Kiel

Working Papers

Kiel Institute
for the World Economy

Reciprocity and Matching Frictions

by Dennis Wesselbaum

No. 1616 | February 2011

Web: www.ifw-kiel.de

Kiel Working Paper No. 1616 | February 2011

Reciprocity and Matching Frictions

Dennis Wesselbaum

Abstract:

The ability of search and matching models to replicate stylized facts - such as volatilities and correlations - have been a center of attraction over the last couple of years. This paper introduces the Akerlof (1982) fair wage approach into an endogenous separation search and matching model. Within a RBC general equilibrium context, we show that the efficiency wage model outperforms its benchmark Nash bargaining pendant. In particular, the model generates the empirically observed volatilities in response to a productivity shock and replicates a strong Beveridge curve. Furthermore, we derive the Solow condition in a search environment and discuss the interactions of search and efficiency wage frictions. We show that search frictions create a wedge between the optimal wage/effort solution in the search and the competitive equilibrium. The efficiency wage consideration adds an additional margin to the firms decision problem. As effort varies over the cycle, it changes the firm's optimal response to exogenous disturbances and amplifies the response to shocks.

Keywords: Efficiency Wages, Endogenous Separations, Search and Matching.

JEL classification: E32, J41, J64.

The Kiel Institute for the World Economy &
EABCN

E-mail:
dennis.wesselbaum@ifw-kiel.de

Reciprocity and Matching Frictions*

Dennis Wesselbaum†
Kiel Institute for the World Economy and EABCN

February 6, 2011.

Abstract

The ability of search and matching models to replicate stylized facts - such as volatilities and correlations - have been a center of attraction over the last couple of years. This paper introduces the Akerlof (1982) fair wage approach into an endogenous separation search and matching model. Within a RBC general equilibrium context, we show that the efficiency wage model outperforms its benchmark Nash bargaining pendant. In particular, the model generates the empirically observed volatilities in response to a productivity shock and replicates a strong Beveridge curve. Furthermore, we derive the Solow condition in a search environment and discuss the interactions of search and efficiency wage frictions. We show that search frictions create a wedge between the optimal wage/effort solution in the search and the competitive equilibrium. The efficiency wage consideration adds an additional margin to the firms decision problem. As effort varies over the cycle, it changes the firm's optimal response to exogenous disturbances and amplifies the response to shocks.

Keywords: Efficiency Wages, Endogenous Separations, Search and Matching.

JEL codes: E32, J41, J64.

1 Introduction

This paper uses a standard Real Business Cycle model with search frictions and enriches the framework by introducing efficiency wage frictions. The idea of efficiency wages in macroeconomics goes back to the work of Akerlof (1982). In his work equilibrium unemployment arises due to the optimal response of firm's to workers behavior, viz. the wage is above the market-clearing wage in order to receive a higher level of effort and hence labor demand falls and unemployment arises. The aim of this paper is to analyze the importance of efficiency wages and matching frictions for labor

*I would like to thank the EES network for financial support. Main part of this research was conducted during my visit of the Department of Economics at the University of Pavia and the Federal Reserve Bank of Chicago. I'd like to thank the Department of Economics in Pavia and the Chicago FED for their hospitality during parts of this project. The opinions and analyses in this paper are the responsibility of the authors and, therefore, do not necessarily coincide with those of the Kiel Institute.

†Kiel Institute for the World Economy, Hindenburgufer 66, 24114 Kiel, Germany. Tel: +49-431-8814-233. Email: dennis.wesselbaum@ifw-kiel.de.

market dynamics and - in particular - for the cyclical patterns of unemployment and vacancies. The paper therefore combines search frictions with efficiency wage frictions, that characterize the wage setting process within firms. In the words of Olivier Blanchard (2008): "The next stage appears to be an integration of the market frictions that characterize the DMP model with those of efficiency wage models, which can explain wage setting within firms [...]."

A justification for the efficiency wage theory can - for instance - be found in Beweley (1998), showing that firms do not use pay cuts because they are afraid of the negative effects on morale. Along this line, Fabiani et al. (2010) use European data from the Wage Dynamics Network and show that firms prefer to separate from a worker rather than to cut his pay. Furthermore, they confirm that the rationale for firms to avoid wage changes is the fear that workers would reduce effort.

An interesting experiment by Adams and Rosenbaum (1962) supports this view of the firm-worker relationship. In this experiment, male college students were hired to conduct interviews on a fixed per hour salary. To be hired, all students had to pass a questionnaire test. Students in the control group have been told that they passed the test. Students in the experimental group were informed that they were not qualified for the job, but nevertheless been hired at the predetermined salary. The result of the experiment was that students in the experimental group conducted more interviews per hour than those in the control group.

Since Shimer (2005) many papers have been written to overcome the so called "Shimer Puzzle". This puzzle describes the inability of the search and matching model to replicate volatilities in response to a productivity shock. Moreover, we know that the endogenous separations matching model has problems in generating the Beveridge curve - the negative correlation between unemployment and vacancies - and observed volatilities jointly. To address the potential role of efficiency wages to overcome the Shimer puzzle, we build an endogenous separation search and matching model. Within a general equilibrium RBC model, efficiency wage frictions follow the approach in de la Croix et al. (2009). However, the basic idea of an effort function goes back to the Akerlof (1982) contribution. He formalizes his ideas of the gift exchange by suggesting the existence of an effort supply function. This function links effort to the current and the reference wage. Here, we follow the assumption of an effort function in a more general specification. In contrast, Danthine and Kurmann (2003) assume that the effort function can be written in log terms. This implies that effort does not vary over the cycle, which is a rather questionable assumption.[1] By using the specification suggested by de la Croix et al. (2009), we allow effort to vary over the cycle.

The paper has two main contribution. First, we derive the Solow condition in a search environment and discuss the interactions of search and efficiency wage frictions. We show that search frictions create a wedge between the optimal wage/effort solution in the search and the competitive equilibrium. This wedge is also a main driver of our second contribution. We find that the efficiency wage model is able to replicate the empirically observed volatilities of key labor market variables, i.e. does not show the Shimer (2005) puzzle. The efficiency wage model adds an additional channel

[1] Consider for instance the importance of variability in effort for the wedge between TFP and "true" technology shocks, described in Burnside et al. (1993)

to the firms decision problem. Namely, fluctuations in the effort level over the business cycle have an impact on unemployment and vacancies, i.e. on the labor market adjustment process.

The paper is structured as follows. The next section derives our model. Section 3 discusses the response of the model economy to an aggregate productivity shock and compares the efficiency wage model with the standard Nash bargaining model. Section 4 provides a robustness analysis, while section 5 concludes.

2 The Model

The description of our model economy proceeds in three steps. First, we define the economy's preferences and technology and we then present the model's assumed market structure. Finally, we conclude with the definition of an equilibrium.

2.1 Preferences and Technology

We now present a general equilibrium model with flexible prices, labor market frictions, and efficiency wage frictions. Our economy inhibts two different agents; households and firms. The labor market is imperfect due to the assumption of search and matching frictions following Mortensen and Pissarides (1994). Furthermore and following Akerlof (1982), firms set wages according to the reciprocity of gift giving and take the household's optimal effort setting behavior into account.

2.1.1 Households

We assume a discrete-time economy with an infinite living representative household whose preferences are given by the following utility function

$$U = E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma} - 1}{1-\sigma} - N_t \Phi\left(E_t\right) \right], \tag{1}$$

where $\beta \in (0,1)$ is the discount factor and $\sigma > 0$ gives the intertemporal elasticity of substitution. Furthermore, C_t is a standard Dixit-Stiglitz aggregator of differentiated goods

$$C_t = \int_0^1 \left[C_{it}^{\frac{e-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2}$$

where $\varepsilon > 0$ gives the elasticity of substitution. It is assumed that a household consists of a continuum of members, inelastically suppling one unit of labor and being represented by the unit interval. In addition, household members insure each other against income fluctuations and have free and unlimited access to complete markets for state-contingent claims to avoid the problem of heterogeneity. Then, N_t is the number of employed household members who suffer from the disutility of providing the effort level E_t, $\Phi\left(E_t\right)$.

Following the description in de la Croix et al. (2009), we assume the following specification for the disutility function

$$\Phi\left(E_t\right) = \left(E_t(j) - \frac{\phi_1}{\zeta}\left[(W_t(j))^{\zeta} - \phi_2\left(\frac{1}{U_t}\right)^{\zeta} - \phi_3 W_t^{\zeta} - (\phi_0 - \phi_2 - \phi_3)\right]\right)^2, \tag{3}$$

where $E_t(j)$ is worker j's effort and $W_t(j)$ indicates worker j's real wage. Then, the effort function is given by

$$E_t(j) = \frac{\phi_1}{\zeta}\left[(W_t(j))^{\zeta} - \phi_2\left(\frac{1}{U_t}\right)^{\zeta} - \phi_3 W_t^{\zeta} - (\phi_0 - \phi_2 - \phi_3)\right]. \tag{4}$$

Let us spend some time to discuss this important equation. Akerlof (1982) used insights from sociology to develop his fair wage approach. The underlying process is mainly driven by the idea of workers developing sentiments for the firm and for each other, and hence *"acquire utility for an exchange of gifts with the firm."* In addition, as workers also develop sentiments for each other, the firm has to treat them as a collective and is not able to negotiate individually with the worker. The concept of gift giving is determined by norms of behavior and can be mainly characterized by the reciprocal nature of gift giving as in Mauss (1954). In the model, norms are mainly influenced by the wage and legal restrictions. From the worker's perspective, the gift is mainly to provide more effort than required (e.g. minimum work standard) in order to receive a wage (the firm's gift) that is above a certain reference wage (e.g. the unemployment benefit), that is considered to be "fair". The fairness of this wage is ensured by comparing the wage with the group's wage.

In the spirit of Akerlof (1982) and following de la Croix et al. (2009) we impose the following parameter restrictions $\phi_0 \in \Re, \phi_1 > 0, \phi_2 > 0, \phi_3 \in [0,1)$ and $\zeta \in [0,1]$. Parameters ϕ_0 and ϕ_1 are scale parameters, while ϕ_2 measures the effect of unemployment on individual effort.[2] ϕ_3 covers the influence of the reference wage on the household's effort decision. The consideration of a reference wage in the effort function is strongly supported by the empirical study from Bewley (1998) and Fabiani et al. (2010). It can be interpreted as a summation of what the worker would earn in other firms or by unemployment benefits. Finally, ζ defines the degree of substitutability between single elements in the effort function.

2.1.2 Technology

There exists a continuum of firms with names $i \in [0,1]$. While aggregate productivity, Z_t, is common to all firms, the specific productivity, z_{it}, is idiosyncratic and every period it is drawn in advance of the production process from a time-invariant distribution with c.d.f. $F(z)$ and positive support $f(z)$. Its mean is given by $\mu_{LN} \geq 0$ and the variance is determined by $\sigma_{LN} > 0$. The firm specific production function is the product of aggregate productivity, the effort level, the number

[2] Here, we should assume that $\phi_0 > 0$ such that firms are not able to hire an infinitely large number of workers and decrease the number of hours worked close to zero. The condition insures that the disutility of effort is positive in steady state.

of jobs and the aggregate over individual jobs productivity and can be written as

$$Y_{it} = Z_t E_{it} N_{it} \int_{\tilde{z}_{it}} z \frac{f(z)}{1 - F(\bar{z}_{it})} da \equiv Z_t E_{it} N_{it} \Psi(\bar{z}_{it}), \tag{5}$$

where $\bar{z}_{it}$ is an endogenously determined critical threshold. If the specific productivity of a job is below this threshold, it is not profitable and separation takes place. Here, Z_t is a Hicks-neutral aggregate technology shock following a first-order autoregressive process,

$$\ln Z_t = \rho^Z \ln(Z_{t-1}) + e_{Z,t}, \tag{6}$$

where $0 < \rho_Z < 1$ is the autocorrelation term and its innovation is i.i.d. over time and normally distributed

$$e_{Z,t} \sim N(0, \sigma_Z). \tag{7}$$

2.2 Market Structure

While the good market is perfectly competitive, the labor market is imperfect due to the assumption of search and matching frictions. Trade in the labor market is uncoordinated, costly and time-consuming. Search takes place on a discrete and closed market. Workers can be either employed or unemployed, such that there is no out of labor force option. Similarly, each firm has one job that is either filled, or vacant. If the job is filled, it is subject to the probability of being either exogenously destructed, $\rho^x > 0$, or being endogenously destructed, $\rho_t^n = F(\bar{z}_t)$. Then, total separations are given by

$$\rho_t = \rho^x + (1 - \rho^x) F(\bar{z}_t). \tag{8}$$

In addition, firms create jobs at the rate $M(U_t, V_t)$ at the non-state-contingent cost of $c > 0$ units of output per vacancy, where M is the homogeneous-of-degree-one-matching-function,

$$M(U_t, V_t) = m U_t^{\mu} V_t^{1-\mu}, \tag{9}$$

where $m > 0$ gives the match efficiency, $\mu > 0$ is the elasticity of the matching function with respect to unemployment and V_t is the vacancy rate. The vacancy-to-unemployment ratio

$$\theta_t = V_t / U_t, \tag{10}$$

reflects labor market tightness. Then, the vacancy filling probability is $q(\theta_t) = M(U_t, V_t) / V_t$. Combining entry and exit definitions yields the evolution of employment

$$N_{t+1} = \left(1 - \rho_{t+1}\right)(N_t + M_t). \tag{11}$$

Similarly, the evolution of aggregate unemployment can be written as

$$U_t = 1 - N_t. \tag{12}$$

Finally, households own all shares in the firm and receive any of their profits as dividends each quarter.

2.3 Optimization and Equilibrium

Optimization of all agents defines equilibrium. We start with the households utility maximization problem and continue with the firms profit maximization problem. Then, we solve the wage setting problem and determine the real wage and the cut-off point. We conclude with a definition of the equilibrium.

2.3.1 Households

We assume that the economy begins with all households having identical financial wealth and consumption histories. This assumption assures that together with the optimal use of the available contingent claims markets, this homogeneity will continue. Moreover, this allows us to only consider the consumption and savings decisions of a representative household. The representative household faces the following budget constraint

$$C_t + T_t = W_t(j)N_t + bU_t + \Pi_t, \tag{13}$$

where benefits b are financed by lump-sum taxes, T_t. Dividends are denoted by Π_t and $W_t(j)$ is the real wage. Then, the household maximizes (1) subject to (13), which gives the standard first order condition

$$C_t^{-\sigma} = \lambda_t, \tag{14}$$

where λ_t is the multiplier on the budget constraint.

2.3.2 Firms

The representative firm in our economy solves its profit maximization problem by choosing the optimal path for $\{N_t, V_t, p_t\}_{t=0}^{\infty}$ by maximizing

$$E_t \sum_{t=0}^{\infty} \beta^t \lambda_t \left[p_t \left(\frac{p_t}{P_t} \right)^{-(1+\epsilon)} Y_t - N_{it} W_{it}(j) - cV_t \right], \tag{15}$$

subject to the evolution of employment (11), the effort function (4), and the production function (5). Then, p_t is the price choosen by the firm and P_t is the aggregate price index, $P_t = \left[\int_0^1 P_{it}^{1-\epsilon} di \right]^{\frac{1}{1-\epsilon}}$. The terms in parenthesis give the real revenue depleted by total wage costs and total vacancy posting costs.

Then, the first-order conditions are

$$\partial N_t : \tau_t = \varphi_t Z_t E_t \Psi(\bar{z}_t) - W_{it}(j) + E_t(1 - \rho_{t+1})\beta_{t+1}\tau_{t+1}, \tag{16}$$

$$\partial V_t : c = (1 - \rho_t) q(\theta_t) E_t \beta_{t+1} \tau_{t+1}, \tag{17}$$

$$\partial W_t : N_t = \frac{\partial E_t}{\partial W_t} \varphi_t Z_t N_t \Psi(\bar{z}_t), \tag{18}$$

$\beta_{t+1} = \beta\frac{\lambda_{t+1}}{\lambda_t}$ is the stochastic discount factor, τ_t is the Lagrangian multiplier on the evolution of employment and φ_t is the multiplier on the production function. Using the first two equations yields the job creation condition

$$\frac{c}{q(\theta_t)} = E_t(1-\rho_{t+1})\beta_{t+1}\left[Z_{t+1}E_{t+1}\Psi(\bar{z}_{t+1})\varphi_{t+1} - W_{t+1}(j) + \frac{c}{q(\theta_{t+1})}\right]. \tag{19}$$

The left-hand side of this equation gives the hiring costs which equal the benefits of creating a new job. The latter depends on the marginal product of labor depleted by the wage and increased by saved hiring costs in the next period in case of non-separation. Here, we obtain an additional term compared to the standard search and matching model. As effort is an input factor in the production function, it changes the marginal product of labor, which is the first part in parenthesis. For the hiring decision, the future path of effort is taken into consideration and the wage/effort decision interacts with the search frictions directly through this term (and also through wages). Therefore, the firm considers the two adjustment margins effort and the number of workers (vacancies) jointly. Workers - due to the search frictions - can not be hired instantaneously, which has implications for the Solow condition and therefore, for the optimal wage/effort decision.

2.3.3 Wage Setting

From the discussion of the household side of the economy we know that the optimal effort niveau is element of the effort schedule eq. (4). Then, in order to determine the real wage, we use the Solow condition.[3] The Solow optimality condition finds the point that minimizes the wage costs per efficiency unit, i.e.

$$\frac{\partial E_t}{\partial W_t}\frac{W_t}{E_t} = 1, \tag{20}$$

in a world without frictions. However, search frictions alter the problem. We start our derivation with the third FOC from the firms problem

$$\frac{\partial E_t}{\partial W_t}\varphi_t Z_t \Psi(\tilde{z}_t) = 1. \tag{21}$$

Furthermore, it follows from (16)

$$\varphi_t Z_t E_t \Psi(\bar{z}_t) = \tau_t + W_t - E_t(1-\rho_{t+1})\beta_{t+1}\tau_{t+1}, \tag{22}$$

and using (17)

$$\varphi_t Z_t \Psi(\bar{z}_t) = \frac{W_t + \frac{c}{q(\theta_{t-1})(1-\rho_t)\beta_t} - \frac{c}{q(\theta_t)}}{E_t}. \tag{23}$$

[3] One might argue that firm and worker should bargain over the reference wage in this model. However, Cheron (2002) has shown that the usual assumption that the reference wage is a geometric average of the average wage and the unemployment benefits leads the results to be unaffected by the choice of the reference wage. Because, efficient risk-sharing and the specification of the reference wage imply that the reference wage equals the average wage in the symmetric equilibrium.

Then, inserting (23) into (21) gives the Solow condition within a search environment

$$\frac{\partial E_t}{\partial W_t}\frac{W_t+\frac{c}{q(\theta_{t-1})(1-\rho_t)\beta_t}-\frac{c}{q(\theta_t)}}{E_t}=1. \tag{24}$$

We know that $\frac{\partial E_t}{\partial W_t}=\phi_1 W_t^{\zeta-1}$, such that we can write

$$\phi_1 W_t^{\zeta-1}\frac{W_t+\frac{c}{q(\theta_{t-1})(1-\rho_t)\beta_t}-\frac{c}{q(\theta_t)}}{E_t}=1. \tag{25}$$

Finally, the optimal effort level is given by[4]

$$E_t=\phi_1 {W_t}^{\zeta-1}\left[W_t+\frac{c}{q(\theta_{t-1})(1-\rho_t)\beta_t}-\frac{c}{q(\theta_t)}\right]. \tag{26}$$

Here, we should spend some time to gain intuition. In a competitive environment, the optimal effort level would be proportional (driven by the factors ϕ_1 and ζ) to the real wage. However, in a world with search frictions, the multiplier on the employment barrier enters the equation and changes the optimal effort/wage level. To be precise, the firm might wants to hire more workers to drive production to the minimum cost level, but is constraint by the search frictions. As a consequence, the wage is increased by the marginal value of a worker to the firm net of hiring costs. Put differently, the search frictions create an additional channel that affects the optimal effort level of employed workers that is absent in the standard competitive model. Here, (re-)hiring costs, or more precise, the ratio between those costs, drives the optimal effort level. The additional two terms in parenthesis rather increase or decrease the real wage and therefore change the optimal effort level. The latter term accounts for the period t hiring costs, while the first term is the marginal value of a worker (or the discounted, conditional (on not being laid-off) hiring costs of the worker in $t-1$) to the firm. If re-hiring costs are smaller - in absolute terms - than the marginal value of the worker (as in the steady state), than the Solow-condition implies that the optimal effort level should be lower compared to the competitive equilibrium. Low re-hiring costs create an incentive for the firm to adjust along the hiring margin, increase employment and reduce individual effort.

Now, let us derive the optimal wage associated with this level of effort. For this purpose, we insert (26) into (4) and find after some algebra

$$(1-\phi_3-\zeta)\,W_t^{\zeta}+\left(\frac{c}{q(\theta_t)}-\frac{c}{q(\theta_{t-1})(1-\rho_t)\beta_t}\right)\zeta {W_t}^{\zeta-1}=\phi_2\left(\frac{1}{U_t}\right)^{\zeta}+(\phi_0-\phi_2-\phi_3)\,. \tag{27}$$

From this equation, we find that there is a negative relationship between unemployment and the wage. Of course, this equation does not have a closed form for $\zeta\in[0,1]$. However, if we assume that effort is e.g. linear in wages, i.e. $\zeta=1$, then we can illustrate the difference between the competitive and the search environment. In this special case, we find that the wage is given by

$$W_t=\frac{\phi_2\left(\frac{1}{U_t}\right)+(\phi_0-\phi_2-\phi_3)}{-\phi_3}+\frac{\frac{c}{q(\theta_t)}-\frac{c}{q(\theta_{t-1})(1-\rho_t)\beta_t}}{\phi_3}, \tag{28}$$

[4]Notice that all firms will pay the same wage in equilibrium, i.e. $W_{it}=W_t\forall i$. This follows from the fact that all components of the wage function are predetermined for the firm.

and, as in our example above, if the hiring costs are smaller than the marginal value of the worker, the firm will lower the effort level and, the real wage will be smaller compared with the competitive equilibrium. More generally, in this specification, the steady state optimal wage will be lower in the search model as in the competitive one. This result follows directly from the fact that the firm is not able to freely adjust the level of employment and hence is constraint in reaching the minimum cost level of production. The search frictions generate a wedge between the optimal competitive equilibrium and the frictional search equilibrium that is increasing in the cost of posting vacancies, the separation rate and in the elasticity of the matching function with respect to unemployment, while it is decreasing in the matching efficiency.

For the separation decision of the firm, we infer that the firm will endogenously separate from a worker if and only if

$$\mathcal{S}_t\left(\bar{z}_t\right) < 0, \tag{29}$$

i.e. if the worker's asset value $\mathcal{S}_t$ is smaller than zero. In the following, we have to determine the value of the worker for the firm, i.e. the asset value $\mathcal{S}_t$. In terms of a Bellman equation this value can be written as[5]

$$\mathcal{S}_t\left(\bar{z}_t\right) = \varphi_t Z_t E_t z_t - W_t + \frac{c}{q(\theta_t)}. \tag{30}$$

The first term gives the output of one worker depleted by her wage, the second term. The latter describes the opportunity cost character by representing re-hiring costs. After some algebra, the threshold is then defined by

$$\bar{z}_t = \frac{W_t - \frac{c}{q(\theta_t)}}{\varphi_t Z_t E_t}. \tag{31}$$

The cut-off point for idiosyncratic productivities depends crucially on the real wage and the vacancy posting costs. Higher wages imply a higher cut-off point and more lay-offs. An increase in vacancy posting costs, drives up re-hiring costs and therefore lowers the cut-off point, because firms prefer to keep more workers in order to save those re-hiring costs.

2.3.4 Equilibrium

In the symmetric equilibrium, factor and goods market clear and the resource constraint is

$$Y_t = C_t + cV_t. \tag{32}$$

In addition, the consumption good is used to pay vacancy posting costs. We assume that the government collects these costs and re-distributes them to the household via lump-sum transfers. Furthermore, the government pays unemployment benefits and finances them by collecting lump-sum transfers.

[5]Notice that the latter term can be derived by using the standard vacancy posting asset value function. To be precise, the latter $c/q\left(\theta_t\right)$ equals the expected profit of posting a vacancy in steady state, which is its value to the firm.

For the given stochastic process $\{Z_t\}$, a determined equilibrium is a state-contingent sequence of $\{C_t, E_t, Y_t, V_t, M_t, N_t, U_t, W_t, \theta_t, \bar{z}_t, \lambda_t, \rho_t\}_{t=0}^{\infty}$. Then, the set of equations forming the equilibrium is linearized around the non-stochastic steady-state.

The calibration of the model is on a quarterly basis for the United States and parameter values are set according to stylized facts and the relevant literature.

The intertemporal elasticity of substitution σ is set to the value 2, the discount factor β is 0.99. We set $\mu = 0.5$ to ensure that Hosios (1990) efficiency condition is satisfied. Exogenous job destruction ρ^x is set to 0.068 according to den Haan et al. (2000), while we calibrate the steady state separation rate $\bar{\rho}$ to be 0.09. The endogenous separation rate in steady state can be computed to be 0.034. The critical threshold can be computed by building the inverse function, i.e. $\bar{z} = F^{-1}(\rho^n)$. The steady state unemployment rate is set to $\bar{u} = 0.15$ reflecting the shortcoming of the unemployment rate namely the nonconformity of effective searchers and unemployed workers discussed in Cole and Rogerson (1999). Because idiosyncratic productivity follows a lognormal c.d.f., the parameters μ_{LN} and σ_{LN} have to be calibrated. Based on Krause and Lubik (2007), the distribution function is normalized, such that $\mu_{LN} = 0$, while the parameter for the variance σ_{LN} is 0.12. Finally, the autocorrelation ρ_A is 0.95 like in Cooley and Quadrini (1999).

Efficiency wage parameters are entirely taken from the estimations of de la Croix et al. (2009). The authors estimate the same functional form for the effort equation as in eq. (4). Therefore, we set $\zeta = 0.36$. In addition, we impose $\phi_2 = 0.004$, such that unemployment affects effort only slightly. Furthermore, $\phi_3 = 0.795$ such that spill-overs between firms are quite important, such that small employment changes will be transmitted more strongly towards aggregate wages. Finally, $\phi_0 = 0.3$ and $\phi_1 = 1.7$ are scaling parameters. While we take those estimated parameter values as our benchmark case, we will provide a robustness check on the parameters in the effort function.

Then, to determine the steady state of wages and effort, we use the fsolve function of Matlab to find the solution for $\{E, W\}$ to the following linear problem

$$\begin{aligned} E - \phi_1 W^{\zeta-1}\left[W_t + \frac{c}{q(\theta)(1-\rho)\beta} - \frac{c}{q(\theta)}\right] &= 0, \quad (33) \\ (1-\phi_3-\zeta)\, W^{\zeta} + \left(\frac{c}{q(\theta)} - \frac{c}{q(\theta)(1-\rho)\beta}\right)\zeta W^{\zeta-1} - \phi_2\left(\frac{1}{U}\right)^{\zeta} - (\phi_0-\phi_2-\phi_3) &= 0. \end{aligned}$$

3 Discussion

Let us consider that our model economy is hit by a stationary one percent favorable technology shock. Figure 1 shows the response of the efficiency wage model. As a result of the favorable shock, firms can produce more output and start to decrease separations. The firm consistently increases the cut-off point and now protects even less productive workers. The job destruction rate drops and converges from below to the old steady state. On the flipside, vacancy posting activities are reduced, a phenomenon that is widely known in enodgenous separation models and refers to the separation driven adjustment mechanism. The job creation rate increases on impact, as the large drop in the separation rate implies that more matches survive, but then falls as vacancies drop.

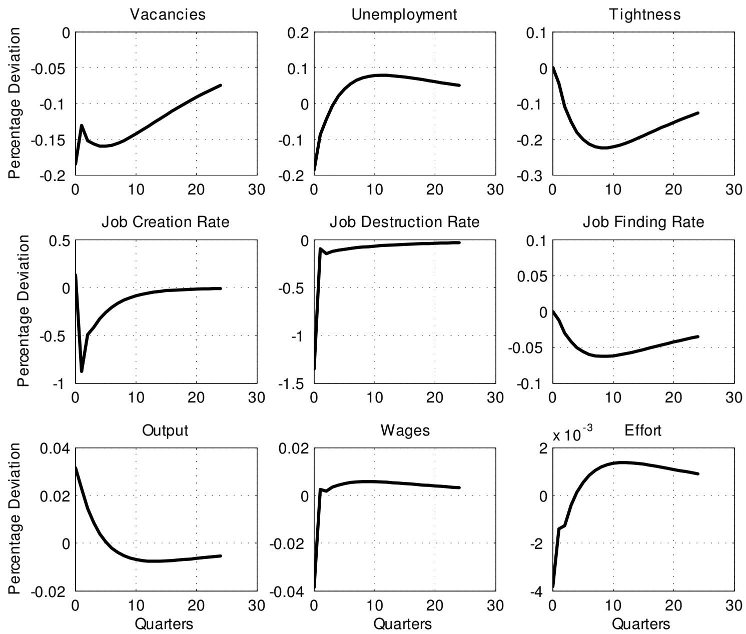

Figure 1: Response of the efficiency wages model to a one percent favorable technology shock. Horizontal axes measure quarters, vertical axes deviations from steady state.

Fully rational firms - and determined by (27) - set lower wages, in order to ensure that the Solow condition holds. Put differently, they produce on the highest stream - given the wage schedule - in the effort-wage gure that yields the highest effort-to-wage ratio. Here, we have to isolate two effects. The first effect steams from unemployment and drives wages up. The second and dominant effect is created by the search frictions. To be precise, from eq. (27) we infer that the search friction term is driven by labor market tightness, the separation rate, and the stochastic discount factor. The latter effect only marginally influences the quantitative and qualitative implications. More important are the first two effects. The drop in labor market tightness puts downward pressure on wages, because now it is easier for the firm to find and select new employees. On the other hand, the decrease of the separation rate puts upward pressure on wages, because the expected return from a worker increases. Overall, the labor market tightness effects dominates and the introduction of search frictions leads the wage to decrease on impact. The efficiency wage considerations per se imply that the firm should set higher wages to ensure a higher effort level. However, in a search environment, the firm also takes into consideration the value of a worker versus re-hiring costs, which are mainly driven by the labor market tightness. Therefore, search and efficiency wage frictions interact and change the optimal firm's behavior. Now, eq. (26) implies that - given our discussion on the effects steaming from search frictions - falling wages lead to a decrease in effort.

Let us now compare the efficiency wage model with the standard Nash bargaining model. The latter model is a standard RBC search and matching model with endogenous separations and

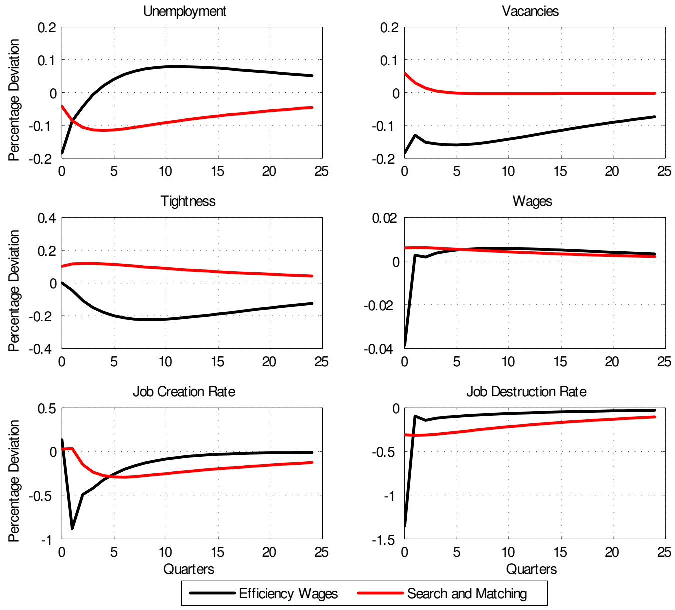

Figure 2: Comparison between the efficiency wage model and the Nash bargaining baseline model. Horizontal axes measure quarters, vertical axes deviations from steady state.

individual Nash bargaining. Figure 2 compares the impulse responses of key labor market variables. We observe that the dynamics in the Nash bargaining model are significantly different compared with the efficiency wage model. Unemployment converges from below to the old steady state, while it overshoots in the efficiency wage model generating the strong Beveridge curve relationship. In the efficiency wage model the impact from the effort dynamics lead the firm to reduce employment over time. This channel is absent in the Nash bargaining model and affects the firm's job destruction as well as the job creation decision. As we can infer from the Figure, vacancies decrease in the efficiency wage model, while they increase in the Nash bargaining model. The separation driven adjustment mechanism leads the firm to adjust along the exit margin and simultaneously decrease hiring activities. Wages play an important role for hiring and firing decisions and are quite different between the two models. As we have discussed above, search frictions imply that the wage decreases in the efficiency wage model. In the Nash bargaining model, workers obtain their share of the increased productivity and wages increase.

Let us turn to the second moments of our simulation. Table 2 presents the volatilities of key labor market variables, written as standard deviation relative to output, while Table 4 shows the correlation matrix. We find that the efficiency wage model does not show the Shimer (2005) puzzle. Shimer (2005) found that the standard search and matching model is not able to reproduce the observed standard deviations of key labor market variables. A result that is confirmed by the Nash bargaining version of our model. However, the efficiency wage specification performs reasonably well in replicating the observed standard deviations. In detail, we find that the volatility

Table 1:

	U.S. Data	Efficiency Wage	Nash Bargaining
$std(u)$	6.90	7.44	4.23
$std(v)$	8.27	12.79	0.67
$std(\theta)$	14.96	17.89	4.33
$std(w)$	0.69	0.86	0.21

Table 2: Volatilities of key labor market variables. Standard deviations are theoretical moments relative to output. Data values are taken from Krause and Lubik (2007).

of unemployment is much closer to its empirical value than in the baseline model (7.44 vs 6.90). The additional efficiency wage channel and the interaction of search and efficiency wage frictions amplifies the response of unemployment over the cycle. The largest performance gain is obtained for the standard deviation of vacancies. Although, vacancies are too volatile compared with the empirical value (12.79 vs. 8.27), what stands out is the strongly increased volatility compared with the Nash bargaining model. As effort varies over the cycle and changes the incentives to post vacancies according to eq. (19), vacancies fluctuate more over the cycle. Effort has a small standard deviation (0.14), is counter-cyclical and positively comoves with wages. As the standard deviations of unemployment and vacancies are close to their respective empirical counterparst, it is not surprising that also the volatility of labor market tightness is in line with the value found in the data. Finally, we find that the efficiency wage model also replicates the observed volatility of real wages reasonably well. In contrast, the Nash bargaining model creates a much smaller value. It appears that the introduction of search frictions and the wage setting within firms (here modelled as efficiency wages) generate important interactions that amplify the intial shock and help the model to generate the observed volatilities.

While the performance advantage in terms of matching volatilities is obvious, it is less clear in matching correlations. As Table 4 shows, the efficiency wage model generates a much stronger Beveridge curve (-0.53 compared to -0.08). However, besides this clear advantage, it is less clear which model performes better in replicating the observed correlations. Therefore, what stands out is the much stronger Beverdige curve.

Finally, we can draw the conclusion, that the Nash bargaining model is outperformed by the effciency wage model in terms of matching volatilities and - less clearly - correlations. In the next section, we provide a robustness analysis on effort function parameters.

4 Robustness

In this section, we will provide the reader with a robustness analysis of the effort function parameters. Before we start the discussion of different calibrations, we would like to come back to the

Table 3:

	u	v	θ	jfr	ρ	Z
U.S. Data						
u	1	-0.89	-0.97	-0.95	0.68	-0.38
v		1	0.98	0.85	-0.70	0.40
θ			1	0.92	-0.71	0.40
jfr				1	-0.55	0.41
ρ					1	-0.50
Efficiency Wage						
u	1	-0.53	-0.79	-0.79	0.32	0.40
v		1	0.94	0.94	0.50	-0.99
θ			1	1	0.22	-0.87
jfr				1	0.22	-0.87
ρ					1	-0.54
Nash Bargaining						
u	1	-0.08	-0.99	-0.99	0.98	-0.97
v		1	0.23	0.23	-0.28	0.33
θ			1	1	-0.99	0.99
jfr				1	-0.99	0.99
ρ					1	-0.99

Table 4: Correlation matrices, theoretical moments. Data values are taken from Shimer (2005).

benchmark calibration. The results are presented in Table 6.

Let us begin with ϕ_0 a scaling parameter that only influences steady state wages and effort. The smaller its value, the larger is the wage level and the less volatile is the wage relative to the shock. This implies that the labor market becomes more volatile, because the steady state wage is moved closer to steady state productivity (which is normalized to be 1), which increases its response to the shock. Hagedorn and Manovskii (2008) have shown that if wages do not move too much with productivity (and are close to productivity) the standard model is able to generate the observed fluctuations. In their paper, they achieve this by having a low bargaining power (as wages are determined by Nash bargaining) and a large outside option.

The second parameter to be considered is ϕ_1, linking wages to effort. This parameter turns out to be very important for the correlation of unemployment and vacancies. It turns out that a stronger linkage between wages and effort creates a stronger Beveridge curve and slightly increases labor market volatilities. The reason is that if $\phi_1 \to 0$, the dynamics in effort become more and more decoupled from dynamics in wages. This implies that firms are less reluctant to cut pay and the initial reaction to the shock becomes larger. Effort becomes more volatile and more important the initial drop is larger and creates repercussions with the search frictions. Because effort is a driver of the expected return of posting a vacancy, vacancy posting activities are reduced and the adjustment process on the labor market proceeds faster. It also implies that vacancies and unemployment are now positively correlated.

Now, let us consider ϕ_2, which determines the influence (the inverse) of unemployment on wages. We find that a stronger linkage between unemployment and wages works against the model's performance. As before, if ϕ_2 gets larger, the response of our model becomes larger and larger interactions arise that in this case work against the Beveridge curve relation. In terms of volatilities, the model gets closer to the empirically observed values.

Parameter ϕ_3 influences wages. Our robustness check shows that this parameter mainly drives the model's volatility. We find that smaller values of ϕ_3 significantly reduce the steady state wages. In this case, wages increase in response to the shock and so does effort. The increased effort supply then influences the firm's vacancy posting decision. In fact, it is the only specification in which vacancies increase on impact. The very large volatility of wages depresses the volatility of the labor market and therefore yields the worst result. Larger values lead to a stronger reaction of wages which again trigger the effort-to-search-friction channel.

Finally, ζ determines the non-linearity of effort in wages. The smaller ζ, the more linear is effort in wages and the closer those two variables are tied to each other. Moreover, for small values steady state wages are driven away from productivity and the volatility over the cycle significantly increases, which dampens the labor market fluctuations. However, while the benchmark model

Table 5:

			ϕ_0		ϕ_1		ϕ_2		ϕ_3		ζ	
	Benchmark	Nash	0	0.6	0.5	2	0.001	0.01	0.5	1	0.1	0.6
$std(U)$	7.44	4.23	6.15	9.67	7.59	7.21	7.06	7.48	2.43	6.48	5.38	6.28
$std(V)$	12.79	0.67	8.49	19.89	9.91	11.51	13.86	9.78	3.18	14.25	8.13	13.90
$std(W)$	0.86	0.21	0.60	2.57	0.46	0.84	0.57	1.35	2.80	0.35	9.25	0.45
$corr(U,V)$	-0.53	-0.08	-0.37	-0.56	0.83	-0.70	-0.74	0.17	-0.41	-0.87	-0.99	-0.96
$\frac{std(W)}{std(Z)}$	1.44	0.69	1.11	5.27	1.73	1.77	1.2	2.12	8.78	1.35	13.35	8.46
W	3.04	0.91	5.01	0.97	3.04	3.04	3.06	3.00	0.08	1.86	0.01	1.07

Table 6: Robustness check. Standard deviations are reported as relative to output.

generates fluctuations of wages that are not too large compared with productivity, this does not entirely confirm the Hagedorn and Manovskii (2008) result for our model environment. As we have discussed, also much larger fluctuations can generate the observed volatilities and the Beveridge curve relation. Causative is the interaction of search and efficiency wage frictions, which is obviously not present in the standard search and matching model. The effort channel influences the firm's decision to post vacancies, while search frictions alter the optimal wage/effort setting.

Furthermore, one might be tempted to interpret the introduction of efficiency wages as an alternative to introduce hours. However, if we compare our odel with a matchign model that features hours (e.g. Krause and Lubik (2007)), we find that this type of model is not able to replicate the observed volatilities. In those type of models wages and hours are often set simultaneously by a Nash bargaining problem. However, as we find strong interactions of efficiency wage frictions and search frictions, those strong interactions are absent in the hours model.

5 Conclusion

This paper combines the standard search and matching framework with efficiency wage frictions. Within a RBC environment we derive the Solow condition in a search environment and discuss the interactions of search and efficiency wage frictions. Given the search environment, the firm might wants to hire more workers to drive production to the minimum cost level, but is constraint by the search frictions. Therefore, the search frictions create an additional channel that affects the optimal effort level of employed workers that is absent in the standard competitive model. Here, (re-)hiring costs, drives the optimal effort level and a wedge between the search and the competitive equilibrium. If re-hiring costs are smaller - in absolute terms - than the marginal value of the worker (as in the steady state), than the Solow-condition implies that the optimal effort level should be lower compared to the competitive equilibrium. Low re-hiring costs create an incentive for the firm to adjust along the hiring margin, increase employment and reduce individual effort.

Besides this theoretical consideration, we consider the response of our model economy to a favorable stationary technology shock and compare the results with the standard Nash bargaining model. Our simulation shows that there is no evidence for the Shimer (2005) puzzle in the efficiency wage specification. To be precise, we find that the standard deviation of key labor market variables fits the empirically observed values fairly well. Furthermore, we find a much stronger Beveridge curve in the efficiency wage model.

The reason for the superiority of the efficiency wage model lies in the behavior of effort over the cycle. Worker's effort is an additional endogenous adjustment margin for the firm to respond to changes in the state of the economy. Search and efficiency wage frictions interact and change the optimal firm's behavior. In the efficiency wage model, the impact from the effort dynamics lead the firm to reduce employment over time. This channel is absent in the Nash bargaining model and affects the firm's job destruction as well as the job creation decision. In addition, wages are at the heart of the differences across the two models. As we seen, search frictions imply that the wage decreases in the efficiency wage model, while they increase in the Nash bargaining model, as workers obtain a share of the increased productivity. In summation, the interaction of search and efficiency wage frictions alter the optimal reaction of the firm to shocks and amplify the response of the model economy.

References

[1] Adams, J. Stacy and William B. Rosenbaum 1962. "The relationship of worker productivity to cognitive dissonance about wage inequalities." *Journal of Applied Psychology*, 46: 161-164.

[2] Akerlof, George A.. 1982. "Labor Contracts as Partial Gift Exchange." *The Quarterly Journal of Economics*, 97(4): 543-569.

[3] Bewley, Truman. 1998. "Why not cut pay?" *European Economic Review*, 42: 459–490.

[4] Blanchard, Olivier J.. 2008. "The State of Macro." NBER Working Papers No. 14259.

[5] Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo, "Labor Hoarding and the Business Cycle." *Journal of Political Economy*, 101: 245-73, 1993.

[6] Cheron, Arnaud. 2002. "Labor market search and real business cycles: Nash bargaining vs. fair wage." *Economics Letters*, 77: 279-285.

[7] Danthine, Jean-Pierre and André Kurmann. 2003. "Fair Wages in a New Keynesian Model of the Business Cycle." CIRPÉE Working Paper, No. 03-20.

[8] de la Croix, David, Gregory de Walque, and Rafael Wouters. 2009. "A Note on Inflation Persistence in a Fair Wage Model of the Business Cycle." *Macroeconomic Dynamics*, 13: 673-684.

[9] Fabiani, Silvia, Kamil Galuscak, Claudia Kwapil, Ana Lamo, and Tairi Rõõm. 2010. "Wage Rigidities and Labour Market Adjustment in Europe." *Journal of the European Economic Association*, 8(2-3): 1-9.

[10] den Haan, Wouter J., Garey Ramey, and Joel Watson. 2000. "Job Destruction and the Propagation of Shocks." *American Economic Review*, 90(3): 482-498.

[11] Hagedorn, Marcus and Iourii Manovskii. 2008. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited." *American Economic Review*, 98(4): 1692-1706.

[12] Hosios, Arthur J. (1990): "On the Efficency of Matching and Related Models of Search and Unemployment." *Review of Economic Studies*, Vol. 57(2): 279-298.

[13] Krause, Michael U., and Thomas A. Lubik. 2007. "The (Ir)relevance of Real Wage Rigidity in the New Keynesian Model with Search Frictions." *Journal of Monetary Economics*, 54(3): 706-727.

[14] Krause, Michael U., and Thomas A. Lubik. 2007. "Aggregate Hours Adjustment in Frictional Labor Markets." mimeo.

[15] Mauss, M.. 1954. "The Gift: Forms and Functions of Exchange in Archaic Societies." translated by Ian Cunnison (London: Cohen and West, 1954).

[16] Mortensen, Dale T. and Christopher A. Pissarides. 1994. "Job creation and Job Destruction in the Theory of Unemployment." *Review of Economic Studies*, 61(3): 397-415.