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The Shimer Puzzle and the Correct Identification of Productivity Shocks

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Abstract
Shimer (2005a) claims that the Mortensen-Pissarides search model of unemployment lacks an ampiflication mechanism because it cannot generate the observed business cycle fluctuations in unemployment given labor productivity shocks of plausible magnitude. This paper argues that part of the problem lies with the correct identification of productivity shocks. Because of the endogeneity of measured labor productivity, filtering out the trend component as in Shimer (2005a) may not correctly identify the shocks driving unemployment. Using a New-Keynesian framework with search unemployment, this paper estimates that close to 50% of the Shimer puzzle is due to the misidentification of productivity shocks. In addition, I show that extending the search model with an aggregate demand side remarkably improves the ability of the standard search model to match the moments of key labor market variables.

JEL classifications: E32, E37, J63, J64
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1 Introduction

In a very influential paper, Shimer (2005a) argues that the Mortensen-Pissarides search model of unemployment lacks an amplification mechanism because it cannot generate the observed business cycle fluctuations in unemployment given labor productivity shocks of plausible magnitude. In this paper, I argue that close to 50% of this so-called Shimer puzzle is simply due to the misidentification of labor productivity shocks.

In the Mortensen-Pissarides (MP) model of unemployment, shifts in labor demand are caused by changes in productivity, and productivity is seen as the central driving force of unemployment fluctuations. However, Shimer (2005a) shows that when one considers productivity changes of plausible magnitude, these are far too small to explain unemployment fluctuations. Quantitatively, the standard MP model can only explain 5% of the observed volatility in the vacancy-unemployment ratio.

Indeed, the MP model has a weak amplification mechanism: following an increase in productivity, the higher job-worker match surplus leads firms to post more vacancies but the higher number of posted vacancies reduces the duration of unemployment and puts upward pressures on the wage. In a reasonably calibrated version of the model, the wage absorbs virtually all of the productivity increase. As a result, a productivity shock barely affects unemployment, and one needs very large productivity shocks to account for the magnitude of unemployment fluctuations.

The Shimer puzzle has attracted a lot of interest in the literature, and a number of researchers have focused on ways to create more amplification so that small productivity movements generate large fluctuations in unemployment.[1] This paper follows a different route and claims that part of the Shimer puzzle is in fact due to the misidentification of productivity shocks. Shimer (2005a) estimates his productivity shocks series by filtering out the trend component of labor productivity (output per hour) with an HP-filter. His approach is consistent

[1] See, among others, Hagedorn and Manovski (2005) , Hall (2005), Hall and Migrom (2005), Shimer (2005b), and Mortensen and Nagypal (2005) for a review of recent efforts.

with a neoclassical setting in which productivity movements are exogenous and in which firms' labor demand responds to the marginal product of labor. However, when the firm is demand constrained, it is aggregate demand, not the marginal product of labor, that determines the optimal level of employment, and in Barnichon (2007), I argue that aggregate demand plays an important role in driving unemployment fluctuations. Since firms can respond to changes in demand by adjusting their level of capacity utilization of inputs (capital or labor), measured labor productivity fluctuates *endogenously* with aggregate demand and hence unemployment. As a result, what the MP model interprets as a causal relationship may in fact be a simple comovement as unobserved true shocks (such as aggregate demand shocks) drive both unemployment and labor productivity. The cyclical component of labor productivity does not identify the true shocks driving unemployment but captures the small and transitory endogenous response of measured labor productivity to some unobserved shocks. Because the endogenous response of productivity is small, it is natural to observe that the cyclical component of measured labor productivity fluctuates less than unemployment, and part of Shimer's puzzle is simply the by-product of the endogeneity of productivity.

To quantify the proportion of Shimer's puzzle due to this phenomenon, I use a calibrated New-Keynesian model with search unemployment, and I estimate that close to 50% of the low volatility of productivity relative to unemployment can be explained by the misidentification of shocks. In addition, I show that extending the search model with an aggregate demand side remarkably improves the ability of the standard search model to match the second moments and cross-correlations of labor productivity and key labor market variables. An equilibrium wage determined by Nash-bargaining fares relatively well whereas a wage norm such as the one suggested by Hall (2005) is rejected by the data.

The remainder of the paper is organized as follows: Section 2 presents the Shimer puzzle as well as statistics of key labor market variables; Section 3 describes possible explanations for the low volatility of unemployment relative to productivity; Section 4 shows the results of simulations using a calibrated New-Keynesian model with unemployment; and Section 5 offers some concluding remarks.

2 The Shimer puzzle

In this section, I reproduce Shimer's (2005a) exercise and show that detrended productivity is more than twenty times less volatile than labor market tightness. Table 1 presents summary statistics for productivity, unemployment, labor market tightness (the vacancy unemployment ratio) and the real wage. I use quarterly data taken from the U.S. Bureau of Labor Statistics (BLS) covering the period 1951:Q1 to 2005:Q4. Labor productivity is measured as real average output per hour in the non-farm business sector, and unemployment is the quarterly average of the monthly unemployment rate series constructed by the BLS from the Current Population Survey. Labor market tightness is defined as the vacancy-unemployment ratio and vacancies are the quarterly average of the monthly Conference Board help-wanted advertising index. The wage is real hourly compensation in the non-farm business sector, constructed by the BLS from the NIPA and CES. In order to study business cycle fluctuations, I remove low-frequency movements using a standard HP-filter with $\lambda = 1600$.[2]

As originally argued by Shimer (2005a), the volatility of productivity is only a fraction (here less than 4%) of the volatility of labor market tightness. Note also that the real wage fluctuates as little as productivity and hence a lot less than labor market tightness or unemployment. Turning to the correlation matrix, and unemployment and labor market tightness are weakly correlated with productivity with correlations of respectively -0.23 and 0.19. Digging a little deeper, Figure 1 and 2 plot the cross-correlograms between productivity and, respectively, unemployment and labor market tightness. The peak "impact" of productivity on unemployment and labor market tightness occurs after 2 to 3 quarters with correlations of respectively -0.50 and 0.49. Finally, the real wage is mostly acyclical but, if anything, weakly procyclical as it is weakly correlated with productivity (0.38), negatively correlated with unemployment (-0.23)

[2] This departs from Shimer (2005) who uses a less standard smoothing parameter of $\lambda = 10^5$. However, the results presented in this paper are robust to using a filter with a lower frequency trend (such as Shimer's) or using other filtering methods (such as the Baxter-King filter).

and positively correlated with labor market tightness (0.24).

In the context of a standard MP model where productivity movements are the central driving force of unemployment fluctuations, Shimer (2005a) shows that productivity has to be as volatile as unemployment for the MP model to account for the observed magnitude of unemployment fluctuations. He estimates that productivity shocks are only 10% as volatile as unemployment fluctuations and concludes that the MP model cannot account for more than 10% of unemployment fluctuations. Furthermore, Shimer (2005a) notes that the MP model exhibits virtually no propagation as it implies a contemporaneous correlation between unemployment and productivity of -1 when the data show a contemporaneous and peak unemployment-productivity correlation of respectively only -0.23 and -0.50. This point has drawn relatively less attention from the literature but is nonetheless an important aspect of a successful theory of unemployment fluctuations.

3 Reconciling the MP model with the data

In this section, I first review the approach followed by the literature to reconcile the MP model with the Shimer puzzle. Then, I propose a new explanation for the low volatility of productivity relative to unemployment.

3.1 The current approach: fixing the model to add more amplification

One way to reconcile the MP model with the data is to modify the model so that it generates more amplification, i.e. that a given shock to productivity has a larger impact on unemployment. Mortensen and Nagypal (2006) provide a detailed review of the current effort in that direction, and I will only emphasize two influential examples. A first possibility, suggested by Hall (2005) and Shimer (2005a), is to introduce real wage rigidity. In the standard MP model, the Nash bargaining real wage responds so much to movements in productivity that it effectively absorbs most of the changes in productivity. As a result, the surplus of the match responds only weakly to fluctuations in productivity. By introducing a degree of real wage rigidity, movements in productivity have a less muted impact on the match surplus, on the incentives of firms to post vacancies and hence on equilibrium unemployment.

Another possibility, suggested by Hagedorn and Manovskii (2004), does not rely on real wage rigidity but uses a standard MP model with a different calibration than the one used in Shimer's. Hagedorn and Manovskii (2004) show that when the opportunity cost of employment is high, the job finding rate becomes very responsive to changes in productivity, and the MP model can quantitatively account for the magnitude of unemployment fluctuations. While this approach is different from the one proposed by Hall (2005) and Shimer (2005a), the underlying philosophy is the same: one needs to modify the MP model (either its equations or its calibration) so that the surplus of the match becomes more responsive to changes in productivity.

3.2 The misidentification of productivity shocks

The approach that I propose here is different. I argue that the Shimer puzzle is not necessarily the symptom of some misspecification within the MP model or its calibration but simply the result of the misidentification of shocks.

In a neoclassical setting, firms post more or fewer vacancies depending on the return of the match. However, this needs not be the case when firms have to satisfy a given level of demand for their products. In a New-Keynesian setting with monopolistically competitive firms and costly price adjustment, firms may have to hire more workers when demand is unexpectedly high even if productivity (and hence the match surplus) does not increase. Put differently, the number of posted vacancies could increase without any change in productivity. In practice, this will not be the case because labor productivity has an endogenous component. Faced with higher demand, firms may also respond by increasing capacity utilization of inputs (capital or labor). As a result, measured labor productivity fluctuates with aggregate demand and hence unemployment.[3]

[3] This idea is given empirical support in Barnichon (2007), following Gali (1999).

By taking the residual from a low-frequency trend of output per hour, Shimer (2005a) does not identify the true productivity shocks but mostly the endogenous response of productivity to unobserved aggregate demand shocks. And because the endogenous response of productivity is small, it is natural to observe that the cyclical component of measured labor productivity fluctuates less than unemployment. I now present a New-Keynesian model with unemployment that allows me to capture formally this argument, and I will use a calibrated version to quantitatively evaluate the proportion of Shimer's puzzle that is due to the misidentification of shocks.

4 A New-Keynesian model with search unemployment

I extend the MP model by introducing nominal frictions so that hiring firms are demand constrained in a New-Keynesian fashion. In addition, I make a distinction between the extensive (number of workers) and the intensive (hours and effort) labor margins. In this framework, unemployment fluctuations are the product of two disturbances: technology shocks and monetary policy (or aggregate demand) shocks. By definition, positive technology shocks permanently raise productivity.[4] Positive monetary policy shocks decrease unemployment *and* increase measured productivity temporarily, because firms increase labor effort to satisfy demand in the short run. As a result, measured labor productivity is the product of two components: permanent and temporary disturbances. Filtering out the trend component of labor productivity will not correctly identify the shocks driving unemployment but will capture the transitory movements in productivity.

In the next subsections, I evaluate quantitatively how small these movements are in order to quantify the fraction of Shimer's puzzle that is due to the misidentification of shocks. I use a calibrated version of my New-Keynesian model with search unemployment to simulate data on unemployment and productivity, and I replicate Shimer's exercise on these artificial data.

[4] They also temporarily raise unemployment because with nominal rigidities, aggregate demand does not adjust immediately to the new productivity level, and firms use less labor.

Finally, this exercise allows me to study the performance of the model across key labor market variables.

4.1 The model

In this section, I present a New Keynesian model with search unemployment. The main ingredients are monopolistic competition in the goods market, hiring frictions in the labor market and nominal price rigidities in the form of costly price adjustment. There are three types of agents: households, firms and a monetary authority.

4.1.1 Households

I consider an economy populated by a continuum of households of measure one. With equilibrium unemployment, ex-ante homogenous workers become heterogeneous in the absence of perfect income insurance because each individual's wealth differs based on his employment history. To avoid distributional issues, I follow Merz (1995) and Andolfatto (1996) in assuming that households are extended families that pool their income and choose per capita consumption and assets holding to maximize their expected lifetime utility. Moreover, I assume that the family employment rate is equal to the aggregate employment rate n_t. In order to generate endogenous productivity, each employed family member supplies hours h_t and effort per hour e_t to the firm. Employed workers receive the wage payment $w_t h_t e_t$ with w_t the wage per efficiency unit, and unemployed workers receive unemployment benefits $b_t = bA_t$ with A_t the aggregate technology index. Unemployment benefits are taken as given by workers and firms. Denoting $g(h_t, e_t)$ the individual disutility from working, the representative family seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t) + \lambda_m \ln(\frac{M_t}{P_t}) - n_t g(h_t, e_t) \right]$$

subject to the budget constraint

$$\int_0^1 P_{it} C_{it} di + M_t + B_t = n_t w_t h_t e_t + (1 - n_t) b_t + M_{t-1} + (1 + i_{t-1}) B_{t-1} + \Pi_t + T_t$$

with λ_m a positive constant, M_t nominal money holdings, B_t bonds holdings paying an interest rate i_t, Π_t aggregate profits, T_t transfers from the government and C_t the composite consumption good index defined by

$$C_t = \left(\int_0^1 C_{it}^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

where C_{it} is the quantity of good $i \in [0, 1]$ consumed in period t, P_{it} is the price of variety i, and $\varepsilon > 1$ is the elasticity of substitution among consumption goods. The aggregate price level is defined as $P_t = \left(\int\limits_0^1 P_{it}^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}$. The disutility from supplying hours of work h_t and effort per hour e_t is the sum of the disutilities of the members who are employed. The individual period disutility of labor takes the form:

$$g(h_t, e_t) = \frac{\lambda_h}{1 + \sigma_h} h_t^{1+\sigma_h} + h_t \frac{\lambda_e}{1 + \sigma_e} e_t^{1+\sigma_e}$$

where λ_h, λ_e, σ_h and σ_e are positive constants. The last term reflects disutility from exerting effort with the marginal disutility of effort per hour rising with the number of hours. An infinite value for σ_e generates the standard case with inelastic effort.

4.1.2 Firms and the labor market

Each differentiated good is produced by a monopolistically competitive firm using labor as the only input. There is a continuum of large firms distributed on the unit interval. At date t, each firm i hires n_{it} workers to produce a quantity

$$y_{it} = A_t n_{it} L_{it}^{\alpha} \tag{1}$$

where A_t is an aggregate technology index, L_{it} the effective labor input supplied by each worker and $0 < \alpha < 1$. I define effective labor input as a function of hours h_{it} and effort per hour e_{it}:

$$L_{it} = h_{it} e_{it}. \tag{2}$$

Total effective labor input can be adjusted through three channels: the extensive margin n_{it}, and the two intensive margins: hours h_{it} and effort per hour e_{it}. With variable effort, the model will be able to generate endogenous procyclical movements in productivity.

Being a monopolistic producer, the firm faces a downward sloping demand curve $y_{it}^d = (\frac{P_{it}}{P_t})^{-\varepsilon} Y_t$ and chooses its price P_{it} to maximize its value function given the aggregate price level P_t and aggregate output Y_t. When changing their price, firms face quadratic adjustment costs $\frac{\nu}{2}\left(\frac{P_{i,t}}{P_{i,t-1}} - \pi^*\right)^2$ with $\nu > 0$ and π^* the steady-state level of inflation.

In a search and matching model of the labor market, workers cannot be hired instantaneously and must be hired from the unemployment pool through a costly and time-consuming job creation process. Firms post vacancies at a unitary cost, $c_t = cA_t$, and unemployed workers search for jobs. Vacancies are matched to searching workers at a rate that depends on the number of searchers on each side of the market. I assume that the matching function takes the usual Cobb-Douglas form so that the flow m_t of successful matches within period t is given by

$$m_t = m_0 u_t^{\eta} v_t^{1-\eta}$$

where m_0 is a positive constant, $\eta \in (0, 1)$, u_t denotes the number of unemployed and $v_t = \int_0^1 v_{it} di$ the total number of vacancies posted by all firms. Accordingly, the probability of a vacancy being filled in the next period is $q(\theta_t) \equiv m(u_t, v_t)/v_t = m_0 \theta^{-\eta}$ where $\theta_t \equiv \frac{v_t}{u_t}$ is the labor market tightness. Similarly, the probability for an unemployed to find a job is $m(u_t, v_t)/u_t = m_0 \theta_t^{1-\eta}$. Matches are destroyed at a constant rate λ, and the law of motion for a representative firm is given by

$$n_{it+1} = (1-\lambda)n_{it} + q(\theta_t)v_{i,t}.$$

When a firm and a worker meet, they must decide on the allocation of hours and effort to satisfy demand. I assume that both parties negotiate the hours/effort decision by choosing the optimal allocation and set hours and effort per hour to satisfy demand at the lowest utility cost for the worker. More precisely, they solve

$$\min_{h_{it},e_{it}} \frac{\lambda_h}{1+\sigma_h} h_{it}^{1+\sigma_h} + h_{it}\frac{\lambda_e}{1+\sigma_e} e_{it}^{1+\sigma_e} \tag{3}$$

subject to satisfying demand $A_t n_{it} h_{it}^{\alpha} e_{it}^{\alpha} = y_{it}^{d}$ at date t, and this implies that effort per hour is a function of total hours

$$e_{it} = e_0 h_{it}^{\frac{\sigma_h}{1+\sigma_e}} \tag{4}$$

where $e_0 = \left(\frac{1+\sigma_e}{\sigma_e}\frac{\lambda_h}{\lambda_e}\right)^{\frac{1}{1+\sigma_e}}$ is a positive constant. Thus, changes in hours can proxy for changes in effort, and I can write a reduced-form relationship between output and hours

$$y_{it} = y_0 A_t n_{it} h_{it}^{\varphi}$$

with $y_0 = e_0^{\alpha}$ and $\varphi = \alpha\left(1+\frac{\sigma_h}{1+\sigma_e}\right)$. For $\varphi > 1$, the production function displays short run increasing returns to hours, and endogenous labor productivity (i.e. output per hour) movements are procyclical.

4.1.3 Wage bill setting

Firms and workers take the market real wage w_t as given. The equilibrium real wage is determined by Nash-bargaining between a representative firm and a representative worker but I allow for the possibility of real wage rigidity, so that the market wage is described by a simple partial adjustment model:[5]

$$\ln\left(\frac{w_t}{A_t^*}\right) = \varpi.\ln\left(\frac{w_t^{nb}}{A_t^*}\right) + (1-\varpi)\ln\left(\frac{w_{t-1}}{A_{t-1}^*}\right) \tag{5}$$

where $\varpi \in [0,1]$ and w_t^{nb} is the Nash-bargaining wage. Denoting γ the bargaining power of the worker, one can show that the Nash-bargaining wage of the representative match takes the form

$$w_t^{nb} h_{it} e_{it} = \gamma\left(\frac{P_{it}}{P_t}\frac{y_{it}}{n_{it}} + c_t\theta_t\right) + (1-\gamma)\left(b_t + g_0 y_t h_{it}^{1+\sigma_h}\right) \tag{6}$$

with $g_0 = \frac{\lambda_h}{1+\sigma_h} + \frac{\lambda_e}{1+\sigma_e} e_0^{1+\sigma_e}$.

4.1.4 The firm's problem

Given the market wage and aggregate price level, firm i will choose a sequence of price $\{P_{it}\}$ and vacancies $\{v_{it}\}$ to maximize the expected present discounted value of future profits subject to the demand constraint, the hours/effort choice and the law of motion for employment. Formally, the firm maximizes its value

$$E_t \sum_j \beta^j \frac{u'(c_{t+j})}{u'(c_t)}\left[\frac{P_{i,t+j}}{P_{t+j}} y_{i,t+j}^d - n_{i,t+j}h_{i,t+j}e_{i,t+j}w_t - cA_t v_{i,t+j} - \frac{\nu}{2}\left(\frac{P_{i,t+j}}{P_{i,t+j-1}} - \pi^*\right)^2 Y_t\right]$$

subject to the hours/effort choice

$$e_{it} = e_0 h_{it}^{\frac{\sigma_h}{1+\sigma_e}}$$

the demand constraint

$$y_{it}^d = A_t n_{it} h_{it}^{\varphi} = (\frac{P_{i,t}}{P_t})^{-\varepsilon} Y_t$$

and the law of motion for employment

$$n_{it+1} = (1-\lambda)n_{it} + q(\theta_t)v_{it}.$$

[5] Blanchard and Gali (2005) or Cristoffel and Linzert (2005) follow a similar approach to introduce real wage rigidity.

4.1.5 Technological progress and the central bank

Technology is comprised of a deterministic and a stochastic component: $A_t = A_t^* \tilde{A}_t$ with $\frac{A_t^*}{A_{t-1}^*} = e^a$ and $\tilde{A}_t = e^{a_t}$ with $a_t = a_{t-1} + \varepsilon_t^a$ and $\varepsilon_t^a \sim N(0, \sigma^a)$. ε_t^a is a technology shock with a permanent impact on productivity.

Consistent with a growing economy and zero inflation in "steady-state", the quantity of money M^s evolves according to $M_t = M_t^* \tilde{M}_t$ with $\frac{M_t^*}{M_{t-1}^*} = e^a$ and $\tilde{M}_t = e^{m_t}$ with $\Delta m_t = \rho_m \Delta m_{t-1} + \varepsilon_t^m + \tau^{cb} \varepsilon_t^a$, $\rho_m \in [0,1]$ and $\varepsilon_t^m \sim N(0, \sigma^m)$. I interpret ε_t^m as an aggregate demand shock. As in Gali (1999), when $\tau^{cb} \neq 0$, the monetary authority responds in a systematic fashion to technology shocks.

4.1.6 Closing and solving the model

Since firms are homogenous, in equilibrium $n_{it} = n_t$, $P_{it} = P_t$, $y_{it} = y_t$, and total employment evolves according to $n_{t+1} = (1 - \lambda) n_t + v_t q(\theta_t)$. The labor force being normalized to one, the number of unemployed workers is $u_t = 1 - n_t$. Finally, assuming that vacancy posting costs are distributed to the aggregate households, $C_t = Y_t$ in equilibrium. To solve the model, I log-linearize the first-order conditions around the (zero-inflation) long run equilibrium.[6]

4.2 Calibration

I now discuss the calibration of the parameters of the model. I set the quarterly discount factor β to 0.99 and the matching function elasticity to $\eta = 0.4$ as measured by Blanchard and Diamond (1994). The scale parameter of the matching function m_0 is chosen such that, as reported in den Haan, Ramey and Watson (2000), a firm fills a vacancy with probability $q(\theta) = 0.7$ and, as reported by Shimer (2005b) and used in Shimer (2005a), a worker finds a job with probability $\theta q(\theta) = 0.6$.[7] Following Shimer (2005a), the separation rate is 10% so jobs last for about 2.5 years on average. The income replacement ratio is set to 40% of mean

[6] The equations are presented in the Appendix.

[7] den Haan, Ramey and Watson (2000) use a lower value $\theta q(\theta) = 0.45$ but the main results do not rely on this particular choice of calibration.

income so that $b = 0.4w^*h^*e^*$. I assume that the mark-up of prices over marginal costs is on average 10 percent. This amounts to setting ε equal to 11. I set the growth rate of technology (and money supply) to $a = 0.5\%$ a quarter so that the economy is growing by 2% on average each year. Turning the money supply, I use a money growth autocorrelation parameter ρ_m of 0.6, in line with the first autocorrelations of M1 and M2 growth in the US. The standard deviations of technology shocks and monetary policy shocks σ^a and σ^m are chosen to match the average standard deviations of technology shocks and non-technology shocks identified in Barnichon (2007) over 1948-2005. Finally, I set the price adjustment cost parameter ν to 100 so that the Phillips curve coefficient $\delta = 0.10$, and as estimated in Barnichon (2007), I set the short run scale parameter of the production function φ to 1.30 and the degree of monetary policy accommodation τ^{cb} to -0.43.

I now consider three calibration exercises with different degrees of real wage rigidity, and I study the moment properties of the simulated data.

4.3 Simulation with a flexible Nash-bargaining real wage

In order to make the case that real wage rigidity is not at play here, and that the low volatility of productivity shocks is due to the misidentification of the shocks, I start with a simulation that uses a flexible Nash-bargained real wage ($\varpi = 0$). Figure 3 and 4 show the impulse response functions, and Table 2 presents the results of the simulation. Despite a standard calibration and the assumption of full wage flexibility, the labor market tightness is 12.5 times more volatile than labor productivity. This result is striking; in US data, labor market tightness is 25 times more volatile than productivity, so this means that close to 50% of Shimer's puzzle can be accounted for by the misidentification of shocks. Interestingly, this finding is in line with the work by Pissarides (2007) who reconsiders the Shimer puzzle in the context of an MP model with endogenous job destruction. Pissarides (2007) reestimates the unemployment volatility puzzle downwards and claims that "with endogenous job destruction, the model fails to account for about half to two thirds of the volatility in unemployment" instead of the 90% originally estimated by Shimer (2005). But if 50% of the Shimer puzzle is due to the misidentification of productivity shocks and another 30 to 50% is due to the omission of endogenous job destruction, this means that the original puzzle is close to being fully resolved.

With full wage flexibility, the real wage appears slightly too volatile and too procyclical. It fluctuates 1.4 times more than in US data, and it comoves strongly with productivity with a correlation of 0.81 instead of 0.38 in US data. This can also be seen in Figure 3 and 4 where the real wage responds strongly to shocks. However, Pissarides (2007) questions Shimer's (2004, 2005a) use of an aggregate wage series as a benchmark to evaluate the search and matching model. In the MP model, job creation is determined by the expected cost of labor which depends on the wage in *new* matches, not on the wage in continuing matches. Reviewing the microeconometric studies on wages in new jobs, Pissarides (2007) finds a very procyclical "new job" wage with a wage-productivity elasticity close to 0.95. In this context, the strong procyclicality of the simulated wage cannot be used as a criteria to reject the model.

4.4 Simulation with rigidities in Nash-bargaining real wage

When prices are fully flexible (i.e. costless to adjust), the model should reduce to a standard neoclassical MP model. However, with vacancy posting costs and unemployment benefits proportional to the technology index, the Nash-bargaining wage becomes proportional to A_t. As a result, a positive technology shock leaves the unemployment rate unchanged because the wage increase absorbs all of the surplus and leaves the firm's profit unchanged. This property is not satisfactory as it is at odds with the search literature that views unemployment fluctuations originating mainly in exogenous labor productivity changes. Hence, I now impose $\varpi = 0.75$ implying an average duration of real wages of one year. With real wage rigidity, the firm's surplus increases temporarily following a positive technology shock, and the model is consistent with the MP model.

Figure 3 and 4 show the impulse response functions, and Table 3 present the results of the simulation. This time the real wage has a standard deviation of 0.009 and a correlation with productivity of 0.37; values that are close to the ones observed in US data. In other dimensions, the model also performs remarkably well as the cross-correlations have the right signs and are not far off the true values. In particular, unemployment is only weakly correlated with productivity (-0.12). Again, because the MP model exhibits virtually no propagation, the various simulations from Shimer (2005a, 2005b) cannot account for this weak contemporaneous correlation. On the other hand, as Figure 5 shows, a search model extended with an aggregate demand side and technology and aggregate demand shocks is remarkably successful at matching the cross-correlogram between unemployment and productivity. However, we can see in Figure 6 that if the simulated productivity-labor market tightness cross-correlogram resembles its empirical counterpart, the simulated contemporaneous correlation is too high and labor market tightness lacks persistence. In the model, firms can adjust vacancies immediately, and the vacancy-unemployment ratio does not display enough persistence because of this excessively rapid response of vacancies. Indeed, looking at Table 3, we can see that the simulated labor market tightness autocorrelation parameter is 0.73 instead of 0.89 for US data. This problem was already pointed out by Ramey and Fujita (2004) and incorporating sunk costs for vacancy creation as in Ramey and Fujita (2004) would presumably correct this shortcoming.

4.5 Simulation with a wage norm

For the last calibration exercise, I depart from the Nash-bargaining assumption and consider instead the case of a wage norm (in the sense of Hall, 2005) in which the real wage does not respond to transitory aggregate disturbances (such as nominal shocks) but adjusts progressively to permanent shocks (such as technology shocks) with $\varpi = 0.75$. In the absence of a consensus regarding the specification of the wage, it is interesting to study how well Hall's wage norm fares at matching the data. In addition, if this real wage specification is arguably ad-hoc, it has the merit of being consistent with the empirical evidence. Edge, Laubach and Williams (2003) show that the real wage responds progressively to technology shocks but is virtually insensitive to monetary policy shocks. As Figure 3 and 4 show, the behavior of the wage norm is now consistent with this evidence.[8]

Table 4 shows the results of the simulation. A general observation is that, for statistics independent of the wage, the results are not drastically changed by the real wage specification, and Table 4 and 5 look relatively similar. Because of real wage rigidity, the model now displays more persistence following a monetary shock (Figure 4). However, the main conclusion from this exercise is that a wage norm cannot match the data. It is not volatile enough with a standard deviation of only 0.005, and it is marginally countercyclical as the unemployment-wage correlation equals 0.15. Even with large confidence intervals, this is in contradiction with the empirical correlation of -0.23. Similarly, the wage-labor market tightness correlation is now counterfactually countercyclical. Finally, note that using wages in new jobs as the relevant wage measure does not change the main conclusion. The wage norm is still rejected by the data since Pissarides (2007) observes that wages in new jobs are negatively correlated with unemployment.

These simulations show two sets of results. First, around 50% of the low volatility of productivity shocks relative to unemployment fluctuations can be explained by the misidentification of shocks. Second, an MP model extended with an aggregate demand side fares better than a standard MP model at matching the moments of key labor market variables. The Nash-bargaining wage with real rigidities fares remarkably well at matching the data except for the unemployment-wage correlation: the real wage is too procyclical and too responsive to aggregate demand shocks. A wage norm such as the one suggested by Hall (2005) cannot match the volatility and cyclicality of the real wage as it fluctuates too little and is counterfactually countercyclical.

[8] Looking at Figure 3, a perhaps surprising result is the fact that the impulse responses to technology shocks look similar under a rigid wage norm and under a flexible Nash bargaining wage. Following a positive technology shock, the real wage increases faster under wage flexibility. However, the increase in unemployment dampens the increase in the real wage in the case of Nash-bargaining. Because of this feedback effect, the Nash-bargaining wage adjusts only slowly to technology shocks. In my calibration, the Nash-bargaining wage behaves like a wage norm with $\varpi = 0.75$ and as a result the impulse responses to technology shocks look very similar. However, this result is a coincidence and disappears when $\varpi \neq 0.75$.

5 Conclusion

Shimer (2005a) claims that the Mortensen-Pissarides search model of unemployment lacks an amplification mechanism because it cannot generate the observed business cycle fluctuations in unemployment given labor productivity shocks of plausible magnitude.

In this paper, I show that because of the endogeneity of measured labor productivity, filtering out the trend component of output per hour as in Shimer (2005a) does not correctly identify the shocks driving unemployment. In fact, isolating the cyclical component of productivity mostly captures the small and transitory endogenous response of measured labor productivity to unobserved true shocks (such as aggregate demand shocks). Using a calibrated version of a New-Keynesian model with search unemployment, I estimate that close to 50% of the Shimer puzzle is due to the misidentification of productivity shocks.

In addition, I show that extending the search model with an aggregate demand side remarkably improves the ability of the standard search model to match the second moments and cross-correlations of labor productivity and key labor market variables. An equilibrium wage determined by Nash-bargaining fares relatively well whereas a wage norm (in the sense of Hall, 2005) is rejected by the data.

Appendix

Log-linearized equilibrium dynamics

To analyze the behavior of the economy with real wage rigidity and costly price adjustment, I log-linearize the first-order conditions around the (zero-inflation) long run equilibrium.

Since firms are homogenous, I can drop the i index from the equations, and the log-linearized job posting condition takes the form

$$\frac{c\sigma}{q(\theta^*)}\hat{\theta}_t = E_t\beta\left[\chi^*\hat{\chi}_{t+1} + \frac{c(1-\lambda)\eta}{q(\theta^*)}\hat{\theta}_{t+1}\right] + \frac{c}{q(\theta^*)}E_t\left(\hat{y}_t - \hat{y}_{t+1}\right)$$

with the average value of a marginal worker $\hat{\chi}_t$ is given by

$$\hat{\chi}_t = \hat{w}_t + \psi(\hat{y}_t - \hat{n}_t)$$

and where $\hat{\theta}_t = \ln\left(\frac{\theta_t}{\theta^*}\right)$, $\hat{n}_t = \ln\left(\frac{n_t}{n^*}\right)$ and $\hat{y}_t = \ln\left(\frac{Y_t/A_t}{y^*}\right)$ are the log-deviations of rescaled variables from their long-run equilibrium values denoted by stars. Each firm posts vacancies until the expected cost of hiring a worker (the left-hand side) equals the expected discounted future benefits $\left\{\chi_{it+j}\right\}_{j=1}^{\infty}$ from an extra worker (the right-hand side).

The log-linearized price setting condition yields the standard New-Keynesian Phillips curve

$$\pi_t = \delta\hat{s}_t + \beta E_t\pi_{t+1}$$

with $\delta = \frac{\varepsilon-1}{\nu}$ and the firm's real marginal cost $\hat{s}_t$ given by

$$\hat{s}_t = \hat{w}_t + (\psi - 1)\left(\hat{y}_t - \hat{n}_t\right)$$

The log-linearized law of motion for the wage is

$$\hat{w}_t = \varpi.\hat{w}_t^{nb} + (1-\varpi)\hat{w}_{t-1} - (1-\varpi)\varepsilon_t^a$$

with $\hat{w}_t = \ln\left(\frac{w_t^m/A_t}{w^*}\right)$ the log-deviation of the rescaled wage from its long run equilibrium value and $\hat{w}_t^{nb} = \ln\left(\frac{w_t^m/A_t}{w^*}\right)$ the log-linearized Nash-bargaining wage given by

$$\hat{w}_t^{NB} = \gamma c\theta\hat{\theta}_t + \omega_y \hat{y}_t - \omega_n \hat{n}_t$$

with $\omega_y = \frac{1}{(1-(1-\gamma)b_0)w^*h^*e^*}\gamma\frac{y}{n} + (1-\gamma)\frac{2+\sigma_h}{1+\sigma_h}\lambda_h h^{1+\sigma_h}y - (1-(1-\gamma)b_0)\frac{w^*h^*e^*}{\alpha}$
and $\omega_n = \frac{1}{(1-(1-\gamma)b_0)w^*h^*e^*}\left(\gamma\frac{y}{n} + (1-\gamma)\lambda_h h^{1+\sigma_h}y - (1-(1-\gamma)b_0)\frac{w^*h^*e^*}{\alpha}\right)$.

Log-linearizing the first-order conditions for the household and denoting $\hat{m}_t = \ln\left(\frac{M_t/P_tA_t}{(M/P)^*}\right)$ the log-deviation of real rescaled money from its constant value in the zero-inflation equilibrium, I get $\hat{y}_t = E_t\hat{y}_{t+1} - (\hat{\imath}_t - E_t\pi_{t+1})$ and $\hat{m}_t = \hat{y}_t - \eta_i\hat{\imath}_t$ with $\hat{\imath}_t = \ln\left(\frac{1+i_t}{1+i^*}\right)$.

Finally, the log-linearized law of motion for employment can be written

$$\hat{n}_{t+1} = (1-\lambda-\theta q(\theta))\hat{n}_t + \frac{1-n}{n}(1-\eta).\theta q(\theta)\hat{\theta}_t.$$

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Table 1: Summary Statistics, Quarterly US Data, 1951-2005

		u	*v/u*	*w*	*p*
Standard deviation		0.007	0.257	0.010	0.010
Quarterly autocorrelation		0.88	0.89	0.81	0.69
Correlation matrix	*u*	1	-0.97	-0.23	-0.23
	v/u	-	-1	0.24	0.19
	w	-	-	1	0.38
	p				1

Notes: Seasonally adjusted unemployment *u* is constructed by the BLS from the Current Population Survey (CPS). The seasonally adjusted help-wanted advertising index *v* is constructed by the Conference Board. The wage *w* is real hourly compensation in the non-farm business sector, constructed by the BLS from the NIPA and CES. Average labor productivity *p* is seasonally adjusted real average output per person in the non-farm business sector, constructed by the Bureau of Labor Statistics (BLS) from the National Income and Product Accounts and the Current Employment Statistics. Except for u, all variables are reported in logs as deviations from an HP trend with smoothing parameter 1600.

Table 2: Model-generated data, Simulation with flexible wage

		u	*v/u*	*w*	*p*
Standard deviation		0.009 (0.008, 0.011)	0.118 (0.102, 0.137)	0.014 (0.013, 0.017)	0.009 (0.008, 0.011)
Quarterly autocorrelation		0.84 (0.79, 0.88)	0.72 (0.63, 0.80)	0.74 (0.68, 0.80)	0.62 (0.52, 0.71)
Correlation matrix	*u*	1	-0.71 (-0.78, -0.62)	-0.54 (-0.65, -0.44)	-0.08 (-0.24, -0.08)
	v/u	-	-1	0.73 (0.64, 0.81)	0.44 (0.30, 0.57)
	w	-	-	1	0.81 (0.74, 0.86)
	p	-	-	-	1

Notes: Numbers in parentheses indicate the 90% confidence interval calculated with 5000 model simulations.

Table 3: Model-generated data, Simulation with staggered one year contract for real wages

		u	*v/u*	*w*	*p*
Standard deviation		0.009 (0.008, 0.011)	0.117 (0.102, 0.133)	0.009 (0.007, 0.011)	0.010 (0.008, 0.011)
Quarterly autocorrelation		0.84 (0.79, 0.88)	0.73 (0.65, 0.79)	0.92 (0.90, 0.94)	0.65 (0.55, 0.73)
Correlation matrix	*u*	1	-0.71 (-0.77, -0.63)	-0.71 (-0.81, -0.60)	-0.12 (-0.27, 0.01)
	v/u	-	-1	0.52 (0.40, 0.63)	0.47 (0.34, 0.60)
	w	-	-	1	0.37 (0.24, 0.50)
	p	-	-	-	1

Notes: Numbers in parentheses indicate the 90% confidence interval calculated with 5000 model simulations.

Table 4: Model-generated data, Simulation with real wage norm

		u	*v/u*	*w*	*p*
Standard deviation		0.010 (0.008, 0.012)	0.128 (0.107, 0.150)	0.005 (0.004, 0.006)	0.009 (0.008, 0.011)
Quarterly autocorrelation		0.89 (0.84, 0.92)	0.80 (0.73, 0.86)	0.93 (0.90, 0.95)	0.66 (0.56, 0.73)
Correlation matrix	*u*	1	-0.79 (-0.85, -0.71)	0.12 (-0.09, 0.34)	-0.14 (-0.29, 0.01)
	v/u	-	1	-0.05 (-0.25, 0.16)	0.42 (0.28, 0.56)
	w	-	-	1	0.60 (0.47, 0.71)
	p	-	-	-	1

Notes: Numbers in parentheses indicate the 90% confidence interval calculated with 5000 model simulations.

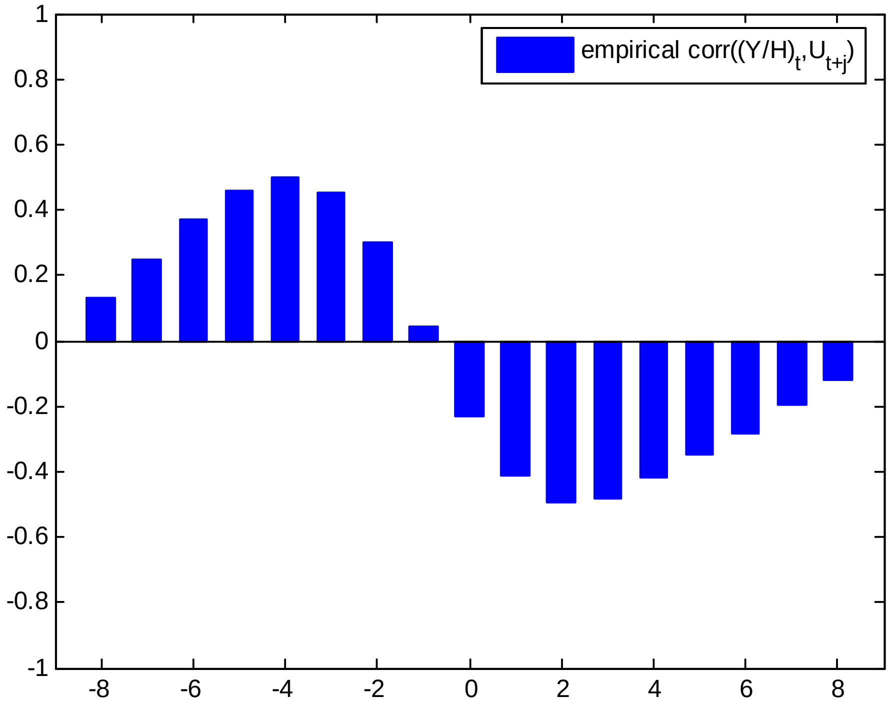

Figure 1: Empirical cross-correlogram of Productivity and Unemployment. 1951:Q1-2005-Q4

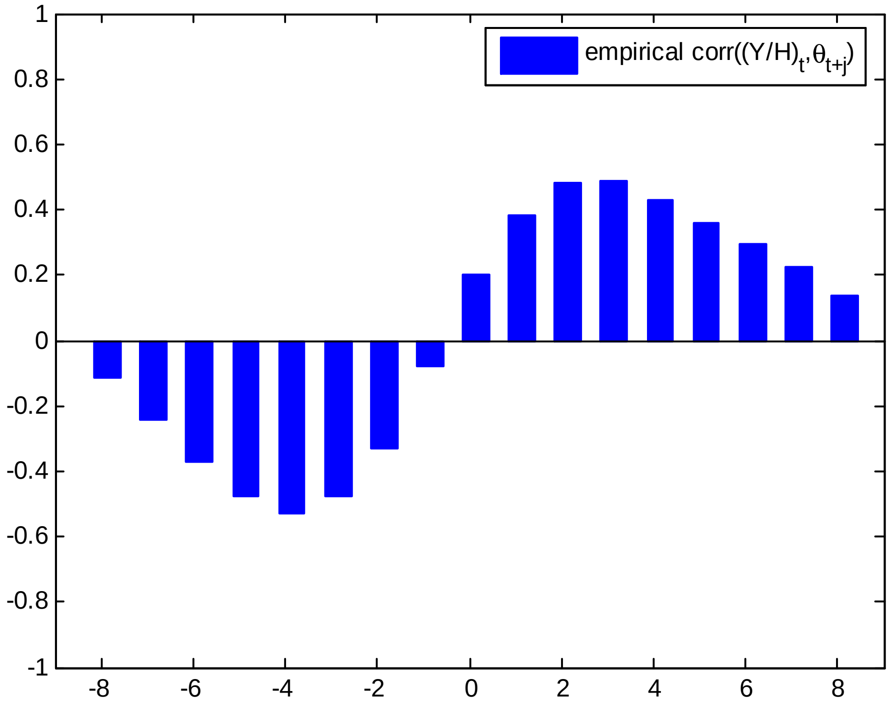

Figure 2: Empirical cross-correlogram of Productivity and Labor Market Tightness. 1951:Q1-2005-Q4.

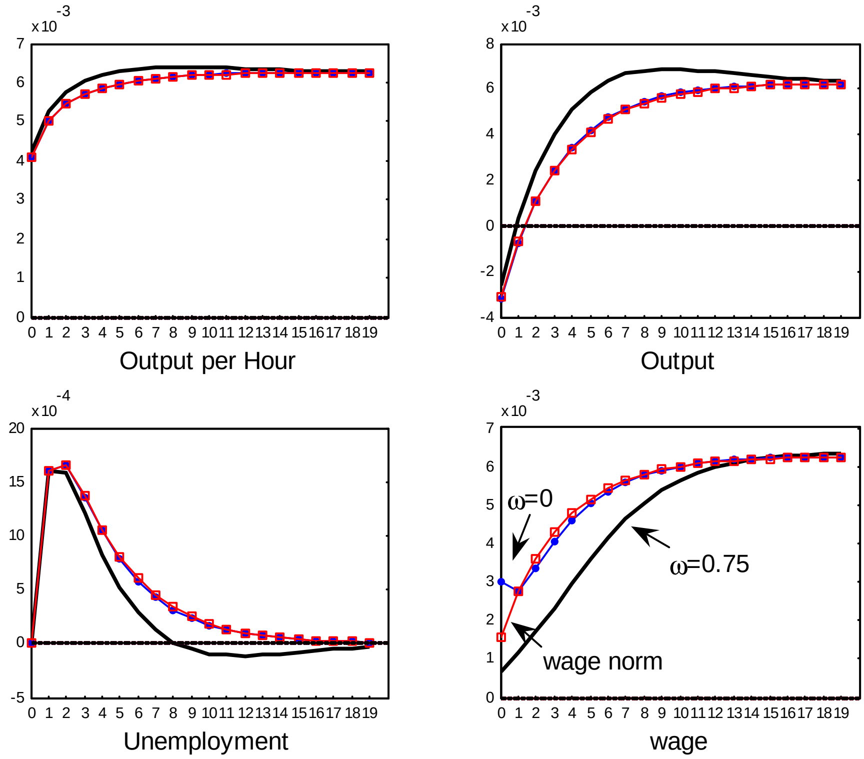

Figure 3: Model impulse response functions to a positive technology shock under different calibrations. The plain lines show estimates using a Nash-bargaining wage with $\varpi = 0.75$, circled lines using a Nash-bargaining wage with $\varpi = 0$ and squared lines using a wage norm with $\varpi = 0.75$.

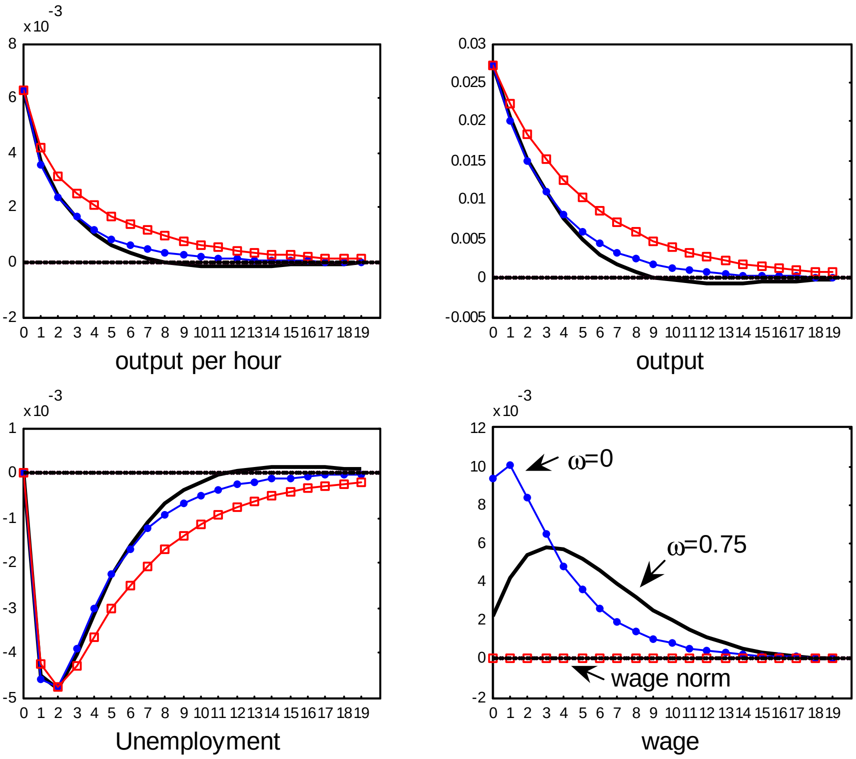

Figure 4: Model impulse response functions to a positive monetary policy shock under different calibrations. The plain lines show estimates using a Nash-bargaining wage with $\varpi = 0.75$, circled lines using a Nash-bargaining wage with $\varpi = 0$ and squared lines using a wage norm with $\varpi = 0.75$.

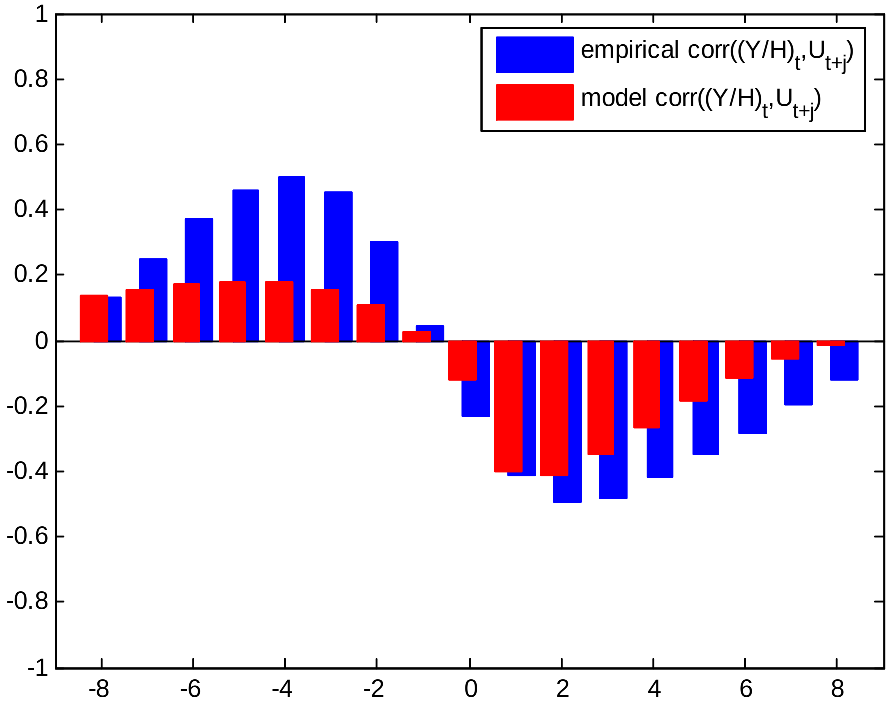

Figure 5: Model (foreground) and empirical (background) cross-correlogram of Productivity and Unemployment. 1951:Q1-2005-Q4.

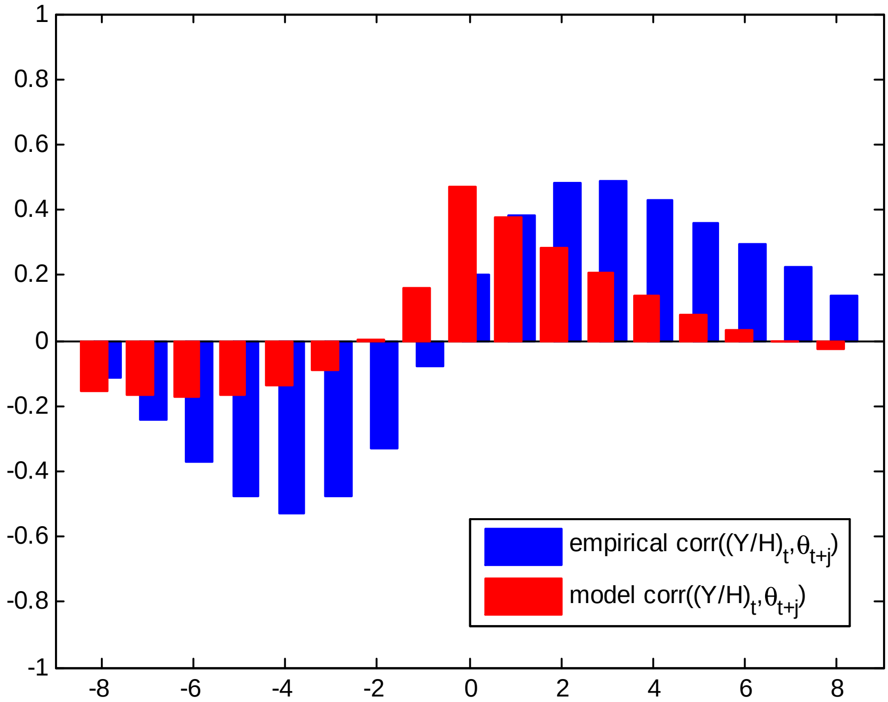

Figure 6: Model (foreground) and empirical (background) cross-correlogram of Productivity and Labor Market Tightness. 1951:Q1-2005-Q4.

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