constraint over time.

The dynamic properties of all labor search models are very sensitive to the value of unit search costs γ . Increasing its value from 0.125 to 0.25 reduces the standard deviation of output from 1.38 to 1.22, while reducing the value of γ to 0.1 increases the standard deviation of output to 1.81. With regards to the moments of concern here, changes in the unit cost also significantly affect relative volatilities of labor market variable. For example, the relative volatility of vacancies ranges from 7.80 to 13.18 with the choices for γ .

The elasticity of the matching function with respect to unemployment plays a large role in translating movements in the labor market tension into new jobs. Increasing the elasticity with respect to vacancies, i.e. reducing the elasticity with respect to unemployment, greatly increases the response of the model to exogenous innovations. For example, decreasing ϵ from 0.6 to 0.5 increase the standard deviation of output to 1.55 and the relative volatility of unemployment to 5.36. On the other hand, the relative volatilities of vacancies and θ decrease.

Finally, raising the target steady state rate of unemployment, while increase the volatility of aggregate output, has only a minor downward impact on the relative volatilities of vacancies, unemployment and the v-u ratio. The converse is true for a reduction in the target steady state rate of unemployment.

4 Extension to endogenous labor separation

(TO BE COMPLETED)

The previous section assumed that all labor separation occurred at a constant, exogenous rate. There is a large body of evidence to the effect that a significant portion of separations are cyclical, and in particular are countercyclical. We briefly review the importance of time varying separation rates and how these may relate to financial constraints before extending the model to allow for the endogenous separation of labor.

4.1 Empirical motivation

Separation of labor and physical capital from firms can occur, of course, for many different reasons. One of these reasons are credit constraints that require firms to sell assets, reorganize or even declare bankruptcy. While there is convincing evidence that financial distress is counter-cyclical, it is difficult to evaluate its effects on labor and capital separations.¹⁶ To glean a better idea we use the information contained in the Bankruptcy Research Database (BRD) to quantify the importance and behavior of separations at financially distressed firms.¹⁷

There is evidence that more financially constrained firms engage in stronger employment contractions during periods of financial distress. Using size as a proxy for access to credit markets, as in Gertler and Gilchrist (1994), the slowdown and contraction in employment growth at small firms is more pronounced than at larger, presumably less credit constrained, firms. A more direct measure of financial constraint is the firm's credit rating which dictates the terms of external financing. As the second panel of Figure 5 shows, the contraction in employment at firms with a lower credit rating is much more severe. Following this evidence, the model is extended to allow for job separations to be influenced by the tightness of financial constraints. Unfortunately this information cannot distinguish changes in employment due to a hiring freeze or a rise in job separations, due to layoffs or quits, as only information on the number of employees is provided.¹⁸

¹⁶As evidence to the first point, Covas and Den Haan (2006) document that in the U.S., default rates for corporate bonds peak at the end of recessions. The H.-P. filtered contemporaneous correlation of default rates with real GDP is -0.33 for the period 1971-2004.

¹⁷This database, compiled by Lynn PoLucky at UCLA, contains information on every large public firm in the United States having filed for bankruptcy since October 1979. See Petrosky-Nadeau (2008) for details.

¹⁸Indeed, it may be that current employees, observing private information concerning the productivity of the firm before outsiders, begin to search for other jobs on the current job. On the importance of job-to-job transitions see,

Figure 5: Employment growth during financial distress - by size and credit rating.

Nonetheless, the work of Davis, Faberman and Haltiwanger (2006) indicates that an overwhelming majority of the change in employment at contracting firms is due to separations. Moreover, these same authors find that layoffs are the dominant source of separations during contractions greater than 15% of employment, and play an equal role in minor contraction as quits. This lends support to the notion that firms lay off workers to avoid bankruptcy procedures rather than sell physical capital.

4.2 Extension to endogenous job separation

Assume that each job within a firm draws an i.i.d., productivity z , with $z \in [0, \infty($ with cdf $H(z)$, pdf $h(z)$ and $E(z) = 1$, and that this job productivity is observed by both the worker and the firm. Firms and individual workers negotiate a wage conditional on the productivity of the job, $W(z)$, and, as determined further below, a job drawing productivity $z < \bar{z}$ is not profitable and is terminated. As a result expected net revenues are $\int_{\bar{z}}^{\infty} (zX - W(z)) dH(z) \tilde{N}$, where $\tilde{N} = \int_{\bar{z}}^{\infty} N dH(z)$, and total job separation is $\delta = \delta^x + \int_0^{\bar{z}} dH(z)$. This extension leaves the expected gross shares of net revenue unchanged, and the optimal contract for this problem is now:

$$\begin{aligned}
 J(N_t) &= \max_{V_t, \bar{x}_t, \bar{z}_t} [1 - \Gamma(\bar{x}_t)] \int_{\bar{z}_t}^{\infty} (zX_t - W_t(z)) dH(z) \tilde{N}_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J(N_{t+1}) \\
 &\text{subject to } [\Gamma(\bar{x}_t) - \mu G(\bar{x})] \int_{\bar{z}_t}^{\infty} (zX_t - W_t(z)) dH(z) \tilde{N}_t = (\gamma V_t - A_t) \\
 N_{t+1} &= (1 - \delta_t) N_t + V_t p(\theta_t) \\
 \tilde{N}_t &= \int_{\bar{z}_t}^{\infty} N_t dH(z)
 \end{aligned}$$

for example, Fallick and Fleischmann (2004), Nagypal (2004) or Faberman and Nagypal (2007).

and the evolution of assets is given by $A_{t+1} = \varsigma [1 - \Gamma(\bar{x}_t)] \int_{\bar{z}_t}^{\infty} (zX_t - W_t(z)) dH(z) \tilde{N}_t$. The optimality conditions for vacancy postings and the monitoring threshold retain the same form as earlier. The job destruction threshold will be determined by to optimality condition

$$(\bar{z}_t) : [1 - \Gamma(\bar{x}_t) + \phi_t [\Gamma(\bar{x}_t) - \mu G(\bar{x}_t)]] [-\bar{z}_t X_t + W_t(\bar{z}_t)] - \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_N(N_{t+1}) = 0$$

Using the same notation as earlier, $\Omega(\bar{x}_t) = \phi_t [\Gamma(\bar{x}_t) - \mu G(\bar{x}_t)] - \Gamma(\bar{x}_t)$, the separation condition can be expressed as

$$W_t(\bar{z}_t) = \bar{z}_t X_t + \frac{\gamma \phi_t}{p(\theta_t) [1 + \Omega(\bar{x}_t)]}, \quad (10)$$

noting that in the limit $\lim_{\bar{x}_t \rightarrow 0} \Phi(\bar{x}_t, \bar{z}_t) = 0$ and $\lim_{\bar{x}_t \rightarrow 0} \phi_t = 1$, this condition collapses to the familiar

$$\bar{z}_t X_t + \frac{\gamma}{p(\theta_t)} = W_t(\bar{z}_t).$$

in which the value of marginal worker separated equals his wage cost. XXXX

Closing the extension to endogenous job separation, the intertemporal vacancy condition is now

$$\frac{\gamma \phi_t}{p(\theta_t)} = \frac{1}{1 + r_t} E_t \left[[1 + \Omega(\bar{x}_{t+1})] \int_{\bar{z}_{t+1}}^{\infty} (zX_{t+1} - W_{t+1}(z)) dH(z) + (1 - \delta_{t+1}) \frac{\gamma \phi_{t+1}}{p(\theta_{t+1})} \right] \quad (11)$$

and the negotiated wage:

$$W_t(z) = \eta \omega_t [(1 + \Omega(\bar{x}_t)) zX_t + \gamma \theta_t \phi_t] + (1 - \eta) \omega_t b \quad (12)$$

4.3 Quantitative results

(TO BE COMPLETED)

The idiosyncratic shock z is assumed to follow a log-normal distribution with mean $E(z) = 1$; i.e. $\log(z) \sim N(-\frac{\sigma_{\log(z)}^2}{2}, \sigma_{\log(z)}^2)$. The steady state endogenous job separation rate set to 0.03, or 1/2 of total separations, which is in-line with evidence on the rate of layoffs in Davis, Faberman and Haltiwanger (2006) mentioned earlier.

The effects of introducing endogenous labor separation are immediately apparent in the impulse response presented in Figure ???. With endogenous separation plotted with the solid line, and exogenous separation represented by the circled line, countercyclical separation amplifies the

response of employment and output, while the responses of vacancies and the job finding hazard remain similar.

As a result (see Table 4), the relative volatility of vacancies in the model with endogenous separation is lower than is the model with exogenous separation and, importantly, is in line with the value of its empirical counterpart. This is because the countercyclical separation rate, by increasing employment at the firm rapidly following an expansionary innovation, decreases the marginal value of an additional job vacancy, thereby reducing the response of vacancies during upturn.

Table 4: Unconditional 2nd moments

Variable:	U.S. data		Labor search - Credit friction			
			Exogenous δ		Endogenous δ	
	a	b	a	b	a	b
V	8.82	0.89	9.89	0.96		
θ	15.41	0.89	13.35	0.97		
U	6.82	-0.84	4.50	-0.79		
N	0.48	0.82	0.50	0.79		
δ	3.34	-0.86	-	-		
$\sigma(y)$	1.59		1.38			

a: Standard deviation relative to output; b: contemporaneous correlation with output.

All moments, but output growth, are Hodrick-Prescott filtered; Data sources: BLS, BEA.

5 Conclusion

TO BE COMPLETED

This paper introduced a financial friction in the funding of current job vacancy costs in an otherwise standard labor search model to investigate the potential for propagating exogenous shocks. Counter-cyclical constraints on external finance are found to greatly increase the volatility of vacancies and unemployment through a powerful financial accelerator. An extension to endogenous labor separation furthers the propagation properties of credit market imperfections while remain-

ing consistent with labor market statistics of interest such as the Beveridge curve, or the negative correlation between unemployment and vacancies.

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