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Unemployment and Vacancy Dynamics with Imperfect Financial Markets *

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Abstract

This paper proposes a simple general equilibrium model with labour market frictions and an imperfect financial market. The aim of the paper is to analyse the transitional dynamics of unemployment and vacancies when financial constraints are in place. We model the financial sector as a monopolistically competitive banking sector that intermediates financial capital between firms. This structure implies a per period financial resource constraint which has a closed form solution and describes the transition path of unemployment and vacancies to their steady state values. We show that the transition path crucially depends on the degree of wage flexibility. When wages do not depend on the unemployment rate the transition path is always downward sloping. This implies unemployment and vacancies adjust in opposite directions as observed in the data. When calibrating the model to the Great Recession and its aftermath we find that the lack of an improvement in the financial sector's effectiveness to intermediate resources played a crucial role in the slow recovery of the labour market.

Keywords: Job search, unemployment, financial markets.
JEL: J63, J64, G10.

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1 Introduction

The Great Recession has highlighted the importance financial markets can have on the performance of the labour market. Most countries that were affected by the 2007/2008 financial crisis saw a burst of layoffs that made their unemployment rates increase dramatically and stay stubbornly high during the recovery period. Since the financial crisis particularly affected the ability of firms to expand and create new vacancies due to the lack of available investment funds, it has been argued that the credit crunch played an important role in slowing down the recovery of unemployment. In this paper we investigate to what extent the adjustment of unemployment and vacancies depends on the effectiveness of financial markets to intermediate resources.

We construct a simple general equilibrium model with labour market frictions and an imperfect financial market. Our focus is to analyse the transitional dynamics of unemployment and vacancies in response to unexpected job displacement and financial shocks. We are particularly interested in assessing the effects of these shocks on unemployment and vacancies when financial constraints are in place.

Our framework extends the canonical search and matching model (as described in Pissarides, 2000) by adding a monopolistically competitive banking sector that firms must visit in order to finance job creation. Once jobs are filled and firms become productive, they service their debts over time until the job is exogenously destroyed. This simple structure implies that at any point in time firms flow profits must be used to cover the cost of posting vacancies. The resulting per period financial resource constraint is the key element of our analysis. It shows that the number of vacancies is positively related to firms' flow profits. Since in the search and matching framework, the latter is directly related to the level of unemployment, the resource constraint then describes the relation unemployment and vacancies must satisfy to guarantee equilibrium in the banking sector.[1] Furthermore, this constraint has a closed form solution and describes the transition or saddle path of the economy towards its steady state.

These features allow us to characterise the out-of-steady-state dynamics of our model. In particular, we are able to characterise how the out-of-steady-state dynamics of unemployment and vacancies depend on unexpected changes to the variables of interest. A decrease in labour productivity or in the productivity of the banking sector, for example, shifts the transition path downwards and decreases the rate at which unemployment and vacancies adjustment towards the new steady state. Changes in the rate at which employed workers become unemployed or changes in the parameters governing the matching technology generate movements along the transition path without affecting the rate at which unemployment and vacancies adjustment towards the new steady state.

We show that the dynamics of unemployment and vacancies along the transition path crucially depends on the degree to which labour market tightness and, in particular, the unemployment rate affects wages. When firms and workers Nash bargain over the expected match surplus (as is traditionally assumed), wages depend on unemployment because agents' outside options

[1] Benmelech, Bergman and Seru (2012) document, using data for the US and Japan, a negative relation between firms' cash flows and employment as well as a negative relation between the extent of credit availability to firms and local unemployment rates.

and disagreement payoffs equal their respective values of search. In this case unemployment and vacancies adjust following a non-monotonic relationship. For low levels of unemployment and vacancies, they both adjust in the same direction. For larger values they adjust in opposite directions. The resource constraint implies that as unemployment increases the number of productive firms decreases, reducing the available funds for job creation and generating a negative relation between unemployment and vacancies. However, the non-monotonicity arises due to the feedback effect of the job finding rate on wages and ultimately profits. An increase in unemployment reduces workers' outside options and increases firms' flow profits, which in turn implies there are more funds per productive firms to finance vacancies, generating a positive relation between unemployment and vacancies. At low levels of unemployment and vacancies the latter force dominates, while for larger values the former force dominates. As wages become less dependent on the unemployment rate due to some form of wage rigidity, this feedback effect diminishes.[2] We show that when there is no interaction between unemployment and wages, such as when firms and workers Nash bargain over the *flow* surplus (see Marcusee, 2016), one always obtains a negative relation between unemployment and vacancies along the transition path.

Being able to generate such an adjustment process is important as a main feature of the canonical search and matching model, as described in Pissarides (2000), is that unemployment and vacancies always adjust in the same direction along the transition path. Blanchard and Diamond (1989) document, however, that unemployment and vacancies adjust in opposite directions after a shock to output or to the rate at which workers and firms separate. Furthermore, Shimer (2005) and many others have shown that when the canonical search and matching model is calibrated to the US, shocks to the job destruction rate generate a counterfactual positive correlation between unemployment and vacancies. Given that we are able to solve for the transition path in closed form, we provide an analytical characterisation of how unexpected changes to aggregate output, the job destruction rate or to banking sector parameters affect the rate by which unemployment and vacancies adjust between steady states.

In the quantitative section of the paper we analyse whether the out-of-steady-state dynamics implied by our model can replicate the observed dynamics of the unemployment and vacancy rate in the US economy for the period 2007-2014. Through the lenses of our model, we interpret a sequence of observed unemployment and vacancy points as movements along a saddle path towards a new steady state. We first calibrate the model to match the transition of the unemployment and vacancy rates from the beginning to the end of the Great Recession. We then explore changes in vacancy costs, the rate of job destruction and in the parameters governing the financial sector that can account for the observed unemployment and vacancy dynamics during the recovery period. We find that the calibration favours wages that are isolated from the unemployment rate. This property delivers a downward sloping transition path that replicates the observed sequence of unemployment and vacancy points very well. The main message of this exercise is that the observed slow recovery in the labour market was due to the lack of a

[2]In the sequential bargaining protocol proposed by Hall and Milgrom (2008), for example, outside options are still described by the agents' values of search but are no longer equal to their disagreement payoffs. In this case, unemployment affects wages through the risk of negotiation breakdown, which in Hall and Milgroms' (2008) calibration, drastically reduces the effects of unemployment on wages.

significant improvement in the effectiveness of the banking sector in intermediating resources to fund job creation.

Our approach to model the banking sector using a monopolistic competitive structure is consistent with the evidence presented by Bikker and Haaf (2002). These authors evaluate the degree of competition and concentration of the banking sector in 23 OECD countries, including the US, for the period 1988 to 1998. They find that across all these countries the banking sector can be best characterised by monopolistic competition. Kadir et al. (2015) show that our approach to model the banking sector is also in accordance with the vast majority of studies that evaluate the degree of competition and concentration of the banking sector across developed and developing economies.[3] Gerali et al. (2010) and La Croce and Rossi (2015) followed this approach and embed a monopolistic competitive banking sector into a dynamic general equilibrium framework. They, however, assume a perfectly competitive labour market and hence cannot explore the interaction between imperfect competition in the banking sector and search frictions in the labour market.

Recently a large body of work has appeared which studies the interaction between financial and labour market frictions. To be best of our knowledge, none of these studies formulates the banking sector using a monopolisticaly competitive market structure. For example, Carlstrom and Fuerst (1997), Chugh (2013) and Petrosky-Nadeau (2014), among many others, assume a competitive financial market where frictions arise due to costly state verification. In this environment, the current (idiosyncratic) state of the firm (the borrower) is private information to the firm, but the lender can learn it by paying a verification cost. Firms and lenders sign one-period debt contracts that specify the size of the loan and a liquidation threshold. Jermann and Quadrini (2012), Garin (2015) and Buera et al. (2015), among others, use a somewhat related approach and assume frictions arise because the ability of firms to borrow is limited by an enforcement constraint which is subject to random shocks. Wasmer and Weil (2004) and Petrosky-Nadeau and Wasmer (2013) propose an alternative approach and model the financial market as a frictional market govern by a meeting function that brings together lenders and vacant firms, taking the interest rate as given.

Most of the aforementioned papers also develop their theories in the context of a dynamic stochastic general equilibrium environment or in the context of a stochastic version of the search and matching model (see Andolfatto, 1996, and Shimer, 2005, among others). Instead we propose a model without aggregate uncertainty (as in Pissarides, 2000). In our model the evolution of unemployment and vacancies is studied after an unexpected shock to aggregate variables using the out-of-steady-state dynamics implied by our model, characterised by the transition path between steady states. In reality the dynamics of unemployment and vacancies are probably driven by a combination of a sequence of random shocks and movements along a transition path that shifts when these shocks get realised. Our parsimonious approach allows us to solve and explore the model's mechanism analytically. We emphasize the resource constraint, imposed by the financial sector, as an important determinant of the relationship between unemployment

[3]Kadir et al. (2015, Table 1) present an extensive list of studies that find that across developed and developing countries the banking sector can be characterised by monopolistic competition.

and vacancies in an economy's adjustment process.

The rest of the paper is outlined as follows. In the next section we present the search and matching model that describes the aggregate labour market and the monopolistically competitive banking model that describes the financial sector. In Section 3 we characterise the equilibrium and discuss the steady state and out-of-steady-state dynamics. Here we analyse the main implications of the financial resource constraint on the transition path of vacancies and unemployment and show how parameters governing the financial market affect this transition path. Section 4 presents the calibration procedure and describes its main results. Section 5 concludes discussing briefly the main results of the paper. All proofs and tedious derivations are relegated to a technical Appendix.

2 The Model

2.1 Basic framework

The labour market setup follows Pissarides (2000, ch.1). Since our objective is to understand the transitional dynamics of the economy we consider out-of-steady-state analysis. Time is continuous with infinite horizon. There is a unit mass of workers and a mass of firms. Both agents discount the future at a potentially time-dependent interest rate $r(t)$. Workers can be either employed or unemployed. Unemployed workers receive constant benefits z per unit of time. An employed worker receives a wage rate of $w(t)$ per unit of time. Each firm has only one job that can be either vacant or filled. A filled job generates a constant flow of output $p > z$. A firm with a vacant job pays a cost measured in terms of productivity units of $k > 0$ per unit of time. Jobs are destroyed at an exogenous Poisson rate $s > 0$. Once destroyed, the firm's job becomes vacant and the worker becomes unemployed.

Agents must search for each other to find a match. The search process is sequential and random and we assume that only vacancies and unemployed workers search. Meetings are governed by a meeting or "matching function" $m\left(u\left(t\right),v\left(t\right)\right)$ which gives the number of meetings that take place per unit time as a function of the number of unemployed workers $u\left(t\right)$ and the number of vacancies $v\left(t\right)$. Assume that $m\left(.\right)$ is increasing and concave in both arguments and exhibits constant returns to scale. Let $\theta\left(t\right)\equiv v\left(t\right)/u\left(t\right)$ denote the labour market tightness. Constant returns to scale then imply that the job filling rate is given by $q(\theta(t))\equiv m\left(u(t),v(t)\right)/v(t)$, while the job finding rate is then $\lambda\left(\theta(t)\right)=\theta(t)q\left(\theta(t)\right)$. These rates govern the Poisson processes by which agents meet in this labour market.

2.2 Bellman equations for workers and firms

Workers and firms are risk neutral. The workers' objective is to maximise the expected present value of their lifetime income $E_0\int_0^\infty e^{-\int_0^s r(s)ds}y(t)dt$ with flow income $y(t)=\{z,w(t)\}$. Let U denote the expected value of an unemployed worker and let W denote the expected value of a worker employed at some net wage w. Dynamic programming arguments imply that the following U and W satisfy the Hamilton-Jacobi-Bellman equations

$$r(t)U(t) = z + \dot{U}(t) + \lambda(\theta(t))[W(t) - U(t)], \tag{1}$$

$$r(t)W(t) = w(t) + \dot{W}(t) + s[U(t) - W(t)]. \tag{2}$$

The firm's flow profit from a filled job is

$$\pi(t) = p - w(t). \tag{3}$$

An unfilled job yields a flow profit of $-k$ with $k > 0$. Firms are infinitely lived and their objective is to maximise the expected present value of total profits $E_0 \int_0^\infty e^{-\int_0^s r(s)ds} \varpi(t)dt$ with flow profits $\varpi(t) = \{-k, \pi(t)\}$. Let V denote the expected value of holding a job vacant. Let J denote the expected value of a filled job paying w. We then obtain the corresponding Hamilton-Jacobi-Bellman equations by dynamic programming arguments,

$$r(t)V(t) = -k + \dot{V}(t) + q(\theta(t))[J(t) - V(t)], \tag{4}$$

$$r(t)J(t) = \pi(t) + \dot{J}(t) + s[V(t) - J(t)]. \tag{5}$$

The interpretation of the above equations is identical to the canonical search and matching model model only that discounting takes place at an endogenous interest rate $r(t)$.

2.3 Free entry and wage determination

For a given tightness and wage rate, the number of vacancies is determined by a free entry condition. As long as the value V of opening a vacancy is positive, firms will create vacancies and enter the labour market. Firms will stop entering only when there are no more (intertemporal) profits to be made; i.e. $V = 0$. Using the Bellman equation (4), we obtain that

$$J(t) = \frac{k}{q(\theta(t))}. \tag{6}$$

When an unemployed worker and a vacant firm meet, $p > z$ insures that they immediately form a productive match. It has been standard to use the generalised Nash bargaining solution as a way to determine wages. In this case, it is typically assumed that the worker's and firm's outside options and disagreement payoffs are the same and given by $U(t)$ and $V(t)$, respectively. This protocol implies agents receive a constant fraction of the expected match surplus and yields a fully flexible wage that is a linear function of p, z and θ. On the other extreme, Hall (2005) proposed an alternative wage determination mechanism motivated by his observation that wages do not seem to behave as spot wages in the data. He uses a Nash demand game in which wages are fixed within the bargaining set. In this setup, wages are not renegotiated until they lie outside the bargaining set and hence prevent inefficient separations.

Other wage determination mechanisms that lie somewhere in between the above two cases have also been studied in the literature. In particular, the sequential bargaining protocol proposed by Hall and Milgrom (2008) generates a form of wage rigidity by partially isolating wages from the influence of θ. The crucial aspect of their bargaining protocol is that agents' disagreement payoffs are no longer equal to agents' outside options, $U(t)$ and $V(t)$. The disagreement payoffs are independent of θ and agents' receive their outside options only when negotiations break down, which happens with some probability every period.[4]

In this paper we follow an agnostic approach to wage determination and use the following relation:

$$w(t) = (1-\beta)\, z + \beta \left[p + \tau\theta(t)k \right]. \tag{7}$$

In this wage equation β is the worker's exogenous bargaining power standard in the Nash bargaining protocol. The crucial parameter, however, is $\tau \in [0,1]$ which determines the extend to which θ affects wages. When $\tau = 1$, for example, we are back to the well known Nash bargaining solution of the canonical search and matching framework. When $\tau \in (0,1)$ we have an outcome that partially isolates the wage from the influences of labour market tightness. This case captures, in reduced form, the *spirit* of Hall and Milgrom's (2008) wage determination protocol. When $\tau = 0$ the outcome is the same as the one obtained when workers and firms Nash bargain over the *flow* surplus, $p - z$. In this case, wages are fully isolated from the influence of labour market tightness.[5]

The main reason for the choice of the functional form presented in equation (7) is that we are interested in understanding the role wage rigidity plays in the interaction between the financial and labour markets. Equation (7) presents a specification that allows us to do this in a simple and tractable way. In the quantitative section we recover τ and β from our calibration procedure.

2.4 Equilibrium without a financial sector

Given a time-dependent interest rate, equilibrium can then be described by the evolution of the unemployment rate $\dot{u}(t)$ and the evolution of labour market tightness $\dot{\theta}(t)$. Inflows to unemployment amount to $s\left[1-u(t)\right]$, while $\lambda(\theta(t))\, u(t)$ unemployed individuals find a job at each instant. For a path of labour market tightness, the unemployment rate $u(t)$ in this economy evolves over time according to

$$\dot{u}(t) = s\left[1-u(t)\right] - \lambda\left(\theta(t)\right) u(t). \tag{8}$$

The evolution of labour market tightness can be determined by the value of a filled vacancy (6) and by an equation describing its evolution over time. After some steps (see app. A.1), we

[4] See also the staggered wage setting protocol proposed by Gertler and Trigari (2006) as another example of a wage determination protocol that delivers wage rigidity.

[5] Marcusse (2016) argues that Nash bargaining over the flow surplus can be thought of as a similar bargaining protocol as that of Hall and Milgroms' (2008) under the conditions that offers arrive instantaneously and there is no risk of negotiation breakdown during bargaining. Mortensen and Nagypal (2007) also argue that one can obtain the wage equation $w = z + 0.5(p-z)$ as the solution to a symmetric sequential bargaining game under the assumption that a worker obtains flow utility z and the firm a zero flow payoff while bargaining continues and that agents negotiate over p.

obtain a differential equation describing the evolution of labour market tightness

$$\dot{\theta}(t) = \left[\frac{q(\theta(t))}{q'(\theta(t))}\right] \left[\frac{(1-\beta)}{k}(p-z)\, q(\theta(t)) - r(t) - s - \tau\beta\lambda(\theta(t))\right]. \tag{9}$$

Equations (8) and (9) determine the paths of $u(t)$ and $\theta(t)$ as a function of $r(t)$.

2.5 The financial sector

We now close our matching model by including a financial sector. We consider a banking sector that is the only source for financing the vacancy costs and to which all profits of productive firms flow. In this environment, a potential market entrant that wants to finance a vacancy must visit a bank and ask for a flow of resources allowing to cover the vacancy costs k to be paid at each point in time until a worker is found. In order to get these resources, the firm needs to sign a contract that says that the entrant commits to repay the bank by the flow of profits it makes once the vacancy is filled and until the next separation takes place. The bank bears all the risk and diversifies across all entrants and productive firms such that the bank behaves as if the world was deterministic.

Suppose that the banking sector consists of $n(t)$ different types of banks offering each one single banking service i at any time t. Banks operate under monopolistic competition. Financial services are aggregated to one big "financing package for opening a vacancy" by a technology of the Dixit-Stiglitz type

$$Y(t) = \left[\int_0^{n(t)} x(i,t)^{\gamma}\, di\right]^{1/\gamma}, \tag{10}$$

where $x(i,t)$ is the amount of services provided by bank i at time t and $\gamma \in (0,1)$ determines the degree of substitution between financial services. The elasticity of substitution between financial services is then given by $(1-\gamma)^{-1}$.

Banking service i is produced by the technology

$$x(i,t) = by(i,t) - \phi, \tag{11}$$

where b is a productivity parameter, $y(i,t)$ is the input of the final good produced and consumed in this economy and ϕ describes the fixed costs to be paid by monopolistic competitors. Just as with vacancy costs, fixed costs in the banking sector are measured in units of the output good.

Service providers maximise profits by choosing output $x(i,t)$ optimally at each point in time. As all firms use the same technology, service provision will be symmetric and the usual steps (see app. A.2.1) imply aggregate output of the banking sector (10) amounts to

$$Y(t) = n(t)^{1/\gamma} x(t) = n(t)^{1/\gamma}\left[b\frac{\pi(t)\,[1-u(t)]}{n(t)} - \phi\right]. \tag{12}$$

A crucial assumption here is that we require that all resources available for financing vacancies must actually be used for financing vacancies. Resources must not be lost or allowed to enter the model. Making such a market-clearing assumption for the banking sector implies that the aggregate banking output (12) equals the total cost of financing vacancies. The latter is given by the cost k per vacancy times the number of vacancies, $\theta(t)u(t)$, such that

$$n(t)^{1/\gamma}\left[b\frac{\pi(t)[1-u(t)]}{n(t)}-\phi\right]=k\theta(t)u(t). \tag{13}$$

Economically speaking, market clearing for financial services (13) determines the number of vacancies $v(t)$. Technically, as vacancies are already determined in (9), this additional market fixes the endogenous interest rate $r(t)$.

While the resource constraint described in (13) makes sure that resources used for financing vacancies can only come from profits made by firms, it does not guarantee that there are no resources left unused. As monopolistic service providers make a profit, this profit needs to go somewhere. It can actually not be ruled out at this point that firms would even make negative profits, given that there are fixed costs ϕ to be paid per period. To guarantee that all resources supplied by firms making a profit are used either for covering fixed costs for the provision of services or for financing vacancies, we apply the standard assumption here as well and assume that there is free entry into and exit from the banking sector. This implies (see app. A.2.1) that the number of services is given by

$$n(t)=(1-\gamma)b\frac{\pi(t)[1-u(t)]}{\phi}. \tag{14}$$

Substituting (14) into (13) and some algebra (see app. A.2.1) establishes that

$$\frac{\theta(t)^{\gamma}}{(1-\beta)\frac{p-z}{k}-\tau\beta\theta(t)}=b\left[(1-\gamma)\frac{k}{\phi}\right]^{1-\gamma}\frac{1-u(t)}{u^{\gamma}(t)}\gamma^{\gamma}. \tag{15}$$

Equation (15) describes the resource constraint that is consistent with free entry in the banking sector. Under this specification, all profits made by firms are used for financing vacancies and all costs of vacancies are financed by firms' profits. Profits made by banks are used to pay their fixed costs. This makes sure that the financial market is in equilibrium, no resources leave or enter the model and we have specified a general equilibrium matching model.

3 General Equilibrium

Equations (8) and (9) provide the basis to understand the goods and labour markets dynamics by describing $\dot{u}$ and $\dot{\theta}$. Equation (15) describes equilibrium in the financial market. These three equations simultaneously solve for $u(t)$, $\theta(t)$ and $r(t)$. Before we describe the out-of-steady-state dynamics of this system, we analyse its steady state.

3.1 Zero-motion lines and steady state

From equation (8) we obtain that the zero-motion line for u is given by

$$\lambda(\theta)=s\frac{1-u}{u}\Leftrightarrow u=\frac{s}{s+\lambda(\theta)}, \tag{16}$$

which describes a negative relationship between u and θ. The zero-motion line for θ is implicitly given, from (9), by

$$(1-\beta)\,\frac{p-z}{k}q(\theta)-s-r\,(t)-\tau\beta\lambda(\theta)=0. \tag{17}$$

What is special about this zero-motion line is that the interest rate is a function of time which means that the zero-motion line shifts in the $(u-\theta)$ space. What is standard is that the zero-motion line for θ is not a function of u, i.e. it is horizontal in the $(u-\theta)$ space.

In standard descriptions of phase diagrams, the equilibrium path is to be inferred from the zero-motion lines and laws of motions subsequently. In our system, however, the equilibrium path towards the steady state is described in closed-form by (15). Using the latter equation it is easy to verify that θ falls with u: The right-hand side unambiguously falls in u while the left-hand side rises in θ. Our general equilibrium matching model therefore provides an explicit expression for the transition path in terms of unemployment and vacancies, which we discuss below.

In a steady state, the unemployment rate, labour market tightness and the interest rate are constant. Denote their steady state values as u^*, θ^* and r^*. To show the existence of a steady state note from (16) that as u goes to zero, θ grows unboundedly; and while as u goes to one, θ goes to zero. From (15), however, we have that as u goes to zero, θ goes to $(1-\beta)(p-z)/\tau\beta k$; while as u goes to one, θ goes to zero. Hence these functions intersect at $u=1$ and $\theta=0$. Further, since these functions are continuous and decrease monotonically, they can intersect at most once at some $u\in(0,1)$ and $\theta\in(0,\infty)$. Given the steady state values of u and θ, the interest rate r then adjusts such that (17) holds. Since in the case in which $u=1$ and $\theta=0$ (17) implies r is undetermined, in what follows we focus on characterising the transition dynamics towards the interior steady state, (u^*,θ^*,r^*), given that one exists.

In app. A.3 we provide a sufficient condition under which a unique interior steady state exists for any CRS matching function. Further, we show that under a Cobb-Douglas matching function $M(u,v)=Au^{\alpha}v^{1-\alpha}$, the parametric restriction $\gamma+\alpha\geq 1$ is sufficient (but not necessary) to guarantee existence of an interior steady state equilibrium. In the quantitative section of the paper we show that a unique interior steady state always exists in our calibration.

3.2 Transitional dynamics

An insightful way to analyse the transition path described in (15) is to consider it in Beveridge space; i.e. $v-u$ space. It is well documented that unemployment and vacancies move in opposite directions. Blanchard and Diamond (1989) and, more recently, Shimer (2005) and Sniekers (2016) show that unemployment and vacancies move in opposite directions during the adjustment process of the US economy; and similar results have been obtained for European countries (see Elsby et al., 2013). It is of interest to understand the conditions under which the interaction between the labour market and the financial sector, as modelled in this paper, has the potential to generate such a negative relation.

Re-writing equation (15) in $v-u$ space, we obtain that the sign of the slope of the transition path is determined by (see app. A.4)

$$sign\left[\frac{dv}{du}\right] = sign\left[\frac{\partial \pi}{\partial u}(1-u) - \pi\right].$$

To understand this condition, note that equation (13) implies that aggregate firm profits and the number of vacancies must move in the same direction along the equilibrium path. Aggregate firms' profits, however, depend positively on (i) the number of jobs filled and negatively on (ii) the wage paid to workers; and both are inversely related to the unemployment rate. The slope of the transition path then depends on how responsive are wages to changes in the unemployment rate.

Using the expression for $\partial\pi/\partial u$, we find that

$$\frac{dv}{du} < 0 \Leftrightarrow \tau < \tau^* \equiv \frac{u^2(1-\beta)(p-z)}{\beta k v}, \tag{18}$$

where τ^* describes the threshold value of our wage rigidity parameter such that when $\tau < \tau^*$ the transition path is downward sloping and when $\tau > \tau^*$ the transition path is upward sloping. Note that for values of $\tau \in (0, 1]$, the transition path is typically non-monotonic as τ^* changes with u and v satisfying (15).[6] When $\tau = 0$, however, this non-monotonicity disappears. In this case the feedback effect between unemployment and profits disappears, $\partial\pi/\partial u = 0$, and the transition path is downward sloping for all values of u and v.

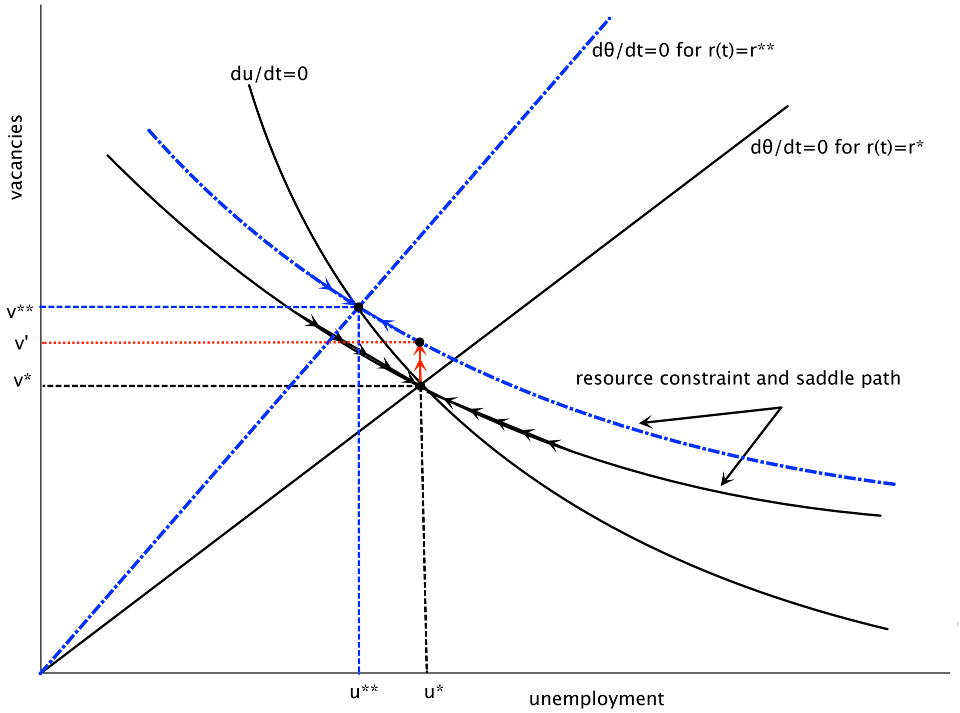
This feature incorporates an important dimension to the canonical search and matching model. In the latter, with a constant interest rate, the transition path towards the steady state is given by the zero-motion line for θ for any value of τ. This implies that during adjustment, vacancies and unemployment move in the same direction irrespectively of the degree of wage rigidity as modelled in (7). Here the above arguments imply that during adjustment vacancies and unemployment can move in *opposite* directions.

3.3 Changes in output and the job destruction rate

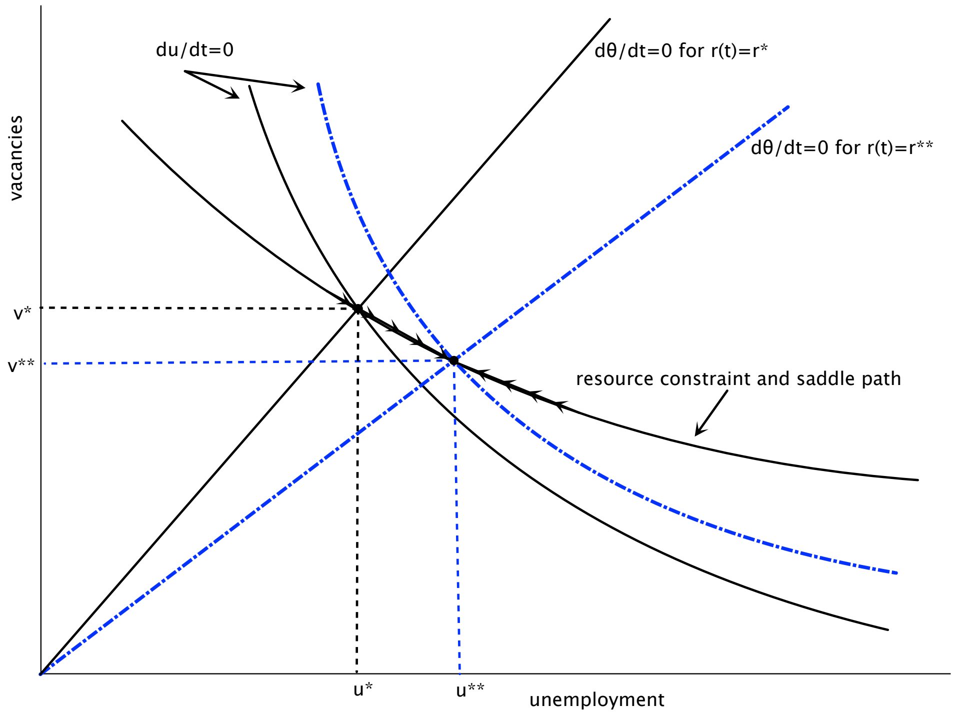
To illustrate this difference consider a one time unexpected increase in aggregate productivity p. Figure 1.a depicts this exercise in $v - u$ space assuming the existence of an interior steady state and a range of values for v and u within which the transition path is downward sloping. In this section we want to show the qualitative workings of the model under the latter conditions. In Section 4.3 we explore quantitatively how much insulation from θ is required to obtain a downward sloping transition path on the relevant range of values for v and u.

An increase in p generates in both models an upward rotation of the zero-motion line for θ. In our model, in addition, the resource constraint shifts outwards. In the figure, the new curves are depicted as dashed curves. The increase in p makes labour market tightness jump upwards as firms create new vacancies up to the point in which the economy is on the new transition path at the original unemployment rate. In our model the initial jump of vacancies (shown by the

[6] In all our numerical simulations we find that in this case the transitions path first increases and then decreases as we increase u.



(a) Increase in aggregate productivity



(b) Increase in the job destruction rate

Figure 1: Transitional dynamics after a one time unexpected shock to p and s

solid arrowed line from v^* to v') is smaller than in the canonical search and matching model as our transition path lies below the zero-motion line for θ, over the relevant range. Further, along this path the unemployment rate decreases, while the vacancy rate increases. These transitional dynamics then yield counter-clockwise movements of u and v and a new steady state that is characterised by a higher vacancy rate and a lower unemployment rate. These features are consistent with the evidence in Blanchard and Diamond (1989), who show that the counter-clockwise movements of u and v around the zero-motion line for u after a productivity shock involve these rates moving in opposite directions.

As a second example consider a one time unexpected increase in the job destruction rate, s. Figure 1.b shows this exercise. Here the difference between the two models is starker. After an increase in s, both models imply that the zero-motion line for u shifts to the right, while the zero-motion line for θ rotates downwards (in $v-u$ space). Once again, in the figure, these are depicted by the dashed curves. In the canonical model, however, v jumps downwards, while u stays constant immediately after impact. As the economy adjusts, both variables then increase along the new zero-motion line for θ until the new steady state is achieved. In our model, the transition path does not depend on s (see (15)), which implies that v does not jump. Instead v decreases and u increases smoothly along the transition path until the new steady state is achieved. Furthermore, an increase in the job destruction rate will always imply a new steady state with a lower vacancy rate and a higher unemployment rate, while in the canonical model the new steady state can be characterised by a higher vacancy and unemployment rates. These features are also consistent with the evidence presented in Blanchard and Diamond (1989) and Shimer (2005) on the effects of reallocations shocks on v and u.

Note also that in our model changes in the matching function parameters will have similar effects as changes in the job destruction rate, although in the opposite direction. For example, consider a Cobb-Douglas matching function, $M(u,v) = Au^{\alpha}v^{1-\alpha}$. Changes in A and α will shift the zero-motion line for unemployment along the transition path of the economy, generating different dynamics relative to the canonical model.

In addition since in our model changes in p affect both the position and the slope of the transition path, output affects the rate at which unemployment and vacancies adjust from one steady state to another. On the contrary, since the job destruction rate and the matching function parameters do not determine the transition path, the rate at which unemployment and vacancies adjustment along the transition path to the new steady state is independent of these variables.

3.4 Changes in the financial sector

We now consider how the market power of banks, measured by the price mark-up, $1/\gamma$, the productivity of each bank, b, and the fixed cost, ϕ, affect the transitional dynamics of this economy and the steady state equilibrium. For this purpose, re-write (15) in implicit form as

$$\Psi(\theta,u) \equiv \theta u - \frac{\gamma}{(1-\gamma)}\frac{\phi}{k}\left[\frac{b(1-\gamma)[(1-\beta)(p-z)-\tau\beta k\theta][1-u]}{\phi}\right]^{\frac{1}{\gamma}} = 0. \qquad (19)$$

Note that its slope is given by

$$\frac{d\theta}{du} = -\frac{n[\theta(1-\gamma)k(1-u) + \phi n^{\frac{1}{\gamma}}]}{k(1-\gamma)(1-u)[nu + n^{\frac{1}{\gamma}}\tau(1-u)b\beta]} < 0, \tag{20}$$

and recall that when $u = 0$, $\theta = (1-\beta)(p-z)/\tau\beta k$ and that when $u = 1$, $\theta = 0$. Therefore, since the intersections of Ψ with the axis are independent of γ, ϕ or b, to analyse the impact of these variables on the transition path it is sufficient to analyse their impact on (20).

First consider an increase in the banks' fixed cost. Differentiation of (20) with respect to ϕ implies that the transition path experiences a leftward expansion and becomes flatter for all values of u when $(1-\beta)(p-z)u > \tau\beta\theta k$. Note that this is the same condition required to guarantee a downward sloping transition path in Beveridge space. Since the zero-motion line for unemployment is independent of ϕ, in those cases in which the latter condition is satisfied, the new steady state unemployment rate increases, while labour market tightness decreases which, by virtue of (17), implies that the interest rate increases. Because the transition path becomes flatter, the rate at which unemployment and vacancies arrive to the new steady state decreases.

Now consider an increase in bank's productivity. Differentiation of (20) with respect to b implies that the transition path experiences a rightward expansion and becomes steeper for all values of u when $(p-z)(1-\beta)u > \tau\beta\theta k$. In these cases and given that the zero-motion line for unemployment is independent of b, the new steady state is characterised by a lower level of unemployment, a higher labour market tightness and, by virtue of (17), a lower interest rate. Furthermore, the rate at which unemployment and vacancies arrive to the new steady state increases.

Finally consider an increase in γ, such that the elasticity of substitution between financial products increases and banks' mark-ups decrease. In this case differentiation of (20) shows that there is an ambiguous impact of γ on the slope of the transition path. In app. A.5 we show conditions under which an increase in γ has the same effects as an increase in b, at least for the cases in which $\gamma \to 1$ and $\gamma \to 0$. We will turn to these comparative statics in more detail in the next section, where we quantitatively evaluate the model.

4 Quantitative Analysis

The objective of this section is to analyse whether the transition path implied by our model can replicate the dynamics of the unemployment and vacancy rates in the US economy for the period 2007-2014. To do so, we consider two sub-periods: (i) The Great Recession (November 2007 – August 2009) and (ii) the Recovery (September 2009 – December 2014). Through the lenses of our model, we interpret a sequence of (u, v) points within a given sub-period as movements along the transition path towards a new steady state. This section proceeds by calibrating the model to match the unemployment and vacancy dynamics during the Great Recession. That is, we calibrate the model to match the transition from the beginning of the Great Recession period to the end of the Great Recession. We then explore changes in vacancy costs and changes in the financial sector that can account for the observed unemployment and vacancy dynamics during the recovery period.

4.1 Parametrisation

The length of a period in the model is set to one month. We use information on the number of vacancies from the Job Openings and Labor Turnover Survey (JOLTS) and seasonally adjusted monthly series on the stock of employed, unemployed and short-term unemployed workers provided by the Bureau of Labor Statistics.[7] From these series we construct monthly series of job-finding-, unemployment- and vacancy rates (see Figures 5 to 7 in app. A.7).[8]

We use a Cobb-Douglas specification for the matching function, $M(u_t, v_t) = Au_t^{\alpha}v_t^{1-\alpha}$, which implies a job finding rate of $\lambda(\theta_t) = A\theta_t^{1-\alpha}$. The parameters A and α are then obtained from regressing the (log) job finding rates on a constant and (log) labour market tightness using data for the pre-crisis period December 2000 – October 2007. Given our estimates of A and α, we set the job destruction rate such that we match the steady-state unemployment rate u^* at the end of the Great Recession, i.e. $s = \frac{u^*\lambda(\theta^*)}{1-u^*}$. Furthermore we set the interest rate $r^* = 0.0027$ such that it corresponds to the (annual) bank prime loan rate of 3.25% at end of the Great Recession.[9]

After normalising the productivity parameters to unity, $p = b = 1$, we are then left with $\mathbf{x} = \{k, z, \beta, \tau, \phi, \gamma\}$ parameters to recover. For this we exploit the variation in the observed values of u and v during the Great Recession. In particular, we minimise the squared relative distance between the observed vacancy rates and the ones implied by our transition path taking the observed unemployment rates as given. That is, we choose

$$\mathbf{x} = \arg\min \sum_t \left(\frac{v_t - \hat{v}(\mathbf{x}; u_t)}{v_t}\right)^2 \quad \text{subject to (17) and } v^* = \hat{v}(\mathbf{x}; u^*), \tag{21}$$

where $\hat{v}(\mathbf{x}; u_t)$ denotes the vacancy rate that solves (15) given the vector of parameters $\mathbf{x}$ and the observed unemployment rate u_t. The first restriction is given by the zero-motion line for θ, while the second restriction requires that the transition path must go through the steady state (u^*,v^*) at the end of the Great Recession. In addition, we impose two further restrictions to pin down $\mathbf{x}$. First, we interpret z to represent unemployment benefits and set the replacement ratio to one half. Second, we follow Silva and Toledo (2007) and Petrosky-Nadeau and Wasmer (2013) and require that the total vacancy cost amount to 3.6% of the wage rate. In app. A.6 we present further details on the implementation of the optimisation problem.

Table 1 shows the parameter values obtained from our calibration procedure as well as the steady state targets. Note that the elasticity of the matching function is close to Shimer (2005) and Hall (2005). Also note that to generate a sufficiently downward sloping resource constraint,

[7] We use the BLS series LNS13000000, LNS13008396 and LNS12000000.

[8] Let U_t denote the number of unemployed in month t, and let U^s_{t+1} correspond to the number of short-term unemployed with unemployment durations of less than 5 weeks in month $t+1$. Following standard practice in the literature, the job-finding rate in month t is then given by $U2E_t$ = 1 - $(U_{t+1}$ - $U^s_{t+1})/U_t$. Similarly, the job-destruction rate in month t is given by $E2U_t = U^s_{t+1}/E_t$, where E_t denotes the number of employed workers in month t (see Figure 6 in app. A.7).

[9] The data on bank prime loan rates are taken from the online data base of the Federal Reserve Bank St. Louis: https://research.stlouisfed.org/fred2.

Table 1: Calibrated Parameters

Labour Market Parameters		Financial Sector Parameters		Steady state (8/2009)	
Matching efficiency A	0.430	Fixed costs financial sector ϕ	0.028	u^*	0.096
Elasticity of matching function α	0.709	Elasticity of substitution $\frac{1}{1-\gamma}$	1.097	θ^*	0.155
Vacancy cost k	2.320	Banks' productivity b	1.000	r^*	0.0027
Worker's bargaining weight β	0.919			s^*	0.027
Wage rigidity τ	9.12e-8			$\lambda(\theta^*)$	0.250
Unemployment benefits z	0.479				
Labour productivity p	1.000				

the calibration procedure yields a value of τ very close to zero. In Section 4.3, below, we discuss this result further. Further, since the calibration gives workers a high bargaining power, the implied wage equals to 0.96 similar to the one obtained by Hall (2005). Although the value of k seems high, this value is calculated as $v^*k = 0.036w = 0.0346$ and hence the low vacancy rate observed in August 2009 ($v^* = 0.015$) implies a $k = 2.32$. Also note that the value of the elasticity of substitution between financial services, $1/(1-\gamma) = 1.097$, implies that the banking sector in our calibration is far from competitive and enables banks to command high monopoly rents.

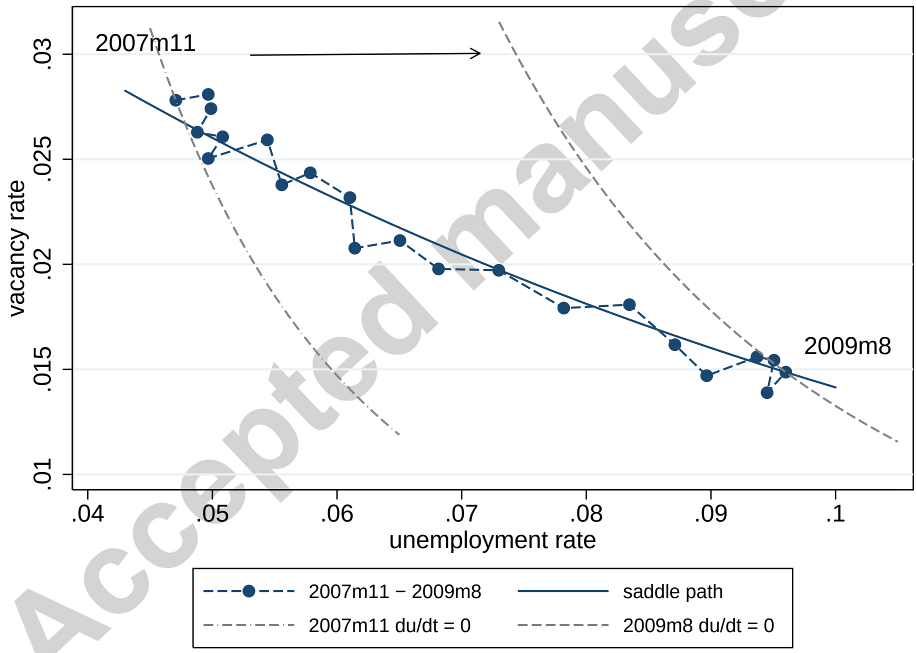


Figure 2: Unemployment and vacancy dynamics

Figure 2 shows the model implications for the observed unemployment and vacancy dynamics during the Great Recession. The dots depict the unemployment and vacancy rate pairs observed during this period, which moved from low unemployment-high vacancy rates to high unemployment-low vacancy rates. In November 2007, immediately before the crisis, the US economy experienced an unemployment rate of 4.7% and a labor market tightness of 0.59. We assume that this was the steady state of the economy before the Great Recession with a job destruction rate of 0.018 that is consistent with the observed unemployment rate at that time. As discussed by Elsby and Smith (2010), the Great Recession in the US was characterised by a sharp increase in the job destruction rate. In our model the increase in s shifts the zero-motion line of unemployment such that the post-crisis steady state implies a higher unemployment level. As one can observe from Figure 2, v decreased and u increased sharply during the Great Recession and our saddle-path tracks these movements closely. Given the unexpected nature of the financial crisis (see Caballero and Kurlat, 2009), Figure 2 can then be interpreted as the empirical counterpart to Figure 1.b shown in Section 3.3 when discussing the effects of an unexpected shock in s.

4.2 The recovery

During the period September 2009 – December 2014 the economy underwent a slow recovery, where the unemployment and vacancy rates slowly reverted to their pre-recession levels (see Figure 7 in app. A.7). We now analyse what change in the parameters p, k, γ, b are required to match the observed transition to the new steady state during the recovery.[10] This exercise informs us whether the model requires drastic changes to the parameters governing the financial sector to explain the transitional dynamics of unemployment and vacancies in the aftermath of the Great Recession. This exercise also informs us about the magnitude of the change the model requires in output per worker and vacancy costs to fuel firm entry and converge to the new steady state.

For this exercise we take the new steady state to be December 2014 (the end period of our window of observation). This steady state is characterised by $u^{**} = 0.058$, $\theta^{**} = 0.54$ and $r^{**} = 0.0027$. Since by December 2014 the job destruction rate decreased relative to August 2009 (see Figure 6 in app. A.7), the zero-motion line for the unemployment rate shifted to the left. As before, we set the job destruction rate such that we match the steady-state unemployment rate u^{**}, i.e. $s = \frac{u^{**}\lambda(\theta^{**})}{1-u^{**}} = 0.22$. We then calibrate $\{p, k, \gamma, b\}$ by solving the optimisation problem in (21) using data on vacancies and unemployment during the Recovery. All other parameters are held fixed. As before we require that the transition path goes through the steady state (u^{**}, v^{**}).

Figure 3 shows the model's implications for the observed unemployment and vacancy dynamics during the Recovery under this exercise. Relative to the Great Recession, the model's transition path shifted to the right with a slight upward rotation. However, note that the transition path during the Recovery period is still relatively flat, implying that the unemployment and vacancy rates converge slowly to the new steady state. The new values for the calibrated parameters are $p = 0.98$, $k = 1.08$, $b = 0.97$ and $\gamma = 0.078$, where the latter implies an elasticity of substitution between financial products of 1.085.

The first implication of this exercise is that, from the lenses of our model, the observed

[10] We keep the banks' fixed cost of entry, ϕ, constant in this exercise, as a joint minimisation with respect to b and ϕ exhibits many local minima. Further, holding ϕ constant is consistent with the evolution of the ratio between banks operational expenses and the employment in the financial sector as obtained from the OECD Banking Statistics: Financial Statements of Banks. This series shows basically no change during the period 2007-2014.

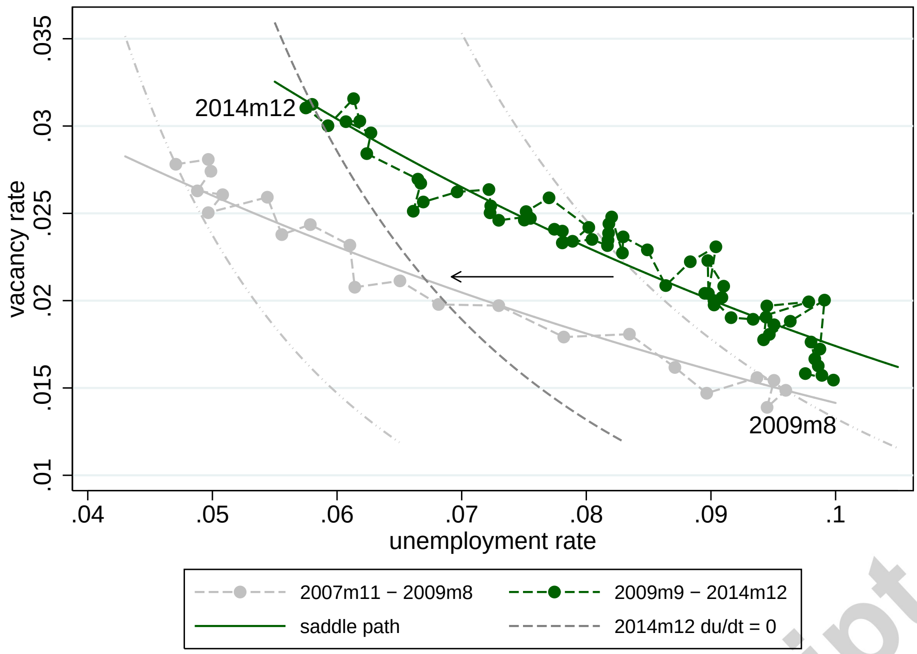


Figure 3: Unemployment and vacancy dynamics

recovery in the labour market during the 2010-2014 period was not due to improvements in the effectiveness of banks to intermediate financial resources, b, or due to an increase in the degree of competition among banks γ. When compared to the values in Table 1, the value of these parameters hardly changed. Indeed, b only dropped by 3 percentage points and the elasticity of substitution dropped by about one percentage point. Compared to the Great Recession period the number of banks in the financial sector decreased from $n_{GR} = 1.25$ to $n_R = 1.23$ and the aggregate output of banks remained unchanged $Y_{GR} = Y_R = 0.034$. This implication seems to have some support in the data. For example, Figure 8 in the app. A.7 shows that the money multiplier, a measure related to the productivity of banks, had a large drop during 2008 and then stayed essentially flat through the rest of the period.

The second implication of this exercise is that convergence to the new steady state was propelled by a lower vacancy cost and job destruction rate, which led to an increase in firm entry.[11] However, as opposed to the canonical search and matching model firm entry is not a jump variable. In our model job creation needs to be financed by the profit of existing firms using the banking sector to intermediate the financial resources. Given that the effectiveness of the banking sector to undertake such a task hardly changed during this period, the increase in firm entry developed slowly over time and hence produced a slow recovery in the unemployment and vacancy rates.

[11] As an alternative calibration we restricted the value of p to stay constant at one and obtained that $k = 1.13$, $\gamma = 0.078$ and $b = 0.93$, confirming that changes in p are of second order importance for our results.

4.3 The role of wage rigidity

Table 1 shows that to replicate the dynamics of unemployment and vacancies as observed during the Great Recession, the calibration requires workers and firms to be essentially (Nash) bargaining over the flow surplus, $p - z$, such that wages become nearly isolated from θ and hence u. Given that this form of wage rigidity is important to match the data, we now investigate how much isolation wages require in our calibrated model in order to guarantee a downward sloping transition path in the observed range of v and u values.

Figure 4 shows a collection of transition paths (dotted curves) generated by assuming different values of $\tau \in [0, 0.019]$, but maintaining the rest of the parameters at the values shown in Table 1. The higher transition path is obtained when $\tau = 0$, while the lowest transition path is obtained when $\tau = 0.019$. For $\tau > 0$, each transition path starts at the origin and slopes upwards until condition (18) is satisfied. At the implied inflexion point the transition paths become downward sloping. The solid line in Figure 4 trace the negative relation between the different values of τ and the inflexion points of the transition paths. The dash line shows the transition path generated by $\tau = 0.003$, the highest value of τ that guarantees a downward sloping transition path for all the observed values of the unemployment rate in our data, 4.7% to 10%. The main message from this exercise is that, holding constant the rest of the parameter values, our model requires wages to be quite strongly isolated from labour market tightness to be consistent with the observed negative relationship between unemployment and vacancies.[12]

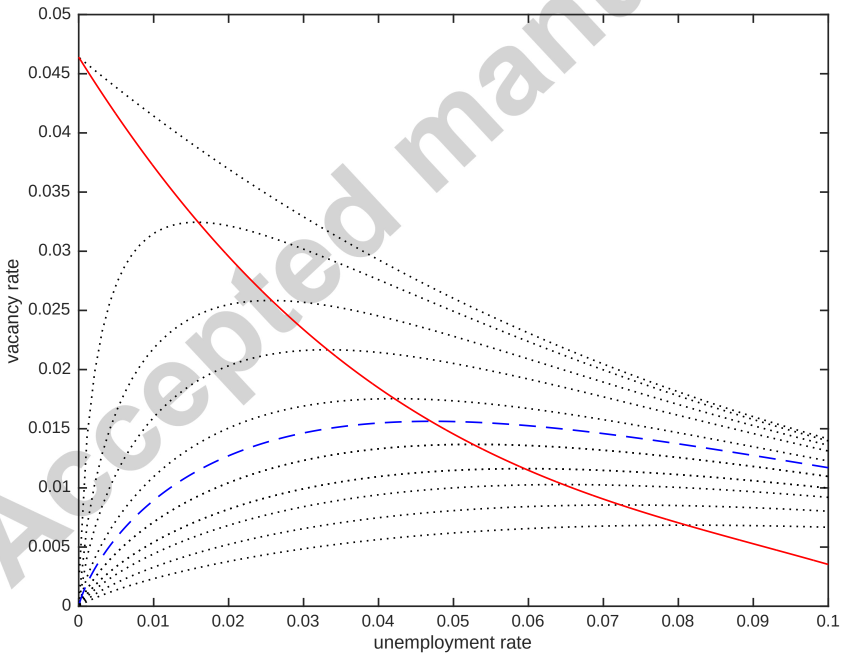


Figure 4: Transition path for different values of τ

The need for wages to be strongly isolated from θ in order to replicate the data is consistent with the finding of Marcusse (2016). In particular, this author analyses whether Nash bargaining

[12]The latter conclusion holds also in the presence of a larger difference between p and z, as in Shimer (2005), or with a lower value for workers' bargaining power, $\beta = 0.5$.

over flow surplus allows the canonical search and matching model to better explain the observed relationship between unemployment and vacancies in the US labour market relative to other forms of wage determination: Nash bargaining over the match surplus, Hall and Milgrom's (2008) sequential bargaining and Kalai and Smorodinski (1975) bargaining. Marcusse (2016) consistently finds that Nash bargaining over the flow surplus improves the ability of the canonical search and matching model in replicating the observed Beveridge curve under productivity (p) and job destruction (s) shocks. Here we obtain a similar result. In the presence of job destruction shocks, our model essentially requires workers and firms to Nash bargain over the flow surplus in order to replicate the negative co-movement of v and u observed in the data.[13]

Given this result, one could question whether it is necessary to have an imperfect financial market in order to generate a downward sloping transition path in the presence of a τ close to zero. Note that our banking sector market-clearing assumption implies that the resource constraint, equating aggregate banking output to total vacancy costs, must be satisfied at any point in time. Equation (13) describes such a resource constraint under monopolistic competition. Irrespective of the market structure imposed on the banking sector, however, the resource constraint will imply that aggregate banking output will be increasing in aggregate firm profits and total vacancy cost will be increasing in unemployment. This generates a relationship between v and u. As discussed in Section 3.2, the role of τ is to influence this relationship by isolating the impact of u on wages and ultimately on firms' profits. Therefore, it is possible to have a different market structure describing the banking sector and have a downward sloping transition path when τ is close to zero. In this paper we have assumed that the banking sector is characterised by monopolistic competition because this is inline with a large body of work that studies the observed degree of competition and concentration in the banking sector across countries and time periods (see Bikker and Haaf, 2002, Kadir et al., 2015, and the reference within). In turn, this structure allows us to study, in a parsimonious way, the rate at which our economy recovers from unexpected shocks to the productivity of and the degree of competition in the banking sector.

5 Conclusion

In this paper we have constructed a simple general equilibrium matching model with an imperfect financial market in the form a monopolistically competitive banking sector. The role of the financial sector is to fund job creation through the firms' profits. The critical element of our model is the per period financial resource constraint that determines the transitional dynamics of vacancies and unemployment towards the steady state. The resource constraint adds a new dimension to the canonical search and matching model. It makes it potentially consistent with the fact that vacancies and unemployment adjust in opposite directions. We show that this feature is readily obtained when wages are Nash bargained over the flow surplus, $p - z$. To illustrate some of the quantitative implications of our model we calibrated to match the transi-

[13] Hall and Milgrom (2008) also calibrate the risk of breakdown during bargaining to be 0.0055% a day, suggesting a need to strongly isolate wages from labour market tightness in order for their sequential bargaining model to replicate the data.

tional dynamics of the Great Recession and its aftermath. We find that observed slow recovery in the labour market was due to the lack of a significant improvement in the effectiveness of the banking sector in intermediating resources to fund job creation.

The model we developed is very parsimonious as our goal was to understand its main mechanism using analytical solutions, rather than numerical simulations. Clearly this comes at the cost of presenting a perhaps too simplistic model. In particular, an important assumption made here is that firms always required external funding to finance job creation. This assumption might be reasonable among small firms, but it is somewhat more difficult to defend among bigger firms with large internal financial reserves. Indeed it has been argued that some firms where not short of funds but where just reluctant to spend some of it to finance investment and hence job creation (see Monacelli et al., 2011). Adding this feature is an important extension to the model developed here. However, we leave this extension for future research.

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A Appendix

A.1 Deriving equation (9)

The equation describing the evolution of J over time results from (5) with $V = 0$,

$$\dot{J}(t) = [r(t) + s] J(t) - \pi(t).$$

With profits and the wage being substituted out from the profit equation (3) and wage equation (7), i.e. with

$$\begin{aligned} \pi(t) &= p - w(t) = p - ((1-\beta) z + \beta [p + \tau\theta(t)k]) \\ &= (1-\beta)(p-z) - \beta\tau\theta(t) k \end{aligned} \tag{22}$$

we get

$$\dot{J}(t) = [r(t) + s] J(t) - (1-\beta)[p-z] + \tau\beta\theta(t)k. \tag{23}$$

Using (6) to compute $\dot{J}(t) = -\frac{k}{q(\theta(t))^2} q'(\theta(t))\dot{\theta}(t)$ and substitute $J(t) = \frac{k}{q(\theta(t))}$ into (23), we find (9).

A.2 The financial sector

In this section we derive in more detail the financial sector assuming that the banking sector is described by a monopolistically competitive industry.

A.2.1 Monopolistic Competition

A service provider i maximizes

$$\pi_s(i,t) = \hat{p}(i,t)\, x(i,t) - c(x(i,t)).$$

Given the parameter γ, this implies mark-up pricing of

$$\hat{p}(i,t) = \frac{c'(x(i,t))}{\gamma}. \tag{24}$$

We now consider the costs of providing $x(i,t)$. Given the technology (11), $x(i,t) = by(i,t) - \phi$, the cost to produce output $x(i,t)$ is given by

$$c(x(i,t)) = y(i,t)$$

where $y(i,t)$ is the input of the final good whose price is normalized to one. The cost function therefore reads

$$c(x(i,t)) = \frac{\phi + x(i,t)}{b}.$$

From (24), this implies that the price $\hat{p}(i,t)$ of one unit of service is given by the usual mark-up pricing rule

$$\hat{p}\left(i,t\right)=\frac{b^{-1}}{\gamma}. \tag{25}$$

Marginal costs to provide one unit of $x\left(i,t\right)$ are given by the price of the output good (which we normalized to one) divided by the productivity parameter b from (11). The mark-up $1/\gamma$ is determined by the price-elasticity of demand for services $x\left(i,t\right)$ implied by (10).

Profits can therefore be computed to amount to

$$\pi_s(i,t)=\hat{p}(i,t)x(i,t)-\frac{\phi+x(i,t)}{b}=\hat{p}(i,t)x(i,t)-\frac{\hat{p}(i,t)\gamma}{b^{-1}}\frac{\phi+x}{b},$$

where the last equality used (25). Hence,

$$\pi_s(i,t)=\hat{p}(i,t)x(i,t)-\hat{p}(i,t)\gamma\phi-\hat{p}(i,t)\gamma x(i,t)=\hat{p}(i,t)\left[\left(1-\gamma\right)x(i,t)-\gamma\phi\right].$$

As all firms use the same technology, the banking sector is symmetric and input per banking service is given by

$$y\left(i,t\right)=y\left(t\right)=\frac{\pi(t)\left[1-u(t)\right]}{n\left(t\right)}. \tag{26}$$

The second equality shows that the input is given by total real profits of active firms divided by the number of banking services. Note that the second equality is the first crucial component of our general equilibrium setup. Resources available at each point in time are given by real profits $\pi\left(t\right)$ per active firm times the number of active firms, which is given by the number of employed workers $1-u\left(t\right)$. Equation (11) then implies that output per service provider is given by

$$x\left(t\right)=by\left(t\right)-\phi=b\frac{\pi(t)\left[1-u(t)\right]}{n\left(t\right)}-\phi. \tag{27}$$

Given symmetry and (27), we obtain (12) in the text.

The number of banks Monopolistic service providers i choose output $x\left(t\right)$ such that profits are maximized.[14] This yields markup pricing (25) and implies flow profits per service provider are given by $\pi_s\left(t\right)=\hat{p}\left(t\right)\left[\left(1-\gamma\right)x\left(t\right)-\gamma\phi\right]$. After substituting output x from (27) in $\pi_s\left(t\right)=\hat{p}\left(t\right)\left[\left(1-\gamma\right)x\left(t\right)-\gamma\phi\right]$, we obtain

$$\begin{aligned}\pi_s\left(t\right)&=\hat{p}\left(t\right)\left[\left(1-\gamma\right)\left(b\frac{\pi(t)\left[1-u(t)\right]}{n\left(t\right)}-\phi\right)-\gamma\phi\right]\\&=\hat{p}\left(t\right)\left[\left(1-\gamma\right)b\frac{\pi(t)\left[1-u(t)\right]}{n\left(t\right)}-\left(1-\gamma\right)\phi-\gamma\phi\right]\\&=\hat{p}\left(t\right)\left[\left(1-\gamma\right)b\frac{\pi(t)\left[1-u(t)\right]}{n\left(t\right)}-\phi\right].\end{aligned}$$

Given free-entry of banks, profits $\pi_s\left(t\right)$ are driven to zero and we get (14).

[14] We suppress the provider index i as (27) has established symmetry.

Deriving the resource constraint (15) Noting that $b\frac{\pi(t)[1-u(t)]}{n(t)} = \frac{\phi}{1-\gamma}$ and $\frac{\phi}{1-\gamma} - \phi = \frac{\gamma}{1-\gamma}\phi$, the resource constraint (13) can be re-written as

$$\left[(1-\gamma)\, b\frac{\pi(t)\,[1-u(t)]}{\phi}\right]^{1/\gamma} \frac{\gamma}{1-\gamma}\phi = k\theta\,(t)\, u\,(t)\,. \tag{28}$$

Using (3) and (7) to substitute out for profits and wages yields (22). Substituting this into (28) yields

$$\begin{aligned}
\left[(1-\gamma)\, b\frac{((1-\beta)\,(p-z)-\beta\tau\theta\,(t)\,k)\,[1-u(t)]}{\phi}\right]^{1/\gamma} \frac{\gamma}{1-\gamma}\phi &= k\theta\,(t)\,u\,(t) \Leftrightarrow \\
\left[(1-\gamma)\, b\frac{k}{\phi}\left((1-\beta)\,\frac{p-z}{k}-\beta\tau\theta\,(t)\right)[1-u(t)]\right]^{1/\gamma}\gamma &= (1-\gamma)\,\frac{k}{\phi}\theta\,(t)\,u\,(t) \Leftrightarrow \\
(1-\gamma)\, b\frac{k}{\phi}\left((1-\beta)\,\frac{p-z}{k}-\beta\tau\theta\,(t)\right)[1-u(t)]\,\gamma^{\gamma} &= \left((1-\gamma)\,\frac{k}{\phi}\right)^{\gamma}\theta^{\gamma}\,(t)\,u^{\gamma}\,(t) \Leftrightarrow \\
b\left[(1-\gamma)\,\frac{k}{\phi}\right]^{1-\gamma}\left((1-\beta)\,\frac{p-z}{k}-\beta\tau\theta\,(t)\right)[1-u(t)]\,\gamma^{\gamma} &= \theta^{\gamma}\,(t)\,u^{\gamma}\,(t) \Leftrightarrow \\
b\left[(1-\gamma)\,\frac{k}{\phi}\right]^{1-\gamma}\frac{1-u(t)}{u^{\gamma}\,(t)}\gamma^{\gamma} &= \frac{\theta^{\gamma}\,(t)}{(1-\beta)\,\frac{p-z}{k}-\beta\tau\theta\,(t)}.
\end{aligned}$$

The last expression is (15).

A.3 Existence of an interior steady state

We characterise conditions under which a unique interior steady state exists. To do so we analyse how does the equilibrium path (15) behaves with respect to labour market tightness after substituting out for unemployment using (16). Let the left-hand side of (15) by described by

$$T_1(\theta) = \frac{\theta}{[(1-\beta)(p-z)-\tau\beta k\theta]^{1/\gamma}}. \tag{29}$$

Similarly, substituting out for u using (16), the right-hand side of (15) can be described by

$$T_2(\theta) = C\frac{(s+\lambda(\theta))}{s}\Big[\frac{\lambda(\theta)}{s+\lambda(\theta)}\Big]^{\frac{1}{\gamma}}, \tag{30}$$

where

$$C = \frac{\gamma}{(1-\gamma)^{-\frac{1-\gamma}{\gamma}}}\frac{\phi^{-\frac{1-\gamma}{\gamma}}}{k}b^{\frac{1}{\gamma}} \tag{31}$$

describes a constant. Note that both T_1 and T_2 take the value of zero when $\theta = 0$.

Differentiation of T_1 and T_2 with respect to θ implies that both functions are increasing in θ.

$$\frac{dT_1}{d\theta} = \frac{1}{\gamma}\Big[\frac{\gamma(1-\beta)(p-z)+\theta\tau\beta k(1-\gamma)}{[(1-\beta)(p-z)-\tau\beta k\theta]^{\frac{1-\gamma}{\gamma}}}\Big] > 0,$$

$$\frac{dT_2}{d\theta} = \frac{C\lambda'(\theta)}{s}\Big(\frac{\lambda(\theta)}{s+\lambda(\theta)}\Big)^{\frac{1}{\gamma}}\Big[1+\frac{s}{\gamma\lambda(\theta)}\Big] > 0.$$

Further differentiation implies that $d^2T_1/d\theta^2 > 0$, while

$$\frac{d^2T_2}{d\theta^2} = \frac{C}{s}\Big(\frac{\lambda(\theta)}{s+\lambda(\theta)}\Big)^{\frac{1}{\gamma}}\frac{1}{(\lambda(\theta)\gamma)^2}\Big[\lambda''(\theta)\lambda(\theta)\gamma(\lambda(\theta)\gamma+s)+\frac{\lambda'^2s^2}{s+\lambda(\theta)}(1-\gamma)\Big].$$

The sign of $d^2T_2/d\theta^2$ is then determined by the sign of the term in squared brackets. Note that the first term inside the squared brackets is negative (as the job finding rate is concave in θ), while the second term is positive. Given $d^2T_2/d\theta^2 < 0$ for all θ, continuity of T_1 and T_2 imply that in this case there exists a unique interior steady state equilibrium. If $d^2T_2/d\theta^2 > 0$ or non-monotone, we could also have multiple interior steady state equilibria or no equilibria at all.

Given that in the quantitative section of the paper we focus on a Cobb-Douglas matching function, $M(u,v) = Au^\alpha v^{1-\alpha}$, it is instructive to analyse the conditions for existence under such a parametrisation. Noting that under this matching function the job finding rate and its derivatives are given by: $\lambda(\theta) = A\theta^{1-\alpha}$, $\lambda'(\theta) = (1-\alpha)A\theta^{-\alpha}$ and $\lambda''(\theta) = -\alpha(1-\alpha)A\theta^{-(1+\alpha)}$, the term in the squared bracket in the above expression for $d^2T_2/d\theta^2$ is given by

$$-\frac{A^2\theta^{-2\alpha}(1-\alpha)}{s+A\theta^{(1-\alpha)}}\Big[s^2(\gamma-(1-\alpha))+\alpha\gamma A\theta^{(1-\alpha)}[s(1+\gamma)+A\theta^{(1-\alpha)}\gamma]\Big].$$

Inspection shows that $\gamma+\alpha \geq 1$ provides a sufficient (but not necessary) condition for $d^2T_2/d\theta^2 < 0$ and hence for existence of a unique interior steady state equilibrium.

A.4 The slope of the resource constraint

A.4.1 Preliminaries

Re-writing equation (15) in $v-u$ space using an implicit formulation yields

$$G(v,u) \equiv v - \frac{\gamma\phi}{(1-\gamma)k}\Big[\frac{(1-\gamma)b[(1-\beta)(p-z)-\tau\beta k\frac{v}{u}][1-u]}{\phi}\Big]^{\frac{1}{\gamma}} = 0. \tag{32}$$

It follows from (32) that when all workers are unemployed, $u = 1$, there are no vacancies $v = 0$. In this case no firm is producing and hence firms profits are zero implying that there are no available funds to pay for vacancies.

Now consider the slope of $G(v,u)$. Note that the resource constraint shows that aggregate firms' profits and the number of vacancies must move in the same direction along the equilibrium path. Aggregate firms' profits, however, depend positively on (i) the number of jobs filled and negatively on (ii) the wage paid to workers; and both are inversely related to the unemployment rate. The slope of $G(v,u)$ then depends on how responsive are wages to changes in the unemployment rate. Employing the implicit function theorem, we obtain (see app. A.4.2)

$$\frac{dv}{du} = \frac{\partial n}{\partial u}\left[\left[\frac{\gamma\phi n^{\frac{1}{\gamma}}}{(1-\gamma)k}\left(\frac{1}{\gamma n}\right)\right]^{-1} + \frac{(1-\gamma)b\tau\beta k(1-u)}{u\phi}\right]^{-1},$$

where the slope of the equilibrium path in Beveridge space is determined by

$$sign\left[\frac{\partial n}{\partial u}\right] = sign\left[\frac{\partial \pi}{\partial u}(1-u) - \pi\right], \tag{33}$$

which in turn depends on how the unemployment rate affects firms flow profits via wages.

A.4.2 Total differentiation of $G(v,u)$

Total differentiation of $G(v,u)$ implies $\frac{dv}{du} = -\frac{\frac{\partial G(v,u)}{\partial u}}{\frac{\partial G(v,u)}{\partial v}}$. Originally, equation (32) reads

$$G(v,u) \equiv v - \frac{\gamma\phi}{(1-\gamma)k}\left[\frac{(1-\gamma)b[(1-\beta)(p-z) - \tau\beta k\frac{v}{u}][1-u]}{\phi}\right]^{\frac{1}{\gamma}}.$$

As from (14) and (22),

$$n = \frac{(1-\gamma)b[(1-\beta)(p-z) - \tau\beta k\frac{v}{u}][1-u]}{\phi}, \tag{34}$$

we can express it more compactly as

$$G(v,u) = v - \frac{\gamma\phi}{(1-\gamma)\,k}n^{\frac{1}{\gamma}} = 0.$$

It follows that

$$\begin{aligned}
\frac{\partial G(v,u)}{\partial u} &= -\left[\frac{\gamma\phi}{(1-\gamma)\,k}\frac{n^{\frac{1}{\gamma}}}{\gamma n}\frac{\partial n}{\partial u}\right] = -\frac{\partial n}{\partial u}\left[\frac{\gamma\phi n^{\frac{1}{\gamma}}}{(1-\gamma)\,k}\frac{1}{\gamma n}\right] \\
\frac{\partial G(v,u)}{\partial v} &= 1 - \frac{\partial n}{\partial v}\left[\frac{\gamma\phi n^{\frac{1}{\gamma}}}{(1-\gamma)\,k}\frac{1}{\gamma n}\right].
\end{aligned}$$

Thus

$$\frac{dv}{du} = -\frac{-\frac{\partial n}{\partial u}\left[\frac{\gamma\phi n^{\frac{1}{\gamma}}}{(1-\gamma)k}\frac{1}{\gamma n}\right]}{1-\frac{\partial n}{\partial v}\left[\frac{\gamma\phi n^{\frac{1}{\gamma}}}{(1-\gamma)k}\frac{1}{\gamma n}\right]} = \frac{\frac{\partial n}{\partial u}}{\left[\frac{\gamma\phi n^{\frac{1}{\gamma}}}{(1-\gamma)k}\frac{1}{\gamma n}\right]^{-1} - \frac{\partial n}{\partial v}} = \frac{\partial n}{\partial u}\left[\left[\frac{\gamma\phi n^{\frac{1}{\gamma}}}{(1-\gamma)\,k}\left[\frac{1}{\gamma n}\right]\right]^{-1} - \frac{\partial n}{\partial v}\right]^{-1}.$$

Note that from (34)

$$\frac{\partial n}{\partial v} = -\frac{(1-\gamma)\,b\tau\beta k\,(1-u)}{\phi u},$$

so that

$$\frac{dv}{du} = \frac{\partial n}{\partial u}\left[\left[\frac{\gamma\phi n^{\frac{1}{\gamma}}}{(1-\gamma)\,k}\left[\frac{1}{\gamma n}\right]\right]^{-1} + \frac{(1-\gamma)\,b\tau\beta k\,(1-u)}{\phi u}\right].$$

A.4.3 The slope of $G(v,u)$

The resource constraint is falling by (33) iff

$$\frac{dv}{du} < 0 \Leftrightarrow sign\left[\frac{\partial \pi}{\partial u}(1-u) - \pi\right] < 0.$$

As $\partial\pi/\partial u = \beta\tau v k/u^2 > 0$ from (22), this holds iff, using (22),

$$\begin{aligned}\frac{\beta\tau v k}{u^2}(1-u) - \pi \quad &< \quad 0 \Leftrightarrow \frac{\beta\tau v k}{u^2}(1-u) < \pi \Leftrightarrow \frac{\beta\tau v k}{u^2}(1-u) < (1-\beta)(p-z) - \beta\tau\theta k \\ &\Leftrightarrow \quad \beta\tau\frac{v}{u}\frac{1-u}{u} < (1-\beta)\frac{p-z}{k} - \beta\tau\frac{v}{u} \Leftrightarrow \frac{\beta\tau v}{u^2} < (1-\beta)\frac{p-z}{k} \\ &\Leftrightarrow \quad \tau < \frac{1-\beta}{\beta v}\frac{p-z}{k}u^2.\end{aligned}$$

A.5 Comparative statics for the slope of Ψ

We want to analyse how changes in ϕ and b affect $d\theta/du$, the slope of Ψ, as described in (20). To do this let

$$\Psi_1 = -n[\theta(1-\gamma)k(1-u) + \phi n^{\frac{1}{\gamma}}],$$
$$\Psi_2 = k(1-\gamma)(1-u)[nu + n^{\frac{1}{\gamma}}(1-u)\tau b\beta].$$

Changes in ϕ

Noting that $dn/d\phi = -n/\phi$, we have that

$$\frac{\partial \Psi_1}{\partial \phi} = \frac{n}{\phi\gamma}\left[\theta(1-\gamma)k(1-u)\gamma + \phi n^{\frac{1}{\gamma}}\right],$$

$$\frac{\partial \Psi_2}{\partial \phi} = -\frac{k(1-\gamma)(1-u)}{\phi\gamma}\left[nu\gamma + n^{\frac{1}{\gamma}}(1-u)\tau b\beta\right].$$

Since the

$$\frac{\partial[d\theta/du]}{\partial\phi} = \frac{1}{\Psi_2^2}\left[\frac{\partial\Psi_1}{\partial\phi}\Psi_2 - \frac{\partial\Psi_2}{\partial\phi}\Psi_1\right],$$

the sign of the change is determined by the expression in the squared bracket. Substituting the corresponding expressions and some algebra establishes that

$$\frac{\partial[d\theta/du]}{\partial\phi} = \frac{1}{\Psi_2^2}\frac{nk(1-\gamma)^2(1-u)n^{\frac{1}{\gamma}}}{\phi\gamma}\left[nu\phi - \theta(1-\gamma)k(1-u)^2\tau b\beta\right].$$

Noting that $n = (1-\gamma)\, b\frac{[(1-\beta)(p-z)-\beta\theta k][1-u]}{\phi}$, the above expression can be simplified to

$$\frac{\partial[d\theta/du]}{\partial\phi} = \frac{1}{\Psi_2^2}\frac{nbk(1-\gamma)^3(1-u)^2 n^{\frac{1}{\gamma}}}{\phi\gamma}\left[(1-\beta)(p-z)u - \tau\beta\theta k\right].$$

The slope of Ψ increases with ϕ when $(1-\beta)(p-z)u > \tau\beta\theta k$. Since Ψ is downward sloping, an increase in its slope implies it becomes flatter, which in turn imply that Ψ shifts to the left towards the origin.

Changes in b

In this case we have that $dn/db = n/b$ and

$$\frac{\partial \Psi_1}{\partial b} = -\frac{n}{b\gamma}\left[\theta(1-\gamma)k(1-u)\gamma + \phi n^{\frac{1}{\gamma}}(1+\gamma)\right],$$

$$\frac{\partial \Psi_2}{\partial b} = \frac{k(1-\gamma)(1-u)}{b\gamma}\left[nu\gamma + n^{\frac{1}{\gamma}}(1-u)\tau b\beta(1+\gamma)\right].$$

Since the

$$\frac{\partial[d\theta/du]}{\partial b} = \frac{1}{\Psi_2^2}\left[\frac{\partial \Psi_1}{\partial b}\Psi_2 - \frac{\partial \Psi_2}{\partial b}\Psi_1\right],$$

the sign of the derivative is determined by the expression in the squared bracket. Substituting the corresponding expressions and some algebra establishes that

$$\frac{\partial[d\theta/du]}{\partial b} = -\frac{1}{\Psi_2^2}\frac{nk(1-\gamma)(1-u)n^{\frac{1}{\gamma}}}{b\gamma}\left[nu\phi - \theta(1-\gamma)k(1-u)^2\tau b\beta\right],$$

where the term in squared brackets is the same as in the case of changes in ϕ. Using the expression for n we obtain that

$$\frac{\partial[d\theta/du]}{\partial b} = -\frac{1}{\Psi_2^2}\frac{nk(1-\gamma)^2(1-u)^2n^{\frac{1}{\gamma}}}{\gamma}\left[(1-\beta)(p-z)u - \tau\beta\theta k\right].$$

The slope of Ψ decreases with b when $(1-\beta)(p-z)u > \tau\beta\theta k$. Since Ψ is downward sloping, a decrease in its slope implies it becomes stepper, which in turn imply that Ψ shifts to the right away from the origin.

Changes in γ

In this case we have that $dn/d\gamma = -n/(1-\gamma)$ and that

$$\frac{\partial(n^{\frac{1}{\gamma}})}{\partial\gamma} = -\frac{n^{\frac{1}{\gamma}}}{\gamma^2(1-\gamma)}\left[(1-\gamma)ln(n) + \gamma\right].$$

These expressions together imply

$$\frac{\partial \Psi_1}{\partial\gamma} = 2n\theta k(1-u) + \frac{\phi n^{\frac{1}{\gamma}}}{\gamma^2(1-\gamma)}\left[\gamma(1+\gamma n) + (1-\gamma)ln(n)\right],$$

$$\frac{\partial \Psi_2}{\partial\gamma} = -2nuk(1-u) - \frac{k(1-u)^2n^{\frac{1}{\gamma}}\tau b\beta}{\gamma^2}\left[\gamma(1+\gamma) + (1-\gamma)ln(n)\right].$$

Since the

$$\frac{\partial[d\theta/du]}{\partial\gamma} = \frac{1}{\Psi_2^2}\left[\frac{\partial \Psi_1}{\partial\gamma}\Psi_2 - \frac{\partial \Psi_2}{\partial\gamma}\Psi_1\right],$$

once again the sign of the change is determined by the expression in the squared bracket. Substituting the corresponding expressions and some algebra establishes that the sign of $\partial[d\theta/du]/\partial\gamma$ equals the sign of

$$\phi u[n\gamma^2+(1-\gamma)ln(n)]-\Big[\tau b\beta\theta k(1-u)^2(1-\gamma)^2(\gamma+ln(n))+\phi u\gamma+\phi n^{\frac{1-\gamma}{\gamma}}(1-u)\tau b\beta(n-1)[\gamma+(1-\gamma)ln(n)]\Big].$$

Consider the sign of $\partial[d\theta/du]/\partial\gamma$ as $\gamma \to 1$. Since in this limit $n \to 0$, we find that $\partial[d\theta/du]/\partial\gamma < 0$ when $\tau b\beta\lambda(\theta) - s > 0$. On the other hand, when $\gamma \to 0$, we find that in this limit $\partial[d\theta/du]/\partial\gamma < 0$ when $n > 1$. In both case a decrease in the slope of Ψ implies it becomes stepper, which in turn imply that Ψ shifts to the right away from the origin.

A.6 Calibration

To calibrate the parameters $\mathbf{x} = \{k, z, \beta, \tau, \phi, \gamma\}$, we minimise the squared relative distance between the observed vacancy rates and the ones implied by our transition path taking the observed unemployment rates as given. That is, we choose

$$\mathbf{x} = \arg\min \sum_t \left(\frac{v_t - \hat{v}(\mathbf{x}; u_t)}{v_t}\right)^2, \tag{35}$$

where $\hat{v}(\mathbf{x}; u_t)$ denotes the vacancy rate that solves (15) given the vector of parameters $\mathbf{x}$ and the observed unemployment rate u_t. The minimisation problem is subject to the following equality constraints:

$$\begin{aligned}(1-\beta)\frac{p-z}{k}q(\theta^*) - s - r^* - \tau\beta\lambda(\theta^*) &= 0\\ v^* - \hat{v}(\mathbf{x}; u^*) &= 0\\ 0.5w - z &= 0\\ 0.036w - v^*k &= 0\end{aligned}$$

In practice, we use the `fmincon` function from the Optimization Toolbox (Version 7.2) in Matlab (Version 8.5.0.197613 (R2015a)) designed to find the minimum of a function $f(x)$ with linear and nonlinear inequality and equality constraints. Note that at every evaluation of the objective function, we also have to solve for the series of vacancy rates $\hat{v}(\mathbf{x}; u)$. Given a guess for the parameter vector $\mathbf{x}$ and the observed unemployment rates, we can numerically solve equation (15) to obtain the series of vacancy rates implied by our model. In practice, we use the `lsqnonlin` function from the Optimization Toolbox - a nonlinear least square solver - to perform this step and check that the value of the objective function is close to 0. The advantage of the non-linear least square solver compared to Matlab's built-in solver for nonlinear systems, `fsolve`, is that we can impose a non-negativity constraint ensuring the stability of the optimisation procedure.

A.7 The Impact of the Financial Crises: Time series

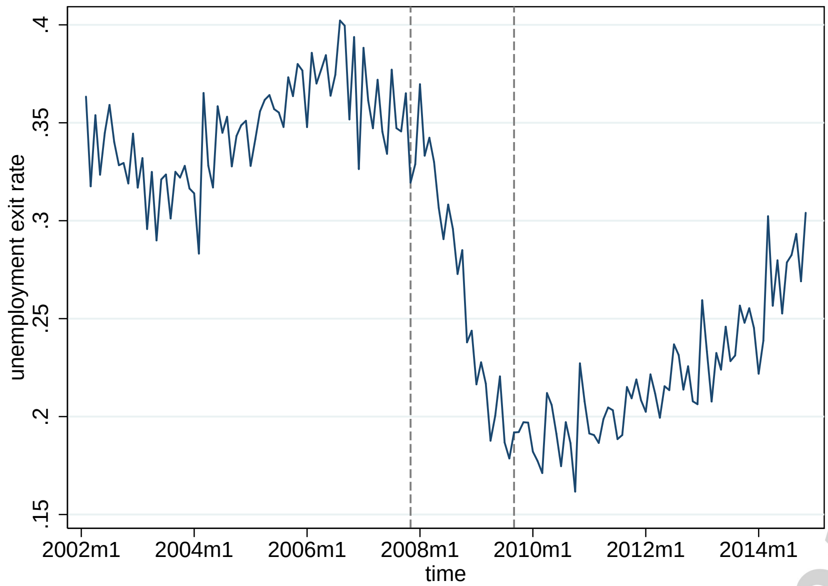

Figure 5: Unemployment exit rate

Notes: This figure shows the monthly unemployment exit rate for the US. The exit rate was calculated following footnote (8) using BLS data on the seasonal adjusted number of unemployed and unemployed with durations less than 5 weeks. The Great Recession is the period between the two dashed lines.

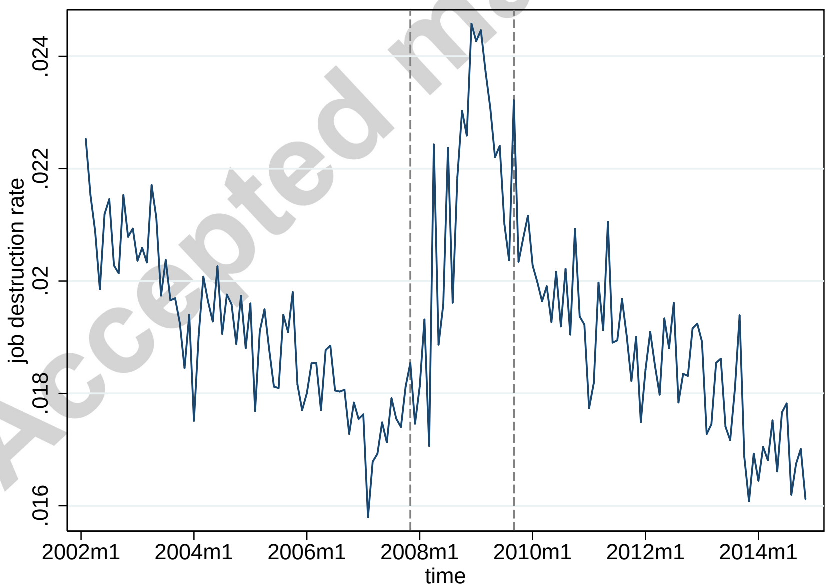

Figure 6: Job destruction rate

Notes: This figure shows the monthly employment exit rate for the US. The exit rate was calculated following footnote (8) using BLS data on the seasonal adjusted number of employed and unemployed with durations less than 5 weeks. The Great Recession is the period between the two dashed lines.

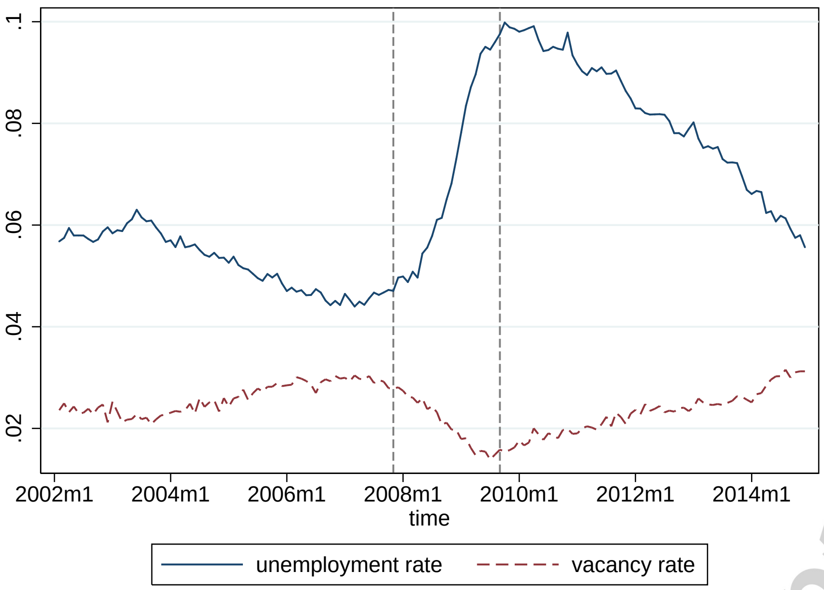

Figure 7: Unemployment and vacancy dynamics

Notes: This figure shows the monthly unemployment and vacancy rate for the US. The data is taken from the BLS and the JOLTS. Rates are calculated by dividing the number of vacancies and unemployed by the sum of the employed and unemployed in a given month. The Great Recession is the period between the two dashed lines.

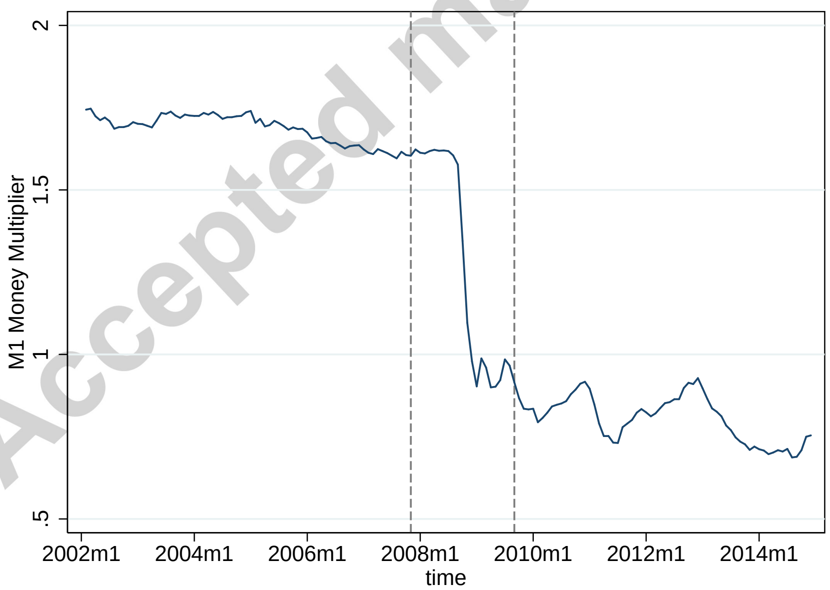

Figure 8: Money multiplier

Notes: This figure shows the evolution of the M1 money multiplier over time. The data is provided by the Federal Reserve Bank of St. Louis (https://research.stlouisfed.org/fred2/series/MULT). The Great Recession is the period between the two dashed lines.