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Staggered Wages, Sticky Prices, and Labor Market Dynamics in Matching Models*

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1 Motivation

In recent years, macroeconomic research is characterized by an increased importance of labor market imperfections. The standard model to introduce such imperfections is the Mortensen and Pissarides (1994) (MP, henceforth) search and matching model. In this prototyp model, separations are driven by job-specific productivity shocks affecting new and old jobs, drawn from a time-invariant distribution. These shocks generate a flow of workers into unemployment, while the transition process from unemployment to employment is subject to search frictions, characterized by a matching function. A widely used assumption is, that the economic rent of a match is splitted in individual Nash bargaining.[1] This partial equilibrium core is often expanded to a general equilibrium model with sticky prices. In addition, since Erceg et al. (2000) staggered wages are a widely recognized feature of New Keynesian models when it comes to explaining inflation dynamics.[2] In contrast, our contribution is to shed light on the importance of sticky prices and staggered wages for the performance of the MP model with respect to labor market dynamics. We show that the partial equilibrium core creates too much volatility of key variables. The general equilibrium sticky price model outperformes the staggered wage model in terms of explaining standard deviations. Both rigidities perform reasonably well in replicating cyclical patterns. We conclude that he introduction of sticky prices or staggered wages alone does not help the model in explaining the stylized facts.
The paper is structured as follows. In the next section, we develop our model and in section 3 we discuss the role of price and wages stickiness. Section 4 considers endogenous separations, while section 5 concludes.

2 Model Derivation

2.1 Preferences

We assume that our economy is populated by a continuum of infinitively-living identical households. Furthermore, and in line with Merz (1995), households equally share income and risk among all family members. Utility of a representative household is defined by

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma} - 1}{1-\sigma} - \chi n_t \right], \tag{1}$$

where C is aggregate consumption and $n \in [0,1]$ is the fraction of employed household members. $\beta \in (0,1)$ is the standard discount factor, while χ gives the disutility of labor. Household members either search for a job on the labor market or supply labor services. However, employment is determined by the search process and hence is not subject to the households control. Then, the budget constraint is

$$C_t + T_t = w_t n_t + (1 - n_t) b + \Pi_t, \tag{2}$$

[1] See Faia and Rossi (2009) for a paper that features unionized wage setting.
[2] See e.g. Huang and Liu (2002).

benefits b are financed by a lump-sum tax, T. Π_t are dividends, while w_t is the wage. The household solves its maximization problem by choosing the path of consumption. Optimization yields the Euler equation

$$C_t^{-\sigma} = \lambda_t, \tag{3}$$

where λ_t is the Lagrange multiplier in the budget constraint.

2.2 Search Process

The firm searches for workers on a discrete and closed market. Trade in the labor market is uncoordinated, costly and time-consuming. Therefore, labor market frictions are modelled via a Cobb-Douglas type matching function with constant returns to scale, viz. $m(u_t, v_t) = \mu u_t^{\xi} v_t^{1-\xi}$. Job seekers, vacancies respectively are given by u_t, v_t respectively. $0 < \xi < 1$ is the match elasticity with respect to unemployment and μ reflects match efficiency. The vacancy filling probability is $q(\theta_t) = m(v_t, u_t)/v_t$, where $\theta_t = v_t/u_t$ is labor market tightness. We assume that separations, $0 < \rho < 1$, are determined exogenously such that the evolution of employment, defined as $n_t = 1 - u_t$, is given by

$$n_t = (1-\rho)\left[n_{t-1} + v_{t-1} q(\theta_{t-1})\right]. \tag{4}$$

2.3 Production

2.3.1 Flexible Price Equilibrium

Firms, acting on a monopolistically competitive market, produce differentiated products subject to labor adjustment costs. In addition, the vacancy posting process is modelled along the lines of Rotemberg (2006), such that total recruiting costs are given by $\frac{\kappa}{\psi} v_t^{\psi}$. Output y_t is produced with labor being the only input, i.e.

$$y_t = A_t n_t^{\alpha}, \tag{5}$$

where A_t is an aggregate technology shock and $0 < \alpha \leq 1$. The firm chooses $\{n_t, v_t, p_t\}_{t=0}^{\infty}$ by maximizing

$$E_t \sum_{t=0}^{\infty} \beta^t \lambda_t \left[p_t \left(\frac{p_t}{P_t} \right)^{-(1+\epsilon)} Y_t - w_t n_t - \frac{\kappa}{\psi} v_t^{\psi} \right], \tag{6}$$

where p_t is the price choosen by the firm and P_t is the aggregate price index. The demand elasticity is given by ϵ. Finally, the first-order conditions read as

$$\partial n_t : \tau_t = \alpha \frac{y_t}{n_t} \varphi_t - w_t + (1-\rho) E_t \beta_{t+1} \tau_{t+1}, \tag{7}$$

$$\partial v_t : \kappa v_t^{\psi-1} = (1-\rho) q(\theta_t) E_t \beta_{t+1} \tau_{t+1}, \tag{8}$$

$\beta_{t+1} = \beta\frac{\lambda_{t+1}}{\lambda_t}$ is the stochastic discount factor and φ_t is the Lagrangian parameter w.r.t. eq. (5) and represents real marginal cost. Melting these two equations yields the job creation condition

$$\frac{\kappa v_t^{\psi-1}}{q(\theta_t)} = (1-\rho)E_t\beta_{t+1}\left[\alpha\frac{y_{t+1}}{n_{t+1}}\varphi_{t+1} - w_{t+1} + \frac{\kappa v_{t+1}^{\psi-1}}{q(\theta_{t+1})}\right]. \tag{9}$$

The left-hand side of this equation gives the hiring costs which equal the benefits of creating a new job (right-hand side). 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.

2.3.2 General Equilibrium

In addition, to the previous section we now introduce nominal rigidities following Rotemberg (1982). This assumption allows us to consider a representative firm. Therefore, the firm problem reads as

$$E_t\sum_{t=0}^{\infty}\beta^t\lambda_t\left[p_t\left(\frac{p_t}{P_t}\right)^{-(1+\epsilon)}Y_t - w_t n_t - \frac{\kappa}{\psi}v_t^{\psi} - \frac{\vartheta}{2}\left(\frac{p_t}{p_{t-1}}-\pi\right)^2 Y_t\right], \tag{10}$$

and the additional derivative is given by

$$\partial p_t \quad : \quad 1-\vartheta(\pi_t-\pi)\pi_t + E_t\beta_{t+1}\left[\vartheta(\pi_{t+1}-\pi)\pi_{t+1}\frac{Y_{t+1}}{Y_t}\right] = \epsilon(1-\varphi_t), \tag{11}$$

where π_t is the inflation rate and π is steady state inflation. Log-linearizing this FOC gives us the New Keynesian Phillips curve

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \zeta\hat{\varphi}_t, \tag{12}$$

where $\zeta = (\epsilon-1)/\vartheta$.

2.4 Wage Setting

2.4.1 The Benchmark Case: Nash Bargaining

We use the Nash bargaining regime as the baseline model in order to be able to compare the effects of staggered wages with the standard case used in the literature. Therefore, we assume that the economic rent is splitted by maximizing the bargaining function[3]

$$\mathcal{S}_t = \left(\frac{1}{\lambda_t}\frac{\partial\mathcal{W}_t(n_t)}{\partial n_t}\right)^{\eta}\left(\frac{\partial\mathcal{J}_t(n_t)}{\partial n_t}\right)^{1-\eta}, \tag{13}$$

[3] See Lubik (2009).

where η is the worker's bargaining power. The first parenthesis contains the marginal value of a worker of being employed and the latter contains the marginal value of a worker to the firm.[4] The marginal value of a worker is given by[5]

$$\frac{\partial \mathcal{W}_t(n_t)}{\partial n_t} = \lambda_t w_t - \lambda_t b - \chi + \beta E_t \frac{\partial \mathcal{W}_{t+1}(n_{t+1})}{\partial n_{t+1}} \frac{\partial n_{t+1}}{\partial n_t}. \tag{14}$$

The optimality rule can be written as

$$\frac{\partial \mathcal{S}_t}{\partial w_t} : (1-\eta) \frac{1}{\lambda_t} \frac{\partial \mathcal{W}_t(n_t)}{\partial n_t} = \eta \frac{\partial \mathcal{J}_t(n_t)}{\partial n_t}. \tag{15}$$

Finally, by substituting the marginal values in, the individual wage follows

$$w_t = \eta \left[\alpha \frac{y_t}{n_t} \varphi_t + \kappa v_t^{\psi-1} \theta_t \right] + (1-\eta) \left[b + \chi C_t^{\sigma} \right]. \tag{16}$$

We can infer that the wage is a linear combination of the firm's surplus and the worker's payments in case of being unemployed. In contrast to other models, the latter also contains the consumption utility of leisure as in Lubik (2009).

2.4.2 Staggered Wages

As in Erceg et al. (2000), each household supplies specialized labor $L_t(j)$ which is combined according to

$$L_t(j) = \left[\int_0^1 L_t(j)^{\frac{1}{\epsilon_t^w}} dj \right]^{\epsilon_t^w}, \tag{17}$$

by a representative labor aggregator, where ϵ_t^w is a time varying measure of substitutability across labor services. Profit maximization by the aggregator implies that demand is given by

$$L_t(j) = \left[\frac{w_t(j)}{W_t} \right]^{-\frac{\epsilon_t^w}{\epsilon_t^w - 1}} L_t, \tag{18}$$

where the aggregate wage index is given by

$$W_t = \left[\int_0^1 w_t(j)^{\frac{1}{\epsilon_t^w - 1}} dj \right]^{\epsilon_t^w - 1}. \tag{19}$$

Following Sala et al. (2010) we assume that in any given period a fraction $1-\theta_w$ of households is able to re-set its wage. In addition, households who are not able to re-set index their wages to past inflation and steady state inflation, i.e.

$$w_t(j) = w_{t-1}(j) \pi_{t-1}^{\gamma_w} \pi^{1-\gamma_w}. \tag{20}$$

[4] $\frac{\partial \mathcal{J}_t(n_t)}{\partial n_t} = \tau_t$.

[5] $\frac{\partial n_{t+1}}{\partial n_t} = (1-\rho)\left[1 - \theta_t q(\theta_t)\right]$.

Then, the aggregate wage index in the presence of staggered wages evolves as[6]

$$W_t = \left[(1-\theta_w)(W_t^*)^{1/(\epsilon_t^w-1)} + \theta_w(\pi_{t-1}^{\gamma_w}\pi^{1-\gamma_w}W_{t-1})^{1/(\epsilon_t^w-1)}\right]^{\epsilon_t^w-1}. \qquad (21)$$

Here, we assume that the household solves the same maximization problem as in the absence of search frictions, since she has market power by the assumption of specialized labor. Either the search process is successful, such that the household supplies labor and sets wages or the search process in not successful and the worker stays unemployed. While there is no chance to influence labor supply - due to search frictions - wages are set in the standard staggered way.

2.5 Equilibrium

In any specification of our model, the resource constraint is

$$Y_t = C_t + \frac{\kappa}{\psi} v_t^{\psi}. \qquad (22)$$

In addition, in the general equilibrium case the model is closed with a standard Taylor rule, i.e.

$$\left(\frac{i_t}{\bar{i}}\right) = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi}\left(\frac{Y_t}{\bar{Y}}\right)^{\phi_y} \qquad (23)$$

where ϕ_π is the weight on inflation and ϕ_y is the weight on output set by the monetary authority. The aggregate productivity shock follows an AR(1) process, $A_t = \rho_A A_{t-1} + \epsilon_t^A$. We calibrate our model to match quarterly data for the United States. Table 1 summarizes our calibration. Missing parameter values are computed from the steady state.

3 Discussion

In the partial equilibrium core of our model (core, henceforth), a positive productivity shock leads the firm to reduce employment (see Figure 1). In addition, wages gain leading to a higher demand and output. Based on the increased wage and lower re-hiring cost, vacancies run low.
In a general equilibrium context with sticky prices, firms are not able to adjust prices instantaneously, such that consumption and output converge much more persistent. As a consequence, unemployment increases less strongly as in the previous case. This result is driven by (i) a more persistent adjustment and (ii) a larger change of wages. In addition, this explains why the response of vacancies is less strongly pronounced. Since less workers are separated, and demand stays higher for a longer period of time, firms have less incentives to decrease vacancy posting. Staggered wages and flexible prices mainly affect the dynamics of the model through the wage channel. Compared to the core, we

[6]See Erceg et al. (2000) or Sala et al. (2010) for a detailed derivation.

find that since wages are rigid over the cycle, less worker become unemployed and hence demand evolves more persistently. The same reasoning explains the less pronounced decrease in vacancies, since the firm receives a higher share of the profits.
Finally, staggered wages and sticky prices imply a smoother and a less strong adjustment of wages over the cycle. This has an additional effect on lay-offs and employment. Since firms realize higher profits, wages rise less strongly, such that firms keep more employees compared to the previous two cases. As a consequence, demand increases and goes along with higher output. Moreover, higher profits create less incentives to post less vacancies.
We now compare the standard deviations of our three models (see Table 2). We can conclude that our core model creates too much volatility compared with the data. The introduction of sticky prices significantly reduces the volatility of the model such that key variables are closer to their empirical counterparts. Compared with the core model, the introdution of either sticky prices or staggered wages, the sticky price model outperformes the staggered wage model in terms of volatility, while the latter shows a stronger Beveridge curve. However, the sticky price and staggered wages model is able to match the observed volatilities reasonably well. In addition, while all models show a negative correlation between vacancies and unemployment, this model perfectly replicates the Beveridge curve relation.

4 How Do Endogenous Separations Perform?

An essential question in the design of matching models is the definition of the separation margin. In the recent matching literature there is no consensus on the proper determination of the separation margin, whether it is exogenous or endogenous. However, following Ramey (2008) empirical evidence seems to favor endogenous separations.
Therefore, we want to briefly discuss the performance of our model with this feature.[7]
We find that the model with sticky prices and flexible wages outperformes the other specifications. Our results are presented in Figure 2. The sticky price model shows a similar adjustment pattern compared with the exogenous separation model. However, if we compare the second moments of our simulation, we find that the standard deviations of unemployment are close to each other (Data 0.19, Exogenous 0.28, Endogenous 0.27). The volatility of vacancies is closer to the empirical value in the endogenous model (0.2/0.69/0.42), which is also true for tightness (0.38/0.87/0.71) and the job finding rate (0.12/0.36/0.29). Finally, we find a stronger Beveridge curve in the endogenous model, which is remarkable compared to other endogenous models in the literature (see e.g. Krause and Lubik (2007)). This result is driven by the introduction of consumption utility of leisure. Since consumption and output increase, workers demand for an additional compensation for the loss of consumption utility due to being employed, which results in a higher wage. Firms react by separating from more workers and hence unemployment increases, creating the Beveridge curve relation.

[7] A detailed explanation of endogenous separation models can be found in den Haan et al. (2000) and Krause and Lubik (2007).

5 Final Remarks

We consider four different versions of matching models. (i) the baseline flexible price core, the general equilibrium model with (ii) sticky prices, (iii) staggered wages and (iv) sticky prices and staggered wages. Our contribution is to shed light on the importance of sticky prices and staggered wages within this model context. We show that the core creats too much volatility of key labor market variables. The model with sticky prices performes much better because the interaction of prices with labor market variables cause a more gradual adjustment within the labor market. The staggered wage model performs better in explaining the Beveridge curve but is outperformed by the sticky price model in terms of standard deviations. Finally, staggered wages and sticky prices lead the model to match the empirical evidence for standard deviations and the Beveridge curve. The reason is that the interaction of sticky prices and rigid wages cause more sluggishness in the labor market. Firms profits increase and change incentives in vacancy posting and employment adjustment.

Endogenous separation models have been analysed and the sticky price version shows the best performance. The model performs better compared to the exogenous sticky price model but is outperformed by the exogenous separation sticky price and staggered wage version. However, the introduction of consumption utility of leisure proposed by Lubik (2009) creates a Beveridge curve solving this well-known shortcoming.

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Tables and Figures

Table 1: Calibration.

Parameter	Value	Source
σ	1	Lubik (2009)
ξ	0.4	Blanchard and Diamond (1989)
ρ	0.15	Lubik (2009)
η	0.5	Trigari (2004)
κ	0.05	Lubik (2009)
ψ	2.53	Lubik (2009)
α	2/3	Lubik (2009)
ψ	105	Krause and Lubik (2007)
q	0.7	Lubik (2009)
ρ_A	0.95	Lubik (2009)
β	0.99	Standard
n	0.75	Trigari (2004)
ϵ	11	Trigari (2004)
ϵ^w	0	Sala et al. (2010)
μ	0.81	Lubik (2009)
χ	1	Lubik (2009)
ϕ_π	1.5	Standard
ϕ_y	0.125	Standard
γ_w	1.15	Sala et al. (2010)
θ_w	0.75	Sala et al. (2010)

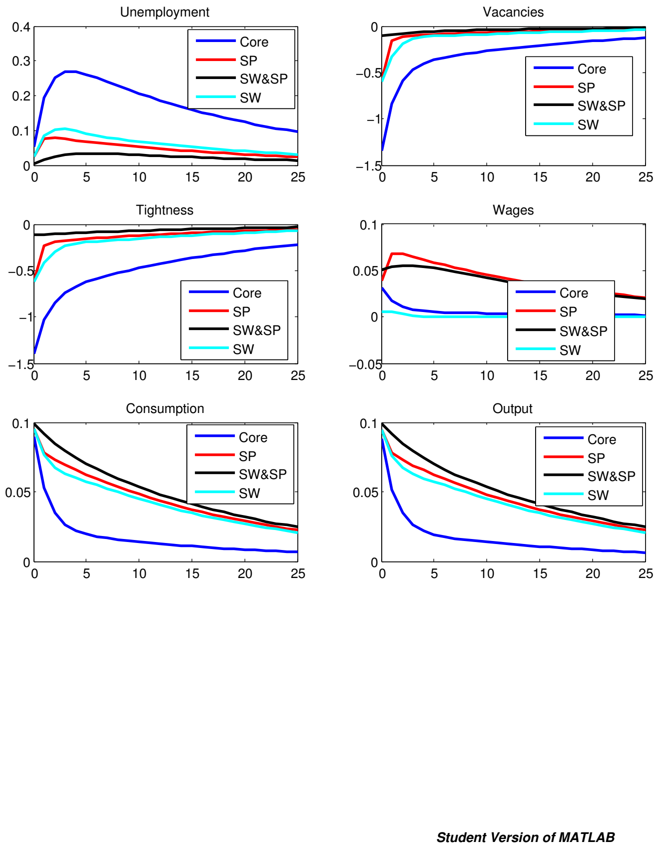
Unemployment
Vacancies
Tightness
Wages
Consumption
Output
Core
SP
SW&SP
SW
Student Version of MATLAB

Figure 1

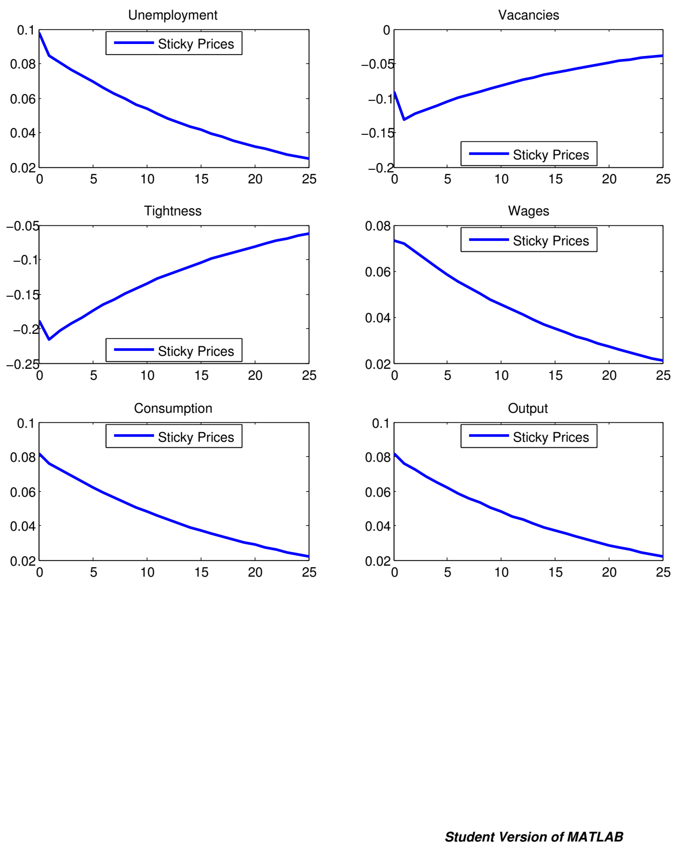
Unemployment
Sticky Prices
Vacancies
Sticky Prices
Tightness
Sticky Prices
Wages
Sticky Prices
Consumption
Sticky Prices
Output
Sticky Prices
Student Version of MATLAB

Figure 2

Table 2: Theoretical Moments - Comparison Exogenous Separations.

Variable	Data	Core	SP	SW	SP & SW
Standard Deviation					
u	0.19	0.99	0.27	0.34	0.13
v	0.20	3.11	0.69	0.81	0.25
θ	0.38	3.67	0.87	1.07	0.37
jfr	0.12	1.11	0.36	0.44	0.15
Correlations					
u, v	-0.89	-0.46	-0.60	-0.67	-0.85

Notes: Data for the U.S. are taken from Shimer (2005). Core = Partial equilibrium model. SP = General equilibrium model with sticky prices. SW = Sticky wages.