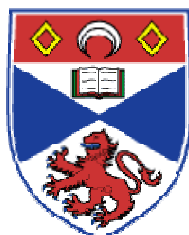


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# A DSGE Model from the Old Keynesian Economics: An Empirical Investigation\*

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## ABSTRACT

In this paper we estimate a DSGE model built along the lines of the recent Farmer's micro-foundation of the *General Theory*. Estimating a simple demand-driven competitive-search model, we test the ability of this new theoretical proposal to match the behaviour of the US and Euro Area labour markets. We show that within a relatively simple model we are able to fairly replicate their salient features, confirming for instance the conventional wisdom according to which the US labour market is more flexible than its Euro Area counterpart. Moreover, we provide an estimation of the not-yet-measured (unobserved) Euro Area job vacancies time series.

**JEL Classification:** E24, E32, E52, J64.

**Keywords:** Old Keynesian Economics, Competitive Search, DSGE Model, Bayesian Estimation.

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\* Comments are very welcome.

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# 1 Introduction

In a recent array of papers and a book, Farmer (2008a,b, 2010a,b) provides a new micro-foundation of the *General Theory* grounded on modern search and business cycle theories. The key ingredients of his theoretical proposal are the ideas that there is something distinctive about the labour market with respect to its Walrasian representation while beliefs and self-fulfilling expectations are the main drivers of the economic activity. The output of this ambitious research agenda is a competitive-search framework with multiple steady-states in which output and employment are demand driven, the money wage is used as numeraire and prices are flexible. In the remainder of the paper we will refer to this set-up with the adjective ‘Farmerian’ - or ‘Old Keynesian’ - in order to distinguish the suggested proposal from the traditional New Keynesian paradigm grounded on nominal and/or real rigidities.

Empirical contributions rooted in the new ‘Farmerian’ economics are still in progress. For instance, calibrating and simulating a simplified version of that framework in order to match the US first-moment data, Guerrazzi (2010) shows that the Farmer’s theoretical proposal can provide a rationale for the Shimer puzzle – Shimer (2005) –, i.e., the relative stability of real wages in spite of large volatility of labour market tightness indicators that the standard search model à la Mortensen and Pissarides (1994) is unable to replicate unless augmented with nominal and/or real rigidities, e.g. Shimer (2005), Hall (2005a,b), and Gertler et al. (2008).

In this paper we try to move one step forward by developing and estimating a DSGE version of the Guerrazzi’s model – Guerrazzi (2010). Specifically, estimating a simple demand-driven competitive-search model, we test the ability of the Farmer’s theoretical setting to match the dynamic behaviour of the US and Euro Area (EA henceforth) labour markets.<sup>1</sup> In particular we estimate the key parameters of the two mentioned labour markets, i.e. the matching elasticities in the Beveridge curve, and we provide a wide analysis of the dynamics implied by the models.

An important aspect of our analysis is that the ‘Farmerian’ approach allows for a distinctive role for equilibrium unemployment in the model economy and therefore we use the unemployment rate as an observable variable in our estimations. This is a relevant issue since there is a growing literature about incorporating unemployment in DSGE models. Hence, our aim is to contribute to the current macro-debate proposing an alternative way – the ‘Farmerian’ one – to model labour market variables such as

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<sup>1</sup>Our simple set-up may be subject to the critique that many of the relevant features of the most common macroeconomic aggregate are neither taken into account nor reproduced by the model, as for instance it is done by more structured models like Christiano et al. (2005) and Smets and Wouters (2003, 2005, 2007). We are conscious of such a possibility, but we think that providing a meaningful analysis without the use of those sophisticated models is an interesting challenge. Nevertheless, our next step will be to incorporate the Farmer’s labour market set-up into the Smets and Wouters (2003, 2005, 2007) framework.

(un)employment, vacancies and real wages.

The mentioned debate starts from the consideration that in DSGE models labour market is typically modelled using the Erceg et al. (2000) model of monopolistic competition and Calvo wage setting, like in Smets and Wouters (2007). In that framework there is no reference to unemployment, and hence no role for it in the model economy. This also implies that there is no reason to consider unemployment among the time series data in an estimated model.

Galí et al. (2010) is one of the most recent and prominent attempt to overcome both those theoretical and empirical limits. Galí (2010) proposes a reformulation of the Erceg, Henderson and Levin model, which implies a simple dynamic relation between wage inflation and unemployment. Galí et al. (2010) embeds this reformulation in the Smets and Wouters (2007) model by adding the unemployment rate as an observable variable.<sup>2</sup> One of the main conclusions of their contribution is that unemployment data bring relevant information to the estimation. In fact, they conclude that adding unemployment in the standard Smets and Wouters model (SW) helps in identifying labour supply from labour mark-up shocks. Moreover, it helps in estimating the Phillips wage-curve and generally improves the marginal likelihood of the original system.

Another important paper which characterizes a different and more popular approach is Gertler et al. (2008).<sup>3</sup> They develop and estimate a medium scale macroeconomic model à la Smets and Wouters (2007) that allows for unemployment and staggered nominal wage contracting, i.e. they introduce sluggish labour market adjustments into a version of the Mortensen and Pissarides search and matching framework.<sup>4</sup> One of the main drawbacks of this contribution is that it does not use any unemployment measure in the estimation. Interestingly, the authors themselves write that ‘more work is necessary ... to ensure a robust identification of the key labor market parameters’.

Taking into account the arguments above, we believe that our estimated parameters are sufficiently robust because we use the unemployment rate to estimate our models.

Our analysis focuses also on another controversial issue, i.e. the cyclicity of real wages. There is not a clear consensus about their empirical behaviour, especially in relation to the effects of different shocks. It is quite standard to find that according to their correlation with output they show to be pro-cyclical.<sup>5</sup> Nevertheless, more sophisticated analysis, like VAR, structural VAR, and panel data analysis, highlight that this may not be the case, especially if a distinction between supply and demand shock is made and if

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<sup>2</sup>Unfortunately the paper is not available and a straightforward comparison with it is difficult.

<sup>3</sup>Other recent contributions along the same line are: Trigari (2006) and Walsh (2005) who were among the first to integrate a search and matching setup within a monetary DSGE model with nominal price rigidities. Blanchard and Galí (2006) who develop a qualitative version of the Gertler et al. (2008)’s model with a simple form of real wage rigidities. Christoffel et al. (2006) who have also estimated a monetary DSGE model with labor market frictions and wage rigidity.

<sup>4</sup>See Mortensen and Pissarides (1994) and Pissarides (2000).

<sup>5</sup>This is also the case of the series generated by our estimated models.

detrending methods and identification issues are properly taken into account.

For instance, using a VAR approach Moccann and Baytas (1991) demonstrate that a supply shock generates pro-cyclical real wages, whereas a demand shock yields counter-cyclical. Estimating a structural VAR identified by long-run restrictions, Fleishman (1999) finds that real wages are pro-cyclical in response to technology shocks and oil price shocks, but are counter-cyclical in response to labor supply shocks and aggregate demand shocks. On the contrary, Lastrapes (2001) stresses that there is a contradictory evidence about the real wage response to a demand shock and this can be explained by differences in either data transformation used to achieve stationarity, or in the choice of empirical proxy for the economic variables, or in the lag length used to specify the VAR. Finally, Bils (1985) strongly supports the cyclical based on aggregate data.

We show that the counter-cyclical of real wages implied by the demand (for goods) shock in our model – associated with the supply shock that generates pro-cyclical wages – is an appealing structural feature to reconcile the fact that wages are either counter or pro-cyclical, depending on the time window considered.<sup>6</sup> Our counter-cyclical result firmly distinguishes our approach from the standard DSGE one in which the real wages pro-cyclical for the demand shock is the rule.

Finally, a by-product of our analysis is the estimation of the EA job vacancy series which is currently unavailable. We first consider the job vacancies series coming from the estimated model for the US. We validate it comparing it with two available data series (the Conference Board help-wanted advertising index – HWOL – and the series collected in the Job Openings and Labor Turnover Survey – JOLTS) and with some statistics of the observed US job vacancies. Given the success of the validation we rely on the Euro Area estimated model to provide a time series for the unobserved job vacancies data for that area.<sup>7</sup> This also allows us to compare the job vacancies dynamics in US and EA.

The paper is arranged as follows. Section 2 provides the theoretical framework. Section 3 provides a description of the estimation procedure, the data used and the prior distributions chosen for the single parameters. In section Section 4 we present and comment the estimation results. Finally, section 5 concludes.

## 2 Theoretical Framework

The theoretical framework exploited for the empirical estimations draws on Guerrazzi (2010) who builds a competitive two-sided search model in discrete time in which out-

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<sup>6</sup>See Huang et al. (2004).

<sup>7</sup>For an application of the same procedure in a different context see De Graeve (2008) and Gelain (2010). Specifically, those contributions estimate the external finance premium using a DSGE model with financial frictions for the US and the EA respectively.

put and employment are driven by effective demand, prices are flexible and the nominal wage rate is used as numeraire. A distinctive feature of this theoretical proposal routed in the new ‘Farmerian’ economics is that it also resumes some element of the Cambridge theory of distribution. Specifically, Guerrazzi (2010) assumes that economic agents are divided in two broad categories, i.e., wage and profit earners, which also are assumed to differ in their propensities to consume and their tasks.<sup>8</sup> On the one hand, wage earners - the owner of a fixed amount of labour services normalized to one - are assumed to dislike saving and consume the whole income earned by supplying their labour endowment. On the other hand, profit earners - the owners of the capital stock and/or overhead workers - are assumed to save the total income earned by employing a given amount of wage earners and arranging a stochastic production process aimed at financing capital accumulation. Moreover, profit earners can employ wage earners alternatively in recruiting or production activities. Finally, consistently with Farmer (2008a), Guerrazzi (2010) formalizes the ‘animal spirits’ of profit earners by assuming that their nominal investment expenditure measured in wage units follows an autonomous stochastic process such as those usually exploited for total factor productivity (TFP) in conventional real business cycle (RBC) models.

The Guerrazzi’s model can be summarized in four distinct blocks. On the one hand, the blocks from 1 to 3 provide the conditions for a symmetric demand constrained equilibrium (DCE), i.e., feasibility and market clearing in the market for goods, consistency with the optimal choices of wage and profit earners and search market equilibrium (e.g. Farmer (2008a,b, 2010a,b)). On the other hand, block 4 provides the laws of motion of the model economy. In what follows, we provide a formal description of each of them.

## 2.1 Feasibility and Market-Clearing in the Market for Goods

A distinctive feature a DCE is that all the purchased goods are produced by profit earners while there is no certainty that all the wage earners are actually employed.

Consider a given time period  $t$ . Profit earners output ( $Y_t$ ) is described by a constant-returns-to-scale Cobb-Douglas production function. Hence,

$$Y_t = A_t K_t^\alpha X_t^{1-\alpha} \quad 0 < \alpha < 1 \quad (1)$$

where  $A_t$  is common-knowledge stochastic productivity shock,  $K_t$  is the stock of capital,  $X_t$  is the fraction of wage earners employed in production activities while  $\alpha$  is the capital share.

Wage earners can be alternatively allocated to production or recruiting activities. As a consequence, total employment ( $L_t$ ) can be break down as

$$L_t = X_t + V_t \quad (2)$$

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<sup>8</sup>More detailed arguments on the Cambridge theory of distribution can be found in Kaldor (1956–1957) and Solow (1968).

where  $V_t$  is the fraction of wage earners employed as corporate recruiters.

The labour service endowment of wage earners is normalized to one. As a consequence, the unemployment rate is given by

$$U_t = 1 - L_t \quad (3)$$

Finally, the national account identity implies that

$$C_t + Q_t \tilde{I}_t = Y_t \quad (4)$$

where  $C_t$  is aggregate consumption in real terms,  $\tilde{I}_t$  is the nominal investment expenditure measured in wage units while  $Q_t$  is the real wage rate, i.e., the ratio between the nominal wage rate  $w_t$  and the price level  $p_t$ .<sup>9</sup>

## 2.2 Consistency with the Optimal Choices of Wage and Profit Earners

As stated above, wage earners dislike saving and consume the whole income earned by offering their labour services in a competitive-search labour market. Therefore, aggregate consumption equals the aggregate wage bill. Hence,

$$C_t = Q_t L_t \quad (5)$$

Substituting equation 5 in equation 4 allows to derive the value of aggregate demand measured in nominal wage units, i.e.,  $\frac{AD_t}{w_t} = L_t + \tilde{I}_t$ .

By contrast, profit earners employ a given fraction of wage earners by aiming at maximizing their net-of-wage payments. Obviously, this means that the marginal product of labour will equal the real wage all the times. As a consequence, taking into account of the production function in 1, it holds

$$(1 - \alpha) \frac{Y_t}{L_t} = Q_t \quad (6)$$

Equation 6 is a simple first-order condition for labour that allows to derive the value of aggregate supply measured in nominal wage units (i.e.,  $\frac{AS_t}{w_t} = \frac{L_t}{1-\alpha}$ ) and the equilibrium wage function.<sup>10</sup> Its counterpart for capital is missing because profit earners are assumed to invest the whole net-of-wage payments in productive investments.<sup>11</sup>

<sup>9</sup>As a consequence,  $Q_t \tilde{I}_t$  provides real investments.

<sup>10</sup>Guerrazzi (2010) shows that the equilibrium wage function implied by a DCE has a turning point in its concavity in the neighborhood of the first-best allocation. This is an endogenous source of wage stickiness that allows to resolve the Shimer (2005) puzzle.

<sup>11</sup>Obviously, this means that  $Y_t - Q_t L_t = Q_t \tilde{I}_t$ . Moreover, the real interest rate consistent with a zero-profit condition on the profit earners' side would be equal to  $Q_t \tilde{I}_t K_t^{-1}$ .

## 2.3 Search Market Equilibrium

The two-sided search framework implies that in each period wage earners have a certain probability to find a job while profit earners have a certain probability of fill their vacant positions by allocating wage earners to recruiting activities.

On the one hand, the probability to find a job ( $H_t$ ) equals aggregate employment.<sup>12</sup> Hence,

$$H_t = L_t \quad (7)$$

On the other hand, the recruiting effectiveness of a single wage earners employed as a recruiter is given by

$$R_t = \frac{L_t}{V_t} \quad (8)$$

Equation 8 is aimed at providing a micro-foundation for applications processing and suggests that each profit earner knows that  $V_t$  corporate recruiters can hire  $R_t V_t$  wage earners  $X_t$  of whom will be employed in production activities.

Finally, once (un)employment is determined by the level of aggregate demand in the market for goods, the fraction of wage earners allocated to recruiting activities is determined by a deterministic version of the Beveridge curve:

$$V_t = (1 - U_t)^{\frac{1}{1-\gamma}} \quad 0 < \gamma < 1 \quad (9)$$

where  $\gamma$  is the matching elasticity.

The Beveridge curve in equation 9 summarizes the operation of search and production externalities in the whole economy and suggests that in the Farmer's framework labour instead of output is used to post vacancies. Moreover, equation 9 has the nice geometrical feature that the higher (lower)  $\gamma$ , the closer (more distant) the Beveridge curve from its axes. Since Solow (1998) provided a definition of labour market flexibility exactly in terms of such a distance,  $\gamma$  also provides a straightforward measure of the underlying job market degree of the rigidity. Finally, the ratio  $\frac{V_t}{U_t} = \frac{V_t}{1-R_t V_t}$  still provides a measure of labour market tightness (e.g. Pissarides (2000)).

## 2.4 Laws of Motion

Equations from 1 to 9 determine a real wage  $Q_t$ , a production plan  $\{Y_t, V_t, X_t, L_t, U_t\}$ , a consumption allocation  $C_t$  and a pair of search probability  $\{H_t, R_t\}$  as function of the parameter set  $\{\alpha, \gamma\}$  and the state variables  $\bar{I}_t, A_t$  and  $K_t$ . As a consequence, the definition of the laws of motion of those three state variables closes the model.

<sup>12</sup>Conversely, the probability to remain unemployment is  $1 - L_t$ .

On the one hand, in the model economy under examination, investment are not derived from rational optimization. Following Farmer (2008a), Guerrazzi (2010) formalizes the profit earners' animal spirits by assuming that their nominal investment expenditure measured in wage units is driven by an autonomous stochastic AR(1) process. Hence,

$$\tilde{I}_t = \kappa + \rho_i \tilde{I}_{t-1} + \epsilon_t \quad (10)$$

where  $\kappa$  is a positive drift,  $\rho_i$  measures the persistence of the exogenous investment sequence and  $\ln \epsilon_t = \rho_\epsilon \ln \epsilon_{t-1} + u_t^\epsilon$  with  $u_t^\epsilon \sim N(0, \sigma_\epsilon^2)$  is a stochastic disturbance.

The expression in 10 pins down the DCE of the model economy and formalizes in a very simple way a central issue of the *General Theory*, i.e., the idea that investment expenditure exogenously evolves with no regard for expected profits.<sup>13</sup>

In the other hand, as in standard RBC models, the log of TFP is assumed to follow a stochastic AR(1) process. Thus,

$$\ln A_t = \ln \mu + \rho_a \ln A_{t-1} + u_t^a \quad (11)$$

where  $\mu$  is a positive drift,  $\xi$  measures the persistence of productivity shocks and  $u_t^a \sim N(0, \sigma_a^2)$  is a stochastic productivity disturbance.

The expression in 11 provides the stochastic trend that drives output, real investments, capital and real wages.

Finally, productive capital evolves according to the usual dynamic accumulation law. Hence,

$$K_t = Q_{t-1} \tilde{I}_{t-1} + (1 - \delta) K_{t-1} \quad 0 < \delta < 1 \quad (12)$$

where  $\delta$  is the depreciation rate of capital.

An illustration of a DCE is given in figure 1.

In panel (a) of figure 1 there is the equilibrium in the market for goods and services represented by the intersection of the value of aggregate demand ( $AD_t$ ) with the value of aggregate supply ( $AS_t$ ) both expressed in nominal wage units. In panel (b) there is the one-to-one relationship between employment and unemployment. In panel (c) there is a 45-degree line. Finally, in panel (d) there is the Beveridge curve and the equilibrium wage function.<sup>14</sup>

<sup>13</sup>Along these lines, Kurz (2008) provides a piece of micro-foundation for 10 by deriving a similar first-order autoregressive process as a limit posterior of a Bayesian learning inference in a non-stationary environment.

<sup>14</sup>Taking into account of the results in 1, 2, 6, and 9, the expression for the equilibrium wage function is given by  $Q_t = (1 - \alpha) A_t K_t \left(1 - L_t^{\frac{\gamma}{1-\gamma}}\right)^{1-\alpha} L_t^{-\alpha}$ .



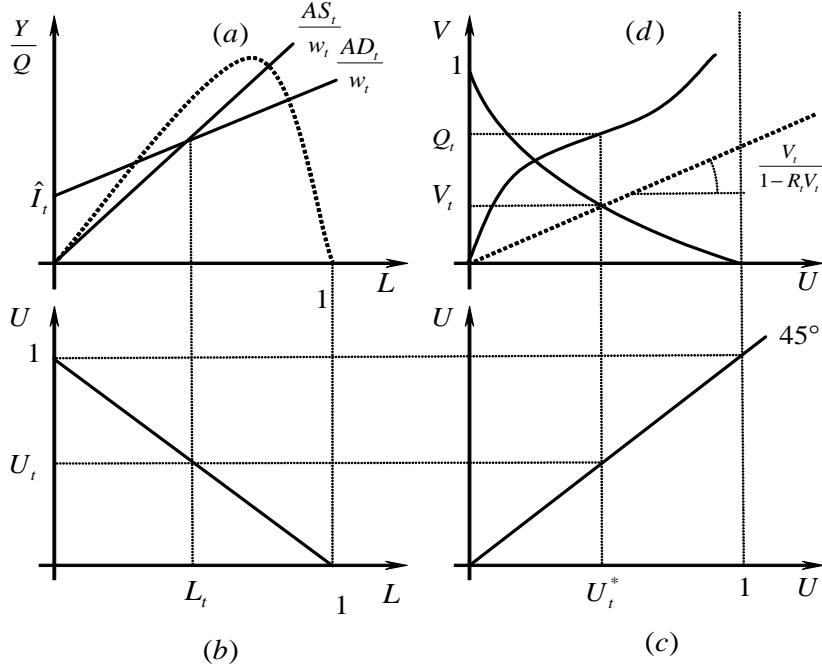


Figure 1: Demand constrained equilibrium.

### 3 Estimation

In this section we briefly describe the calibrated parameters, the data exploited for the estimation, the prior distributions assumed for the estimated parameters and the implemented estimation procedure.

#### 3.1 Calibration

The model is calibrated as follows. First, we set the consumption–output ratio  $C^*/Y^*$  at 0.7. As a consequence, the implied value for the labour share in the production function  $\alpha$  is 0.3, e.g. Kydland and Prescott (1982). Thereafter, the capital depreciation rate  $\delta$  is assumed to take the common value of 0.025, e.g. Guerrazzi (2010). Finally, the productivity drift  $\mu$  is set equal to 1, e.g. Chang (2000).

#### 3.2 Data and Priors

For both the US and the EA we use time series data for the following macroeconomic aggregates: real GDP, real consumption, real investments, real wages and unemployment rate.

The EA data are taken from the Euro Area Wide Model database developed by Fagan et al. (2004). The US data are available from the Bureau of Economic Analysis with the exception of the vacancies that come from the Conference Board while real wages come from the Bureau of Labor Statistics.<sup>15</sup> The estimation for both the US and the Euro Area is for the period from 1980q1 to 2008q4. All variables are per capita and detrended with their own linear trend.

We are conscious about the possible non-robustness of the results due to the detrending method. Hence we performed other estimations using variables detrended with the HP filter. Results are very robust to that change. We also tried the estimations taking the observables in growth rates. Results seem less robust for the US, but still acceptable, and robust for the EA. We discarded the growth rates alternative because the poor performance of the model in terms of fit with the data with respect to the other two alternatives. We will make some detailed references to how results change in the next sections where appropriate.

Another issue is the availability of time series data for the US job vacancies. One may wonder what could be the consequence for the estimation results if that series is used in the estimation. Also in this case US estimation are not affected by the use of this extra observable. Again we will discuss about the differences in the next sections where appropriate.

The choice of the priors has been done according to the following criteria. We choose an Inverse Gamma distribution for the standard deviation of shocks because it has a positive support. We allowed for an infinite variance to allow for the searching algorithm to explore a big portion of the support, although lower weights are given to higher values. The persistence parameters of the shocks are assumed to have a Beta distribution, because it is bounded between 0 and 1. Moreover, it allows to put higher prior weights on values close to unity, i.e. implying more persistence as we expect. The matching elasticity  $\gamma$  is distributed as a Beta with a 0.5 mean. The most appropriate prior for that parameter would have been a uniform distribution because we do not have strong a priori beliefs about it. Nevertheless, this type of prior puts the same weights on all the possible values in the support. The matching elasticity is strictly between 0 and 1. If values too close to those bounds are selected, the steady state of the model may be strongly affected. Hence, to reduce the number of draws to close to the bounds (or at least to give them less importance) we impose the Beta distribution.

### 3.3 Methodology

The aim of the estimation is to obtain the posterior distributions of the parameters and make inference out of them. Since the posterior distributions are unknown, we

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<sup>15</sup>For the real wages we use the series of the quarterly average hourly earnings of production workers divided by the GDP deflator.

used a Markov Chain Monte Carlo (MCMC) simulation method, namely the so-called random walk Metropolis–Hasting algorithm, which uses an acceptance–rejection rule to converge to the posterior distribution.<sup>16</sup> Before the simulation the maximization of the posterior kernel has been done in order to find the posterior modes and the variance-covariance matrix (evaluated at the modes) to be used in the initialization of the Metropolis-Hasting algorithm. The entire procedure is implemented in DYNARE for MATLAB<sup>TM</sup> (see Juillard (2004)).<sup>17</sup> For a detailed description, see An and Schorfheide (2007) and Canova (2007).

## 4 Analysis

In this section we present and comment the estimation results. Given the relative simplicity of the model, part of them are not very different for the US and the EA. For instance, the parameters point estimate do not differ significantly.

Nevertheless, impulse response functions do show relevant quantitative differences. Moreover, we can rely on the shock decomposition to extract interesting information about the US and the EA economies. It allows us also to make some comparisons between them, and to provide an explanation for the discrepancies we found. Moreover, the analysis of the estimated (smoothered) series for vacancies makes our study appealing, allowing at the same time to highlight more distinctive features of the US and EA labour markets.

### 4.1 Posterior results

In this subsection we describe two elements of the estimation outcome. On the one hand the quality of model’s fit. On the other hand the posterior distributions of the estimated parameters.

The former is evaluated through the comparison between the actual and the Kalman filtered values. From the charts in figures 9 and 17 it appears that the fit is satisfactory for both the US and the EA.

In what concerns the posterior distributions, we report them in figures 11–12 for the US, and in figures 19–20 for the EA. From the visual inspection it is clear that data contain information about many of the estimated parameters. In particular, the most interesting one for us, i.e. the matching elasticity, is clearly data–determined.

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<sup>16</sup>We run two chains of 500,000 draws each, and we discarded the first 50% as burn-in. The acceptance rate has been tuned to be around 30%, and the convergence of the chains has been evaluated with the checks proposed by Brooks and Gelman (1998). See figures 10 and 18 for the US and for the EA respectively.

<sup>17</sup>DYNARE allows for different kinds of optimization procedure. Here we used the option “mode-compute=6” which uses the Metropolis-Hasting to find the mode of the posterior distributions.

In tables 2 and 5 we summarize the priors chosen for the parameters and their moments, and the posterior means with their 90% probability intervals. The posterior mean of the matching elasticity is 0.8806 for the US and 0.8629 for the EA.<sup>18</sup> This seems to confirm the conventional wisdom that the US labour market is more flexible than the EA one according to the Solow's (1998) criterion, but we cannot argue that the two means are statistically different.<sup>19</sup>

We have two reference values for that parameter. Farmer (2008a) uses a value of 0.5 in his seminal simulations. This justifies in part our prior mean. Guerrazzi (2010) calibrates it at 0.9868. Therefore, our point estimates look very reasonable.

## 4.2 Impulse response functions

Impulse response functions well describe the dynamics of the model. As mentioned, they are quantitatively distinguishable for some endogenous variables. This allows us to disentangle the flexibility–rigidity of the two countries' labour markets issue (at least from the point of view of the demand shock).

We start by describing the implied dynamics, focusing first on demand shocks.<sup>20</sup> A positive (negative) demand shock increases (decreases) consumption, employment, capital, real investments, vacancies and output while it decreases (increases) real wages, unemployment and the recruiting efficiency of corporate recruiters.<sup>21</sup> Those movements are consistent with the thick (thin) market externalities induced by a positive (negative) demand shock within a demand-driven model economy.

It is worth stressing that real wages are counter-cyclical when a demand shock occurs, consistently with the traditional (Old) Keynesian belief about the consistency of Classical postulates.<sup>22</sup> This is in sharp contrast with the evidence in the Smets and Wouters DSGE model, but also with all the other previously quoted papers. The explanation of such a difference is that in our model employment is determined in the goods market, and then wages are set in order to be consistent with the firms' maximum profit

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<sup>18</sup>The posterior means using the HP filter are 0.8842 and 0.8497 for the US and EA respectively with probability intervals 0.8176-0.9541 and 0.7596-0.9493. The posterior means using growth rates are 0.9890 and 0.8561 for the US and EA respectively with probability intervals 0.9877-0.9900 and 0.7664-0.9523. Moreover using the US job vacancies series gives a posterior mean of 0.8636 with 0.8462-0.8811 probability interval.

<sup>19</sup>If  $\gamma$  takes value 1 it means that the economy is frictionless according to the Solow's (1998) criterion.

<sup>20</sup>Impulse response function for the US and the EA are qualitative identical. Therefore we describe their effect without referring to one of the two. We instead discuss extensively about their quantitative differences later on in the text.

<sup>21</sup>One may think about this shock as similar to the shock defined as shock to the investment cost function in Smets and Wouters (2003).

<sup>22</sup>Quoting the General Theory (p. 17): 'in general an increase in employment can only occur through the accompaniment of a decline in real wages. Thus, I am not disputing this vital fact which the classical economists have (rightly) asserted as indefeasible'.

condition, while New Keynesian models are usually embodied with a Real Business Cycle type of wage determination mechanism.<sup>23</sup>

The counter-cyclical effect of a demand shock on wages is easily explained using figure 1. A positive demand shock stimulates the aggregate demand for goods through the investment channel – panel (a). Given the aggregate supply, this requires a higher employments. In turns unemployment decreases – panel (b). In line with the wage equation coming from the firms’ maximum profit condition, a lower level of unemployment imposes a lower wage – panel (d).

On the contrary, in the Smets and Wouters model both wages and employments are determined in the labour market. Moreover, wage dynamics is the result of the well known neo-classical mechanisms of intertemporal substitution between leisure and consumption that leads labour supply to be nearly flat. A positive demand shock, e.g. an investment specific shock or a government spending shock, reduces households’ consumption so that labour supply increases. As a consequence, wages grow.<sup>24</sup> Hence the latter are pro-cyclical.

We would like to stress one more aspect. Our model is able to generate responses to the demand shock which are hump-shaped for all the endogenous variables. This is an important result, because in the DSGE literature the hump-shape for the most part of the endogenous variables is guaranteed by the introduction of specific types of real rigidities. For instance, consumption can be hump-shaped combining habit formation and forward looking behaviour of households. The resulting dynamic Euler equation provides the desired response of consumption. The hump-shape response of investment is obtained from the investments Euler equation, which in turns is the result of the combination of the investments adjustment costs assumption and of the forward looking nature of capital producers.

On the contrary, price and wage rigidities only account for the persistence and impulse response shape of inflation and labour market variables. In fact, the forward looking and indexation assumptions lead to one equation for inflation and one for wages which resemble very much Euler equations.

In our set-up things are different. Real wages are endogenously sticky and they respond in an hump-shaped manner. As expected, this shapes the labour market variables. However, it also influences the other real magnitudes, acting first on real investments – given their definition – and through them on output and consumption. Therefore, in a relatively simple framework with the presence of a small amount of real wage rigidity, it

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<sup>23</sup>An alternative way to highlight the difference is to refer to the slope of labour supply. In our framework the labour supply schedule is vertical. By contrast, in the Smets and Wouters model the labour supply schedule has a strong positive slope.

<sup>24</sup>The inverse relationship between consumption and labour supply is not univocal for all the Smets and Wouters demand shocks. That relationship holds for the equity premium shock, but nor for the remaining shocks, i.e. the preference shock, the inflation objective shock, and the monetary policy shock. The counter-cyclicity of real wages holds for all the demand shocks.

is possible to get hump-shaped impulse response functions, at least for demand shocks.

Quantitative considerations are also relevant. Figure 2 displays impulse responses for both the US and the EA for some labour market variables, those for which we found a significant statistical difference in the mean response to the demand shock. US wages, total employment, hiring effectiveness, and unemployment rate move much more strongly on impact than the corresponding EA variables. In addition, the peaks are more accentuated, and they occur some quarters in advance with respect to the EA peaks. All the US variables reach the peak after 3 quarters, while the EA ones after 5. As a consequence, US variables start the process of converge to the equilibrium beforehand. We interpret this finding as evidence of the conventional wisdom according to which the US labour market is more flexible than the EA one. In fact, after a demand shock the former reacts strongly, more promptly and it starts to converge back faster.

Although US variables seem to reach the steady-state before the EA ones, we cannot use this argument to support our statement on the higher US labour market flexibility, because of the lack of significance.

Turning to the technology shock, given the demand-driven structure of the model economy it affects only consumption, output, real wages, real investments and the capital stock.

The implied dynamics is as follows. A positive (negative) technology shock increases (decreases) consumption, output, real wages, real investments and the capital stock. On this matter, it is worth noting that the positive (negative) effect on real investment occurs through the improvement (drop) of real wages.

Unfortunately we do not find any statistical difference in the impulse response functions generated by a supply shock. Moreover, they do not display any hump-shaped form. This suggests us that allowing for a more rigorous model structure would help in improving the outcome in this respect. As mentioned we leave this extension for future works.

### 4.3 Output gap and shock decomposition

In this section we present the shock decomposition of the US and EA output gap. But before, we define it and we compare its definition with that of the DSGE literature.

The output gap is defined as the deviation of the actual output from its potential value. In our context, potential output is defined as the level of output that would prevail by internalizing search externalities. Obviously, such a level of output corresponds to the first-best allocation but it also entails a positive equilibrium unemployment which depends on the value of the matching elasticity only.<sup>25</sup> This definition is somehow different from the one provided in the DSGE literature. In Smets and Wouters (2003)

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<sup>25</sup>For its formal derivation, see Guerrazzi (2010).

it is defined as the level of output that would prevail under flexible prices and wages in the absence of the cost push shocks (i.e. price and wage mark-ups shocks).

Taking into account that the level of (un)employment that defines the potential output is constant, our equation for the potential output is the following (where ‘GG’ stands for Guerrazzi and Gelain ):

$$\widehat{y}_{GG}^{pot} = \widehat{a}_t + \alpha \widehat{k}_t \quad (13)$$

Despite the different definitions, the equation of the Smets and Wouters potential output is quite similar

$$\widehat{y}_{SW}^{pot} = \widehat{a}_t + \alpha \widehat{k}_t + \frac{\alpha}{1 + \nu} \log(\alpha) \quad (14)$$

where  $\nu$  is the inverse of the Frisch elasticity of labour supply.

Given the different structure of the models, the two potential outputs may be different as well. This depends on the fact that the dynamics of the two determinants, the capital stock and the technology shock, are affected by the model structure. As a consequence, the output gaps (actual output minus potential output) may differ too.<sup>26</sup>

Figure 3 shows the comparison between the Smets and Wouters and our output gaps, together with the capital stock and technology shock implied by the two models, for the EA only.<sup>27</sup> The upper panel picks out the high correlation between the series implied by the two models. The correlation is in fact 61%, but it increases to 80% if the last 15 observations are discarded. This result is explained mainly by the exogenous technology shocks, being them correlated at 71%, regardless whether or not we consider the last observations. Conversely, the capital stock dynamics affects more negatively the overall correlation (capital stocks correlate at a 36% rate).<sup>28</sup>

The main difference between the series is that the Smets and Wouters output gap is more volatile. It drops more significantly during the 1980s and the 1990s, and it positively overreacts in the last part of the sample.

More interestingly, the US and EA output gap shock decomposition reported in figures 5 and 7 allows us to highlight an important aspect of the end-of-sample financial crisis. In fact, the severe decrease of the output gap in the two countries receives a different explanation. In the US the negative output gap is determined by the conjunct effect of a negative demand shock and a negative technology (supply) shock, the former being much more relevant than the latter. In the Euro Area the demand shock positively contributes to the output gap, while the productivity shock strongly and negatively affects it. We would like to interpret this evidence as a sign that the US economy is intrinsically

<sup>26</sup>Figures 4 and 6 report the actual and potential output for the US and EA respectively.

<sup>27</sup>The series for the Smets and Wouters output gap is taken from Gelain (2010b) from the estimated model without the unit root technology shock.

<sup>28</sup>The differences are also due to the fact that in this paper the estimation is done with variable detrended with a linear trend, while in Gelain (2010b) the variables are taken in growth rate.

more productive than the EA while the negative effects of the crisis have been mainly due to demand factors. By contrast, in the EA the low labour productivity mainly determined the bad economic performance. This, besides highlighting the necessity of a reform in the EA labour market, once again confirms our belief that it is more rigid with respect to its US counterpart.

#### 4.4 Estimated EA vacancies

One of the main aims of our work is to provide an estimation of the not-observed job vacancies in the Euro Area by taking the ratio of corporate recruiters as a proxy for those variables. The Kalman smoother allows us to get a time series for that variable which is consistent with the estimated model. In figure 21 we report the smoothened values for the EA vacancies.

The first question one may ask is about the reliability of the estimated series. It is common to test that by comparing the smoothened values with some ready-to-use proxies for the variable if not with the variable itself. Given that neither the first nor the second possibility is available for the EA, we adopt a different strategy. We look at the US model to judge whether or not it is able to deliver trustable results, and given its success we believe in the EA model results. Firstly, we test the US model's ability to replicate the observed US job vacancies. Secondly, we compare the summary statistics of the US vacancies with those of the estimated series.

In figures 13 and 14 we show a comparison between the estimated US vacancies and two available series for them, namely the Conference Board help-wanted advertising index (HWOL) and the series collected in the Job Openings and Labor Turnover Survey (JOLTS). The contemporaneous correlations with the former is very high (0.863). The correlation with the latter is somehow lower but still satisfactorily high (0.822).

In order to strengthen the validation of the estimated job vacancies series we investigate further. Tables 3 and 4 report the standard deviations of the US vacancies and their correlation with the observable used in the estimation and their autocorrelations respectively. We can argue that the second moments of observed and estimated vacancies are pretty similar. The correlations with the main macroeconomic variables are also matched well.

We can then conclude that the estimated model can generate a time series for the job vacancies very in line with the observed one. Hence we can use the EA model to estimate a time series for the EA vacancies. This is reported in figure 21.

A comparison between the observed US vacancies and the EA estimated vacancies is given in figure 8. The overall correlation between the two series is slightly negative (-13%). A visual inspection of figure 8 seems to suggest that this correlation value comes from the fact that the EA series lags behind the US series. Specifically, the EA series seems to delay both expansions and recessions. This lagged behaviour is testified by the correlations reported in table 1 between the current values of the US



vacancies and the lagged EA vacancies. Consistently with our findings on the impulse response functions, this pattern seems to confirm that the US labour market appears more reactive than its EA counterpart. In fact the negative correlation with the lagged EA vacancies increases up to -0.76 in the fifth lag.

## 5 Concluding Remarks

In this paper, we develop and estimate a DSGE version of the Guerrazzi's model – Guerrazzi (2010) – inspired to the new 'Farmerian' economics. Specifically, estimating a simple demand-driven competitive-search model, we test the ability of the recent Farmer micro-foundation of the *General Theory* – Farmer (2008a,b, 2010a,b) – to match the dynamic behaviour of US and EA labour markets.

Our main contribution is to show how a relatively simple model can fairly replicate the salient features of the two mentioned labour markets. The new theoretical approach we propose, different from the Mortensen and Pissarides (1994) one commonly used in the DSGE literature to model the labour market frictions, is the first strong point of our analysis. From an empirical point of view, the strong point is that we use the unemployment rate as an observable variable to have a robust estimation and identification of the labour market parameters.

We find that the fit of the two estimated models with both the US and the EA data is very good. We robustly estimate the labour markets parameters, in what we use unemployment as an observable, finding that the estimated matching elasticity is 0.8806 for the US and 0.8629 for the EA. According to the Solow's (1998) criterion based on the distance of the Beveridge curve from its axes, this seems to confirm the conventional wisdom that the US labour market is more flexible than its EA counterpart, but we cannot argue that the two points estimate are statistically different.

We can nevertheless rely on the impulse response analysis to find evidence of that wisdom (at least for a demand shock). In fact, some of the US labour market variables (i.e. real wages, total employment, hiring effectiveness, and the unemployment rate) respond much strongly on impact than the corresponding EA variables. Moreover, the peak in the US is reached after 3 quarters, while it is reached after 5 quarters only in the EA. This also means that the process of convergence to the steady-state begins in advance in the US.

Further evidence in this sense comes from the output gap decomposition and from the comparison between the job vacancies in the US and EA. The former shows that in the last part of the sample period, when the financial crisis hits the economy, the stochastic driving forces of the output gap in the US and EA are different. In the US demand factors are the main responsible for the drop in the output gap, while in the EA the productivity shock is the relevant one. The latter highlights that the EA job vacancies are lagged with respect to the US ones. The highest correlation of the US

variable is with the 5th lag of the EA counterpart (-76%).

Finally, our analysis sheds some light on the cyclicity of real wages. According to the (Old) Keynesian belief that they are counter-cyclical, our model embodies that feature in what the demand shock makes real wages moving in the opposite direction with respect to output. This, besides being in line with much of the empirical evidence and in clear discordance with the New Keynesian framework, is also a desirable feature to have in the model. In fact, in our sample period real wages are either pro- or counter-cyclical according to the time window considered. Hence, given that the productivity shock implies pro-cyclical real wages, we need a source of counter-cyclicity to cope with the evidence.

## A Steady state values

In this section we derive the steady-state values around which the model is log-linearized. We start from the steady-state equation for the investment expenditure measured in wage units. Specifically, equation 10 implies that

$$\tilde{I}^* = \frac{\kappa}{1 - \rho_i} \quad (\text{A.1})$$

where  $\tilde{I}^*$  is the steady-state investment expenditure.

Taking the result in A.1 into account, it follows that steady-state employment is given by

$$L^* = \frac{1 - \alpha \tilde{I}^*}{\alpha} \quad (\text{A.2})$$

Given A.2, steady-state unemployment is equal to

$$U^* = 1 - L^* \quad (\text{A.3})$$

Taking the result in A.3 into account, it follows that the steady-state rate of corporate recruiters is given by

$$V^* = (1 - U^*)^{\frac{1}{1-\gamma}} \quad (\text{A.4})$$

Finally, the steady-state rate of wage earners allocated to production activities is equal to

$$X^* = L^* - V^* \quad (\text{A.5})$$

All the remaining steady state values follows straightforwardly.

## B Log-Linearization

In this Appendix we provide all the log-linearized equations that describe the model economy in section 2. Small-hatted-variables denote log-deviations from the corresponding steady-state. Production function

$$\widehat{y}_t = \widehat{a}_t + \alpha \widehat{k}_t + (1 - \alpha) \widehat{x}_t \quad (\text{B.1})$$

Total employment

$$\widehat{l}_t = \frac{X^*}{L^*} \widehat{x}_t + \frac{V^*}{L^*} \widehat{v}_t \quad (\text{B.2})$$

Unemployment rate

$$\widehat{u}_t = -\frac{L^*}{U^*} \widehat{l}_t \quad (\text{B.3})$$

National account identity

$$\frac{C^*}{Y^*} \widehat{c}_t + \frac{I^*}{Y^*} \widehat{i}_t = \widehat{y}_t \quad (\text{B.4})$$

Real investments

$$\widehat{i}_t = \widehat{i}_t - \widehat{q}_t \quad (\text{B.5})$$

Wage earners budget constraint

$$\widehat{c}_t = \widehat{q}_t + \widehat{l}_t \quad (\text{B.6})$$

Condition for maximum profits

$$\widehat{y}_t - \widehat{l}_t = \widehat{q}_t \quad (\text{B.7})$$

Probability to find a job

$$\widehat{h}_t = \widehat{l}_t \quad (\text{B.8})$$

Recruiting effectiveness of a single wage earners employed as a recruiter

$$\widehat{r}_t = \widehat{l}_t - \widehat{v}_t \quad (\text{B.9})$$

Beveridge curve

$$V^* (1 + \widehat{v}_t) = [1 - U^* (1 + \widehat{u}_t)]^{\frac{1}{1-\gamma}} \quad (\text{B.10})$$

Capital accumulation

$$\widehat{k}_t = (1 - \delta) \widehat{k}_{t-1} + \delta \widehat{i}_t \quad (\text{B.11})$$

Real investments

$$\widehat{i}_t = \rho_i \widehat{i}_{t-1} + \frac{\widehat{\epsilon}_t}{I^*} \quad (\text{B.12})$$

Shocks

$$\widehat{a}_t = \rho_a \widehat{a}_{t-1} + u_t^a \quad (\text{B.13})$$

$$\widehat{\epsilon}_t = \rho_\epsilon \widehat{\epsilon}_{t-1} + u_t^\epsilon \quad (\text{B.14})$$

Measurement errors

$$\widehat{\epsilon}_t^y = \rho_y \widehat{\epsilon}_{t-1}^y + u_t^y \quad (\text{B.15})$$

$$\widehat{\epsilon}_t^c = \rho_c \widehat{\epsilon}_{t-1}^c + u_t^c \quad (\text{B.16})$$

$$\widehat{\epsilon}_t^{inv} = \rho_{inv} \widehat{\epsilon}_{t-1}^{inv} + u_t^{inv} \quad (\text{B.17})$$

$$\widehat{\epsilon}_t^q = \rho_q \widehat{\epsilon}_{t-1}^q + u_t^q \quad (\text{B.18})$$

$$\widehat{\epsilon}_t^u = \rho_u \widehat{\epsilon}_{t-1}^u + u_t^u \quad (\text{B.19})$$

where  $u_t^y \sim N(0, \sigma_y^2)$ ,  $u_t^c \sim N(0, \sigma_c^2)$ ,  $u_t^{inv} \sim N(0, \sigma_{inv}^2)$ ,  $u_t^q \sim N(0, \sigma_q^2)$ , and  $u_t^u \sim N(0, \sigma_u^2)$ . To close the model, the relations between observables and corresponding theoretical variables

$$\widehat{y}_t^{obs} = \widehat{y}_t + \widehat{\epsilon}_t^y \quad (\text{B.20})$$

$$\widehat{c}_t^{obs} = \widehat{c}_t + \widehat{\epsilon}_t^c \quad (\text{B.21})$$

$$\widehat{inv}_t^{obs} = \widehat{i}_t + \widehat{\epsilon}_t^{inv} \quad (\text{B.22})$$

$$\widehat{q}_t^{obs} = \widehat{q}_t + \widehat{\epsilon}_t^q \quad (\text{B.23})$$

$$\widehat{u}_t^{obs} = \widehat{u}_t + \widehat{\epsilon}_t^u \quad (\text{B.24})$$

## C Tables and Figures

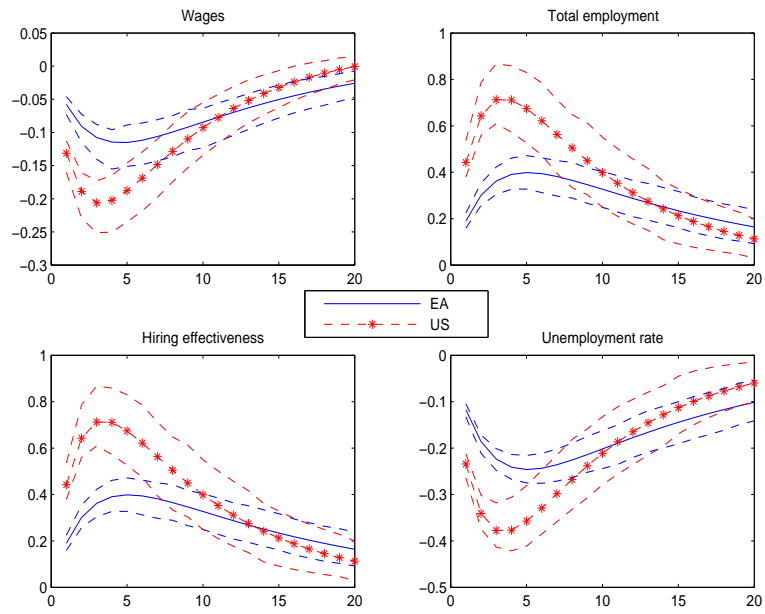


Figure 2: US and Euro Area IRFs comparison.

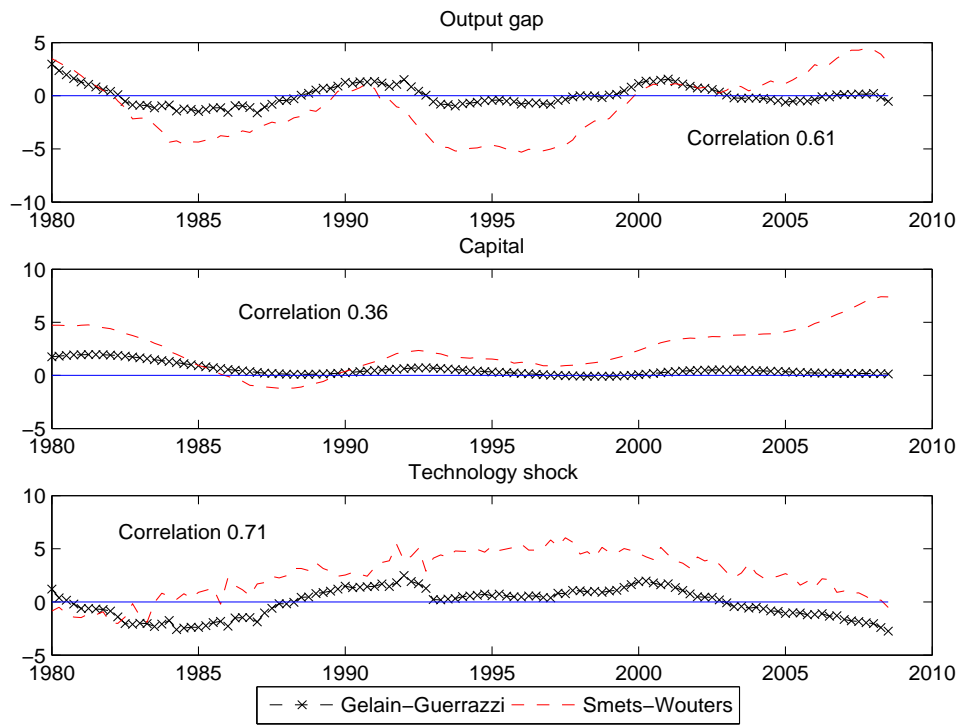


Figure 3: Comparison between the Smets-Wouters Euro Area output gap and the Gelain-Guerrazzi Euro Area output gap and their components.

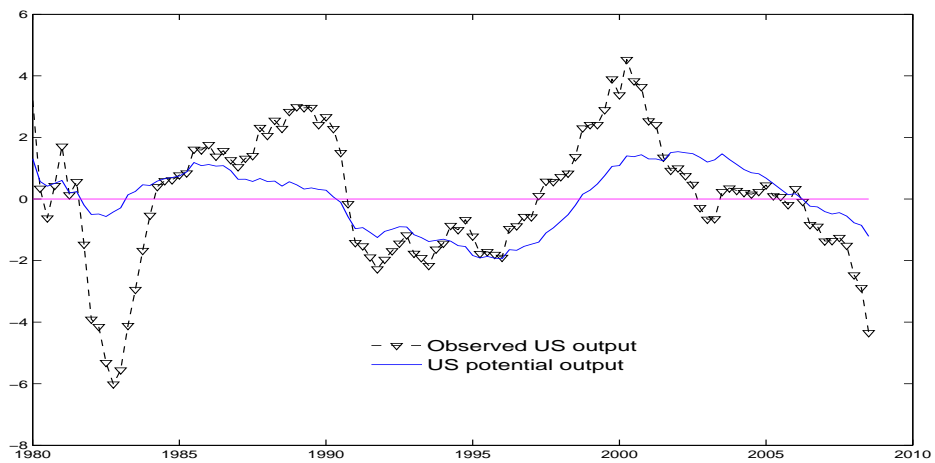


Figure 4: US observed output and potential output.

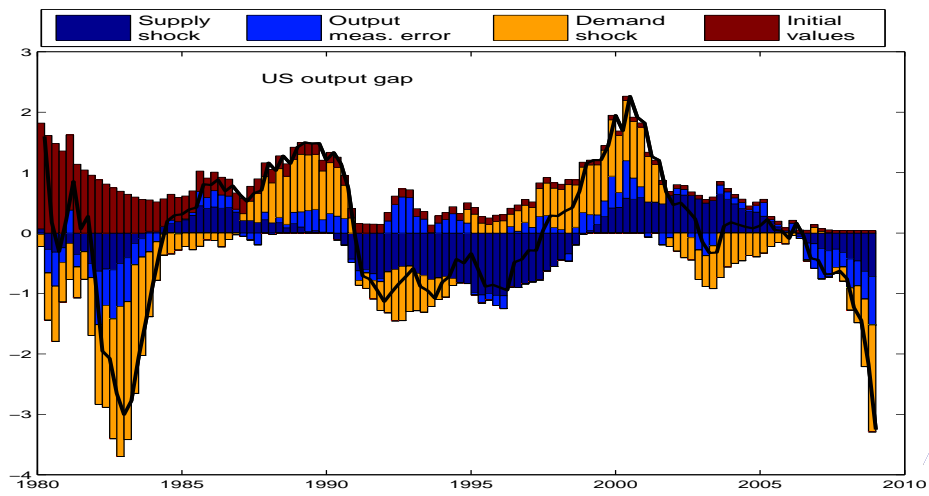


Figure 5: US output gap's shock decomposition. The output gap is computed as the difference between actual and potential output showed in figure 4.

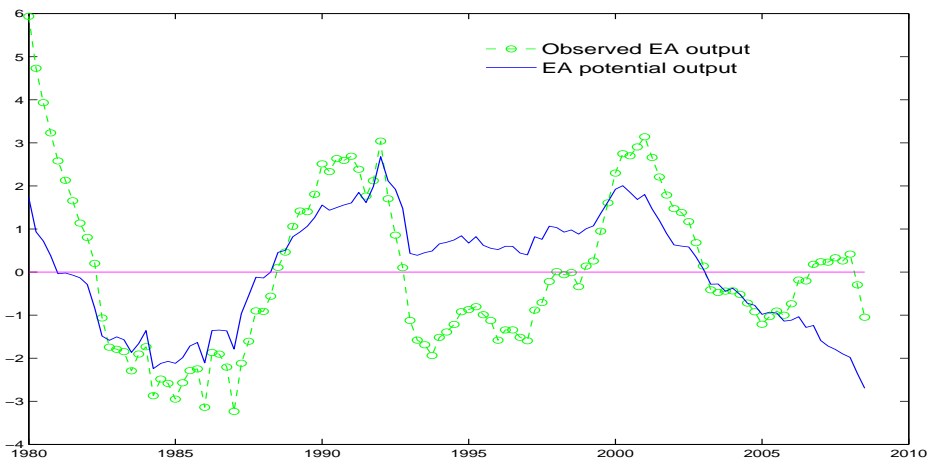


Figure 6: Euro Area observed output and potential output.

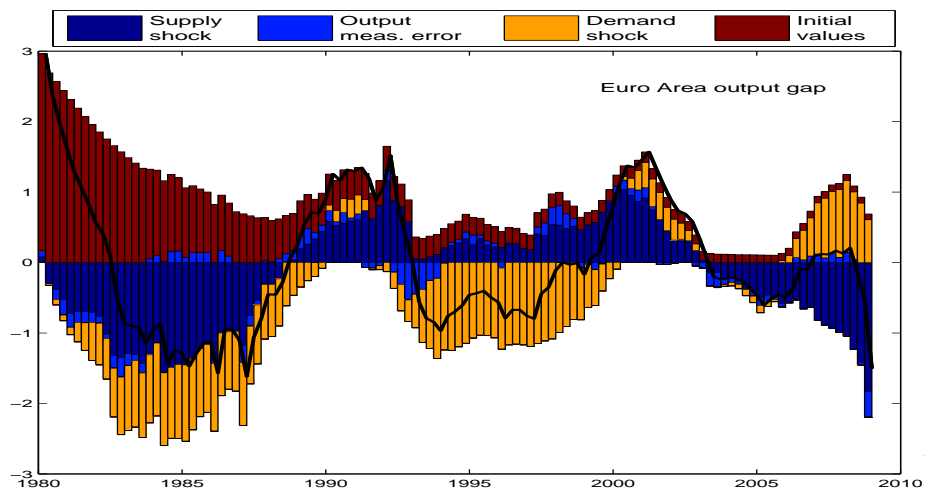


Figure 7: Euro Area output gap's shock decomposition. The output gap is computed as the difference between actual and potential output showed in figure 6.



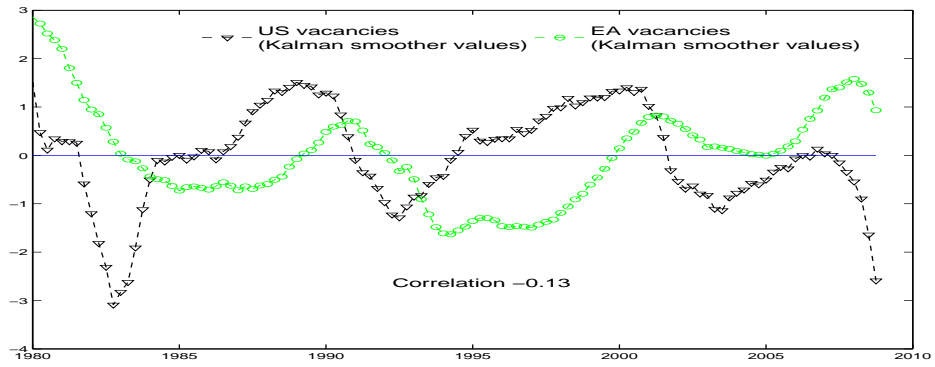


Figure 8: Comparison of the vacancies estimated series for US and Euro Area. All series are standardized.

	EA vacancies at time										
	$t-5$	$t-4$	$t-3$	$t-2$	$t-1$	$t$	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$
US vacancies at time $t$	-0.76	-0.74	-0.72	-0.69	-0.66	-0.13	-0.55	-0.49	-0.42	-0.36	-0.30

Table 1: Correlations between US and Euro Area vacancies.

## C.1 Estimated model for US

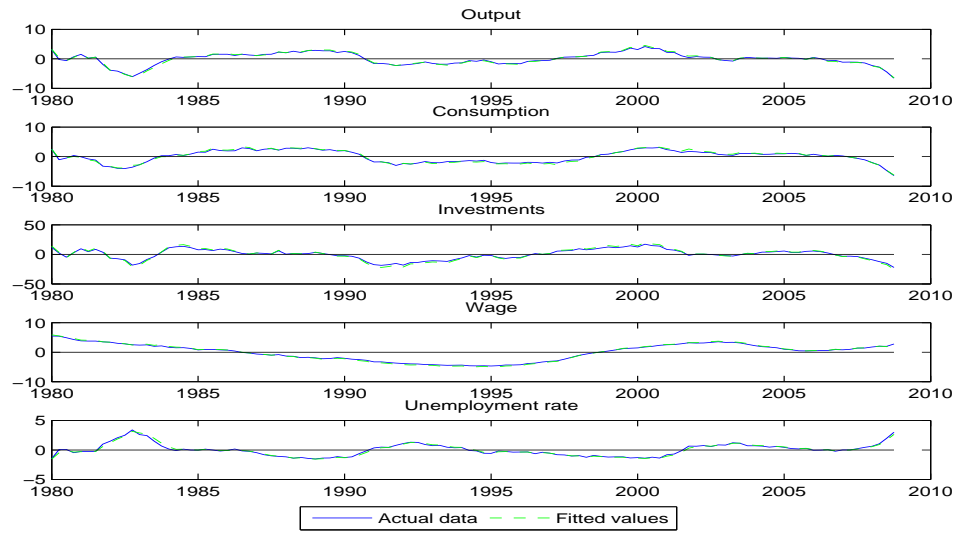


Figure 9: Comparison actual data and fitted (filtered) values. Percentage deviation from steady state.

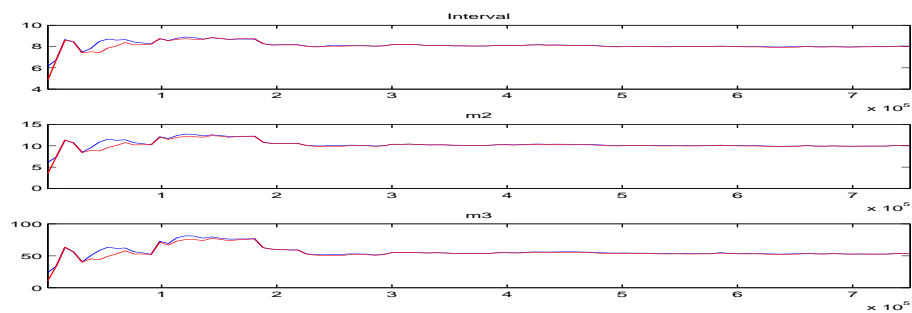


Figure 10: Overall convergence of the model.

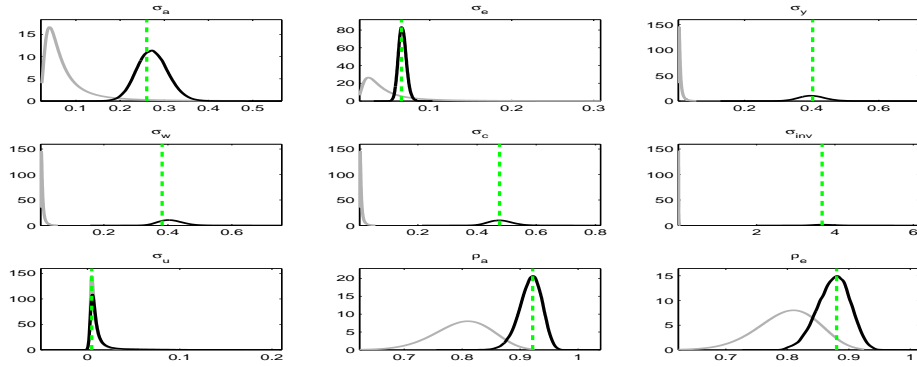


Figure 11: The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

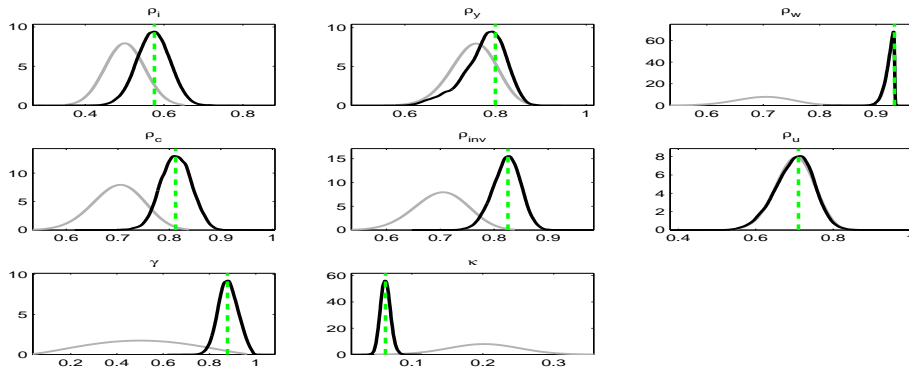


Figure 12: The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

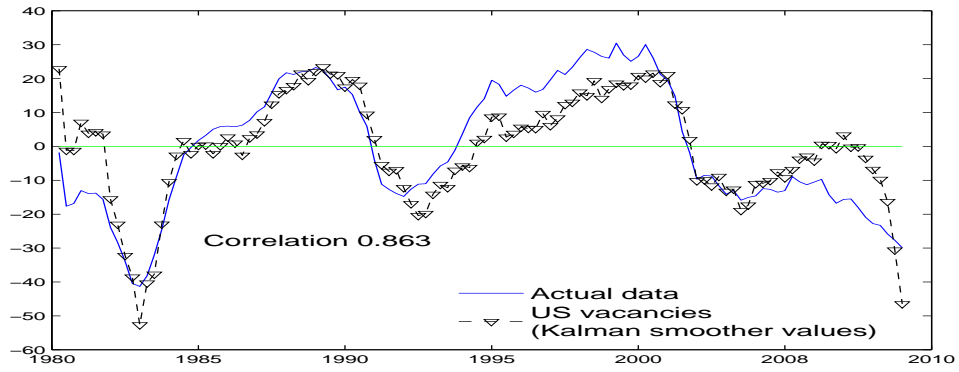


Figure 13: Comparison vacancies data from HWOL and the estimated series for the US. All series are linearly detrended.

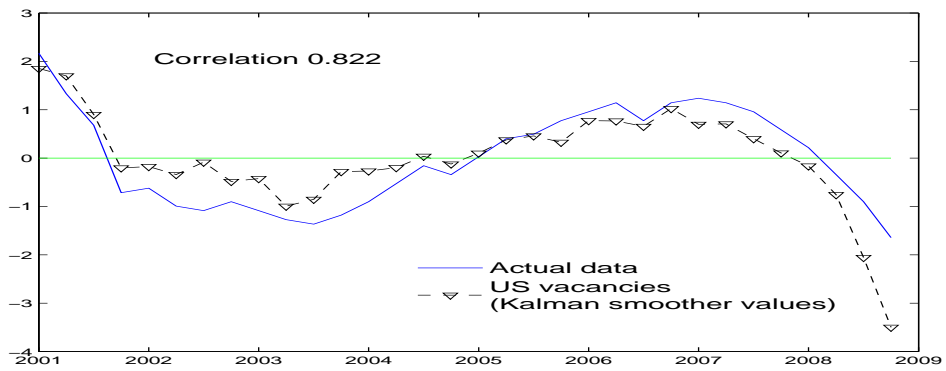


Figure 14: Comparison vacancies data from JOLTS and the estimated series for the US. All series are standardized.

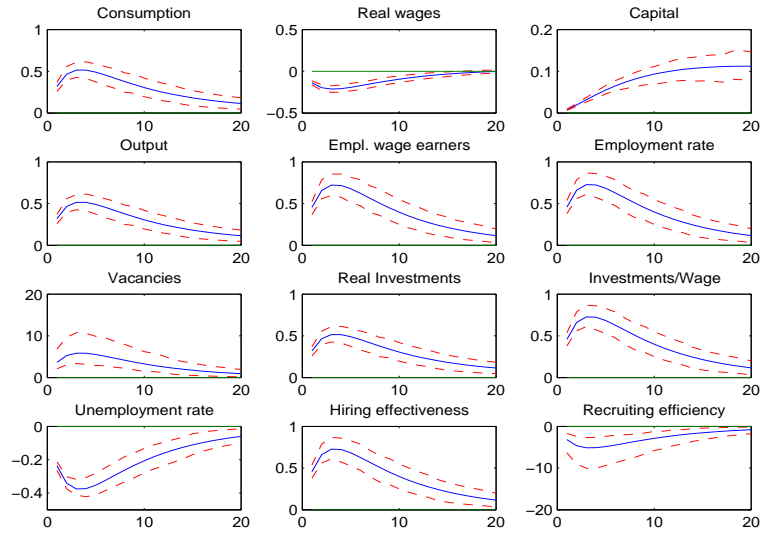


Figure 15: Orthogonalized impulse response functions to a one standard deviation demand shock. Percentage deviation from the steady state.

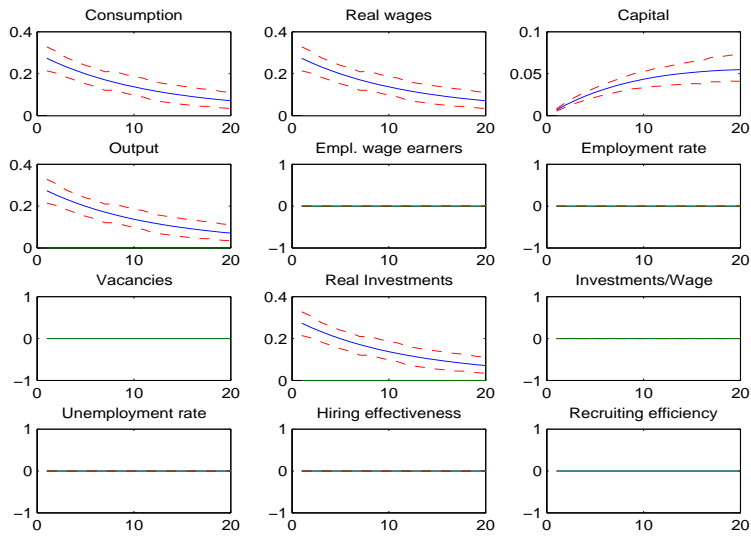


Figure 16: Orthogonalized impulse response functions to a one standard deviation technology shock. Percentage deviation from the steady state.

Parameters	Distribution	Prior		Posterior mean	Probability interval	
		Mean	Std. dev.			
Std. dev. technology shock ( $\sigma_a$ )	Inv. Gamma	0.087	Inf	0.2727	0.2157	0.3298
Std. dev. demand shock ( $\sigma_\varepsilon$ )	Inv. Gamma	0.055	Inf	0.0667	0.0587	0.0743
Std. dev. output measurement error ( $\sigma_y$ )	Inv. Gamma	0.01	Inf	0.4005	0.3365	0.4634
Std. dev. wage measurement error ( $\sigma_q$ )	Inv. Gamma	0.01	Inf	0.4081	0.3468	0.4687
Std. dev. consumption measurement error ( $\sigma_c$ )	Inv. Gamma	0.01	Inf	0.4788	0.4141	0.5440
Std. dev. investment measurement error ( $\sigma_{inv}$ )	Inv. Gamma	0.01	Inf	3.7208	3.3072	4.1364
Std. dev. unemployment measurement error ( $\sigma_u$ )	Inv. Gamma	0.01	Inf	0.0118	0.0021	0.0232
Persistence param. technology shock ( $\rho_a$ )	Beta	0.80	0.05	0.9170	0.8857	0.9494
Persistence param. demand shock ( $\rho_\varepsilon$ )	Beta	0.80	0.05	0.8748	0.8324	0.9181
Persistence param. exogenous investment ( $\rho_i$ )	Beta	0.50	0.05	0.5718	0.5035	0.6413
Persistence param. output measur. error ( $\rho_y$ )	Beta	0.75	0.05	0.7742	0.6998	0.8524
Persistence param. wage measur. error ( $\rho_q$ )	Beta	0.70	0.05	0.9228	0.9115	0.9328
Persistence param. consump. measur. error ( $\rho_c$ )	Beta	0.70	0.05	0.8125	0.7656	0.8609
Persistence param. invest. measur. error ( $\rho_{inv}$ )	Beta	0.70	0.05	0.8224	0.7794	0.8646
Persistence param. unempl. measur. error ( $\rho_u$ )	Beta	0.70	0.05	0.6988	0.6150	0.7777
Matching elasticity ( $\gamma$ )	Beta	0.50	0.20	0.8806	0.8499	0.9626
Investments drift ( $\kappa$ )	Normal	0.202	0.05	0.0629	0.0571	0.0818

The matching elasticity prior distribution is bounded in the interval 0.01-0.99

Table 2: Estimated parameters. Probability interval 90%.

	Data	Model
Vacancies standard deviation	18.435	15.706
Correlation vacancies–output	0.706	0.853
Correlation vacancies–consumption	0.413	0.578
Correlation vacancies–investments	0.506	0.626
Correlation vacancies–wages	-0.465	-0.235
Correlation vacancies–unemployment	-0.846	-0.989

Table 3: US vacancies summary statistics. Data and model.

	US vacancies at time				
	$t-1$	$t-2$	$t-3$	$t-4$	$t-5$
US Vacancies at time $t$ (data)	0.979	0.939	0.884	0.813	0.731
US Vacancies at time $t$ (model)	0.930	0.832	0.711	0.568	0.432

\* The first three autocorrelations are statistically not different

Table 4: US vacancies autocorrelations. Data and model.

## C.2 Estimated model for EA

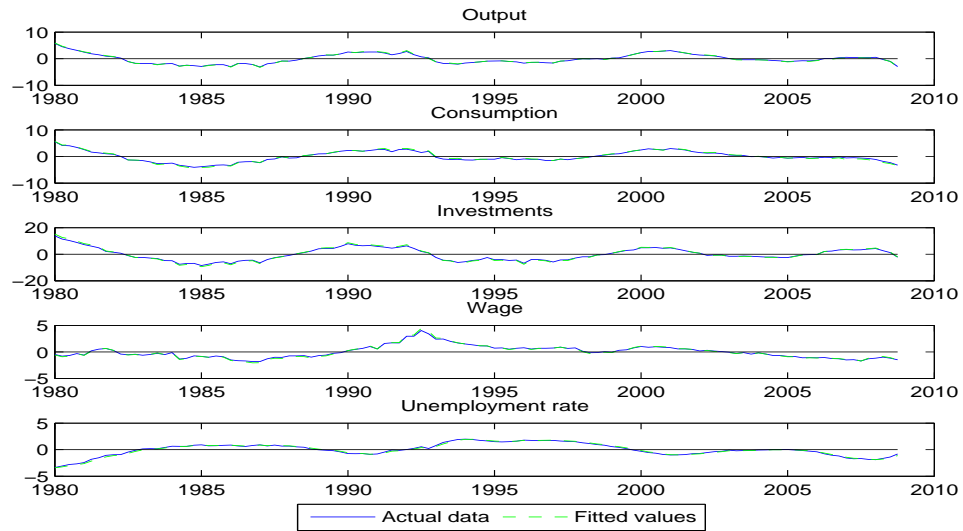


Figure 17: Comparison actual data and fitted (filtered) values. Percentage deviation from steady state.

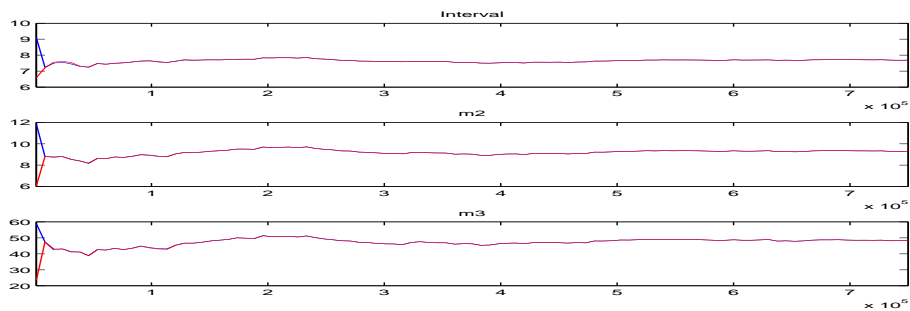


Figure 18: Overall convergence of the model.

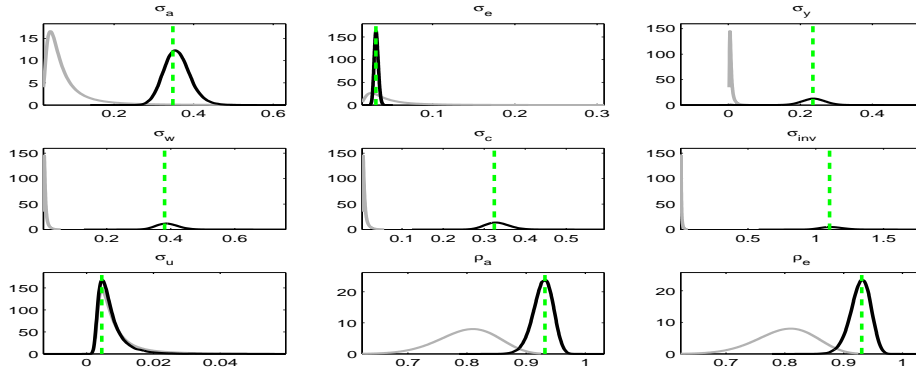


Figure 19: The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

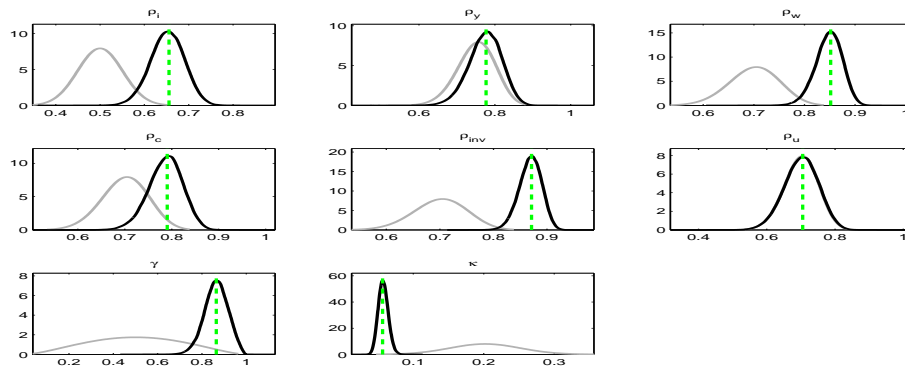


Figure 20: The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.



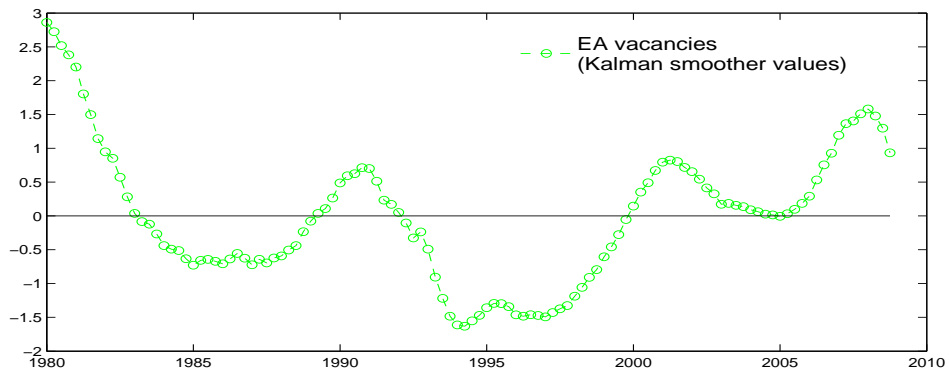


Figure 21: Vacancies smoothed series for the Euro Area. Percentage deviation from the steady state.



Figure 22: Orthogonalized impulse response functions to a one standard deviation demand shock. Percentage deviation from the steady state.

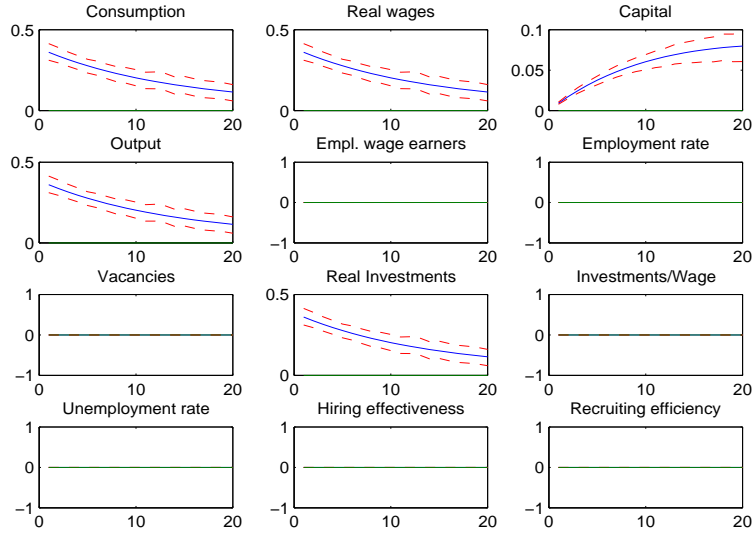


Figure 23: Orthogonalized impulse response functions to a one standard deviation technology shock. Percentage deviation from the steady state.

Parameters	Distribution	Prior		Posterior mean	Probability interval	
		Mean	Std. dev.			
Std. dev. technology shock ( $\sigma_a$ )	Inv. Gamma	0.087	Inf	0.3581	0.3035	0.4117
Std. dev. demand shock ( $\sigma_\epsilon$ )	Inv. Gamma	0.055	Inf	0.0316	0.0275	0.0356
Std. dev. output measurement error ( $\sigma_y$ )	Inv. Gamma	0.01	Inf	0.2342	0.1824	0.2908
Std. dev. wage measurement error ( $\sigma_q$ )	Inv. Gamma	0.01	Inf	0.3896	0.3327	0.4458
Std. dev. consumption measurement error ( $\sigma_c$ )	Inv. Gamma	0.01	Inf	0.3316	0.2829	0.3787
Std. dev. investment measurement error ( $\sigma_{inv}$ )	Inv. Gamma	0.01	Inf	1.1186	0.9830	1.2504
Std. dev. unemployment measurement error ( $\sigma_u$ )	Inv. Gamma	0.01	Inf	0.0071	0.0024	0.0122
Persistence param. technology shock ( $\rho_a$ )	Beta	0.80	0.05	0.9277	0.9008	0.9553
Persistence param. demand shock ( $\rho_\epsilon$ )	Beta	0.80	0.05	0.9279	0.9008	0.9565
Persistence param. exogenous investment ( $\rho_i$ )	Beta	0.50	0.05	0.6511	0.5901	0.7155
Persistence param. output measur. error ( $\rho_y$ )	Beta	0.75	0.05	0.7737	0.7045	0.8446
Persistence param. wage measur. error ( $\rho_q$ )	Beta	0.70	0.05	0.8473	0.8044	0.8898
Persistence param. consump. measur. error ( $\rho_c$ )	Beta	0.70	0.05	0.7862	0.7282	0.8461
Persistence param. invest. measur. error ( $\rho_{inv}$ )	Beta	0.70	0.05	0.8684	0.8341	0.9027
Persistence param. unempl. measur. error ( $\rho_u$ )	Beta	0.70	0.05	0.7001	0.6184	0.7829
Matching elasticity ( $\gamma$ )	Beta	0.50	0.20	0.8629	0.7809	0.9526
Investments drift ( $\kappa$ )	Normal	0.202	0.05	0.0573	0.0456	0.0687

Table 5: Estimated parameters for the Euro Area. Probability interval 90%.

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