

Structural and Cyclical Forces in the Great Recession: Cross-Country Evidence

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June 2012

Preliminary and incomplete

Abstract

We use an estimated monetary business cycle model with search and matching frictions in the labor market and nominal price and wage rigidities to study three countries (the U.S., the U.K., and Sweden) during the financial crisis and the Great Recession. We estimate the model over the period prior to the financial crisis and use the model to interpret movements in GDP, unemployment and vacancies in the period from 2007 until 2011. We show that contractionary financial factors and reduced efficiency in labor market matching were largely responsible for the experience in the U.S. Financial factors were also important in the U.K. and (to a lesser extent) in Sweden, while reduced matching efficiency was considerably less important in the European countries than in the U.S.

Keywords: Business cycles, financial crisis, labor market matching, Beveridge curve.

JEL Classification: E24, E32.

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1 Introduction

The financial crisis and the following “Great Recession” has had deep consequences in most countries. But labor market outcomes have differed considerably across industrial countries. Figure 1 shows unemployment rates and detrended GDP since 2005 in four countries: the U.S., Germany, the U.K., and Sweden.¹ In all countries GDP fell dramatically and unemployment rose in 2008 and 2009. But the relationship between the fall in GDP and the increase in unemployment differed enormously. From peak to trough, detrended GDP fell by 5.7 percentage points in the U.S. while the unemployment rate increased by 5.5 percentage points, implying a one-for-one relationship between GDP and unemployment, a considerably stronger relationship than typical Okun’s law estimates imply (see, e.g., IMF (2010)). The U.K. and Sweden experienced larger drops in GDP (6.7 percentage points in the U.K. and 9.3 percentage points in Sweden), but the rate of unemployment increased by only around 3 percentage points in both countries. Germany saw an increase in unemployment of less than one percentage point despite a drop of 7.7 percentage points in detrended GDP. Since 2010 unemployment has been slow to come down in all countries but Germany, where the rate of unemployment has been on a decreasing trend since 2005.

There are also large differences in the relationship between unemployment and vacancies, the so-called Beveridge curve. Figure 2 shows Beveridge curves for the four countries over the period from 1995 until 2011. The blue section of the curves correspond to the period 1995–2007Q1 and the green section to the period since 2007Q2.² It is well-known that the Beveridge curve in the U.S. has shifted outwards since early 2010, when unemployment has fallen very slowly despite an increase in vacancies. Some commentators have interpreted this as a sign that labor market matching has become less efficient in the U.S. (see, in particular, Kocherlakota (2010)). Sweden also shows signs of an outward shift in the Beveridge curve, while there are no signs of shifts in the U.K. Beveridge curve. In Germany, in contrast, the Beveridge curve seems to have shifted inwards since 2008: for a given level of vacancies the rate of unemployment has decreased.

One possible explanation for these patterns is that different countries were hit by different types of shocks: the U.S. and the U.K. were directly affected by financial shocks, while Sweden and Germany were mainly affected through shocks to the external sector (such as a fall in export demand). Thus, to some extent the differences may be due to cyclical factors. But there are also structural differences across countries that could explain the diverse patterns.

The purpose of this paper is to study the role of structural and cyclical forces in labor market dynamics across these four countries during the financial crisis and the Great Recession. [In the current version of the paper we do not report results for Germany.] For this purpose we estimate a business cycle model with search and matching frictions and nominal wage and price rigidities on data until 2007. We then use the estimated model to interpret the period from mid 2007 until late 2011. To study the determinants of labor market fluctuations, we compare the structural features of the estimated models and their interpretation

¹In Figure 1, GDP was detrended using the Hodrick-Prescott filter and a smoothing parameter of 1,600.

²In Figure 2 unemployment is measured directly in terms of the unemployment rate while vacancies are measured as percent deviation from the historical mean. See below for more details.

of cyclical movements in output, unemployment, and vacancies.

The analysis builds on the model developed and estimated on U.S. data in Gertler, Sala, and Trigari (2008) (henceforth GST). The GST model introduces labor market frictions via a variant of the Diamond, Mortensen, and Pissarides framework into the now conventional monetary business cycle models developed by Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2007) and others. The variant allows for staggered Nash wage bargaining as in Gertler and Trigari (2009), but in nominal terms. As emphasized by Hall (2012), nominal wage rigidities help reconciling search and matching frictions with the recent behavior of unemployment and inflation in the U.S. when monetary policy is restricted by the zero lower bound on nominal interest rates.

We differ from GST in a number of aspects. First, we allow for two types of hiring costs: search costs of recruiting new workers, incurred during the process of finding new workers, and internal costs of adding new workers to a firm's labor force incurred after the workers and the firm have matched and started an employment relationship. While evidence in Silva and Toledo (2009) and Yashiv (2000) indicates that postmatch hiring costs account for a larger fraction of total hiring costs, prematch costs make hiring costs dependent on the tightness of aggregate labor markets (see Furlanetto and Goshenny (2012)). Second, we add to the model a risk-premium shock that creates a wedge between the risk-free rate and the return on assets held by households and a shock to the efficiency of the matching technology. Both changes are justified by the focus on the Great Recession. The risk premium shock has similar effects as a shock to net worth in models that explicitly model the external finance premium (e.g., Bernanke, Gertler, and Gilchrist (1999) and Christiano, Motto, and Rostagno (2003, 2008)). It has the potential to capture the disruptions in financial markets that have characterized the recent financial crisis. The shock to the matching efficiency is a natural candidate for driving labor market fluctuations and may play a significant role in the Great Recession. Changes in matching efficiency have the potential to explain the shifts in Beveridge curves recently experienced by a number of countries, see Figure 2. Finally, we differ from GST by including unemployment and vacancies among the set of observables used in the estimation instead of total hours worked. Unemployment and vacancies are the two key variables in the model when describing the state of the labor market.³

Our analysis proceeds in three steps. After estimating the model on data until 2007Q1, we first discuss the estimated structural parameter in different countries. Next, we interpret movements in the estimated shocks over the sample period as well as the period after 2007. For the U.S., we show that the financial crisis and the Great Recession was characterized by unusually large positive shocks to the risk premium (that is, contractionary financial shocks) and negative shocks to matching efficiency. Also, as monetary policy was restricted by the zero lower bound, our model finds large contractionary monetary policy shocks after 2008. For the U.K. and Sweden contractionary financial shocks and reduced labor market matching efficiency were also important after 2007, but also negative shocks to technology growth.

Finally, we interpret the effects of shocks on output, unemployment, and vacancies over

³To facilitate comparability with the literature, GST estimated the model on the same aggregate variables and including the same structural shocks as Smets and Wouters (2007).

the crisis period, and we compare with the period before the financial crisis. For the U.S., our model assigns important roles to financial factors and reduced matching efficiency in the labor market for explaining the fall in output and vacancies and the increase in unemployment after 2007. These factors are considerably more important during the financial crisis and the Great Recession than in the period prior to 2007, and are crucial in understanding the outward shift in the U.S. Beveridge curve. Financial shocks dominate the story also for the U.K., but were relatively less important in Sweden. Lower matching efficiency mostly affected vacancy posting in the U.K. and Sweden, but had little impact on unemployment.

[Discuss related literature. In particular, Justiniano and Michelacci (2011), Galí, Smets, and Wouters (2012), and Furlanetto and Groshenny (2012).]

Our paper is organized as follows. We develop our model in Section 2. We then discuss the data and our estimation technique Section 3. In Section 4 we present our results. Finally, we conclude in Section 5.

2 The model

The analysis builds on the GST model, which is an evolution of the frameworks in Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2007) and others. The main difference is the treatment of the labor market. GST introduce search and matching frictions via a variant of the Diamond, Mortensen, and Pissarides framework that has staggered Nash bargaining as in Gertler and Trigari (2009). Importantly, Nash bargaining takes place in nominal terms, rather than over real wages as in Gertler and Trigari (2009).

We here provide a sketch of the model; for more details, see Gertler, Sala, and Trigari (2008). There are only two differences relative to GST. First, the set of shocks included in the model is different: we add a risk-premium shock and a shock to the efficiency of the matching technology. But we remove a shock to consumer preference. Second, we allow for a more general hiring cost function that allows for both costs in posted vacancies and costs in filled vacancies or new matches.

There are three types of agents in the model: households, wholesale firms, and retail firms. Following Merz (1995) we assume a representative family in order to introduce complete consumption insurance. Production takes place at competitive wholesale firms that hire workers subject to search and matching frictions and negotiate wage contracts via staggered Nash bargaining. Monopolistically competitive retail firms buy goods from wholesalers, repackaging them as final goods, and set prices on a staggered basis.

2.1 Households

There is a representative household with a continuum of members of measure unity. At each time t a measure n_t of household members are employed and a measure $1 - n_t$ are unemployed. Household members are assumed to pool their labor income to insure themselves against income fluctuations. The household consumes final goods, saves in one-period nominal government bonds, and accumulates physical capital through investment. It transforms physical capital to effective capital by choosing the capital utilization rate, and then rents

effective capital to firms.

The household thus chooses consumption c_t , bond holdings B_t , the rate of capital utilization ν_t , investment i_t , and physical capital k_t^p to maximize the utility function

$$E_t \left\{ \sum_{s=0}^{\infty} \beta^s \log(c_{t+s} - hc_{t+s-1}) \right\}, \quad (1)$$

where β is a discount factor and h measures the degree of habits in consumption preferences.⁴

The capital utilization rate ν_t transforms physical capital into effective capital according to

$$k_t = \nu_t k_{t-1}^p, \quad (2)$$

which is rented to wholesale firms at the rate r_t^k . The cost of capital utilization per unit of physical capital is given by $\mathcal{A}(\nu_t)$, and we assume that $\nu_t = 1$ in steady state, $\mathcal{A}(1) = 0$ and $\mathcal{A}'(1)/\mathcal{A}''(1) = \eta_\nu$, as in Christiano, Eichenbaum, and Evans (2005) and others.

Physical capital accumulates according to

$$k_t^p = (1 - \delta)k_{t-1}^p + \varepsilon_t^i \left[1 - \mathcal{S}\left(\frac{i_t}{i_{t-1}}\right) \right] i_t, \quad (3)$$

where δ is the rate of depreciation, ε_t^i is an investment-specific technology shock with mean unity, and $\mathcal{S}(\cdot)$ is an adjustment cost function which satisfies $\mathcal{S}(\gamma_z) = \mathcal{S}'(\gamma_z) = 0$ and $\mathcal{S}''(\gamma_z) = \eta_k > 0$, where γ_z is the steady-state growth rate.

Let p_t be the nominal price level, r_t the one-period nominal interest rate, w_t the real wage, b_t the flow value of unemployment (including unemployment benefits), Π_t lump-sum profits, and T_t lump-sum transfers. The household's budget constraint is then given by

$$c_t + i_t + \frac{B_t}{p_t \varepsilon_t^b r_t} = w_t n_t + (1 - n_t) b_t + r_t^k \nu_t k_{t-1}^p + \Pi_t + T_t - \mathcal{A}(\nu_t) k_{t-1}^p + \frac{B_{t-1}}{p_t}, \quad (4)$$

where ε_t^b is a risk premium shock with mean ε^b that drives a wedge between the risk-free interest rate set by the central bank and the return on assets held by the households. The first-order conditions with respect to c_t , B_t , ν_t , i_t , and k_t^p imply relationships that jointly determine consumption, capital utilization, the rental rate of capital, investment, and Tobin's Q.

2.2 Unemployment, vacancies and matching

There is a continuum of wholesale firms measured on the unit interval. To attract new workers wholesale firms need to post vacancies v_{it} . The total number of vacancies and employed workers are then equal to $v_t = \int_0^1 v_{it} di$ and $n_t = \int_0^1 n_{it} di$. All unemployed workers are assumed to look for a job, and unemployed workers who find a match go to work immediately

⁴As in GST, we do not allow for variation in hours on the intensive margin. This choice is consistent with the observation that most of the cyclical variation in hours in the U.S. being on the extensive margin.

within the period. Accordingly, the pool of unemployed workers is given by

$$u_t = 1 - n_{t-1}. \quad (5)$$

The number of new hires is determined by the number of searchers and vacancies according to a matching function

$$m_t = \varepsilon_t^m u_t^\sigma v_t^{1-\sigma}, \quad (6)$$

where ε_t^m is a shock to the efficiency of the matching process with mean ε^m . The probability that a firm fills a vacancy is then given by $q_t = m_t/v_t$, and the probability that a worker finds a job is $s_t = m_t/u_t$. Both workers and firms take q_t and s_t as given.

2.3 Wholesale firms

Each wholesale firm i produces output y_{it} using capital k_{it} and labor n_{it} according to the Cobb-Douglas production function

$$y_{it} = (k_{it})^\alpha (z_t n_{it})^{1-\alpha}, \quad (7)$$

where z_t is a common labor-augmenting productivity factor, whose growth rate $\varepsilon_t^z = z_t/z_{t-1}$ follows a stationary exogenous process with steady-state value ε^z which corresponds to the economy's steady-state (gross) growth rate γ_z . Thus, technology is non-stationary in levels but stationary in growth rates. We assume that capital is perfectly mobile across firms and that there is a competitive rental market for capital.

To hire new workers firms post vacancies v_{it} . It is useful to define the hiring rate x_{it} as the ratio of new hires $q_t v_{it}$ to the existing workforce n_{it-1} :

$$x_{it} = \frac{q_t v_{it}}{n_{it-1}}, \quad (8)$$

where the law of large numbers implies that the firm knows x_{it} with certainty at time t , as it knows the likelihood q_t that each vacancy will be filled. Therefore, we can treat the hiring rate as the firm's control variable.

Firms exogenously separate from a fraction $1 - \rho$ of their existing workforce n_{it-1} in each period, and workers who lose their jobs are not allowed to search until the next period. The total workforce is then the sum of the number of surviving workers and new hires:

$$n_{it} = \rho n_{it-1} + x_{it} n_{it-1}, \quad (9)$$

which reflects the assumption that new hires go to work immediately.

Let p_t^w denote the relative price of intermediate goods, w_{it}^n the nominal wage and $\beta \mathbf{E}_t \Lambda_{t,t+1}$ be the firm's discount rate, where $\Lambda_{t,t+s} = \lambda_{t+s}/\lambda_t$ and λ_t is the marginal utility of consumption at time t . Then the value of firm i , $F_t(w_{it}^n, n_{it-1})$, is given by

$$F_t(w_{it}^n, n_{it-1}) = p_t^w y_{it} - \frac{w_{it}^n}{p_t} n_{it} - \frac{\kappa_t}{2} x_{it}^2 n_{it-1} - r_t^k k_{it} + \beta \mathbf{E}_t \{ \Lambda_{t,t+1} F_{t+1}(w_{it+1}^n, n_{it}) \}, \quad (10)$$

where $(\kappa_t/2)x_{it}^2n_{it-1}$ is a quadratic hiring cost with

$$\kappa_t = \kappa z_t q_t^{-\eta_q}, \quad (11)$$

where $\eta_q \in [0, 2]$ is a parameter denoting the elasticity of hiring costs to the vacancy filling rate q_t . As in GST, we allow hiring costs to drift proportionately with productivity z_t in order to maintain a balanced steady-state growth path. We differ from GST by allowing for two types of hiring costs: search costs of recruiting new workers (advertising, screening, interviewing) and internal costs of adding new workers to a firm's labor force (such as training and other). Recruiting costs pertain to posted vacancies, v_{it} , while training costs are associated with filled vacancies or new matches, $m_{it} = q_t v_{it}$. We will also refer to recruiting costs as prematch hiring costs, since they are incurred during the process of finding a new worker, and to training costs as postmatch hiring costs, since they take place after the worker and the firm have matched and start an employment relationship.

Our formulation encompasses both types of costs. If $\eta_q = 0$, hiring costs are given by $(\kappa z_t/2)(q_t v_{it}/n_{it-1})^2 n_{it-1}$ and the cost function reduces to the one used in GST that emphasizes internal costs of adjusting employment. In this case, hiring costs have only to do with new hires and are not associated with the number of vacancies posted *per se*. For this reason, they are not affected by the likelihood q_t that a vacancy is filled. If $\eta_q = 2$, then hiring costs become $(\kappa z_t/2)(v_{it}/n_{it-1})^2 n_{it-1}$ and are only associated with posted vacancies. In this case, an increase in the aggregate likelihood q_t with which each vacancy v_{it} is filled decreases the cost of hiring new workers. Because of the quadratic formulation, when only prematch hiring costs are present the elasticity equals (minus) 2. For intermediate values of η_q , in between 0 and 2, both costs are allowed for, with equal weight given to each cost when $\eta_q = 1$.

The firm maximizes its value by choosing the hiring rate x_{it} and its capital stock k_{it} , given its existing employment stock n_{it-1} , the rental rate on capital r_t^k , the relative price of intermediate goods p_t^w , the likelihood of filling vacancies q_t , and the current and expected path of wages w_{it}^n/p_t . The first-order condition for capital is given by

$$r_t^k = p_t^w \alpha \frac{y_{it}}{n_{it}} = p_t^w \alpha \frac{y_t}{n_t}, \quad (12)$$

where all firms chose the same capital/output ratio due to Cobb-Douglas technology and perfect capital mobility.

Firms choose n_{it} by setting x_{it} . The optimal hiring decision yields

$$\kappa_t x_{it} = p_t^w a_t - \frac{w_{it}^n}{p_t} + \beta \mathbf{E}_t \left\{ \Lambda_{t,t+1} \frac{\kappa_{t+1}}{2} x_{it+1}^2 \right\} + \rho \beta \mathbf{E}_t \{ \Lambda_{t,t+1} \kappa_{t+1} x_{it+1} \}, \quad (13)$$

where

$$a_t = (1 - \alpha) \frac{y_{it}}{n_{it}} = (1 - \alpha) \frac{y_t}{n_t} \quad (14)$$

denotes the current marginal product of labor, which is also equal across firms. The hiring rate x_{it} thus depends on the discounted stream of earnings and the saving on adjustment

costs. Observe that the only firm-specific variable affecting the hiring rate is the wage.

Finally, for the purpose of the wage bargain it is useful to define $J_t(w_{it}^n)$, the value to the firm of having another worker at time t after new workers have joined the firm, i.e., after adjustment costs are sunk. Differentiating $F_t(w_{it}^n, n_{it-1})$ with respect to n_{it} , taking x_{it} as given, and making use of the optimal hiring decision as well as the relation for the evolution of the workforce yields:

$$J_t(w_{it}^n) = p_t^w a_t - \frac{w_{it}^n}{p_t} - \beta \mathbb{E}_t \left\{ \Lambda_{t,t+1} \frac{\kappa_{t+1}}{2} x_{it+1}^2 \right\} + (\rho + x_{it+1}) \beta \mathbb{E}_t \left\{ \Lambda_{t,t+1} J_{t+1}(w_{it+1}^n) \right\}, \quad (15)$$

where $J_t(w_{it}^n)$ is expressed as expected average profits per worker net of first period adjustment costs, with the discount factor accounting for future changes in workforce size.

2.4 Workers

Let $V_t(w_{it}^n)$ be the value to a worker of employment at firm i , and let U_t be the value of unemployment. These values are defined after hiring decisions at time t have been made and are measured in units of consumption goods. The value of employment is given by

$$V_t(w_{it}^n) = \frac{w_{it}^n}{p_t} + \beta \mathbb{E}_t \left\{ \Lambda_{t,t+1} [\rho V_{t+1}(w_{it+1}^n) + (1 - \rho) U_{t+1}] \right\}. \quad (16)$$

To construct the value of unemployment, denote by $V_{x,t}$ the average value of employment conditional on being a new worker, given by

$$V_{x,t} = \int_0^1 \left[V_{it} \frac{x_{it} n_{it-1}}{x_t n_{t-1}} \right] di. \quad (17)$$

Then, U_t can be expressed as

$$U_t = b_t + \beta \mathbb{E}_t \left\{ \Lambda_{t,t+1} [s_{t+1} V_{x,t+1} + (1 - s_{t+1}) U_{t+1}] \right\}, \quad (18)$$

where, as before, s_t is the probability of finding a job, and

$$b_t = b k_t^p \quad (19)$$

is the flow value of unemployment (measured in units of consumption goods). The flow value is assumed to grow proportionately with the physical capital stock in order to maintain balanced growth.

Finally, the worker surplus at firm i , $H_t(w_{it}^n)$, and the average worker surplus conditional on being a new hire, $H_{x,t}$, are given by

$$\begin{aligned} H_t(w_{it}^n) &= V_t(w_{it}^n) - U_t, \\ H_{x,t} &= V_{x,t} - U_t. \end{aligned}$$

It follows that

$$H_t(w_{it}^n) = \frac{w_{it}^n}{p_t} - b_t + \beta E_t \{ \Lambda_{t,t+1} [\rho H_{t+1}(w_{it+1}^n) - s_{t+1} H_{x,t+1}] \}. \quad (20)$$

2.5 Wage bargaining

Firms and workers are not able to negotiate their wage contract in every period, but wage bargaining is assumed to be staggered over time, as in Gertler and Trigari (2009). As in Gertler, Sala, and Trigari (2008), firms and workers bargain over nominal wages. In each period, each firm faces a fixed probability $1 - \lambda_w$ of being able to renegotiate the wage. The fraction λ_w of firms that cannot renegotiate the wage instead index the nominal wage to past inflation according to

$$w_{it}^n = \bar{\gamma}_w \pi_{t-1}^{\gamma_w} w_{it-1}^n, \quad (21)$$

where $\pi_t = p_t/p_{t-1}$ is the gross rate of inflation, $\bar{\gamma}_w = \gamma_w \pi^{1-\gamma_w}$, and $\gamma_w \in [0, 1]$ measures the degree of indexing.

Let w_t^{n*} denote the nominal wage of a firm-worker pair that renegotiates at t . Given constant returns to scale, all sets of renegotiating firms and workers set the same wage. The firm negotiates with the marginal worker over the surplus from the marginal match. Assuming Nash bargaining, the contract wage w_t^{n*} is chosen to solve

$$\max H_t(w_{it}^n)^{\eta_t} J_t(w_{it}^n)^{1-\eta_t}, \quad (22)$$

subject to

$$w_{it+j}^n = \begin{cases} \bar{\gamma}_w w_{it+j-1}^n \pi_{t+j-1}^{\gamma_w} & \text{with probability } \lambda_w \\ w_{t+j}^{n*} & \text{with probability } 1 - \lambda_w. \end{cases} \quad (23)$$

The variable $\eta_t \in [0, 1]$ reflects the worker's relative bargaining power, and is assumed to evolve according to

$$\eta_t = \eta \varepsilon_t^\eta, \quad (24)$$

where ε_t^η is a shock with mean unity that implies a disturbance to the wage equation.

The first-order condition for the Nash bargaining solution is given by

$$\chi_t(w_t^{*n}) J_t(w_t^{*n}) = [1 - \chi_t(w_t^{*n})] H_t(w_t^{*n}), \quad (25)$$

where

$$\chi_t(w_{it}^n) = \frac{\eta_t}{\eta_t + (1 - \eta_t) \mu_t(w_{it}^n) / \epsilon_t} \quad (26)$$

is the (horizon-adjusted) effective bargaining power of workers,

$$\mu_t(w_{it}^n) = 1 + \beta\lambda_w \text{E}_t \left\{ \Lambda_{t,t+1} [\rho + x_{t+1}(\bar{\gamma}_w \pi_t^{\gamma_w} w_{it}^n)] \frac{p_t}{p_{t+1}} \bar{\gamma}_w \pi_t^{\gamma_w} \mu_{t+1}(\bar{\gamma}_w \pi_t^{\gamma_w} w_{it}^n) \right\} \quad (27)$$

is the firm's cumulative discount factor, and

$$\epsilon_t = 1 + \beta\rho\lambda_w \text{E}_t \left\{ \Lambda_{t,t+1} \frac{p_t}{p_{t+1}} \bar{\gamma}_w \pi_t^{\gamma_w} \epsilon_{t+1} \right\} \quad (28)$$

is the worker's cumulative discount factor.

Finally, the average nominal wage is given by

$$w_t^n = \int_0^1 \left[w_{it}^n \frac{n_{it}}{n_t} \right] di. \quad (29)$$

Given that the probability of wage adjustment is i.i.d., the law of large numbers implies that the evolution of the average nominal wage is a linear contract of the target nominal wage and last period's nominal wages of non-adjusters, after factoring in indexing arrangements:

$$w_{t+1}^n = (1 - \lambda_w) w_{t+1}^{*n} + \lambda_w \int_0^1 (\bar{\gamma}_w \pi_t^{\gamma_w} w_{it}^n) \frac{\rho + x_{t+1}(\bar{\gamma}_w \pi_t^{\gamma_w} w_{it}^n) n_{it}}{\rho + x_{t+1}(\bar{\gamma}_w \pi_t^{\gamma_w} w_{it}^n) n_t} di. \quad (30)$$

2.6 Retailers

There is a continuum of monopolistically competitive retailers indexed by j on the unit interval. These buy intermediate goods from the wholesale firms, differentiate them with a technology that transforms one unit of intermediate goods into one unit of retail goods, and sell them to households. Retailers set prices on a staggered basis.

Following Smets and Wouters (2007), we assume that each firm's elasticity depends inversely on its relative market share, as in Kimball (1995), who generalizes the standard Dixit-Stiglitz aggregator. Thus, letting y_{jt} be the quantity of output sold by retailer j and p_{jt} the nominal price, final goods, denoted y_t , are a composite of individual retail goods following

$$\int_0^1 \mathcal{G} \left(\frac{y_{jt}}{y_t}, \varepsilon_t^p \right) dj = 1, \quad (31)$$

where the function $\mathcal{G}(\cdot)$ is increasing and strictly concave with $\mathcal{G}(1) = 1$, and ε_t^p is a shock that influences the elasticity of demand.

We assume that prices are staggered as in Calvo (1983), but with indexing as in Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003). Thus, each retailer faces a fixed probability $1 - \lambda_p$ of reoptimizing its price in a given period, in which case it sets its price to p_t^* to maximize the expected discounted stream of future profits. All firms that reoptimize set the same price. Firms that do not reoptimize instead index their price to past inflation following

$$p_{jt} = \bar{\gamma}_p \pi_{t-1}^{\gamma_p} p_{jt-1}, \quad (32)$$

where $\bar{\gamma}_p = \pi^{1-\gamma_p}$ is an adjustment for steady-state inflation.

It is possible to show that the optimal price p_t^* depends on the expected discounted stream of the retailers' nominal marginal cost given by $p_t p_t^w$. Using the hiring condition (13), real marginal cost is given by

$$p_t^w = \frac{1}{a_t} \left[\frac{w_{it}}{p_t} + \kappa_t x_{it} - \beta \mathbb{E}_t \left\{ \Lambda_{t,t+1} \frac{\kappa_{t+1}}{2} x_{it+1}^2 \right\} - \rho \beta \mathbb{E}_t \{ \Lambda_{t,t+1} \kappa_{t+1} x_{it+1} \} \right], \quad (33)$$

so real marginal cost depends on unit labor cost plus a term that corrects for the cost if hiring workers.

2.7 The government sector

The government sets government spending g_t according to

$$g_t = \left(1 - \frac{1}{\varepsilon_t^g} \right) y_t, \quad (34)$$

where ε_t^g follows an exogenous process. Our model neglects open-economy elements. The estimated process for g_t therefore reflects the sum of government spending and net exports (and inventories). This choice is made for simplicity, but is potentially important when interpreting the recession in Sweden and Germany where external shocks were an important part of the recession.

The central bank sets the short-term nominal interest rate r_t according to the Taylor rule

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r} \right)^{\rho_s} \left[\left(\frac{\mathbb{E}_t \pi_{t+1}}{\pi} \right)^{r_\pi} \left(\frac{y_t}{y_t^n} \right)^{r_y} \right]^{1-\rho_s} \varepsilon_t^r, \quad (35)$$

where y_t^n is the level of output with flexible prices and wages and without shocks to the price markup and the bargaining power of workers, and ε_t^r is a monetary policy shock.

2.8 Resource constraint and model summary

Finally, the resource constraint implies that output is equal to the sum of consumption, investment, government spending, and adjustment and utilization costs:

$$y_t = c_t + i_t + g_t + \frac{\kappa_t}{2} \int_0^1 [x_{it}^2 n_{it-1}] di + \mathcal{A}(\nu_t) k_{t-1}^p. \quad (36)$$

The complete model consists of 28 equations for the 28 endogenous variables. There are also eight exogenous disturbances: to technology, investment, the risk premium, matching efficiency, the price markup, workers' bargaining power, government spending, and monetary policy. The technology shock follows a unit-root process, while the remaining seven shocks are stationary. In particular, technology growth and the other seven shocks follow

$$\log(\varepsilon_t^j) = (1 - \rho_j) \log(\varepsilon^j) + \rho_j \log(\varepsilon_{t-1}^j) + \zeta_t^j, \quad (37)$$

for $j = z, i, b, \sigma, p, \eta, g, r$, where $\varepsilon^i = \varepsilon^b = \varepsilon^\sigma = \varepsilon^\eta = \varepsilon^r = 1$, and where ζ_t^j are mean-zero innovations with constant variances σ_j^2 . We log-linearize the model around its deterministic steady state with balanced growth, allowing for the fact that output, investment, consumption, and the real wage are non-stationary. The derivation of the steady state and the log-linearized system of equations are available in the Appendix A.

3 Estimation

3.1 Data

We estimate the log-linearized version of the model on quarterly data from four countries: the U.S., the U.K., Germany, and Sweden. We estimate the model on data up to 2007Q1, before the start of the financial crisis, to prevent our estimates from being distorted by the non-linearities induced by the different size of the shocks and the zero lower bound on nominal interest rates. We then use the estimated model to interpret the period from 2007Q2 to 2011Q2. The first date of the sample period varies across countries. For the U.S., the data start in 1982Q1 (after the Volcker disinflation), for Germany in 1992Q1 (after the reunification), and for the U.K. and Sweden in 1994Q4 (after the introduction of inflation targeting regimes for monetary policy).

For each country we use data for eight variables: (1) output growth: the quarterly growth rate of per capita real GDP; (2) investment growth: the quarterly growth rate of a measure of per capita real investment; (3) consumption growth: the quarterly growth rate of a measure of per capita real consumption; (4) real wage growth: the quarterly growth rate of a measure of real compensation per hour; (5) inflation: the quarterly growth rate of the GDP deflator; (6) the nominal interest rate: the quarterly average of a short-term interest rate; (7) an unemployment measure; and (8) a measure of vacancies. Data definitions and sources differ slightly across countries; they are available in Appendix B.

We estimate the model using Bayesian likelihood-based methods (see An and Schorfheide (2007) for an overview). Letting $\boldsymbol{\theta}$ denote the vector of structural parameters to be estimated and \mathbf{Y} the data sample, we use the Kalman filter to calculate the likelihood $L(\boldsymbol{\theta}, \mathbf{Y})$, and then combine the likelihood function with a prior distribution of the parameters to be estimated, $p(\boldsymbol{\theta})$, to obtain the posterior distribution, $L(\boldsymbol{\theta}, \mathbf{Y})p(\boldsymbol{\theta})$. We use numerical routines to maximize the value of the posterior, and then generate draws from the posterior distribution using the Random-Walk Metropolis-Hastings algorithm.

We use growth rates for the non-stationary variables in our data set (output, consumption, investment, and the real wage, which are non-stationary also in the theoretical model) and express unemployment and vacancies in percentage deviations from their sample mean. We write the measurement equation of the Kalman filter to match the eight observable series with their model counterparts. Thus, the state-space form of the model is characterized by the state equation

$$\mathbf{X}_t = \mathbf{A}(\boldsymbol{\theta})\mathbf{X}_{t-1} + \mathbf{B}(\boldsymbol{\theta})\boldsymbol{\varepsilon}_t, \quad \boldsymbol{\varepsilon}_t \sim i.i.d. N(\mathbf{0}, \boldsymbol{\Sigma}_\varepsilon), \quad (38)$$

where \mathbf{X}_t is a vector of endogenous variables, $\boldsymbol{\varepsilon}_t$ is a vector of innovations, and $\boldsymbol{\theta}$ is a vector

of parameters; and the measurement equation

$$\mathbf{Y}_t = \mathbf{C}(\boldsymbol{\theta}) + \mathbf{D}\mathbf{X}_t + \boldsymbol{\eta}_t, \quad \boldsymbol{\eta}_t \sim i.i.d. N(\mathbf{0}, \boldsymbol{\Sigma}_\eta), \quad (39)$$

where \mathbf{Y}_t is a vector of observable variables, that is,

$$\mathbf{Y}_t = 100 [\Delta \log Y_t, \Delta \log I_t, \Delta \log C_t, \Delta \log W_t, \log \pi_t, \log R_t, \log(u_t/\bar{u}), \log(v_t/\bar{v})], \quad (40)$$

and $\boldsymbol{\eta}_t$ is a vector of measurement errors.

The model contains 22 structural parameters, not including the parameters that characterize the exogenous shocks and measurement errors. We calibrate four parameters using standard values: the discount factor β is set to 0.99, the capital depreciation rate δ to 0.025, the capital share α in the Cobb-Douglas production function is set to 1/3, and the average ratio of government spending to output G/Y is set to the average value for each country over the sample period. We also calibrate five other parameters. The steady-state growth rate, γ_z is set to the average GDP growth rate over the sample period. The steady-state quarterly job survival and job finding probabilities ρ and s , are computed from the yearly averages of monthly figures reported in Elsby, Hobijn, and Sahin (2010), following Justiniano and Michelacci (2011); the match elasticity to unemployment, σ in the matching function, is calibrated to 0.5, a value within the range of empirical estimates, see Petrongolo and Pissarides (2001). The degree of indexation in price setting, γ_p is set to zero.⁵ The calibrated parameters are shown in Table 1.

We estimate the remaining 13 structural parameters: the elasticity of the utilization rate to the rental rate of capital, η_ν ;⁶ the elasticity of the investment adjustment cost function, η_k ; the habit parameter h ; the steady-state bargaining power of workers η ; the steady-state flow value of unemployment as a fraction of the contribution of the worker to the job, that is, the relative value of non-work to work activity, denoted with \tilde{b} ;⁷ the weight on hiring costs, η_q ; the steady-state price markup ε^p ; the wage and price rigidity parameters λ_w and λ_p ; the wage indexing parameter γ_w ; and the monetary policy rule parameters r_π , r_y , and ρ_s . In addition, we estimate the autoregressive parameters of the eight exogenous shock processes, as well as the standard deviations of the innovations. We allow for an i.i.d. measurement error on the real wage. This could be interpreted as proper errors in the measurement of wages, as in Justiniano, Primiceri, and Tambalotti (2012), or as volatility in the real wage that cannot be explained by our model, possibly due to model misspecification.

3.2 Priors

Before estimation we assign prior distributions to the parameters to be estimated. Most of the priors are standard in the literature; see, for example, Smets and Wouters (2007),

⁵When estimating the model for the U.S., U.K., and Sweden without this restriction, γ_p always ended up very close to zero, with no effect on other parameters.

⁶Following Smets and Wouters (2007), we define ψ_ν such that $\eta_\nu = (1 - \psi_\nu)/\psi_\nu$ and estimate ψ_ν .

⁷The relative flow value of unemployment is given by $\tilde{b} = \bar{b} / [p^w \bar{a} + \beta (\bar{\kappa}/2) x^2]$, where variables with no time index denote steady-state values of stationary variables and variables with a bar denote steady-state values of detrended variables.

Justiniano, Primiceri, and Tambalotti (2010) and GST.

The utilization rate elasticity ψ_ν and the habit parameter h are both assigned Beta priors with mean 0.5 and standard deviation 0.1; while the capital adjustment cost elasticity η_k is assigned a Normal prior with mean 4 and standard deviation 1.5.

The two Calvo parameters for wage and price adjustment, θ_w and θ_p , are assigned Beta priors with means $3/4$ and $2/3$, respectively, and standard deviation 0.1, while the wage indexation parameter γ_w is given a Uniform prior over the unit interval. The steady-state price markup ε^p is assigned a Normal prior centered at 1.15, with a standard deviation of 0.05.

The coefficient r_π on inflation in the monetary policy rule is given a Normal prior with mean 1.7 and standard deviation 0.3, while the coefficient r_y on output growth is given a Gamma prior with mean 0.125 and standard deviation 0.1. The coefficient on the lagged interest rate, ρ_s , is assigned a Beta prior with mean 0.75 and a standard deviation of 0.1. All these are broadly consistent with empirically estimated monetary policy rules.

The steady-state bargaining power of workers η and the relative flow value of unemployment \tilde{b} are both assigned a Beta prior with mean 0.5 and standard deviation 0.1. The parameter η_q , denoting the relative weight of hiring cost is assigned a Gamma distribution with mean 0.145 and standard deviation 0.1. The prior mean has been specified following Silva and Toledo (2009) who estimate the relative importance of hiring (pre-match) versus training (post-match) costs in the U.S. Their estimates correspond to $\eta_q = .145$ in our framework. In the absence of evidence on the value of η_q for the other countries, we will use the same prior for all of them.

All persistence parameters for the shocks are given Beta priors with mean 0.5 and standard deviation 0.1. Following much of the literature, we normalize some of the shocks before estimation, in order to better define a plausible range of variation. Three shocks—the investment-specific shock ε_t^i , the price markup shock ε_t^p , and the bargaining power shock ε_t^w —are normalized to have a unitary contemporaneous impact on the physical capital stock, the real wage and price inflation, respectively.⁸ The priors assigned to the standard deviations of all innovations are Inverse Gamma, with mean 0.15 and standard deviation 0.15. The standard deviation of the measurement error on the real wage is assigned a Beta prior with mean and standard deviation equal, respectively, to $1/3$ and $1/10$ of the sample standard deviation of the real wage growth series.

All prior distributions are summarized in Table 2.

⁸To be more precise, as shown in Appendix A, the log-linearized equation determining the accumulation of physical capital is given by

$$\hat{k}_t = \frac{1-\delta}{\gamma_z} [\hat{k}_{t-1} - \hat{\varepsilon}_t^z] + \left(1 - \frac{1-\delta}{\gamma_z}\right) [\hat{w}_t + \hat{\varepsilon}_t^i].$$

Instead of estimating the stochastic process for the investment shock $\hat{\varepsilon}_t^i$, we define the shock $\tilde{\varepsilon}_t^i \equiv (1 - (1-\delta)/\gamma_z)\hat{\varepsilon}_t^i$, and estimate the properties of $\tilde{\varepsilon}_t^i$, which has a unitary contemporaneous impact on the physical capital stock \hat{k}_t . The same normalization is used in other equations where the investment shock enters. A similar normalization is applied to the bargaining power shock ε_t^w in the wage equation and to the price markup shock ε_t^p in the Phillips curve.

4 Results

4.1 Parameter estimates

We begin by studying the estimated parameters. This will give us an idea of structural differences across countries. Table 2 shows the mode of the posterior distribution in the estimated models.

For the U.S., many parameter estimates are similar to those in the literature, e.g., Smets and Wouters (2007) and Justiniano, Primiceri, and Tambalotti (2010). Some labor market parameters, e.g., the steady-state bargaining power of workers, η , and the flow value of unemployment, \tilde{b} , are very similar to the estimates in GST. Other parameters differ significantly from GST, however. The estimated wage indexing parameter γ_w is zero, compared with 0.8 in GST. At the same time, bargaining power shocks are quite persistent, $\rho_\eta = 0.68$, more so than in GST, where $\rho_\eta = 0.26$. Furthermore, the price markup shocks are not very persistent, $\rho_p = 0.17$, compared with 0.8 in GST.

The weight on hiring costs, η_q , is estimated to be 0.48. This is higher than the prior mean of 0.145, which is taken from Silva and Toledo (2009). Our estimate confirms their results, as well as those of Yashiv (2000), that post-match training costs are quantitatively more important than pre-match hiring costs.

For the U.K. and Sweden, many parameter estimates are similar to those for the U.S. The habit parameter h is smaller in the U.K. and Sweden than in the U.S. The relative flow value of unemployment, \tilde{b} , is considerably larger than in the U.S., in particular in the U.K. This is consistent with the U.S. having a lower replacement rate than European countries.

The weight on search costs of recruiting workers is very small, essentially zero, in both the U.K. and Sweden. As a consequence matching efficiency shocks are less important in driving output and unemployment compared with the U.S.

4.2 Driving forces prior to the financial crisis

We next study the driving forces of business cycle in the estimation period up until 2007Q1. Table 3 shows a long-run variance decomposition of output growth, unemployment, and vacancies over the various estimation periods.

For the U.S., shocks to technology, investment, and the risk premium explain most of the variance in all variables. Matching efficiency shocks are only important for vacancies. They are not important drivers of business cycles since they do not generate a Beveridge curve, that is, they imply a positive co-movement between unemployment and vacancies. As in GST, shocks to the price markup, workers' bargaining power, government spending, and monetary policy are not very important driving forces of business cycle fluctuations.

For the U.K. and Sweden, shocks to government spending (and net exports) have a larger impact on output and vacancies compared with the U.S. Risk premium shocks are relatively more important in Sweden than in the U.K. in the period up until 2007. Bargaining power shocks and price markup shocks do not contribute at all to business cycle fluctuations in the U.K. and Sweden, while matching efficiency shocks are only important for vacancies.

4.3 What happened during the financial crisis?

We now focus on how our estimated models interpret the period after 2007. For this purpose we study the estimated time paths of the shocks before and after 2007. We also present decompositions of output growth, unemployment, and vacancies for our three countries from 2007Q1 until mid-2011. Finally, we decompose movements in the Beveridge curve.

4.3.1 U.S.

Figure 3 presents the time paths of the estimated shocks for the U.S. The vertical lines indicate the last observation in the sample used for estimation.

Until 2006 or so most shocks are fairly stable, without any clear trends. The exception is the government spending shock, which shows a downward trend, similar to the behavior of the U.S. current account and government spending.

The period after 2007 is characterized by a large increase in the risk premium shock (capturing the effects of financial frictions) and a large drop in matching efficiency. Since 2008 there is also an increase in the monetary policy shock, as the zero-lower bound on the nominal interest rates becomes binding, and the interest rate is set at a level higher than that implied by the monetary policy rule.

The technology shock increases gradually in the aftermath of the financial crisis capturing an increase in productivity associated with the slow recovery in employment relatively to output. The shock to workers' bargaining power (that is, to wage setting) rises moderately in the recession, capturing the fact that wage growth did not slow down as much as implied by the severity of the recession. In contrast, the shocks to investment and the price markup are fairly stable throughout.

Figure 4 shows the contribution of different shocks to U.S. GDP growth from 2007 until 2011. The fall in GDP during 2008 and 2009 is mainly explained by financial factors (the risk premium shock) and reduced matching efficiency in the labor market. These shocks are much more important during the financial crisis than in the period prior to 2007. The zero-lower bound meant that monetary policy also had a negative impact on GDP growth, while a more expansionary fiscal policy and improvements in productivity had a positive impact on GDP. Compared with the period before 2007, technology shocks had a relatively small impact on GDP growth during the financial crisis.

The role of financial shocks and reduced matching efficiency is even more clear when explaining the increase in U.S. unemployment, see Figure 5. From the end of 2008 the risk premium shock increases the unemployment rate by more than two percentage points, while reduced matching efficiency explains another percentage point of the total increase in unemployment. These effects are quite persistent, helping to explain why unemployment stayed high through 2011. Shocks to investment are also important for the increase in unemployment.

Wage setting shocks (to workers' bargaining power) are small and therefore have a modest impact on unemployment. This is in stark contrast to Galí, Smets, and Wouters (2012), where similar wage setting shocks (to the wage markup) are the dominant explanation for the increase in unemployment since 2008. In our model, this role seems to be taken over by shocks to the matching process, an explanation that has also featured prominently in

the policy debate (see, for instance, Kocherlakota (2010)). At the same time, the fact that bargaining power shocks are not large indicates that in this model there are not large tensions between the dynamics of wages and employment.

For vacancies in Figure 6, financial shocks lead to a reduction in vacancies, while the reduced efficiency of the matching process has a positive impact on vacancies since early 2008. Matching efficiency shocks thus contribute to keep vacancies high, while at the same time keeping output growth low and unemployment high; that is, they contribute to explain why vacancies have been higher than implied by the historical relation with unemployment (the Beveridge curve). Changes in matching efficiency can capture skill or geographical mismatch. At the same time, they can also capture a reduction in the recruiting intensity with which firms try to fill posted vacancies, as documented by Davis, Faberman, and Haltiwanger (2012), or a reduction in the search intensity of unemployed workers, due to the extended unemployment benefit programs implemented in the U.S. Finally, matching efficiency shocks could capture an increase in separations during the early part of the financial crisis, which is not allowed for in our model where the separation rate is constant.

Figure 7 shows a decomposition of the U.S. Beveridge curve. This figure confirms that the outward shift in the Beveridge curve since 2009 was driven by shocks to the matching efficiency which generate a positive co-movement between unemployment and vacancies. Monetary shocks and risk-premium shocks instead move unemployment and vacancies along a fairly stable Beveridge Curve, with larger magnitudes than observed historically.

4.3.2 U.K.

Figures 8–12 show the results for the U.K. Compared with the period before 2007, the period following the financial crisis is characterized by negative technology shocks (that is negative shocks to the trend growth rate), an increased risk premium, reduced wage pressure (a low bargaining power shock), and reduced matching efficiency. To counter the effects of the crisis, monetary policy was more expansionary after 2007 than implied by the estimated policy rule.

Comparing with the U.S., we note the opposite patterns for the technology shock, the monetary policy shock, and the bargaining power shock. As in the U.S. matching efficiency initially decreased, but it then reverted back, while in the U.S it remained at low levels. The reduction in technology captures the reduction in output per worker partly due to the fact that the fall in employment was mitigated by a non-negligible reduction in hours per worker.

The negative technology shock and the high risk premium put pressure on GDP growth. Low productivity and an increased risk premium also explain most of the increase in unemployment and the fall in vacancies, together with a contraction in government spending and net exports.

The increase in unemployment is moderated by expansionary monetary policy and shocks to investment-specific technology. However, the historical decomposition of unemployment prior to 2007 (not shown here) indicates that the investment shock captures the low-frequency component in unemployment.

Reduced matching efficiency tends to increase vacancies but has little effect on unemployment. This is mainly due to the low estimated share of prematch costs in hiring. There is

no evident shift in the Beveridge curve in the UK, only large movements along the historical relation. These movements are mostly driven by technology shocks and risk premium shocks. The matching efficiency by itself generates a vertical Beveridge curve since post-match costs are dominant.

4.3.3 Sweden

Finally, Figures 13–17 report the results for Sweden. The estimated shocks are similar to those in the U.K., with the exception of the risk premium shock, which does increase much during the financial crisis

The development of output, unemployment, and vacancies have similar driving forces as in the U.K.: negative shocks to technology and positive risk premium shocks tend to reduce output growth and vacancies and increase unemployment. The risk premium shock is relatively less important than in the U.K. Expansionary monetary policy shocks and investment-specific technology shocks instead act to reduce unemployment and increase vacancies.

Reduced matching efficiency tends to increase vacancies but, as in the U.K., have a negligible impact on unemployment. Nevertheless, matching efficiency shocks are largely responsible for the outward shift in the Beveridge curve. Technology shocks instead generate large movements along the Beveridge curve.

5 Conclusions and final remarks

[To be completed.]

A Model appendix

A.1 Steady state calculation

Let \bar{y} denote y_t/z_t evaluated at steady state for any variable y_t .

- Consumption and savings

$$1 = \varepsilon^b r (\beta/\gamma_z) \tag{A1}$$

- Physical capital

$$1 = (\beta/\gamma_z) (1 - \delta + r^k) \tag{A2}$$

- Capital/employment ratio

$$r^k = \alpha p^w (\bar{k}/n)^{-(1-\alpha)} \tag{A3}$$

- Marginal product of labor

$$\bar{a} = (1 - \alpha) (\bar{k}/n)^\alpha \tag{A4}$$

- Investment

$$q^k = 1 \tag{A5}$$

- Rates

$$x = 1 - \rho \tag{A6}$$

- Flows

$$xn = su \tag{A7}$$

- Unemployment

$$u = 1 - n \tag{A8}$$

- Matching

$$su = \varepsilon^\sigma u^\sigma v^{1-\sigma} \tag{A9}$$

- Hiring

$$\bar{k}x = p^w \bar{a} - \bar{w} + \beta \frac{\bar{k}}{2} x^2 + \beta \rho \bar{k}x \tag{A10}$$

- Wages

$$\bar{w} = \chi \left(p^w \bar{a} + \beta \frac{\bar{\kappa}}{2} x^2 + \beta \bar{\kappa} s x \right) + (1 - \chi) \bar{b} \quad (\text{A11})$$

where

$$\chi = \frac{\eta}{\eta + (1 - \eta) \mu / \epsilon}, \quad \mu = \frac{1}{1 - \lambda \beta}, \quad \epsilon = \frac{1}{1 - \rho \lambda \beta}$$

- Hiring and vacancy costs

$$\bar{\kappa} = \kappa q^{-\eta_q} \quad (\text{A12})$$

- Resource constraint

$$1 = \frac{\bar{c}}{\bar{y}} + \frac{\bar{g}}{\bar{y}} + \frac{\bar{i}}{\bar{y}} + \frac{\bar{\kappa}}{2} x^2 \frac{n}{\bar{y}} \quad (\text{A13})$$

where

$$n/\bar{y} = (\bar{k}/n)^{-\alpha} \quad \bar{i}/\bar{y} = \left(1 - \frac{1 - \delta}{\gamma_z} \right) \gamma_z (\bar{k}/n)^{(1-\alpha)}$$

A.2 Loglinear model

- Technology

$$\hat{y}_t = \alpha \hat{k}_t + (1 - \alpha) \hat{n}_t \quad (\text{A14})$$

- Resource constraint

$$\hat{w}_t = y_c \hat{c}_t + y_i \hat{i}_t + y_g \hat{g}_t + y_\nu \hat{\nu}_t + y_x (\hat{\kappa}_t + 2\hat{x}_t + \hat{n}_{t-1}) \quad (\text{A15})$$

where

$$y_c = \bar{c}/\bar{y}, \quad y_i = \bar{i}/\bar{y}, \quad y_g = \bar{g}/\bar{y}, \quad y_\nu = r^k \bar{\kappa}/\bar{y}, \quad y_x = (\bar{\kappa}/2) (x^2 n/\bar{y})$$

- Matching

$$\hat{m}_t = \hat{\varepsilon}_t^\sigma + \sigma \hat{u}_t + (1 - \sigma) \hat{v}_t \quad (\text{A16})$$

- Employment dynamics

$$\hat{n}_t = \hat{n}_{t-1} + (1 - \rho) \hat{x}_t \quad (\text{A17})$$

- Transition probabilities

$$\widehat{q}_t = \widehat{m}_t - \widehat{v}_t \quad (\text{A18})$$

$$\widehat{s}_t = \widehat{m}_t - \widehat{u}_t \quad (\text{A19})$$

- Unemployment

$$\widehat{u}_t = -(n/u) \widehat{n}_{t-1} \quad (\text{A20})$$

- Effective capital

$$\widehat{k}_t + \widehat{\varepsilon}_t^z = \widehat{v}_t + \widehat{k}_{t-1}^p \quad (\text{A21})$$

- Physical capital dynamics

$$\widehat{k}_t^p = \xi \left(\widehat{k}_{t-1}^p - \widehat{\varepsilon}_t^z \right) + (1 - \xi) \left(\widehat{i}_t + \widehat{\varepsilon}_t^i \right) \quad (\text{A22})$$

where

$$\xi = \frac{1 - \delta}{\gamma_z}$$

- Aggregate vacancies

$$\widehat{x}_t = \widehat{q}_t + \widehat{v}_t - \widehat{n}_{t-1} \quad (\text{A23})$$

- Consumption and saving

$$0 = E_t \widehat{\Lambda}_{t,t+1} + \left(\widehat{\varepsilon}_t^b + \widehat{r}_t - E_t \widehat{\pi}_{t+1} \right) - E_t \widehat{\varepsilon}_{t+1}^z \quad (\text{A24})$$

- Marginal utility

$$\left(1 - \widetilde{h} \right) \left(1 - \beta \widetilde{h} \right) \widehat{\lambda}_t = \widetilde{h} \left(\widehat{c}_{t-1} - \widehat{\varepsilon}_t^z \right) - \left(1 + \beta \widetilde{h}^2 \right) \widehat{c}_t + \beta \widetilde{h} E_t \left(\widehat{c}_{t+1} + \widehat{\varepsilon}_{t+1}^z \right) \quad (\text{A25})$$

where

$$\widetilde{h} = h/\gamma_z$$

- Capital utilization

$$\widehat{v}_t = \eta_\nu \widehat{r}_t^k \quad (\text{A26})$$

where

$$\eta_\nu = \mathcal{A}'(1) / \mathcal{A}''(1) = \frac{1 - \psi_\nu}{\psi_\nu}$$

- Investment

$$\hat{i}_t = \frac{1}{1+\beta} (\hat{i}_{t-1} - \hat{\varepsilon}_t^z) + \frac{1/(\eta_k \gamma_z^2)}{1+\beta} (\hat{q}_t^k + \hat{\varepsilon}_t^i) + \frac{\beta}{1+\beta} E_t (\hat{i}_{t+1} + \hat{\varepsilon}_{t+1}^z) \quad (\text{A27})$$

where

$$\eta_k = S''(\gamma_z)$$

- Capital renting

$$\hat{p}_t^w + \hat{y}_t - \hat{k}_t = \hat{r}_t^k \quad (\text{A28})$$

- Tobin's q

$$\hat{q}_t^k = \tilde{\beta} (1 - \delta) E_t \hat{q}_{t+1}^k + [1 - \tilde{\beta} (1 - \delta)] E_t \hat{r}_{t+1}^k - (\hat{\varepsilon}_t^b + \hat{r}_t - E_t \hat{\pi}_{t+1}) \quad (\text{A29})$$

where

$$\tilde{\beta} = \beta/\gamma_z$$

- Aggregate hiring rate

$$(\hat{\kappa}_t + \hat{x}_t) = \varkappa_a (\hat{p}_t^w + \hat{a}_t) - \varkappa_w \hat{w}_t + \varkappa_\lambda E_t \hat{\Lambda}_{t,t+1} + \beta E_t (\hat{\kappa}_{t+1} + \hat{x}_{t+1}) \quad (\text{A30})$$

where

$$\varkappa = (\bar{k}x)^{-1}, \quad \varkappa_a = \varkappa p^w \bar{a}, \quad \varkappa_w = \varkappa \bar{w}, \quad \varkappa_\lambda = \beta(1 + \rho)/2$$

- Hiring-vacancy cost

$$\hat{\kappa}_t = -\eta_q \hat{q}_t \quad (\text{A31})$$

where

$$\eta_q = \frac{2\varphi/\bar{q}}{\varphi/\bar{q} + (1 - \varphi)}$$

- Marginal product of labor

$$\hat{a}_t = \hat{y}_t - \hat{n}_t \quad (\text{A32})$$

- Weight in Nash bargaining

$$\hat{\chi}_t = -(1 - \chi) (\hat{\mu}_t - \hat{\varepsilon}_t) \quad (\text{A33})$$

with

$$\begin{aligned}\widehat{\epsilon}_t &= (\rho\lambda\beta) E_t \left(\widehat{\Lambda}_{t,t+1} - \widehat{\pi}_{t+1} + \gamma\widehat{\pi}_t + \widehat{\epsilon}_{t+1} - \widehat{\epsilon}_{t+1}^z \right) \\ \widehat{\mu}_t &= (x\lambda\beta) E_t \widehat{x}_{t+1} - (x\lambda\beta) (\varkappa_w\mu) \mu E_t \left(\widehat{w}_t + \gamma\widehat{\pi}_t - \widehat{\pi}_{t+1} - \widehat{\epsilon}_{t+1}^z - \widehat{w}_{t+1} \right) \\ &\quad + (\lambda\beta) E_t \left(\widehat{\mu}_{t+1} + \widehat{\Lambda}_{t,t+1} + \gamma\widehat{\pi}_t - \widehat{\pi}_{t+1} - \widehat{\epsilon}_{t+1}^z \right)\end{aligned}$$

- Spillover-free target wage

$$\begin{aligned}\widehat{w}_t^o &= \varphi_a (\widehat{p}_t^w + \widehat{a}_t) + (\varphi_s + \varphi_x) E_t \widehat{x}_{t+1} + \varphi_s E_t \widehat{s}_{t+1} + \varphi_b \widehat{b}_t \\ &\quad + (\varphi_s + \varphi_x/2) E_t \left(\widehat{\kappa}_{t+1} + \widehat{\Lambda}_{t,t+1} \right) + \varphi_\chi \left(\widehat{\chi}_t - (\rho - s) \beta \widehat{\chi}_{t+1} \right) + \widehat{\epsilon}_t^w\end{aligned}\tag{A34}$$

where

$$\begin{aligned}\varphi_a &= \chi p^w \bar{a} \bar{w}^{-1}, \quad \varphi_x = \chi \beta \bar{\kappa} x^2 \bar{w}^{-1}, \quad \varphi_b = (1 - \chi) \bar{b} \bar{w}^{-1} \\ \varphi_s &= (1 - \chi) s \beta \bar{H} \bar{w}^{-1}, \quad \varphi_\chi = \chi (1 - \chi)^{-1} \bar{\kappa} x \bar{w}^{-1} \\ \widehat{\epsilon}_t^w &= \varphi_\eta [1 - (\rho - s) \beta \rho^\eta] \widehat{\epsilon}_t^\eta, \quad \varphi_\eta = \varphi_\chi (1 - \chi) (1 - \eta)^{-1}\end{aligned}$$

- Aggregate wage

$$\widehat{w}_t = \gamma_b (\widehat{w}_{t-1} - \widehat{\pi}_t + \gamma\widehat{\pi}_{t-1} - \widehat{\epsilon}_t^z) + \gamma_o \widehat{w}_t^o + \gamma_f E_t (\widehat{w}_{t+1} + \widehat{\pi}_{t+1} - \gamma\widehat{\pi}_t + \widehat{\epsilon}_{t+1}^z)\tag{A35}$$

where

$$\begin{aligned}\gamma_b &= (1 + \tau_2) \phi^{-1}, \quad \gamma_o = \varsigma \phi^{-1}, \quad \gamma_f = (\tau \lambda^{-1} - \tau_1) \phi^{-1} \\ \phi &= (1 + \tau_2) + \varsigma + (\tau \lambda^{-1} - \tau_1), \quad \varsigma = (1 - \lambda) (1 - \tau) \lambda^{-1} \\ \tau_1 &= [\varkappa_w \mu \varphi_x + \varphi_\chi (1 - \chi) (x \beta \lambda) (\varkappa_w \mu) \mu (\rho \beta) + \varphi_s \Gamma] (1 - \tau) \\ \tau_2 &= -(\varkappa_w \mu) \varphi_\chi (1 - \chi) (x \beta \lambda) \mu (1 - \tau) \\ \Gamma &= (1 - \eta x \beta \lambda \mu) \eta^{-1} \mu \varkappa_w\end{aligned}$$

- Phillips curve

$$\widehat{\pi}_t = \iota_b \widehat{\pi}_{t-1} + \iota_o (\widehat{p}_t^w + \widehat{\epsilon}_t^p) + \iota_f E_t \widehat{\pi}_{t+1}\tag{A36}$$

where

$$\begin{aligned}\iota_b &= \gamma^p (\phi^p)^{-1}, \quad \iota_o = (\varsigma^p / \tau^p) (\phi^p)^{-1}, \quad \iota_f = \beta (\phi^p)^{-1} \\ \phi^p &= 1 + \beta \gamma^p, \quad \varsigma^p = (1 - \lambda^p) (1 - \lambda^p \beta) (\lambda^p)^{-1}, \quad \tau^p = 1 + (\varepsilon^p - 1) \xi\end{aligned}$$

- Monetary policy rule

$$\hat{r}_t = \rho_s \hat{r}_{t-1} + (1 - \rho_s) [r_\pi \hat{\pi}_t + r_y (\hat{y}_t - \hat{y}_{nt})] + \hat{\varepsilon}_t^r \quad (\text{A37})$$

- Government spending

$$\hat{g}_t = \hat{y}_t + \frac{1 - y_g}{y_g} \hat{\varepsilon}_t^g \quad (\text{A38})$$

- Market tightness

$$\hat{\theta}_t = \hat{v}_t - \hat{u}_t \quad (\text{A39})$$

- Benefits

$$\hat{b}_t = \hat{k}_t^p \quad (\text{A40})$$

B Data appendix

B.1 United States

GDP Real Gross Domestic Product in billions of chained 2005 dollars. Source: FRED database, Federal Reserve Bank of St. Louis. Divided by population to obtain real per capita GDP.

Investment Fixed Private Investment + Personal Consumption Expenditures: Durable Goods. Source: FRED database, Federal Reserve Bank of St. Louis. Deflated by the GDP price deflator and divided by population to obtain real per capita Investment.

Consumption Personal Consumption Expenditures: Nondurable Goods + Services. Source: FRED database, Federal Reserve Bank of St. Louis. Deflated by the GDP price deflator and divided by population to obtain real per capita Consumption.

Wages Hourly compensation in the Nonfarm Business Sector. Seasonally adjusted. Source: FRED database, Federal Reserve Bank of St. Louis. Divided by the GDP price deflator to obtain an hourly real wage.

Price level Implicit Price Deflator, index numbers, 2005=100. Seasonally adjusted. Source: FRED database, Federal Reserve Bank of St. Louis. Expressed in quarter to quarter growth rates.

Interest Rate Effective Federal Funds Rate. Source: FRED Database, Federal Reserve Bank of St. Louis.

Unemployment Number of unemployed persons. Source: FRED Database, Federal Reserve Bank of St. Louis.

Unemployment Rate Civilian unemployment rate. Source: FRED Database, Federal Reserve Bank of St. Louis.

Vacancies Quarterly average of the monthly composite Help-Wanted index. Source: Barnichon (2010).

Population Civilian Noninstitutional Population. Average of monthly figures. Source: Source: FRED Database, Federal Reserve Bank of St. Louis.

B.2 Germany

GDP Real Gross Domestic Product in billions of chained 2005 euros. Seasonally adjusted. Source: OECD.Stat, Monthly Economic Indicators, April 2012. Divided by population to obtain real per capita GDP.

Investment Real Gross Fixed Capital Formation in billions of chained 2005 euros. Seasonally adjusted. Source: OECD.Stat, Monthly Economic Indicators, April 2012. Divided by population to obtain real per capita investment.

Consumption Real Private Consumption Expenditure in billions of chained 2005 euros. Seasonally adjusted. Source: OECD.Stat, Monthly Economic Indicators, April 2012. Divided by population to obtain real per capita consumption.

Wages Hourly compensation. Seasonally adjusted, not working day adjusted. Source: European Central Bank.

Price level Implicit Price Deflator, index numbers, 2005=100. Seasonally adjusted. Source: OECD.Stat, Monthly Economic Indicators, April 2012.

Interest Rate Three month interbank offer rate. Data refer to unified Germany from July 1990 and western Germany prior to this date. Source: OECD.Stat, Monthly Economic Indicators, April 2012

Unemployment Number of unemployed. Source: OECD.Stat, Monthly Economic Indicators, April 2012.

Unemployment Rate From 2005, data are supplied by Eurostat and seasonally adjusted by OECD. Prior to 2005, the source for original data is the Federal Statistical Office of Germany and the Federal Bank of Germany for seasonally adjusted series. Source: OECD.Stat, Monthly Economic Indicators, April 2012

Vacancies Data refer to vacancies for jobs of 7 days' duration or more reported by employers to employment agencies to be filled within 3 months and remaining unfilled at the end of the month. Source: OECD.Stat, Monthly Economic Indicators, April 2012

Population Thousands of population between age 15 to 64. Data refer to annual average estimates. Source: OECD.Stat Annual Labour Force Statistics. Annual values are taken as second quarter values and quarterly data are interpolated linearly until 2010. After the second quarter of 2010, data are extrapolated.

B.3 United Kingdom

GDP Real Gross Domestic Product in billions of chained 2005 pounds. Seasonally adjusted. Source: OECD.Stat, Monthly Economic Indicators, April 2012. Divided by population to obtain real per capita GDP.

Investment Real Gross Fixed Capital Formation in billions of chained 2005 pounds. Seasonally adjusted. Source: OECD.Stat, Monthly Economic Indicators, April 2012. Divided by population to obtain real per capita investment.

Consumption Real Private Consumption Expenditure in billions of chained 2005 pounds. Seasonally adjusted. Source: OECD.Stat, Monthly Economic Indicators, April 2012. Divided by population to obtain real per capita consumption.

Wages Wages and Salaries divided by Total actual weekly hours worked. Source: Office for National Statistics (ONS). Deflated by the price level to obtain real hourly compensation.

Price level Implicit Price Deflator, index numbers, 2005=100. Seasonally adjusted. Source: OECD.Stat, Monthly Economic Indicators, April 2012.

Interest Rate Three month interbank offer rate. Quarterly data are averages of monthly figures. Source: OECD.Stat, Monthly Economic Indicators, April 2012

Unemployment Harmonised Unemployment Level. Source: OECD.Stat, Monthly Economic Indicators, April 2012.

Unemployment Rate Harmonized Unemployment Rate. Source: OECD.Stat, Monthly Economic Indicators, April 2012

Vacancies Data refer to job opportunities notified by an employer to a Jobcentre or Careers Office (including self-employed opportunities created by employers) which remained unfilled on the day of the count. The vacancy figures do not represent the total number of vacancies in the economy. Recent estimates suggest that nationally about one third of all vacancies are notified to jobcentres. The suspension of the series in April 1999 was initially due to the discontinuity of vacancy figures for Northern Ireland identified during the introduction of major new computer system. Figures should be available anew from October 2001 but are still provisional and subject to future adjustment. Source: OECD.Stat, Monthly Economic Indicators, April 2012. Due to the presence of a break in the mean of the series in 2001Q1, we have mean corrected the series by assuming that there were no changes in vacancies between 2001Q1 and 2001Q2.

Population Thousands of population between age 15 to 64. Data refer to annual average estimates. Source: OECD.Stat Annual Labour Force Statistics. Annual values are taken as second quarter values and quarterly data are interpolated linearly until 2010. After the second quarter of 2010, data are extrapolated.

B.4 Sweden

GDP Real Gross Domestic Product, constant prices. Seasonally adjusted. Source: Statistics Sweden. Divided by population to obtain real per capita GDP.

Investment Real Gross Fixed Capital Formation, constant prices. Seasonally adjusted. Source: Statistics Sweden. Divided by population to obtain real per capita investment.

Consumption Final Private Consumption Expenditure, constant prices. Seasonally adjusted. Source: Statistics Sweden. Divided by population to obtain real per capita consumption.

Wages Hourly compensation. Seasonally adjusted, not working day adjusted. Source: Statistics Sweden.

Price level Consumer Price Index with Fixed Interest Rate (CPIF). Quarterly averages. Seasonally adjusted. Source: Statistics Sweden.

Interest Rate Repo rate. Quarterly averages. Source: Sveriges Riksbank.

Unemployment Number of unemployed. Quarterly averages. Seasonally adjusted. Source: Statistics Sweden.

Unemployment Rate Quarterly averages. Seasonally adjusted. Source: Statistics Sweden.

Vacancies Quarterly averages. Seasonally adjusted. Source: OECD.Stat, Monthly Economic Indicators, April 2012

Population Population between age 16 to 64. Source: Statistics Sweden.

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Table 1: Calibrated parameters

		U.S.	Germany	U.K.	Sweden
Discount factor	β	0.99	0.99	0.99	0.99
Capital depreciation rate	δ	0.025	0.025	0.025	0.025
Capital share	α	0.33	0.33	0.33	0.33
Government spending to output ratio	G/Y	0.20	0.19	0.20	0.30
Steady-state growth rate	γ_z	1.0048	1.0036	1.0064	1.0068
Job survival probability	ρ	0.897	0.984	0.97	0.95
Job finding probability	s	0.625	0.146	0.283	0.392
Matching function elasticity	σ	0.5	0.5	0.5	0.5
	0.70	0.70	0.80		
Price indexing	γ_p	0	0	0	0

This table reports the calibrated parameters in the estimated models.

Table 2: Prior distribution and estimated posterior mode

			U.S.	Germany	U.K.	Sweden
<i>(a) Structural parameters</i>						
Utilization rate elasticity	ψ_ν	Beta (0.5,0.1)	0.86		0.79	0.81
Capital adjustment cost elasticity	η_k	Normal (4,1.5)	3.20		2.69	3.56
Habit parameter	h	Beta (0.5,0.1)	0.58		0.30	0.43
Bargaining power parameter	η	Beta (0.5,0.1)	0.89		0.74	0.85
Relative flow value of unemployment	\tilde{b}	Beta (0.5,0.1)	0.75		0.92	0.89
Weight on hiring costs	η_q	Gamma (0.145,0.1)	0.48		0.09	0.06
Calvo wage parameter	λ_w	Beta (0.75,0.1)	0.66		0.63	0.67
Calvo price parameter	λ_p	Beta (0.66,0.1)	0.79		0.63	0.70
Wage indexing parameter	γ_w	Uniform (0,1)	0.00		0.00	0.00
Steady-state price markup	ε^P	Normal (1.15,0.05)	1.30		1.26	1.23
Taylor rule response to inflation	r_π	Normal (1.7,0.3)	1.82		1.56	1.71
Taylor rule response to output gap	r_y	Gamma (0.125,0.1)	0.27		0.45	0.27
Taylor rule inertia	ρ_s	Beta (0.75,0.1)	0.71		0.69	0.80
<i>(b) Autoregressive parameters of shocks</i>						
Technology	ρ_z	Beta (0.5,0.15)	0.16		0.20	0.14
Risk premium	ρ_b	Beta (0.5,0.15)	0.90		0.79	0.89
Investment	ρ_i	Beta (0.5,0.15)	0.85		0.70	0.78
Matching efficiency	ρ_m	Beta (0.5,0.15)	0.74		0.54	0.45
Bargaining power	ρ_η	Beta (0.5,0.15)	0.68		0.57	0.58
Price markup	ρ_p	Beta (0.5,0.15)	0.17		0.11	0.10
Government spending	ρ_g	Beta (0.5,0.15)	0.99		0.99	0.91
Monetary policy	ρ_r	Beta (0.5,0.15)	0.43		0.70	0.69
<i>(c) Standard deviations of innovations</i>						
Technology	σ_z	IGamma (0.15,0.15)	0.88		0.54	0.98
Risk premium	σ_b	IGamma (0.15,0.15)	0.24		0.18	0.30
Investment	σ_i	IGamma (0.15,0.15)	0.12		0.11	0.13
Matching efficiency	σ_m	IGamma (0.15,0.15)	4.51		6.53	7.47
Bargaining power	σ_η	IGamma (0.15,0.15)	0.16		0.07	0.08
Price markup	σ_p	IGamma (0.15,0.15)	0.15		0.52	0.48
Government spending	σ_g	IGamma (0.15,0.15)	0.33		0.58	0.56
Monetary policy	σ_r	IGamma (0.15,0.15)	0.12		0.09	0.08
<i>(d) Standard deviation of measurement error on real wage growth</i>						
U.S.		Beta (0.205,0.0649)	0.50			
Germany						
U.K.		Beta (0.296,0.0937)			0.64	
Sweden		Beta (0.257,0.0813)				0.56

This table reports the prior distribution and the posterior mode of the estimated parameters. The two numbers in parentheses are the mean and the standard deviation of the distribution, except for the uniform distribution, where the numbers are the lower and upper bounds of the distribution.

Table 3: Variance decompositions

Shock	Output growth	Unemployment	Vacancies
<i>(a) U.S.</i>			
Technology	0.42	0.19	0.18
Risk premium	0.23	0.29	0.27
Investment	0.18	0.43	0.34
Matching efficiency	0.01	0.02	0.12
Bargaining power	0.00	0.02	0.02
Price markup	0.00	0.00	0.00
Government spending	0.10	0.01	0.04
Monetary	0.06	0.04	0.04
<i>(b) Germany</i>			
Technology			
Risk premium			
Investment			
Matching efficiency			
Bargaining power			
Price markup			
Government spending			
Monetary			
<i>(c) U.K.</i>			
Technology	0.28	0.30	0.11
Risk premium	0.18	0.06	0.19
Investment	0.08	0.46	0.23
Matching efficiency	0.00	0.00	0.09
Bargaining power	0.00	0.00	0.00
Price markup	0.00	0.00	0.00
Government spending	0.32	0.09	0.22
Monetary	0.13	0.08	0.16
<i>(d) Sweden</i>			
Technology	0.24	0.27	0.17
Risk premium	0.30	0.26	0.31
Investment	0.10	0.33	0.20
Matching efficiency	0.00	0.00	0.06
Bargaining power	0.00	0.00	0.00
Price markup	0.00	0.00	0.00
Government spending	0.28	0.05	0.16
Monetary	0.09	0.09	0.10

This table shows the contribution of different shocks to the long-run variance of GDP growth, unemployment, and vacancies in the estimated models.

Figure 1: Output and unemployment in four countries, 2005–2011

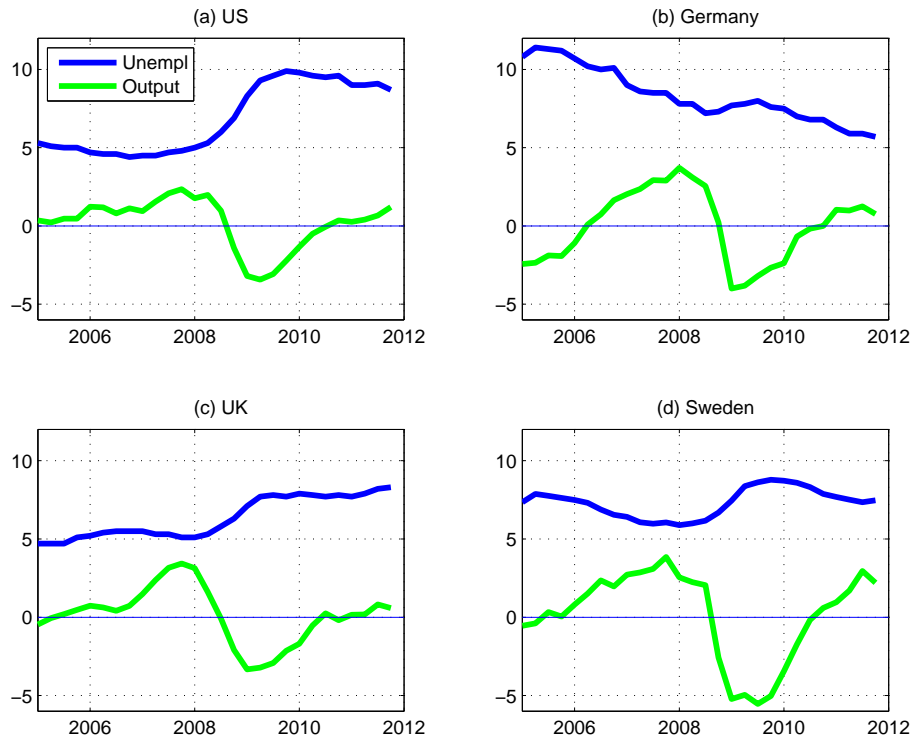


Figure 2: Beveridge curves in four countries, 1995–2011

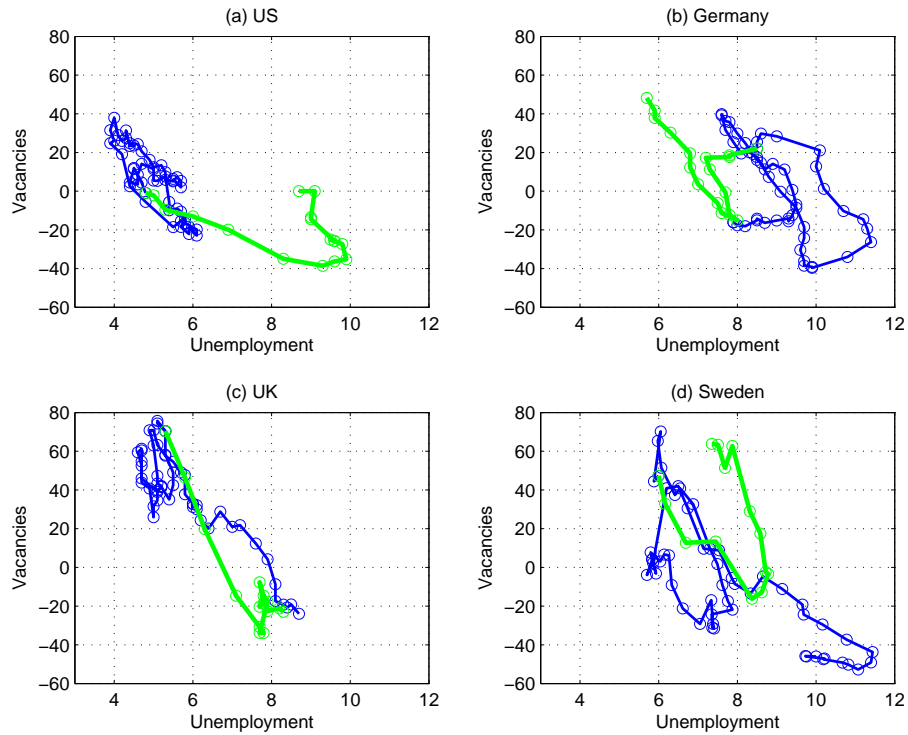


Figure 3: Estimated shocks, U.S.

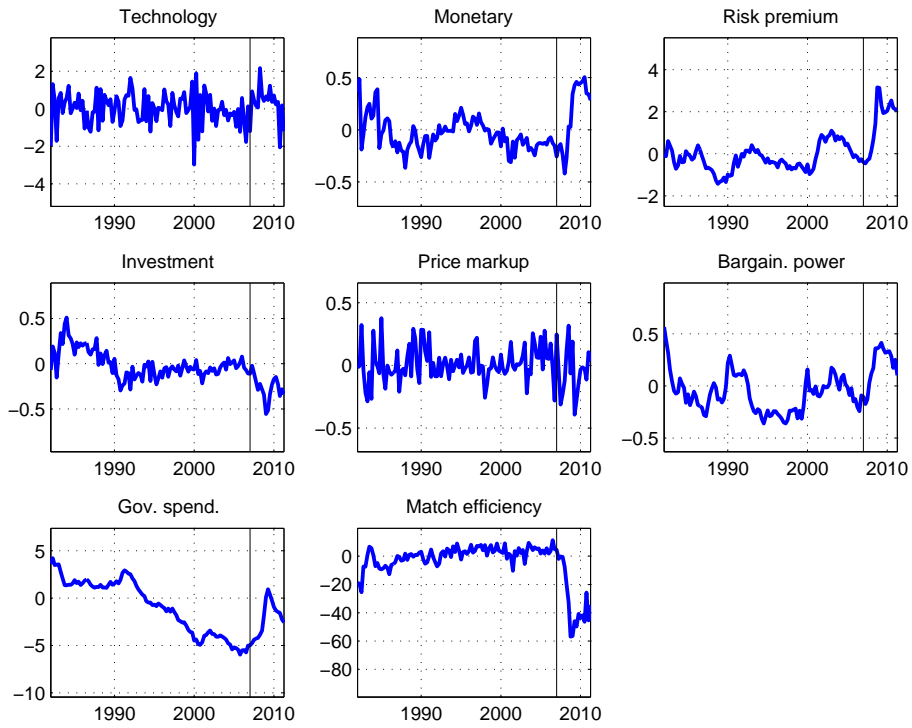


Figure 4: Decomposing GDP growth, U.S. 2007–2011

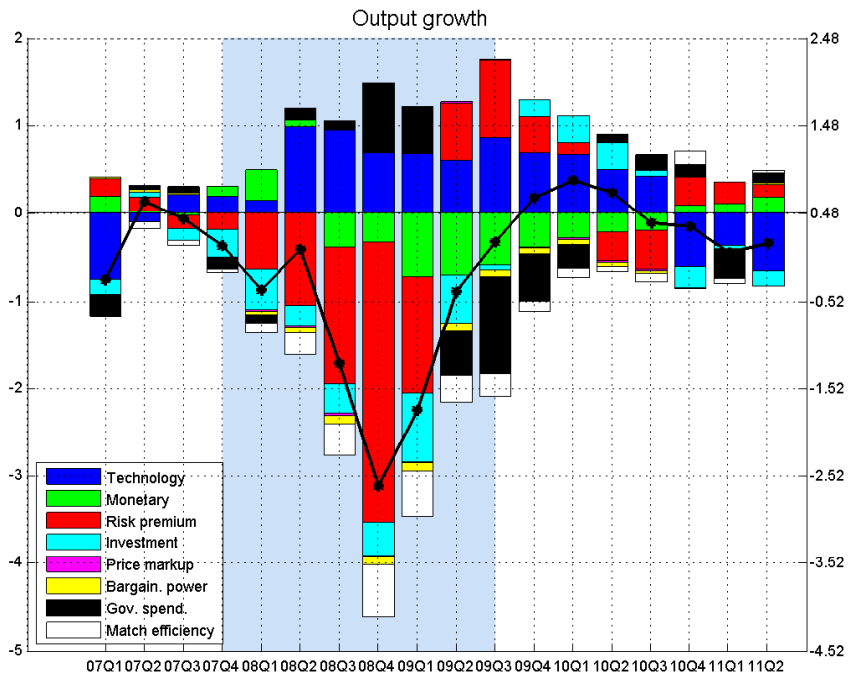


Figure 5: Decomposing the unemployment rate, U.S. 2007–2011

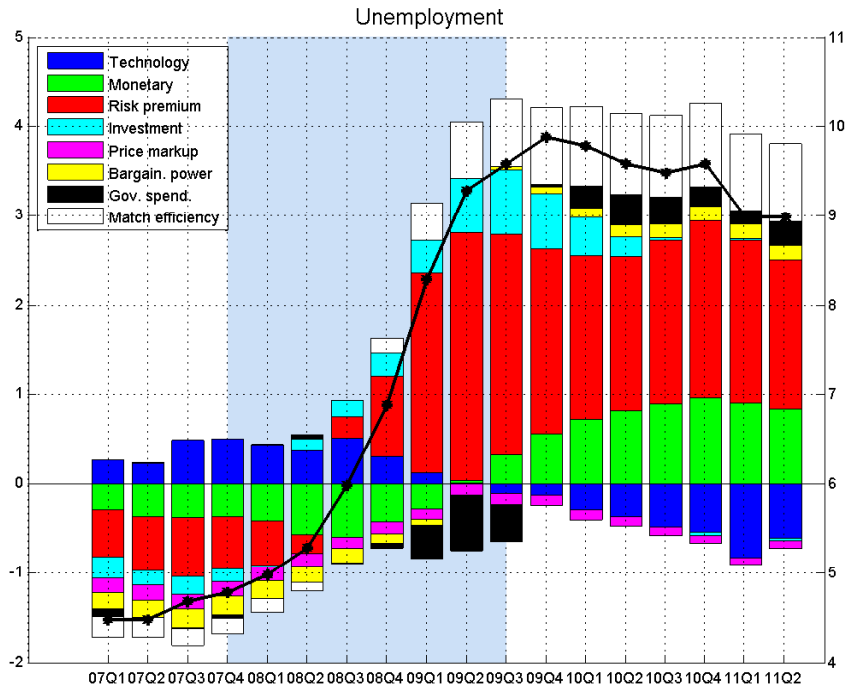


Figure 6: Decomposing vacancies, U.S. 2007–2011

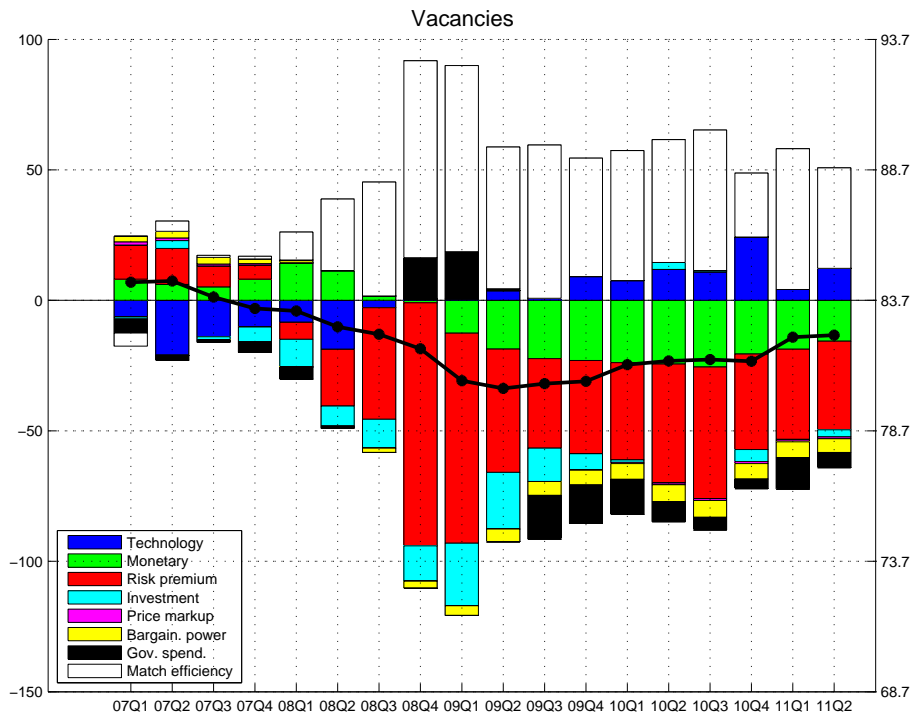


Figure 7: Decomposing the Beveridge Curve, U.S. 1987–2011

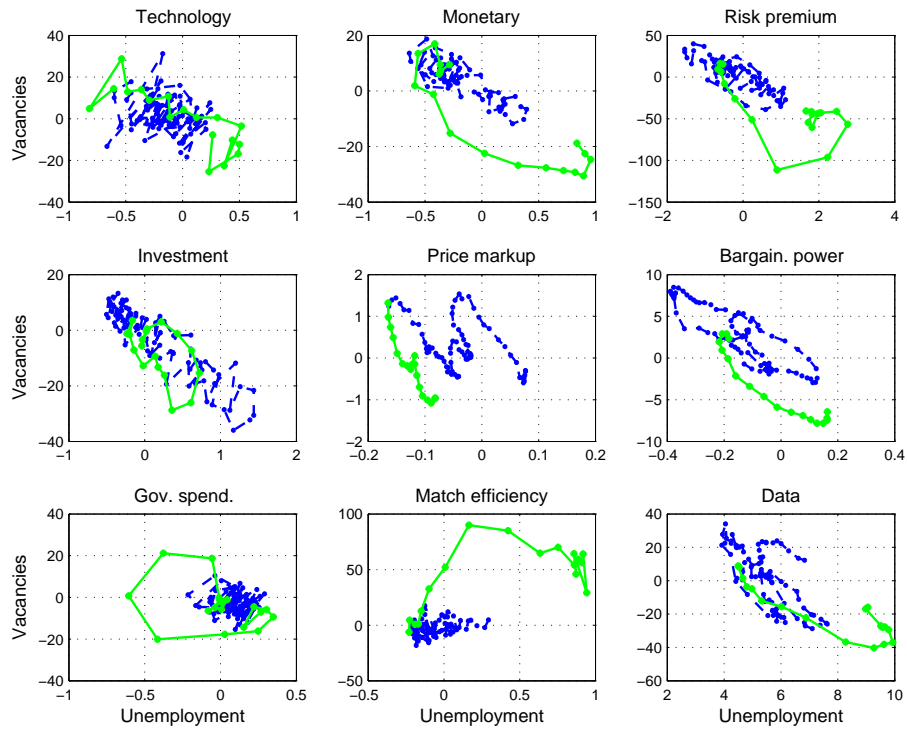


Figure 8: Estimated shocks, U.K.

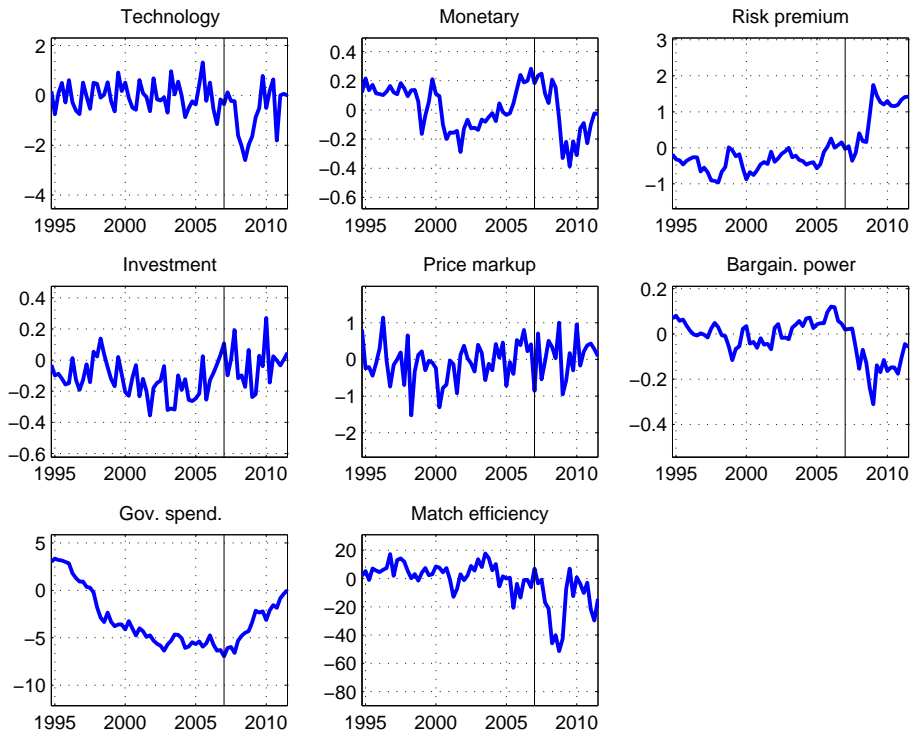


Figure 9: Decomposing GDP growth, U.K. 2007–2011

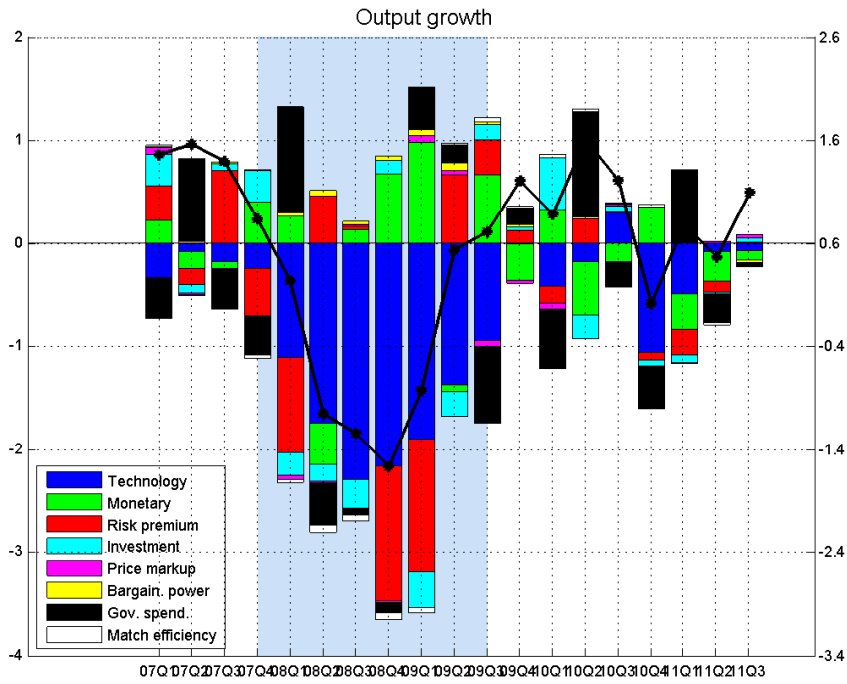


Figure 10: Decomposing the unemployment rate, U.K. 2007–2011

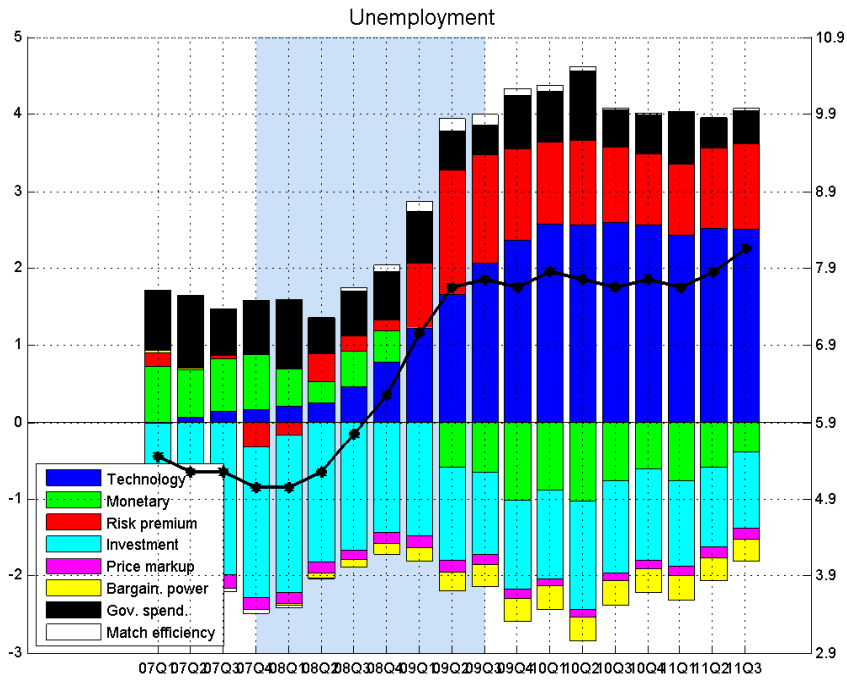


Figure 11: Decomposing vacancies, U.K. 2007–2011

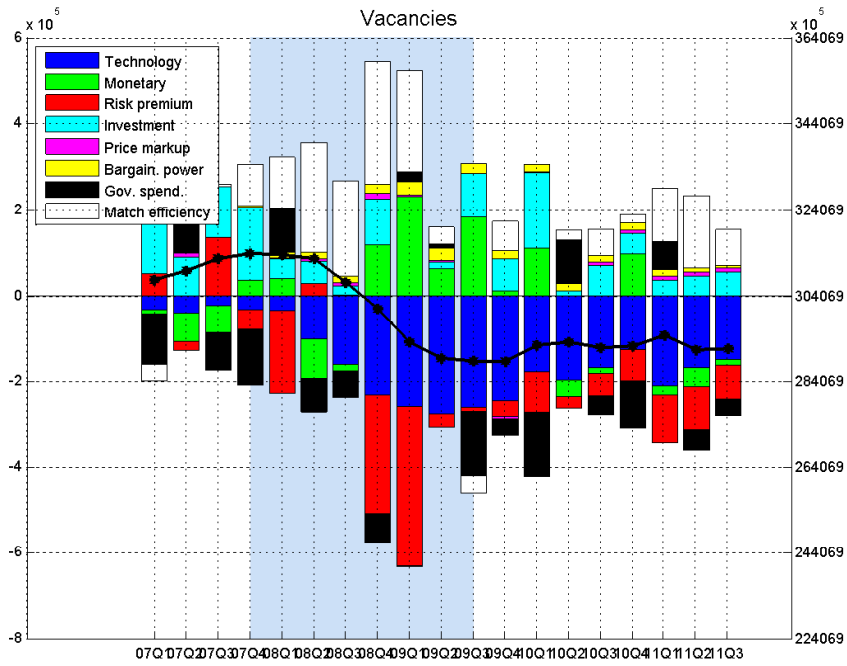


Figure 12: Decomposing the Beveridge Curve, U.K. 1995–2011

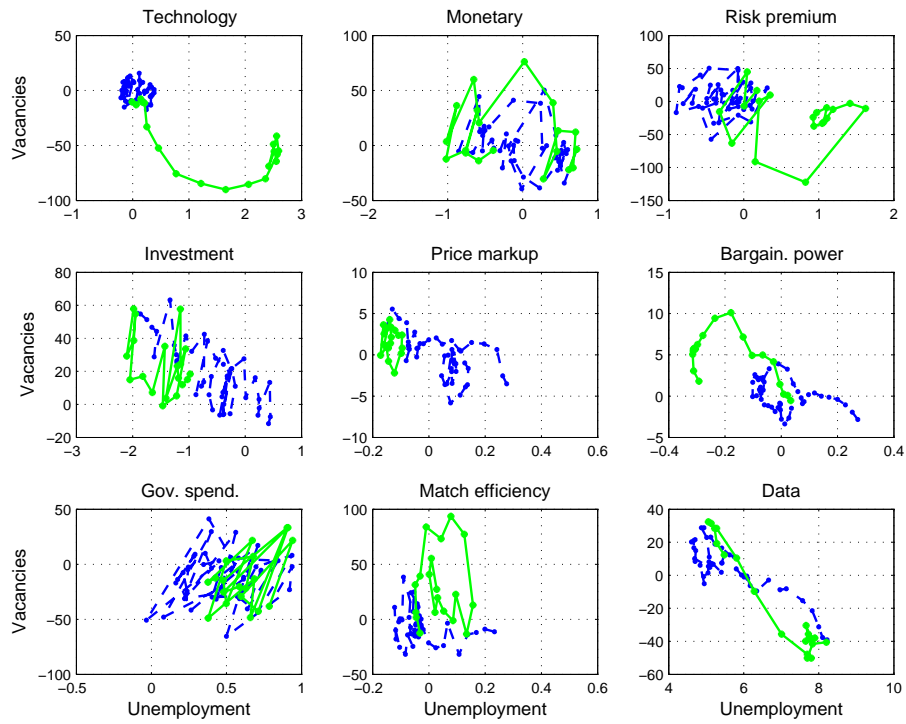


Figure 13: Estimated shocks, Sweden

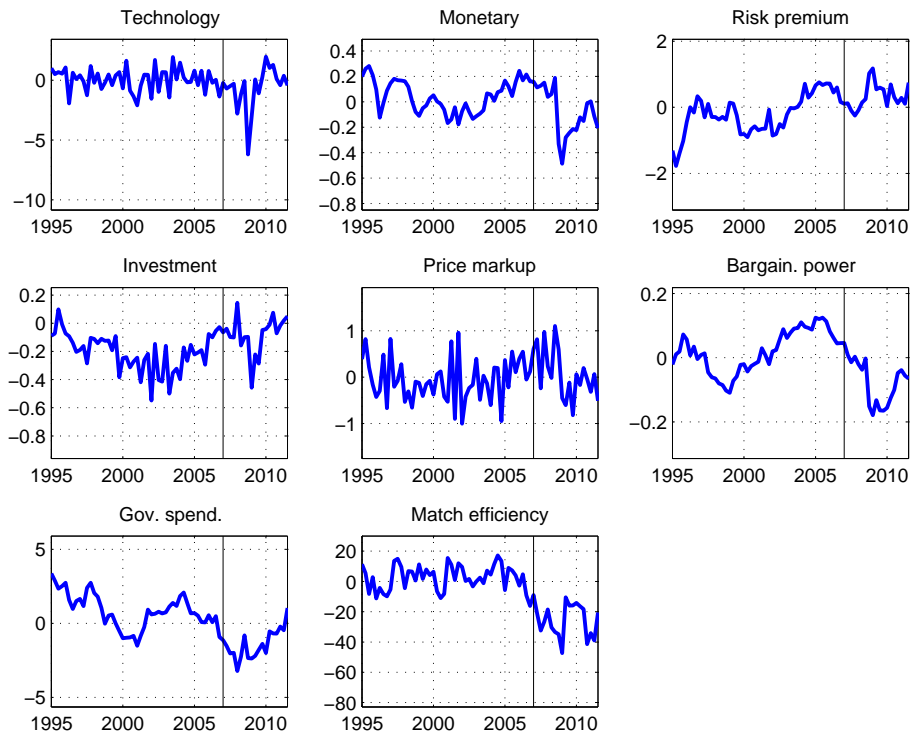


Figure 14: Decomposing GDP growth, Sweden 2007–2011

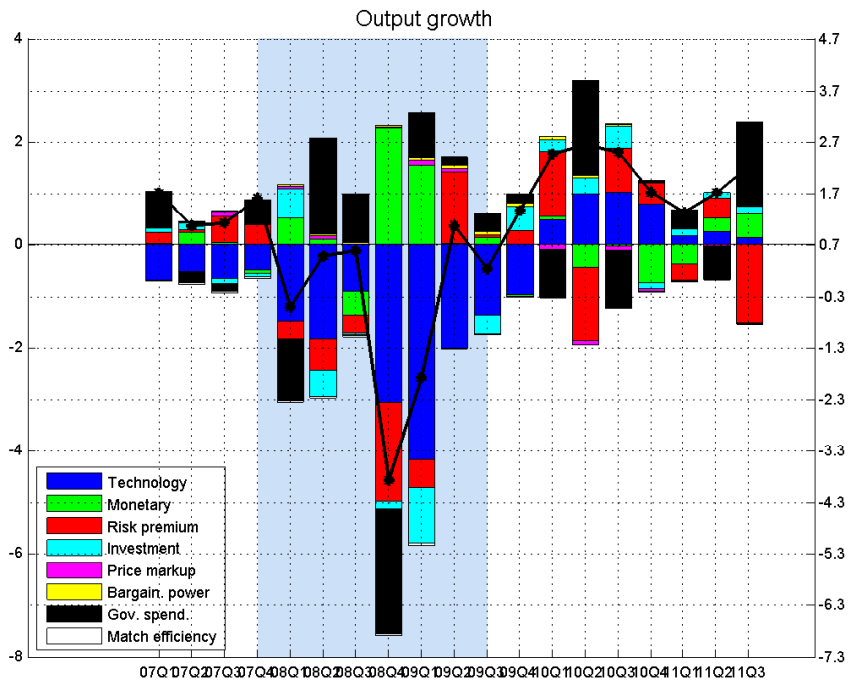


Figure 15: Decomposing the unemployment rate, Sweden 2007–2011

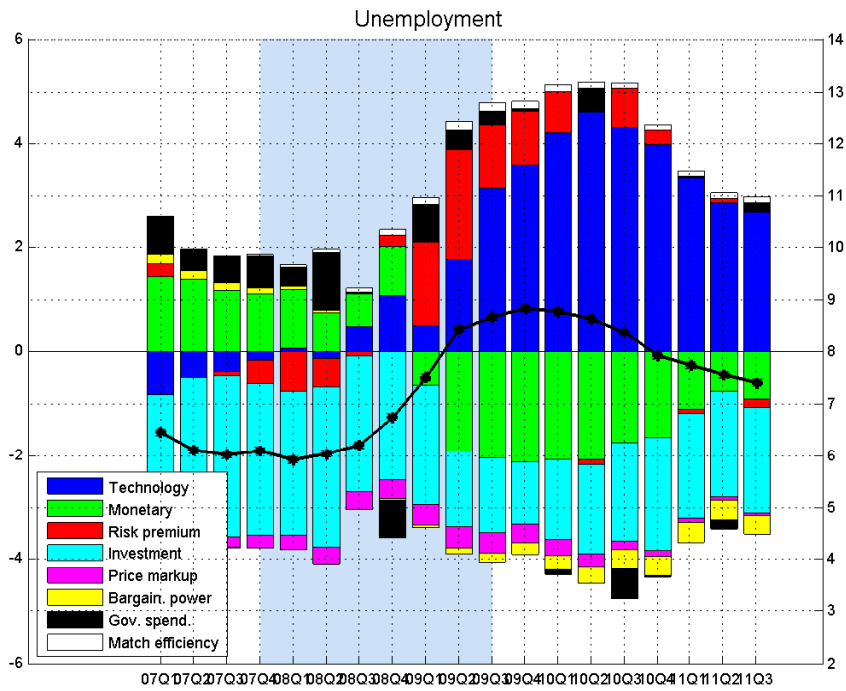


Figure 16: Decomposing vacancies, Sweden 2007–2011

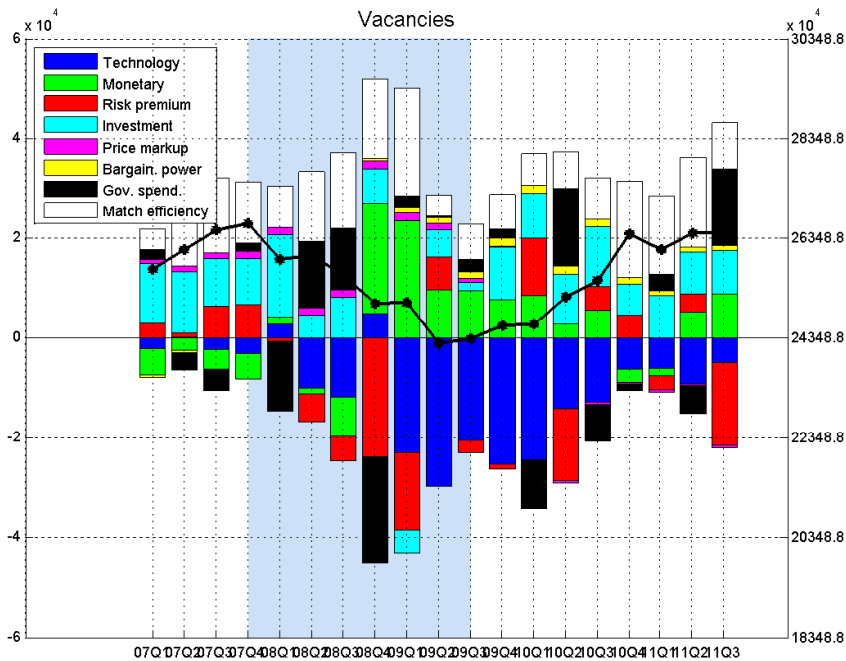


Figure 17: Decomposing the Beveridge Curve, Sweden 1995–2011

