



DP2011/04

**An estimated small open economy model
with frictional unemployment**

**Julien Albertini, Güneş Kamber and Michael
Kirker**

August 2011

JEL classification: E32, J6

www.rbnz.govt.nz/research/discusspapers/

Discussion Paper Series

ISSN 1177-7567

DP2011/04

**An estimated small open economy model with
frictional unemployment***

Julien Albertini, Güneş Kamber and Michael Kirker[†]

Abstract

This paper investigates labour market dynamics in New Zealand by estimating a structural small open economy model enriched with standard search and matching frictions in the labour market. We show that the model fits the business cycle features of key macroeconomic variables reasonably well and provides an appealing monetary transmission mechanism. We then extend our analysis to understand the driving forces behind labour market variables. Our findings suggest that the bulk of variation in labour market variables is solely explained by disturbances pertaining to the labour market.

* The Reserve Bank of New Zealand's discussion paper series is externally refereed. The views expressed in this paper are those of the author(s) and do not necessarily reflect the views of the Reserve Bank of New Zealand. We are grateful to Kirdan Lees, Thomas Lubik and an anonymous referee for their useful comments. We would also like to thank Charles Leung, Peter Gardiner, William Bell, Brian Silverstone, Ram SriRamaratnam, Simon Hall and David Paterson.

[†] Address: Julien Albertini, EPEE et TEPA (FR CARS n° 3126), University of Evry, Bd. François Mitterand, 91025 Cedex, France. Güneş Kamber and Michael Kirker, Economics Department, Reserve Bank of New Zealand, 2 The Terrace, PO Box 2498, Wellington, New Zealand. *Contact email address:* Gunes.Kamber@rbnz.govt.nz
ISSN 1177-7567 ©Reserve Bank of New Zealand

1 Introduction

This paper investigates labour market dynamics in an estimated structural small open economy model. The starting point of the analysis is to incorporate search and matching frictions in the labour market into an otherwise standard micro-founded general equilibrium model. We then estimate the model on New Zealand data using Bayesian estimation techniques. The methodology we adopt allows us to evaluate the ability of the model to match business cycle properties of key macroeconomic and labour market variables in New Zealand.

Based on the theoretical framework developed by Galí and Monacelli (2005) and Monacelli (2005), dynamic stochastic general equilibrium (DSGE) models with staggered price setting have become the workhorses models for analyzing business-cycle fluctuations and monetary policy design in small open economies. For example, using such models, Lubik and Schorfheide (2007) investigate whether small open economy central banks respond to exchange rate movements, and Justiniano and Preston (2010b) and Kam et al (2009) consider the design of optimal policy for inflation targeting small open economies. There is also extensive literature that evaluates the fit of these models, including, Adolfson et al (2007) and Adolfson et al (2008) for Sweden, Justiniano and Preston (2010a) for Canada, and Matheson (2010) for Australia, Canada, and New Zealand.

A number of papers have applied this theoretical framework to the New Zealand economy. Liu (2006) builds and estimates a small open economy DSGE model to investigate the propagation mechanism of various shocks. Lees et al (2007) examine the forecasting performance of these models. Kirker (2008) estimates the natural real rate of interest, inflation target, potential output, and neutral real exchange rate using a DSGE model with time-varying parameters. Furthermore, in the light of the empirical performance of DSGE models, the Reserve Bank of New Zealand has adopted a large scale multi-sector DSGE model (K.I.T.T.) as its core policy model.¹

However, none of the aforementioned models incorporate features to explicitly analyse flows in the labour market. They are therefore silent on the role of unemployment fluctuations over the business cycle and in response to monetary policy shocks. Our paper aims to fill this gap and is related to Campolmi and Faia (2011) and Hairault (2002), who examine labour market frictions in open economy models. However, Campolmi and Faia (2011) fo-

¹ See Lees (2009) and Benes et al (2009) for more details.

cus on the labour market institutions in the Euro Area and Hairault (2002) examines the transmission of productivity shocks in a two country real business cycle model. Our contribution is to develop a small open economy model with sticky prices in which the central bank follows an independent monetary policy rule.

The literature that explicitly introduces labour market flows into closed economy business cycle models is vast. Seminal papers such as Merz (1995), Andolfatto (1996), and den Haan et al (2000) have introduced the concept of equilibrium unemployment in real business cycle models in a tractable way. By allowing the coexistence of workers searching for jobs and firms looking for employees, this setup allows us to explore labour market flows in conjunction with other macroeconomic variables over the business cycle.

Recently, several papers have focused on the implications for inflation dynamics and monetary policy from implicitly taking into account labour market frictions. This body of research incorporates search and matching frictions into otherwise standard New Keynesian business cycle models. Hence, these models explicitly link labour market frictions to inflation dynamics. Relevant papers include among others: Walsh (2005), Krause and Lubik (2007), Krause et al (2008b), Krause et al (2008a), Gertler et al (2008), Christoffel and Kuester (2008), Trigari (2009), and Christoffel and Linzert (2010).

This paper contributes to this literature by analyzing the role of labour market frictions for inflation dynamics and monetary policy in a small open economy. Our main findings are as follows. The estimated model describes well the second moments of the key macroeconomic and labour market variables in New Zealand for reasonable parameter values. It also predicts an appealing monetary transmission mechanism by providing the dynamic response of labour market variables, such as the unemployment and vacancy rates, alongside the usual macroeconomic aggregates. However, the model implies that the bulk of the variation in unemployment and vacancies is solely due to shocks pertaining to the labour market and that there is a strong disconnect between the labour market and the rest of the economy.

The rest of the paper is organised as follows. Section 2 provides some background on the New Zealand economy and labour market. Section 3 details the model. Section 4 presents the data and the estimation method. Section 5 discusses our estimation results. Section 6 investigates the driving forces of unemployment and vacancies. And section 7 provides some concluding remarks.

2 Economic background

During the 1980s and 1990s, New Zealand undertook a vast range of economic reforms designed to deregulate, and open up the economy (see Evans et al 1996 for a detailed discussion of the reforms). From the labour market perspective, the most significant of these reforms was the introduction of the Employment Contracts Act (ECA) in 1991 which removed the requirement for compulsory union membership for industries in which a union existed. This opened up the possibility for employees to negotiate individual employment contracts if they so wished. After the introduction of the ECA, union membership fell by 38 percent in three years (Evans et al 1996) and has continued to decline, making New Zealand one of the least unionised countries in the OECD. And according to estimates in Maloney (1997), the ECA also had the effect of increasing employment (through labour demand) without reducing hourly earnings.

Since undertaking these large scale economic reforms, including the introduction of inflation targeting framework in 1989, New Zealand has become a country that is viewed amongst the best in terms of quality of institution by international standards (McCann 2009). For example according to the World Economic Forum's Global Competitiveness Report 2010-2011, New Zealand ranks third in terms of institutions while it has the 12th most efficient labour market. Moreover, OECD indicators related to the strictness of regulations on dismissals and the user of temporary contracts rank New Zealand amongst the countries with the least strict regulations. Accordingly, the unemployment rate in New Zealand has been generally trending downwards from around 11 percent in the early 1990's, to a low of 3.4 percent in 2007.

Figure 1 shows the historical evolution of New Zealand's unemployment and vacancy rates since 1994Q3 (the start of the sample period considered in this paper).² In late 1997 following the onset of the Asian Financial Crisis, the New Zealand economy entered a recession. Unemployment which has been relatively flat over the previous year jump back up to around eight percent, and the vacancy rate fell to a new low of around 1.2 percent. However, this recession was relatively short lived (three consecutive quarters of negative growth), and the New Zealand economy quickly recovered.

Following the Asian Crisis, the New Zealand economy entered a nearly decade

² The vacancy rate is computed as the Job Ad Series from the Department of Labour divided by the active labour market population.

long period of sustained economic growth. With the increase in economic activity, the unemployment rate continued its decline reaching a minimum of 3.4 percent in 2007Q4. Over this period, the vacancy rate saw a large increase, peaking at 2.9 percent. While some of this trend is as a result of increased economic activity in the New Zealand economy, there was also a methodological change in the series. In March 2000, job listings on four major websites were added to the measures of job listings from the seven major regional newspapers. Since that time, internet lists have grown rapidly, while the number of newspaper lists has trended downwards. In 2000Q1, around six percent of the lists measured by the Job Ad Series were from the internet, while by 2010, this proportion had grown to 80 percent.

With the onset of the Global Financial Crisis the New Zealand economy again entered recession in 2008Q1 (for five consecutive quarters of negative growth). The unemployment rate peaked at seven percent 2009Q3, and the vacancy rate fell to an all-time low of 1.02 percent (2009Q3).

In terms of business cycle characteristics, Table 1 shows some summary statistics of New Zealand's labour market (using detrended data). Individual hours (the intensive margin) and wages are less volatile than GDP, while unemployment and vacancies are significantly more volatile than GDP. As would be expected, individual hours and vacancies are pro-cyclical (positively correlated with GDP), while unemployment is counter-cyclical. Wages in New Zealand show weak negative correlation with GDP. The pro-cyclicality of vacancies and counter-cyclicality of unemployment also produces a fairly robust negative correlation between the two variables giving rise to the relationship known as the Beveridge curve which is graphed in figure 2.

The search and matching framework developed in the literature has been shown to replicate many of the key reduced-form statistics shown in table 1 and figure 2, such as the Beveridge curve, the adjustment of labour at the extensive margin, and the relative variability of unemployment. Furthermore, Razzak (2009) estimates a search and matching function within a partial equilibrium framework for New Zealand and finds important roles for the matching friction and search intensity coefficients. Therefore, *a priori*, augmenting a DSGE model to include search and matching frictions seems to be a suitable candidate model to explain the interactions and dynamics of the labour market with the rest of the New Zealand economy.

3 The model

We build a small open economy DSGE model based on Monacelli (2005), Galí and Monacelli (2005), and Justiniano and Preston (2010a). The model includes a non-Walrasian labour market with matching frictions and hiring costs in the spirit of Mortensen and Pissarides (1994) and Mortensen and Pissarides (1999). We focus on the flow of workers between employment and unemployment. Time is discrete, and our economy is populated by homogeneous workers and firms. Domestic producing firms are large and employ many workers as their only input into the production process. Labour may be adjusted at the extensive margin (employment) as well as at the intensive margin (hours). Wages and hours are both the outcome of a bilateral Nash bargaining process between the large firm and each worker. Firms face nominal wage rigidities. We separate hiring and pricing decisions by assuming that domestic retailers set home prices and face quadratic adjustment cost as in Rotemberg (2008). The import sector buys domestic goods from the rest of the world and set imported good prices under quadratic adjustment cost.

3.1 The labour market

The search process and recruiting activity are costly and time-consuming for both firms and workers. A job may either be filled and productive, or unfilled and unproductive. To fill their vacant jobs, firms publish adverts and screen workers, incurring hiring expenditures. Workers are identical, and they may either be employed or unemployed. The number of matches M_t is given by the following Cobb-Douglas matching function:

$$M_t = X_t S_t^\nu V_t^{1-\nu} \quad \text{with } \nu \in (0, 1), \quad X_t > 0 \quad (1)$$

where X_t is the matching efficiency shock, V_t denote the mass of vacancies, ν stands for the elasticity of the matching function with respect to the number of job seekers, and S_t represents the mass of searching workers. The labour force L is assumed to be constant over time. Assuming $L = 1$ allows to treat aggregate labour market variables in number and rate without distinction. The matching function (1) satisfies the usual assumptions, it is increasing, concave and homogenous of degree one. A vacancy is filled with probability $k_t = M_t/V_t$ and a job seeker finds a job with probability $f_t = M_t/S_t$.

3.2 The sequence of events

As Hall (2005) demonstrates, fluctuations in labour market flows are mainly driven by job creation. So we abstract from job destruction decisions by assuming that in each period a fixed proportion of existing jobs are exogenously destroyed at rate ρ^x .

Employment in period t has two components: new and old workers. New employment relationships are formed through the matching process in period t . The number of job seekers is given by:

$$S_t = 1 - (1 - \rho^x)N_{t-1} \quad (2)$$

This definition has two major consequences. First, it allows workers who lose their job in period t to have a probability of being employed in the same period. Second, it allows us to make a distinction between job seekers and unemployed workers $U_t = (1 - N_t)$. The latter one receive unemployment benefits. The employment law of motion is given by:

$$N_t = (1 - \rho^x)N_{t-1} + M_t \quad (3)$$

3.3 The representative household

All households receive an equal fraction of profits from both domestic and retail firm in the domestic economy. The expected intertemporal utility of the large family (encompassing all households) can be written as:

$$\max_{\Omega_t^H} E_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_{c,t} \left\{ \log(C_t - \chi \bar{C}_{t-1}) - N_t V(h_t) \right\} \quad (4)$$

where $\beta \in (0, 1]$ is the discount factor, $\varepsilon_{c,t}$ is the preference shock, $\chi \bar{C}_{t-1}$ is an external habit taken as exogenous by the household, χ is the deep-habit parameter, N_t the aggregate employment over each firm, and $V(\cdot)$ is the disutility of work. The individual households are too small relative to the size of the economy to make a material impact on aggregate variables. The disutility of work takes the following form:

$$V(h_t) = \kappa^h \frac{h_t^{1+\phi_h}}{1 + \phi_h} \quad (5)$$

where h_t denotes hours work, ϕ_h is the inverse of the Frisch elasticity of labour supply, and κ^h is the work disutility parameter.

C_t is a composite consumption index of domestic and imported bundles of goods such that:

$$C_t = \left[(1 - \alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad (6)$$

where $C_{H,t}$ and $C_{F,t}$ are Dixit-Stiglitz aggregates of the available domestic and foreign produced goods, α corresponds to the balance trade steady state share of foreign goods in the domestic consumption bundle, and $\eta > 0$ denotes the elasticity of substitution between domestic and foreign goods.

The Dixit-Stiglitz aggregates of domestic and foreign produced goods are defined as:

$$C_{H,t} = \left[\int_0^1 C_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}} \quad \text{and} \quad C_{F,t} = \left[\int_0^1 C_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}} \quad (7)$$

where $\epsilon > 1$ the elasticity of substitution between the differentiated goods. Optimal allocation of expenditures between domestic and foreign bundles implies:

$$C_{H,t} = (1 - \alpha) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t \quad \text{and} \quad C_{F,t} = \alpha \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} C_t \quad (8)$$

Optimal allocation between differentiated goods involves the following demand functions:

$$C_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\epsilon} C_{H,t} \quad \text{and} \quad C_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\epsilon} C_{F,t} \quad (9)$$

and P_t is a composite price index of domestic and imported bundles of goods such that:

$$P_t = \left[(1 - \alpha) P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \quad (10)$$

where P_t corresponds to the domestic CPI. $P_{H,t}$ and $P_{F,t}$ denote the domestic goods price and the domestic currency price of imported goods respectively.

The representative household chose the set of processes $\Omega_t^H = \{C_t, B_t, D_t\}_{t=0}^{\infty}$ taking as given the set of processes $\{P_t, W_t, i_t, i_t^*, f_t\}_{t=0}^{\infty}$, initial wealth (D_0), and initial debt (B_0) so as to maximise (4) subject to the budget constraint:

$$\begin{aligned} P_t C_t + D_t + e_t B_t &= D_{t-1}(1 + i_{t-1}) + e_t B_{t-1}(1 + i_{t-1}^*) \phi_t(A_t) \\ &+ W_t N_t h_t + (1 - N_t) b_t P_t + \Pi_{H,t} + \Pi_{F,t} + T_t \end{aligned} \quad (11)$$

and the law of motion of employment:

$$N_t = (1 - \rho^x)N_{t-1} + f_t S_t \quad (12)$$

D_t is the household's holding of one period domestic bonds at date t , and B_t is the household's holdings of one period foreign bonds. The corresponding foreign and domestic interest rates are i_t and i_t^* respectively. e_t denotes the nominal exchange rate. W_t is the nominal wage level. $\Pi_{H,t}$ and $\Pi_{F,t}$ represent profits from holding shares in domestic and imported goods firms. b is the real amount of unemployment benefits an unemployed worker receives and T_t is a lump-sum tax. Following Schmitt-Grohe and Uribe (2003), we introduce a debt elastic interest rate premium to close the model. It is governed by the function ϕ_t which takes the following form:

$$\phi_t = \exp(-\bar{\phi}A_t) \quad (13)$$

where $A_t = (e_{t-1}B_{t-1})/(\bar{Y}P_{t-1})$ is the real quantity of outstanding foreign debt expressed in terms of domestic currency as a fraction of steady-state output.

The optimality conditions of the household's problem can be written as follow:

$$\lambda_t = \varepsilon_{c,t}(C_t - \chi C_{t-1})^{-1} \quad (14)$$

$$\lambda_t/P_t = E_t[(1 + i_t)\beta\lambda_{t+1}/P_{t+1}] \quad (15)$$

$$\lambda_t e_t/P_t = E_t[(1 + i_t^*)\beta\phi_{t+1}\lambda_{t+1}e_{t+1}/P_{t+1}] \quad (16)$$

where λ_t is the Lagrange multiplier on the budget constraint. Equation (14) defines the standard Euler equation, equations (15) and (16) express the portfolio allocation of domestic and foreign bonds.

Combining the two first-order conditions on domestic and foreign bond holdings results in the standard uncovered interest rate parity condition:

$$\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{P_t}{P_{t+1}} \left((1 + i_t) - (1 + i_t^*)\phi_{t+1} \frac{e_{t+1}}{e_t} \right) = 0 \quad (17)$$

It is also useful to derive the marginal value of an employed worker to the household (φ_t) which can be obtained by differentiating the household's value function with respect to N_t and using the envelop condition:

$$\varphi_t = \lambda_t \left(\frac{W_t h_t}{P_t} - b \right) - \varepsilon_{c,t} V(h_t) + \beta E_t (1 - \rho^x)(1 - f_{t+1})\varphi_{t+1} \quad (18)$$

Equation (18) is the expected value of employment minus the expected value of unemployment. In our model, employment is determined by the matching process, and wage and individual hours are the outcome of the bargaining process. Therefore, φ_t will partly determine the total surplus from a match which enters the bargaining problem that we detail below in section 3.4.

3.4 Domestic producers

Domestic intermediate sector

Domestic intermediate good producers operate in a perfectly competitive market using labour as their only input. The production function of domestic intermediate firms is given by:

$$Y_{I,t} = Z_t(N_t h_t)^\zeta \quad (19)$$

where Z_t is a technology shock, and ζ is the employment share of production in the domestic good.

The optimization problem of the intermediate firm is to choose a set of processes $\Omega_t^P = \{V_t\}_{t=0}^\infty$ taking as given the set of processes $\{P_{H,t}, W_t, q_t^m, h_t\}_{t=0}^\infty$. The domestic intermediate good producer maximises the following intertemporal function:

$$\max_{\Omega_t^P} E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[mc_t Y_{I,t} - \frac{W_t}{P_{H,t}} h_t N_t - \Gamma(V_t) - \Upsilon(W_t) N_t \right] \quad (20)$$

subject to the production function (19) and the evolution of employment,

$$N_t = (1 - \rho^x) N_{t-1} + k_t V_t \quad (21)$$

and assuming the wage cost function takes the following form:

$$\Upsilon(W_t) = \frac{\psi_W}{2} \left(\frac{W_t}{\tilde{\pi}_{t-1}^w W_{t-1}} - 1 \right)^2 h_t \bar{Y}_{I,t} \quad (22)$$

where mc_t is the relative price of intermediate good sector in terms of the domestic price level which coincides with the marginal cost of domestic retail firm, $Y_{I,t}$ is the output level of the intermediate good, and $P_{H,t}$ is the domestic goods price. Hiring is costly and incurs a cost $\Gamma(V_t)$ per vacancy posted. The

intermediate goods-producing firm faces a quadratic wage adjustment cost which is proportional to the size of its workforce. $\pi_t^w = W_t/W_{t-1}$ represents the wage inflation, and $\tilde{\pi}_t^w = \pi_t^{w,\gamma_w} \pi^{w,1-\gamma_w}$. The parameter γ_w governs the degree of backward-looking wage setting and π^w is the steady-state wage inflation.

The optimality condition with respect to the choice of vacancies is:

$$\mu_t = \frac{\Gamma'(V_t)}{k_t} \quad (23)$$

$$(24)$$

where μ_t is the Lagrange multiplier associated with the employment constraint. We can also derive an expression for the evolution of μ_t by differentiating the firms' value function with respect to N_t :

$$\mu_t = mc_t \zeta \frac{Y_{I,t}}{N_t} - \frac{W_t}{P_{H,t}} h_t - \Upsilon(W_t) + \beta(1 - \rho^x) E_t \frac{\lambda_{t+1}}{\lambda_t} \mu_{t+1} \quad (25)$$

For firms, μ_t determines the value of employing an extra worker. Combining the two first-order conditions gives the job creation condition:

$$\frac{\Gamma'(V_t)}{k_t} = mc_t \zeta \frac{Y_{I,t}}{N_t} - \frac{W_t}{P_{H,t}} h_t - \Upsilon(W_t) + \beta(1 - \rho^x) E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\Gamma'(V_{t+1})}{k_{t+1}} \quad (26)$$

This condition shows that the expected gain from hiring a new worker is equal to the expected cost of search (which is the marginal cost of a vacancy $\Gamma'(V_t)$ times the average duration of a vacancy $1/k_t$). For the wage derivation we can also rewrite the job creation condition in terms of the real wage defined as the nominal wage divided by the consumer price level.

$$\frac{\Gamma'(V_t)}{k_t} = mc_t \zeta \frac{Y_{I,t}}{N_t} - \frac{W_t}{P_t} a_t^x - \Upsilon(W_t) + \beta(1 - \rho^x) E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\Gamma'(V_{t+1})}{k_{t+1}} \quad (27)$$

where we define the fraction:

$$a_t^x = \frac{P_t}{P_{H,t}} \quad (28)$$

which will be related to the terms of trade below.

Wage and hours setting mechanism

We now turn to how wages and hours are set within the model. At equilibrium, filled jobs generate a return (the marginal value of the job μ_t plus the corresponding employed worker value φ_t) greater than the values of a vacant job and of an unemployed worker. The net gain issued from a filled job is the total surplus of the match:

$$\mathcal{S}_t = \frac{\varphi_t}{\lambda_t} + \mu_t \quad (29)$$

Nominal wages and hours are determined through an individual Nash bargaining process between each worker and his employer who share the total surplus of the match. Each participant's threat point corresponds to the value of the alternative option, which for the worker is the value of being unemployed, and for the firm is the value of a vacant job. The outcome of the bargaining process is given by the solution of the following maximization problem:

$$\max_{W_t, h_t} \left(\frac{\varphi_t}{\lambda_t} \right)^{1-\xi_t} \mu_t^{\xi_t} \quad (30)$$

where $\xi_t \in [0, 1]$ and $1 - \xi_t$ denote the stochastic firms and workers bargaining power respectively. We assume that bargaining power is not constant over time and follows a stochastic process.

The optimality conditions of the above problems are given by:

$$\xi_t \varphi_t \frac{\partial \mu_t}{\partial W_t} = -(1 - \xi_t) \mu_t \frac{\partial \varphi_t}{\partial W_t} \quad (31)$$

$$\xi_t \varphi_t \frac{\partial \mu_t}{\partial h_t} = -(1 - \xi_t) \mu_t \frac{\partial \varphi_t}{\partial h_t} \quad (32)$$

where

$$\begin{aligned} \frac{\partial \varphi_t}{\partial W_t} &= \frac{\lambda_t h_t}{P_t} \\ \frac{\partial \mu_t}{\partial W_t} &= -\frac{h_t}{P_{H,t}} - \psi_w \frac{h_t}{W_t} \frac{Y_{I,t} \pi_t^w}{\tilde{\pi}_{t-1}^w} \left(\frac{\pi_t^w}{\tilde{\pi}_{t-1}^w} - 1 \right) + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \psi_w \frac{h_{t+1}}{W_t} \frac{Y_{i,t+1} \pi_{t+1}^w}{\tilde{\pi}_{t+1}^w} \left(\frac{\pi_{t+1}^w}{\tilde{\pi}_t^w} - 1 \right) \\ \frac{\partial \varphi_t}{\partial h_t} &= \lambda_t \frac{W_t}{P_t} - V'(h_t) \varepsilon_{c,t} \\ \frac{\partial \mu_t}{\partial h_t} &= \zeta^2 m c_t \frac{Y_{I,t}}{N_t h_t} - \frac{W_t}{P_{H,t}} \end{aligned}$$

For the sake of convenience, we define a new variable G_t as the derivative of μ_t with respect to W_t times $(-P_{H,t})$:

$$G_t = -\frac{\partial \mu_t}{\partial W_t} P_{H,t} = h_t + P_{H,t} \Upsilon'_t(W_t)$$

Using the first order conditions (31), (32), and the definitions of μ_t and φ_t , the nominal wage W_t is:

$$\begin{aligned} \frac{W_t h_t}{P_{H,t}} (h_t + \xi_t P_{H,t} \Upsilon'_t(W_t)) &= \xi_t \left(b + \varepsilon_{c,t} \frac{V(h_t)}{\lambda_t} \right) G_t a_t^x + (1 - \xi_t) h_t \left(\zeta m c_t \frac{Y_{I,t}}{N_t} - \Upsilon_t(W_t) \right) \\ &+ \beta(1 - \rho^x) E_t \frac{\lambda_{t+1}}{\lambda_t} \mu_{t+1} \left(h_t(1 - \xi_t) - \frac{G_t a_t^x}{G_{t+1} a_{t+1}^x} (1 - f_{t+1}) \xi_t \frac{1 - \xi_{t+1}}{\xi_{t+1}} h_{t+1} \right) \end{aligned} \quad (33)$$

and the hours of work h_t are given by:

$$h_t \left(\zeta^2 m c_t \frac{Y_{I,t}}{N_t h_t} - \frac{W_t}{P_{H,t}} \right) = \left(a_t^x \frac{V'(h_t)}{\lambda_t} \varepsilon_{c,t} - \frac{W_t}{P_{H,t}} \right) G_t \quad (34)$$

Since these two expressions incorporate all the frictions in our model, it is not straightforward to give a clear intuition on how wage and hours are determined. Therefore, we examine these two equations at the steady state. This allows us to abstract from the effects of nominal rigidities.

Steady state wage and hours equation

At the steady state, wage and hours are given by:

$$\frac{W}{P_H} h = (1 - \xi) \left(\zeta \frac{Y_I}{N} + \Gamma'(V) \theta \right) + \xi a^x \left(b + \frac{V(h)}{\lambda} \right) \quad (35)$$

$$a^x \frac{V'(h)}{\lambda} = \zeta^2 \frac{Y_I}{h N} \quad (36)$$

Equation (35) is the wage setting equation. The wage level is a weighted sum of two components. The first term on the right hand side represents worker's contribution to the firm which is a combination of the worker's marginal productivity and the savings made by the firm from not having to hire. The second term is the worker's outside options which is a combination of unemployment benefits and the (dis)utility of working.

Equation (36) determines the level of hours worked. Similarly to the equilibrium in frictionless labour markets, this equation equates the marginal rate of

substitution between consumption and leisure to the marginal productivity of the worker.

Wage and hours setting in our open economy model is similar to that in closed economy models. As in Campolmi and Faia (2011), one key difference is the effect of terms of trade on the bargaining process (through the a_t^x term). We can show that the term a_t^x depends positively on the terms of trade:

$$a^x = [1 - \alpha + \alpha T^{1-\eta}]^{\frac{1}{1-\eta}} \quad (37)$$

where $T = P_F/P_H$ is the terms of trade. Since firms evaluate wages in terms of domestic prices (product wage) while workers evaluate wages in terms of aggregate prices (consumption wage), deviations of the terms of trade modify the outcome of the bargaining process. For example, an exogenous increase in terms of trade would induce an upward pressure on the negotiated wage, while it would lower the hours worked.

Domestic retail firms

There is a continuum of monopolistically competitive retailers who combine the differentiated goods to produce the final good and sell it to the representative household. They buy the intermediate good from the intermediate good producing firms and set a domestic retail price in a monopolistic environment choosing the process $\Omega_t^R = \{P_{H,t}(i)\}_{i=0}^\infty$ taking as given the set of processes $\{P_{H,t}\}_{t=0}^\infty$, and facing a quadratic price adjustment cost (Rotemberg-style). The optimization problem of the retailers is:

$$\max_{\Omega_t^R} E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[\frac{P_{H,t}(i)}{P_{H,t}} Y_{H,t}(i) - mc_t Y_{H,t}(i) - \frac{\psi_H}{2} \left(\frac{P_{H,t}(i)}{\tilde{\pi}_{t-1} P_{H,t-1}(i)} - 1 \right)^2 Y_{H,t} \right] \quad (38)$$

Subject to:

$$Y_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\epsilon} Y_{H,t} \quad (39)$$

where $\tilde{\pi}_{H,t-1} = \pi_{H,t-1}^{\gamma_H} \pi_H^{1-\gamma_H}$ and inflation is defined as the gross inflation rate $\pi_{H,t} = P_{H,t}/P_{H,t-1}$. The parameter γ_H governs the degree of backward-looking price setting and π_H is the steady state inflation. The optimality

condition of this problem with respect to $P_{H,t}(i)$ gives the standard New Keynesian Phillips Curve (NKPC):

$$\begin{aligned} \psi_H \frac{\pi_{H,t}(i)}{\tilde{\pi}_{H,t-1}} \left(\frac{\pi_{H,t}(i)}{\tilde{\pi}_{H,t-1}} - 1 \right) &= (1 - \epsilon) \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{1-\epsilon} + \epsilon_t mc_t \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{1-\epsilon} \\ &+ \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \psi_H \frac{\pi_{H,t+1}(i)}{\tilde{\pi}_{H,t}} \left(\frac{\pi_{H,t+1}(i)}{\tilde{\pi}_{H,t}} - 1 \right) \frac{Y_{H,t+1}}{Y_{H,t}} \end{aligned} \quad (40)$$

3.5 Import sector

In the small open economy, there are a continuum of firms importing differentiated goods in a monopolistically competitive environment. They set the domestic price of imported goods and face a quadratic price adjustment cost. Firms maximise the expected present value of their profits and chooses the set of processes $\Omega_t^F = \{P_{F,t}(i)\}_{t=0}^\infty$ taking as given the set of processes $\{P_{F,t}\}_{t=0}^\infty$. The optimization problem is as follow:

$$\max_{\Omega_t^F} E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[\frac{P_{F,t}(i)}{P_{F,t}} Y_{F,t}(i) - \frac{\psi_F}{2} \left(\frac{P_{F,t}(i)}{\tilde{\pi}_{F,t-1} P_{F,t-1}(i)} - 1 \right)^2 Y_{F,t} - e_t P_{F,t}^*(i) Y_{F,t} \right] \quad (41)$$

subject to,

$$Y_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\epsilon_t^F} Y_{F,t} \quad (42)$$

As in the case of the domestic retail firms, inflation is defined as gross inflation $\pi_{F,t} = P_{F,t}/P_{F,t-1}$, and $\tilde{\pi}_{F,t-1} = \pi_{F,t-1}^{\gamma_F} \pi_F^{1-\gamma_F}$. the parameter ψ_F is the price adjustment cost parameter, and γ_F governs the degree of backward-looking price setting.

The optimality condition of the above problem is:

$$\begin{aligned} \psi_F \frac{\pi_{F,t}(i)}{\tilde{\pi}_{F,t-1}} \left(\frac{\pi_{F,t}(i)}{\tilde{\pi}_{F,t-1}} - 1 \right) &= (1 - \epsilon_t^F) \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{1-\epsilon_t^F} + \epsilon_t mc_t^F \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{1-\epsilon_t^F} \\ &+ \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \psi_F \frac{\pi_{F,t+1}(i)}{\tilde{\pi}_{F,t}} \left(\frac{\pi_{F,t+1}(i)}{\tilde{\pi}_{F,t}} - 1 \right) \frac{Y_{F,t+1}}{Y_{F,t}} \end{aligned} \quad (43)$$

where $mc_t^F = e_t P_{F,t}^*(i)$ is the marginal cost of providing the foreign good.

3.6 The monetary authorities

We assume that the central bank adjusts the nominal interest rate in response to deviations of inflation, output, and the exchange rate from their steady-state values. The monetary authorities chooses the short-run interest rate i according to a Taylor-type rule:

$$i_t = i_{t-1}^{\rho_R} \left[\frac{1}{\beta} \left(\frac{E_t \pi_{t+1}}{\pi} \right)^{\rho_\pi} \left(\frac{Y_t}{Y} \right)^{\rho_Y} \left(\frac{Y_t}{Y_{t-1}} \right)^{\rho_{\Delta Y}} \left(\frac{e_t}{e_{t-1}} \right)^{\rho_e} \right]^{1-\rho_R} \exp(\varepsilon_t^m) \quad (44)$$

3.7 Market clearing

The real exchange rate is defined as $q_t = e_t P_t^* / P_t$. When the law of one price doesn't hold, we have $e_t P_t^* / P_{F,t} \neq 1$. In the domestic and foreign economies, goods market clearing involves:

$$Y_{H,t} = C_{H,t} + C_{H,t}^* \quad \text{and} \quad Y_t^* = C_t^* \quad (45)$$

The model is closed by assuming foreign demand for the domestically produced good is specified as:

$$C_{H,t}^* = \left(\frac{P_{H,t}^*}{P^*} \right)^{-\eta} Y_t^* \quad (46)$$

The foreign sector is assumed to be exogenous to the small open economy. We assume that the foreign economy variables, foreign inflation, π_t^* , foreign output, Y_t^* , and foreign interest rate, i_t^* , they all follow independent autoregressive processes. Furthermore we assume that the unemployment insurance and government spending are financed by a lump-sum tax.

4 Data and Estimation

4.1 Data

Our estimation uses quarterly data for New Zealand from the period 1994Q3 to 2010Q1 which covers most of the inflation targeting era. The beginning of our sample is dictated by the availability of the vacancy data in New Zealand.

Output per capita (Y_t) is defined as the seasonally-adjusted gross domestic product (GDP) divided by the active labour market population (the sum

of official employment and official unemployment measures). CPI inflation (π_t) is defined as the quarterly percent change in the New Zealand CPI. The nominal interest rate (i_t) is defined as the 90-day bank bill yield. The real exchange rate (q_t) is defined to be the real effective exchange rate. Unemployment (U_t) is measured by the official seasonally adjusted Household Labour Force Survey (HLFS) unemployment rate. Hours per worker (h_t) is defined as the seasonally-adjusted HLFS hours worked divided by the official seasonally-adjusted HLFS employment rate. The real wage (w_t) is defined as the seasonally adjusted Quarterly Employment Survey (QES) measure of average hourly earnings (ordinary time in the private sector) divided by the CPI. Vacancies (v_t) is measured by averaging the monthly Job Ad Series from the Department of Labour over each quarter, seasonally-adjusting the series, and normalizing by the active labour market population.

For the foreign economy variables we use the composite measures published by the Reserve Bank of New Zealand. Foreign output (Y_t^*) is defined as an export weighted measure of the GDP of New Zealand's 16 largest trading partners.³ Foreign inflation (π_t^*) is an import weighted measure of the CPI inflation rates in the same 16 countries. The foreign nominal interest rate (i_t^*) is defined as an 80-20 weighted measure of the United States 90-day bank bill yield and the Australian 90-day bank bill yield. All data series are detrended using Hodrick-Prescott filters with a smoothing parameter of 1600 apart from domestic and foreign inflation rates and interest rates which are detrended using their sample mean.

4.2 Estimation method

We estimate the model's parameters and shock variances using Bayesian techniques.⁴ The posterior density is evaluated using a random-walk Metropolis-Hastings algorithm for which we generate 2,000,000 draws and we target an acceptance ratio of 0.3. We log-linearise the model around the deterministic steady state and apply the Kalman-filter to evaluate the likelihood function. We combine the likelihood function with the prior distribution of the model parameters to obtain the posterior distribution.

We calibrate seven parameters to help pin-down the steady state of the model. We set the discount factor (β) to 0.99, which gives an annual steady state

³ This GDP-16 measure covers around 80 percent of New Zealand's merchandise trade by value.

⁴ See An and Schorfheide (2007) and Lubik and Schorfheide (2006) for a detailed discussion of Bayesian estimation of DSGE models for open economies.

interest rate close to 4 per cent. The share of foreign goods in the domestic consumption bundle (α) is set equal to 0.3 to match the share of imports in New Zealand. The elasticity of the production function with respect to the labour input (ζ) is set to 2/3. The level of unemployment benefits is set to match the average replacement ratio of about 0.5. We set the exogenous job separation rate (ρ^x) to match the evidence reported in Bell and Silverstone (2010). They calculate that over the period 1986-2010, the probability of an employed worker becoming unemployed in the next quarter or “out of the labour force” is on average 6 per cent. In addition, we calibrate the steady-state values of the matching efficiency (X) to reproduce the average unemployment rate of 12 per cent which is larger than the rate observed in the data (about 6.5 per cent) to account for workers not in the labour force but searching for a job. κ_v is set in such a way that the steady-state total cost of vacancies is about 1 percent of output. We normalise the job filling rate (k) to 0.71 to get a steady-state job finding rate similar to the average observed in the data (taking into account the “out of the labour force” pool) which is 0.31 (Bell and silverstone 2010).

We adopt relatively loose priors for the rest of the model parameters (see table 2) and assume a Beta-distribution for share parameters defined on unit intervals and Gamma-distribution for positive-valued parameters. In line with Krause et al (2008b), we choose loose priors for the inverse of the Frisch elasticity of labour supply and the habit persistence which are centered on the means of 1 and 0.5 respectively. We assume the mean of the prior of the elasticity of substitution between domestic and foreign goods are equal to 1. The prior mean of domestic and import price adjustment costs (ψ_H and ψ_F) as well as the wage adjustment cost ψ_w are all set to 50. Similarly, the prior mean for home and foreign price indexation parameters (γ_H and γ_F respectively) and the wage indexation parameter are set to 0.75. Because we do not have any information on the firm bargaining power and the elasticity of the matching function, we follow the common approach and set both equal to 0.5 (in the vein of Petrongolo and Pissarides 2001). The mean prior of the parameter governing the convexity or the concavity of the vacancy adjustment cost function (e) is set to 1 *i.e.* the prior is for a linear function. We set the mean of the prior on the monetary authority’s inflation response to 2 while the response to variation of output, output growth and nominal exchange rate are set to 0.25. Monetary policy parameters are assumed to be normally distributed.

We assume that all the exogenous disturbances follow independent AR(1) processes. The prior means for the persistence of shocks are set to 0.5. Finally, the priors for all of the standard deviation of shocks is set as an

Inverse-Gamma distribution with a prior mean of 0.01 (see table 3).

5 Estimation results

5.1 Parameter estimates

Table 2 reports posterior means of the estimated parameters and the 90 percent confidence intervals. The posterior mean of the habit persistence is 0.29. Krause et al (2008a) also estimate a relatively low values of habit formation parameter in a closed economy model with search and matching frictions. Additionally, Justiniano and Preston (2010b) report low values of this parameter when they estimate a small open economy model for Australia, Canada, and New Zealand. The inverse of the labour supply elasticity is estimated to be between 1.08 and 1.28 with a posterior mean of 1.18. The estimated elasticity of substitution between domestic and foreign goods is quite low (0.51) but consistent with the results of Justiniano and Preston (2010b). The estimated indexation to past inflation in price and wage settings are similar and concentrated around 0.6. However, the model implies that nominal rigidities are more important in the goods market than in the labour market. In particular, the price adjustment cost parameter in the import sector is higher than in the domestic retail sector, possibly in order to capture the low pass through from the exchange rate movements to domestic prices. The search and matching frictions in the labour market seems to limit the need for nominal wage rigidities, since the model doesn't rely on high degrees of nominal rigidities to capture wage dynamics.

The parameters of the interest rate rule we obtain are close to the ones found by Justiniano and Preston (2010b), although their sample period begins in 1988Q3 while we only consider the inflation targeting era. We estimate the coefficient determining the response of monetary policy to inflation to be 2.14. Both the output gap and output growth enter the monetary policy rule with positive coefficients. The response of monetary policy to nominal exchange rate growth is very weak (0.09) but significantly positive and is larger than the estimate of Lubik and Schorfheide (2007), 0.04. Lastly, interest rate setting exhibits substantial smoothing with posterior mean of the interest rate smoothing parameter estimated to be 0.8.

We now turn to the to the values of estimated parameters related to the labour market. The posterior mean of the firm's bargaining power is 0.8, significantly higher than the mean of our prior (0.5). This is consistent with

Hagedorn and Manovskii (2008) who suggest a relatively low value for workers' bargaining weight. The estimated elasticity of the matching function with respect to unemployment is equal to 0.71 which is slightly lower than previous estimates for New Zealand. Razzak (2009) estimates this parameter to be around 0.8. Our estimate is however similar to the one obtained by Shimer (2005) on US data. In addition, according to the confidence interval, there is little evidence the Hosios condition (1990), $\nu = 1 - \xi$, is satisfied. We estimate the vacancy posting adjustment cost parameter to be 5.86, well above the prior mean. This suggests that the vacancy adjustment cost function is clearly convex. The implied value is more inline with Yashiv (2006) than Rotemberg (2008), and highlights the costly process of adjusting the level of vacancies over the cycle.

As for the shock processes, the UIP, preference, and vacancy posting shocks are estimated to be highly persistent while all the other domestic shocks have an AR(1) coefficient below the prior mean of 0.5. In terms of volatilities, the estimated values for monetary policy, technology, and UIP shocks seem plausible. The domestic cost-push shock and shocks pertaining to the labour market are the most volatile disturbances. We examine the role of various shocks in shaping the dynamics of labour market variables in section 6.

5.2 Moments

In this section, we evaluate the model's ability to match the cyclical properties of New Zealand data. In doing so, we take into account both parameter and shock uncertainty. Figures 3, 4, and 5 present the cyclical properties of the data and those implied by the estimated model. In each graph the vertical blue line is the second order moment of the data while the red curve represents the density of the corresponding moment generated by drawing from the posterior distribution of the parameters and shocks.⁵

Figure 3 presents the standard deviation of output and for other variables their relative standard deviations with respect to output. The model matches well the volatility of output, interest rate and inflation. Although the model implies a lower volatility of exchange rate compared to the data, it still able to generate a real exchange rate that is considerably more volatile than output.

We now turn to the performance of the model in terms of replicating the volatilities of the labour market variables. First, the model is able to gen-

⁵ Specifically, we calculate the model based moments by simulating 2,000 artificial data series of equal length to our sample.

erate highly volatile unemployment and vacancies dynamics. However, the volatilities in the data still lie on the upper bound of the model implied values. The model overestimates the volatility of the real wage. The main failure of the model is with regards to the dynamics of individual hours. The model implied volatility of individual hours is higher than output while in the data, individual hours is much less volatile than output.

Figure 4 presents the correlation of key macroeconomic variables with output as well as the correlation between unemployment and vacancies. The model matches the observed correlation between output and the interest rate, inflation, and exchange rate very well. However, the model underestimates the strong counter-cyclicality of unemployment and the strong pro-cyclicality of vacancies. In a related note, the model implied correlation between unemployment and vacancies is not as negative as in the data. In other words, the model based slope of the Beveridge curve is higher in the data. The model also seem to generate a slightly pro-cyclical real wages compared to the a-cyclical wage dynamics in the data. Again, the model implies a much stronger pro-cyclicality of hours.

Figure 5 shows the model and data based persistence for the key variables. We define persistence as the first order autocorrelation of each variable. The model does well for most of the variables that we consider by replicating the observed high level of persistence in the data. Nevertheless, the model overestimates the persistence in inflation, real wages, and individual hours. In particular, the persistence of inflation and individual hours is very low in the data, a feature the model is not able to replicate.

Overall the model seems to do a reasonably good job in describing the second-order properties of the New Zealand data. Nonetheless, the model moments pertaining to labour market variables don't appear to be as close to the data as other macroeconomic variables.

5.3 Impulse response analysis

In this section, we characterise the transmission of monetary policy in New Zealand by presenting the impulse responses implied by the model to a monetary policy shock. We pay particular attention to the dynamics of the labour market variables by presenting in figure 6 the dynamic response of key labour market variables.

We compute the impulse responses at the posterior mode as well as the 90 percent posterior probability intervals around the impulse responses. The

monetary policy shock is scaled to generate a one percent increase in the annualised interest rate (a 0.25 percent increase in the quarterly rate). A first inspection of the impulse responses suggests that the response of all the variables we consider are statistically significant. Following the increase in the interest rate, the real interest rate increases (due to price stickiness) which yields a contractionary impact in the model economy, and output drops by a little more than one percent. The response of inflation (annualised) is gradual over time after dropping 1.5 percent on impact. As a result of higher real interest rates, the exchange rate appreciates persistently.

Now we turn to the dynamic response of labour market variables. Following the contractionary monetary policy, the marginal value of a job decreases for firms which causes them to lower their vacancy posting and cut the hours of work. This increases the number of unemployed workers and the number of job seekers. The unemployment response displays a hump shaped pattern. The unemployment rate increases by around 1.2 percent initially and the impact of the monetary policy shock on unemployment lasts almost two years.

The higher number of job seekers and lower number of vacancies imply that the labour market tightness and the job finding rate are below their steady states. These in turn put downwards pressure on the negotiated wage. Wage inflation drops by 0.5 percent on impact. The real wage drops initially and increases later since the decline in the inflation rate after the monetary policy shock lasts longer than the decline in the wage inflation.

Overall, the monetary policy shocks seems to create statistically significant and quantitatively important fluctuations in the labour market variables.

6 Dynamics of Unemployment and Vacancies

In the previous section, we have shown that our model provides a fairly good description of macroeconomic and labour market variables in New Zealand. In this section, our objective is to use our structural model to investigate which shocks are the drivers of unemployment and vacancies in New Zealand. To do so, we analyse the variance decomposition of unemployment and vacancies.

Figures 7 and 8 presents variance decomposition of vacancies and unemployment. The model is driven by eleven structural shocks. Three of these shocks are directly related to the labour market of the model, namely the match-

ing efficiency shock, the bargaining power shock and the vacancy posting cost shock. In figures 7 and 8, while we detail the contribution of labour market shocks to the fluctuations in unemployment and vacancies, we group together the contribution of all the other shocks. An inspection of figures 7 and 8 makes it clear that the bulk of variation in both series are due to the disturbances pertaining to the labour market. In particular, most of the variation in unemployment is due to shocks to matching efficiency (which is in line with the results of Krause et al 2008a in a closed economy model), while most of the variation in vacancies is due to the vacancy posting cost shock. All the other shocks, foreign, domestic, and policy, play only a marginal role in explaining cyclical variations in these two key labour market variables.

The model is thus unable to generate an internal propagation mechanism from shocks affecting the rest of the economy to the labour market variables. We can see this disconnect between the labour market part and the rest of the model in figure 9 which presents the variance decomposition of output. In accordance with our argument, shocks to the labour market variables contribute only marginally to the fluctuations in output.

This result is consistent with Christoffel et al (2009) who use a model with a shock on the separation rate instead of on the matching function. They find that the contribution of vacancy shocks to unemployment and vacancies fluctuations is important but that the latter shock does not affect output fluctuations. In addition, they find that the contribution of the bargaining shock to the labour market variables is relatively small.

Reallocation shocks, modeled as exogenous movements in the matching efficiency, play a central role in our model since they essentially drive unemployment fluctuations. However, such a shock tends to produce a weak negative correlation between unemployment and vacancies compared to the one observed. As Lubik (2009) notes, these shocks act as a residual and capture what the matching function is not able to explain. Therefore, considering a small open economy with search and matching frictions doesn't change the disconnect between the labour market and the rest of the model.

7 Concluding remarks

In this paper, we have developed and estimated a structural small open economy model for New Zealand enriched with search and matching frictions in the labour market. The methodology we adopt allows us to evaluate

the ability of the model to match business cycle properties of key macroeconomic and labour market variables in New Zealand. We show that the model matches the data well with reasonable parameter values, and impulse response functions analysis highlight a traditional monetary transmission mechanism. However, the model implies that the bulk of the variation in unemployment and vacancies is solely due to shocks pertaining to the labour market and that there is a strong disconnect between the labour market and the rest of the economy.

This last result naturally raises the question whether the model lacks of propagation mechanisms or if exogenous disturbances in the matching function are a plausible explanation. Since the latter captures what the matching function is not able to explain, it is legitimate to question the ability of the matching function to reproduce the Beveridge curve and, at the same time, investigate further the role of this shock.

Implications for macro-modeling

Currently, structural macroeconomic models at the Reserve Bank of New Zealand, including the Bank's core DSGE policy model – K.I.T.T., are predicated on the assumption of a Walrasian labour market with sticky nominal wages as in Erceg et al (2000). Unemployment forecasts are made off-model (in a satellite model) using the Okun's law relationship linking the unemployment gap to the output gap. This approach lacks an explicit feedback mechanism from changes in unemployment to economic activity in the core model. However, the strong disconnect between the labour market and the rest of the economy shown in our model suggests that not explicitly modelling this feedback is unlikely to seriously hinder the performance of these structural macroeconomic models.

Areas of future research

In this paper, we have abstracted from several issues that may be important in shaping labour market dynamics in New Zealand. For example, migration (both emigration and immigration) have been important influences on the New Zealand economy during the past decades. In particular, New Zealand has one of the highest share of migrants that are highly skilled and employed amongst the OECD countries (Jarret 2011). labour market participation is also likely to be important for describing the New Zealand labour market. Thanks in part to a number of legislative changes, labour market

participation has increased from 63.8 per cent to 68.2 per cent over the 20 years from 1989–2009, mainly driven by the rise in the female participation rate. Both of these issues are beyond the scope of the baseline search and matching model that we develop in this paper, but would make for useful extensions to the analysis. In addition, alternative extensions to the baseline search and matching model could also be considered, such as endogenous job destructions (in line with Christoffel et al 2009), alternative wage setting mechanisms.

Finally, our model based monetary policy transmission mechanism implies strong movements in labour market variables in New Zealand. However, the empirical evidence using structural econometric models is scarce on the subject when it comes to small open economies. Future empirical research, in the line of Ravn and Simonelli (2008) and Kamber and Millard (2010), that identify the impact of monetary policy shocks on labour market variables would help improve the modeling of labour market frictions in small open economies.

References

- Adolfson, M, S Laseen, J Linde, and M Villani (2007), “Bayesian estimation of an open economy DSGE model with incomplete pass-through,” *Journal of International Economics*, 72(2), 481–511.
- Adolfson, M, S Laséen, J Lindé, and M Villani (2008), “Evaluating an estimated new Keynesian small open economy model,” *Journal of Economic Dynamics and Control*, 32(8), 2690–2721.
- An, S and F Schorfheide (2007), “Bayesian analysis of DSGE models,” *Econometric Reviews*, 26(2-4), 113–172.
- Andolfatto, D (1996), “Business cycles and labor-market search,” *American Economic Review*, 86(1), 112–32.
- Bell, W and B silverstone (2010), “Labour market flows in New Zealand,” *Mimeo*.
- Benes, J, A Binning, M Fukac, K Lees, and T Matheson (2009), “K.I.T.T.: Kiwi Inflation Targeting Technology,” *Reserve Bank of New Zealand*.
- Campolmi, A and E Faia (2011), “Labor market institutions and inflation volatility in the euro area,” *Journal of Economic Dynamics and Control*, 35(5), 793–812.
- Christoffel, K and K Kuester (2008), “Resuscitating the wage channel in models with unemployment fluctuations,” *Journal of Monetary*

- Economics*, 55(5), 865–887.
- Christoffel, K, K Kuester, and T Linzert (2009), “The role of labor markets for euro area monetary policy,” *European Economic Review*, 53(8), 908–936.
- Christoffel, K and T Linzert (2010), “The role of real wage rigidity and labor market frictions for inflation persistence,” *Journal of Money, Credit and Banking*, 42(7), 1435–1446.
- den Haan, W J, G Ramey, and J Watson (2000), “Job destruction and propagation of shocks,” *American Economic Review*, 90(3), 482–498.
- Erceg, C J, D W Henderson, and A T Levin (2000), “Optimal monetary policy with staggered wage and price contracts,” *Journal of Monetary Economics*, 46(2), 281–313.
- Evans, L, A Grimes, B Wilkinson, and D Teece (1996), “Economic reform in New Zealand 1984-95: The pursuit of efficiency,” *Journal of Economic Literature*, 34(4), 1856–1902.
- Galí, J and T Monacelli (2005), “Monetary policy and exchange rate volatility in a small open economy,” *Review of Economic Studies*, 72(3), 707–734.
- Gertler, M, L Sala, and A Trigari (2008), “An estimated monetary DSGE model with unemployment and staggered nominal wage bargaining,” *Journal of Money, Credit and Banking*, 40(8), 1713–1764.
- Hagedorn, M and I Manovskii (2008), “The cyclical behavior of equilibrium unemployment and vacancies revisited,” *American Economic Review*, 98(4), 1692–1706.
- Hairault, J-O (2002), “Labor-market search and international business cycles,” *Review of Economic Dynamics*, 5(3), 535–558.
- Hall, R E (2005), “Employment fluctuations with equilibrium wage stickiness,” *American Economic Review*, 95(1), 50–65.
- Hosios, A J (1990), “On the efficiency of matching and related models of search and unemployment,” *Review of Economic Studies*, 57(2), 279–98.
- Jarret, P (2011), “Housing, the NZ business cycle and macro imbalances,” in *New Zealand’s Macroeconomic Imbalances Causes and Remedies*.
- Justiniano, A and B Preston (2010a), “Can structural small open-economy models account for the influence of foreign disturbances?” *Journal of International Economics*, 81(1), 61–74.
- Justiniano, A and B Preston (2010b), “Monetary policy and uncertainty in an empirical small open-economy model,” *Journal of Applied Econometrics*, 25(1), 93–128.
- Kam, T, K Lees, and P Liu (2009), “Uncovering the hit list for small in-

- flation targeters: A Bayesian structural analysis,” *Journal of Money, Credit and Banking*, 41(4), 583–618.
- Kamber, G and S Millard (2010), “Using estimated models to assess nominal and real rigidities in the United Kingdom,” *Bank of England, Bank of England working papers*, 396.
- Kirker, M (2008), “Does natural rate variation matter? evidence from New Zealand,” *Reserve Bank of New Zealand, Reserve Bank of New Zealand Discussion Paper Series*, DP2008/17.
- Krause, M U, D Lopez-Salido, and T A Lubik (2008a), “Inflation dynamics with search frictions: A structural econometric analysis,” *Journal of Monetary Economics*, 55(5), 892–916.
- Krause, M U, D J Lopez-Salido, and T A Lubik (2008b), “Do search frictions matter for inflation dynamics?” *European Economic Review*, 52(8), 1464–1479.
- Krause, M U and T A Lubik (2007), “The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions,” *Journal of Monetary Economics*, 54(3), 706–727.
- Lees, K (2009), “Introducing KITT: The Reserve Bank of New Zealand’s new DSGE model for forecasting and policy design,” *Reserve Bank of New Zealand Bulletin*, 72, 5–20.
- Lees, K, T Matheson, and C Smith (2007), “Open economy DSGE-VAR forecasting and policy analysis - head to head with the RBNZ published forecasts,” *Reserve Bank of New Zealand, Reserve Bank of New Zealand Discussion Paper Series*, DP2007/01.
- Liu, P (2006), “A small New Keynesian model of the New Zealand economy,” *Reserve Bank of New Zealand, Reserve Bank of New Zealand Discussion Paper Series*, DP2006/03.
- Lubik, T A (2009), “Estimating a search and matching model of the aggregate labor market,” *Economic Quarterly*, (Spr), 101–120.
- Lubik, T A and F Schorfheide (2006), “A Bayesian look at the new open economy macroeconomics,” in *NBER Macroeconomics Annual 2005, Volume 20*, NBER Chapters, 313–382, National Bureau of Economic Research, Inc.
- Lubik, T A and F Schorfheide (2007), “Do central banks respond to exchange rate movements? a structural investigation,” *Journal of Monetary Economics*, 54(4), 1069–1087.
- Maloney, T (1997), “Has New Zealand’s employment contracts act increased employment and reduced wages?” *Australian Economic Papers*, 36(69), 243–264.
- Matheson, T (2010), “Assessing the fit of small open economy DSGEs,” *Journal of Macroeconomics*, 32(3), 906–920.

- McCann, P (2009), “Economic geography, globalisation and New Zealand’s productivity paradox,” *New Zealand Economic Papers*, 43(3), 279–314.
- Merz, M (1995), “Search in the labor market and the real business cycle,” *Journal of Monetary Economics*, 36(2), 269–300.
- Monacelli, T (2005), “Monetary policy in a low pass-through environment,” *Journal of Money Credit and Banking*, 37(6), 1047–1066.
- Mortensen, D T and C A Pissarides (1994), “Job creation and job destruction in the theory of unemployment,” *Review of Economic Studies*, 61(3), 397–415.
- Mortensen, D T and C A Pissarides (1999), “Job reallocation, employment fluctuations and unemployment,” in *Handbook of Macroeconomics*, eds J B Taylor and M Woodford, vol 1 of *Handbook of Macroeconomics*, chap 18, 1171–1228, Elsevier.
- Petrongolo, B and C A Pissarides (2001), “Looking into the black box: A survey of the matching function,” *Journal of Economic Literature*, 39(2), 390–431.
- Ravn, M O and S Simonelli (2008), “Labor market dynamics and the business cycle: Structural evidence for the United States,” *Scandinavian Journal of Economics*, 109(4), 743–777.
- Razzak, W A (2009), “On the dynamic of search, matching and productivity in New Zealand and Australia,” 6(1), 90–118.
- Rotemberg, J J (2008), “Cyclical wages in a search-and-bargaining model with large firms,” in *NBER International Seminar on Macroeconomics 2006*, NBER Chapters, 65–114, National Bureau of Economic Research, Inc.
- Schmitt-Grohe, S and M Uribe (2003), “Closing small open economy models,” *Journal of International Economics*, 61(1), 163–185.
- Shimer, R (2005), “The cyclical behavior of equilibrium unemployment and vacancies,” *American Economic Review*, 95(1), 25–49.
- Trigari, A (2009), “Equilibrium unemployment, job flows, and inflation dynamics,” *Journal of Money, Credit and Banking*, 41(1), 1–33.
- Walsh, C E (2005), “Labor market search, sticky prices, and interest rate policies,” *Review of Economic Dynamics*, 8(4), 829–849.
- Yashiv, E (2006), “Evaluating the performance of the search and matching model,” *European Economic Review*, 50(4), 909–936.

8 Tables

Table 1
Stylised data moments

	Standard deviation (relative to s.d. of output)	Correlation with output
Individual hours	0.667	0.319
Wages	0.594	-0.066
Unemployment	8.121	-0.525
Vacancies	13.956	0.528

Table 2
Estimation results — Structural parameters

Structural	Symbol	Prior density	Post. Mean	CI
Habit persistence	χ	$\beta(0.5, 0.1)$	0.29	[0.2,0.38]
Inverse of Frisch elast.	ϕ_h	$\Gamma(1, 0.2)$	1.18	[1.08,1.28]
Elasticity of sub. between H & F	η	$\Gamma(1, 0.2)$	0.51	[0.44,0.57]
Backward home price param.	γ_H	$\beta(0.75, 0.1)$	0.58	[0.39,0.76]
Backward foreign price param.	γ_F	$\beta(0.75, 0.1)$	0.61	[0.43,0.81]
Backward wage	γ_w	$\beta(0.75, 0.1)$	0.57	[0.36,0.78]
Price adj. cost home good	ψ_H	$\Gamma(50, 15)$	52.55	[34.58,69.95]
Price adj. cost foreign good	ψ_F	$\Gamma(50, 15)$	77.02	[48.69,104.92]
Wage adj. cost	ψ_w	$\Gamma(50, 15)$	15.53	[9.81,21.16]
Interest rate smooth.	ρ_R	$\beta(0.75, 0.1)$	0.80	[0.74,0.85]
Resp. inflation	ρ_π	$\Gamma(2, 0.25)$	2.14	[1.73,2.55]
Resp. output gap	ρ_Y	$\mathcal{N}(0.25, 0.1)$	0.43	[0.29,0.56]
Resp. Δ output	$\rho_{\Delta Y}$	$\mathcal{N}(0.25, 0.1)$	0.22	[0.07,0.37]
Resp. exch. rate	ρ_e	$\mathcal{N}(0.25, 0.1)$	0.09	[0.01,0.16]
Firm barg. power	ξ	$\beta(0.5, 0.2)$	0.80	[0.61,0.99]
Elast. matching	ν	$\beta(0.5, 0.2)$	0.71	[0.59,0.84]
Hiring cost.	e	$\Gamma(1, 0.5)$	5.88	[4.61,7.18]

Table 3**Estimation results — Shocks**

Shocks	Symbol	Prior density	Post. Mean	CI
Productivity persist.	ρ_z	$\beta(0.5, 0.2)$	0.40	[0.24,0.56]
UIP persist.	ρ_s	$\beta(0.5, 0.2)$	0.77	[0.68,0.87]
Preference persist.	ρ_c	$\beta(0.5, 0.2)$	0.91	[0.84,0.98]
Cost-push persist.	ρ_H	$\beta(0.5, 0.2)$	0.08	[0.01,0.14]
Monetary persist.	ρ_m	$\beta(0.5, 0.2)$	0.36	[0.23,0.5]
Matching persist.	ρ_X	$\beta(0.5, 0.2)$	0.18	[0.03,0.31]
Bargaining persist.	ρ_ξ	$\beta(0.5, 0.2)$	0.18	[0.04,0.32]
Vacancy persist.	ρ_v	$\beta(0.5, 0.2)$	0.82	[0.74,0.91]
Foreign output persist.	ρ_{Y^*}	$\beta(0.5, 0.2)$	0.79	[0.67,0.91]
Foreign inflation persist.	ρ_{π^*}	$\beta(0.5, 0.2)$	0.18	[0.04,0.3]
Foreign interest r. persist.	ρ_{i^*}	$\beta(0.5, 0.2)$	0.87	[0.82,0.92]
Productivity sd.	σ_z	$\Gamma^{-1}(0.01, \infty)$	0.01	[0.01,0.01]
UIP sd.	σ_s	$\Gamma^{-1}(0.01, \infty)$	0.01	[0.00,0.01]
Preference sd.	σ_c	$\Gamma^{-1}(0.01, \infty)$	0.07	[0.031,0.099]
Cost-push sd.	σ_H	$\Gamma^{-1}(0.01, \infty)$	0.40	[0.27,0.52]
Monetary sd.	σ_m	$\Gamma^{-1}(0.01, \infty)$	0.00	[0.002,0.003]
Matching sd.	σ_X	$\Gamma^{-1}(0.01, \infty)$	0.10	[0.088,0.119]
Bargaining sd.	σ_ξ	$\Gamma^{-1}(0.01, \infty)$	0.06	[0.004,0.109]
Vacancy sd.	σ_v	$\Gamma^{-1}(0.01, \infty)$	0.45	[0.355,0.557]
Foreign output sd.	σ_{Y^*}	$\Gamma^{-1}(0.01, \infty)$	0.00	[0.003,0.004]
Foreign inflation sd.	σ_{π^*}	$\Gamma^{-1}(0.01, \infty)$	0.00	[0.002,0.003]
Foreign interest r. sd.	ρ_{i^*}	$\Gamma^{-1}(0.01, \infty)$	0.00	[0.001,0.002]

9 Figures

Figure 1
Unemployment and vacancy rates

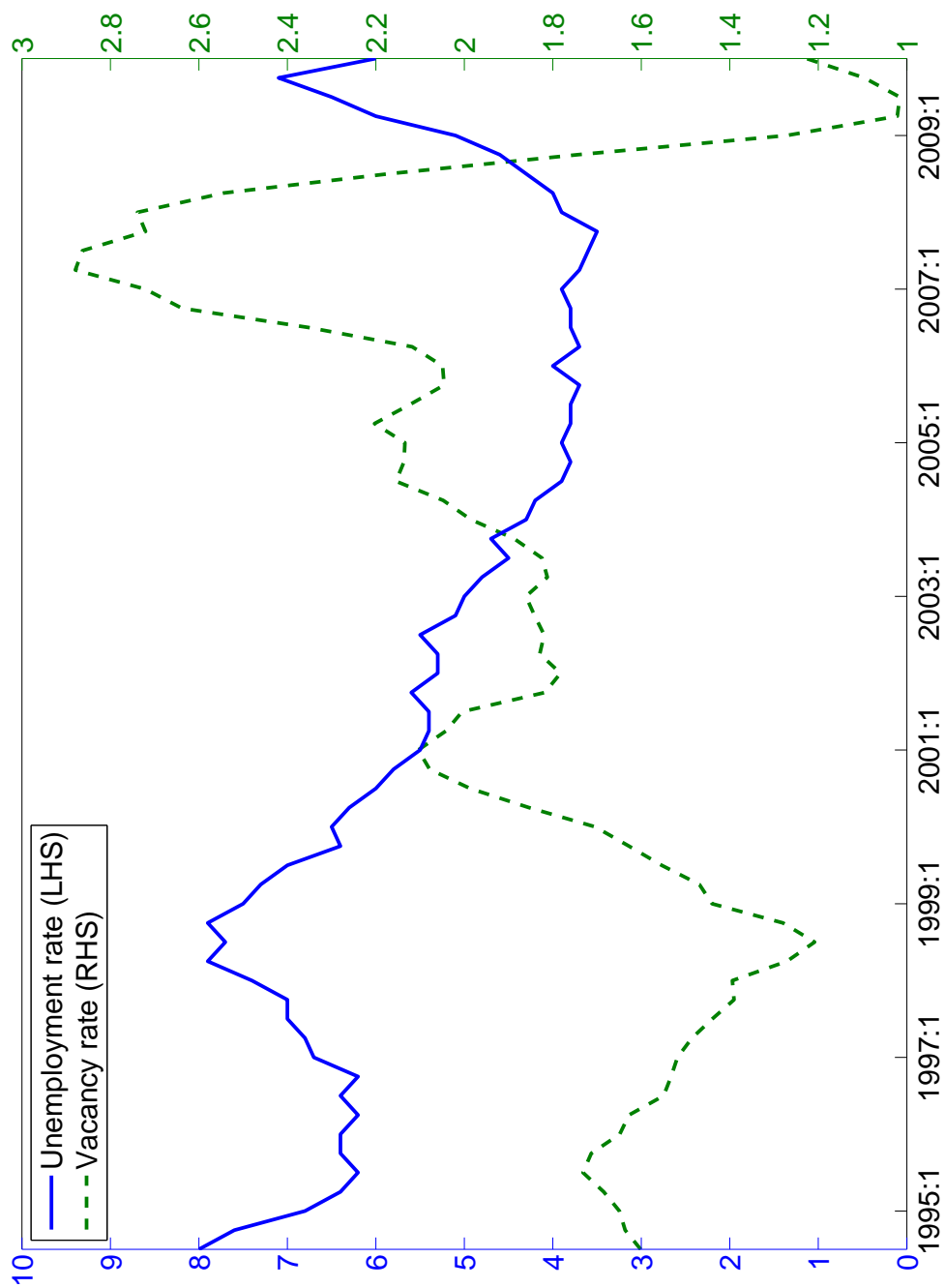


Figure 2
Beveridge curve (detrended data)

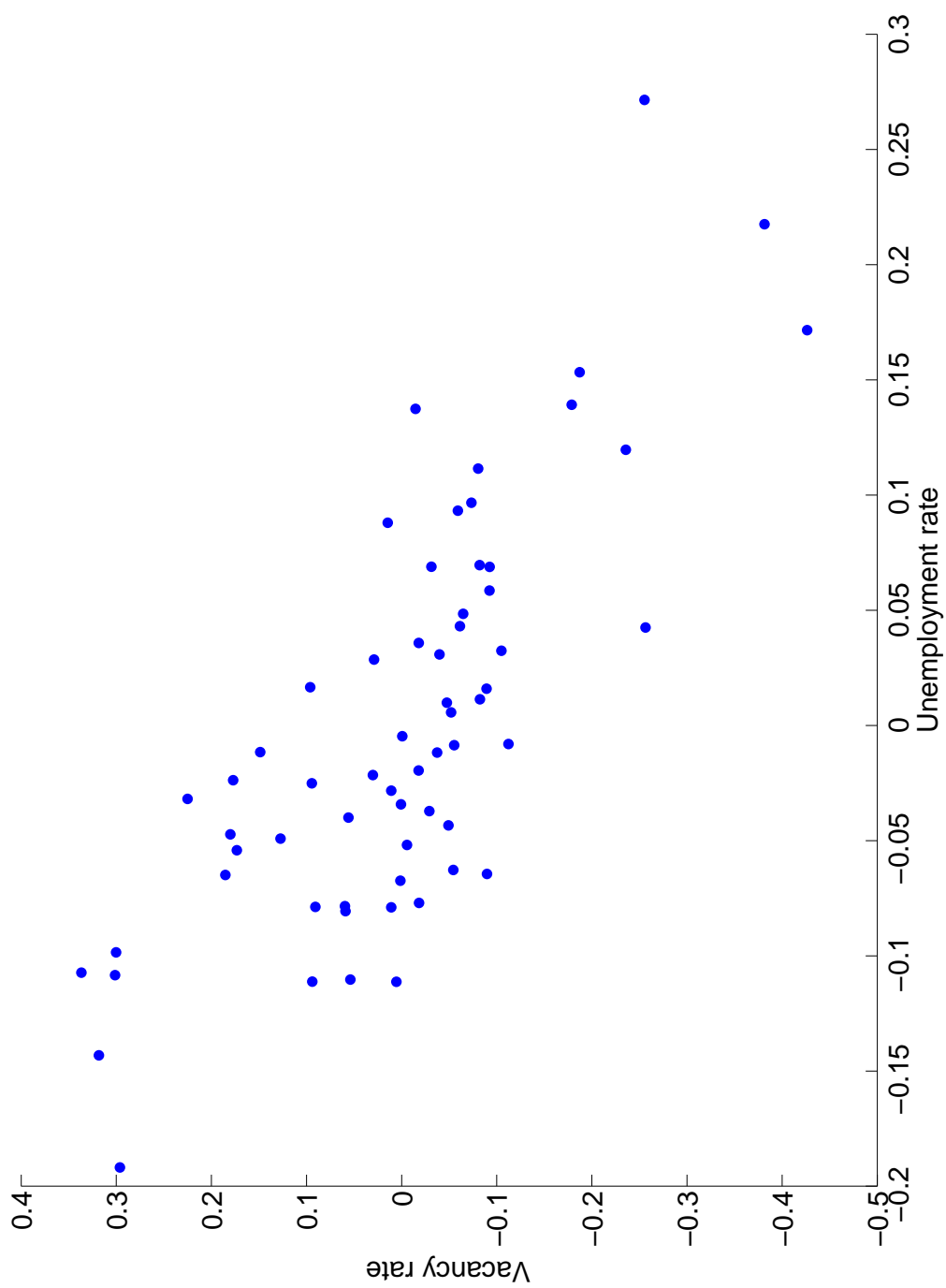


Figure 3
Standard deviations

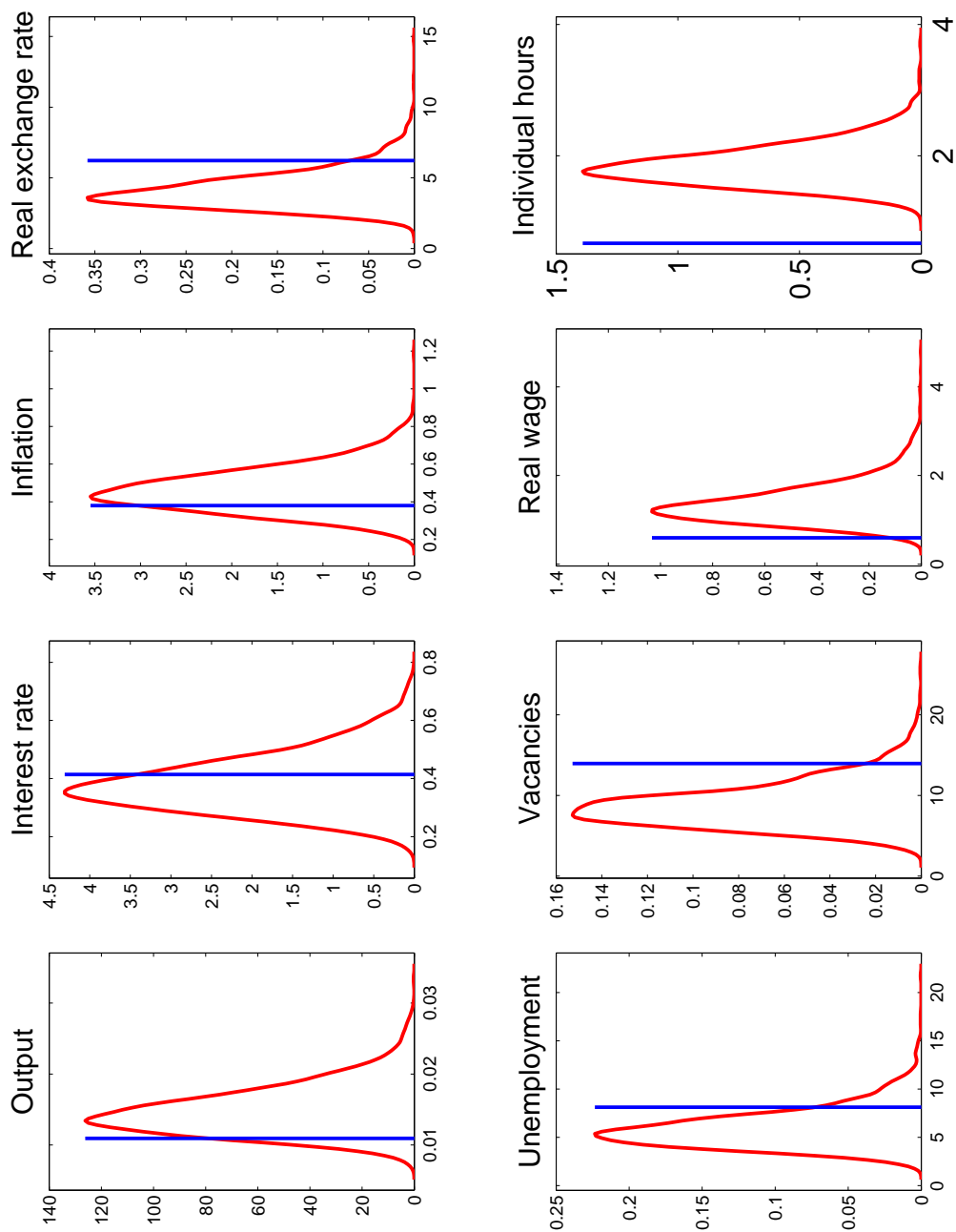


Figure 4
Correlation

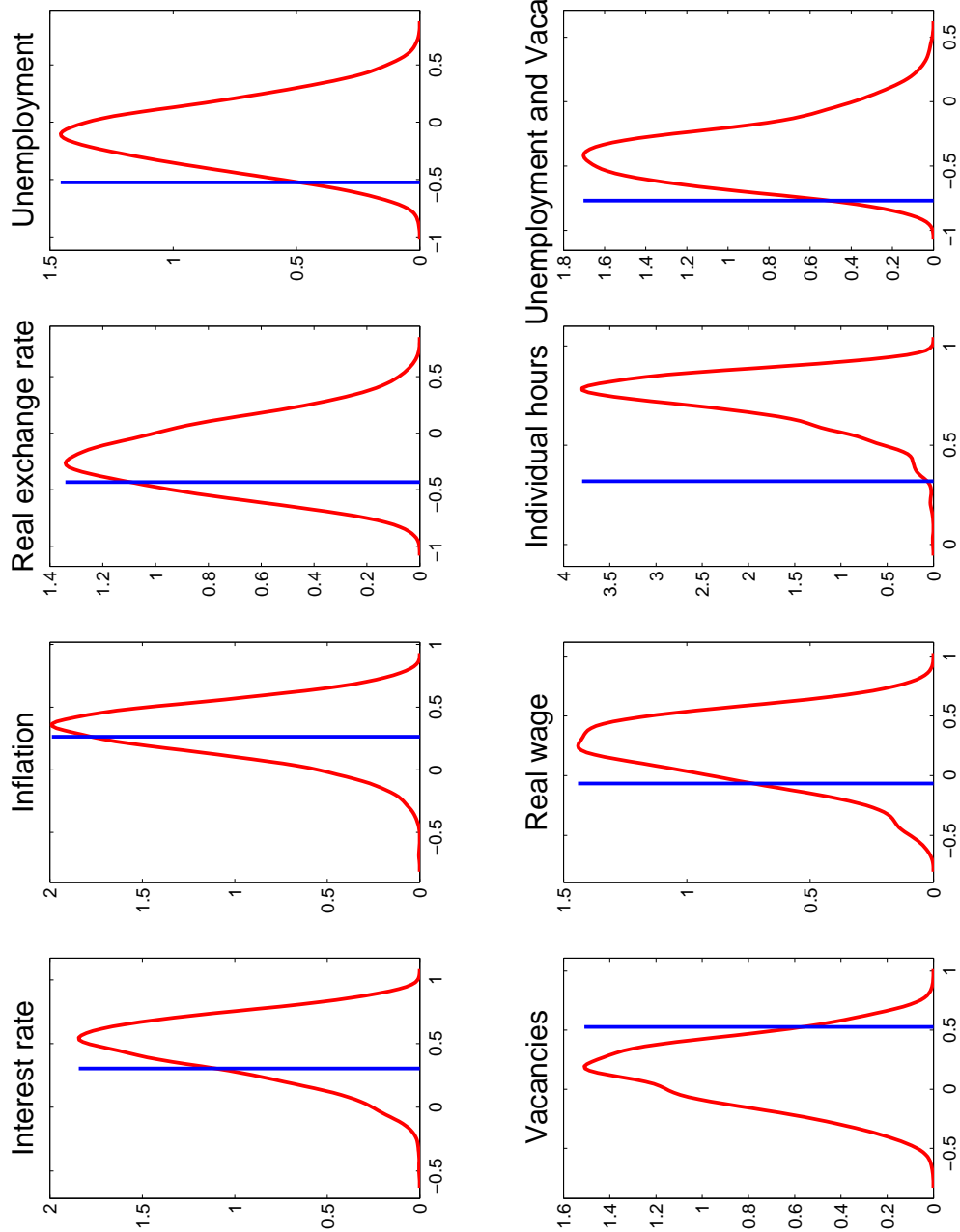


Figure 5
Persistence

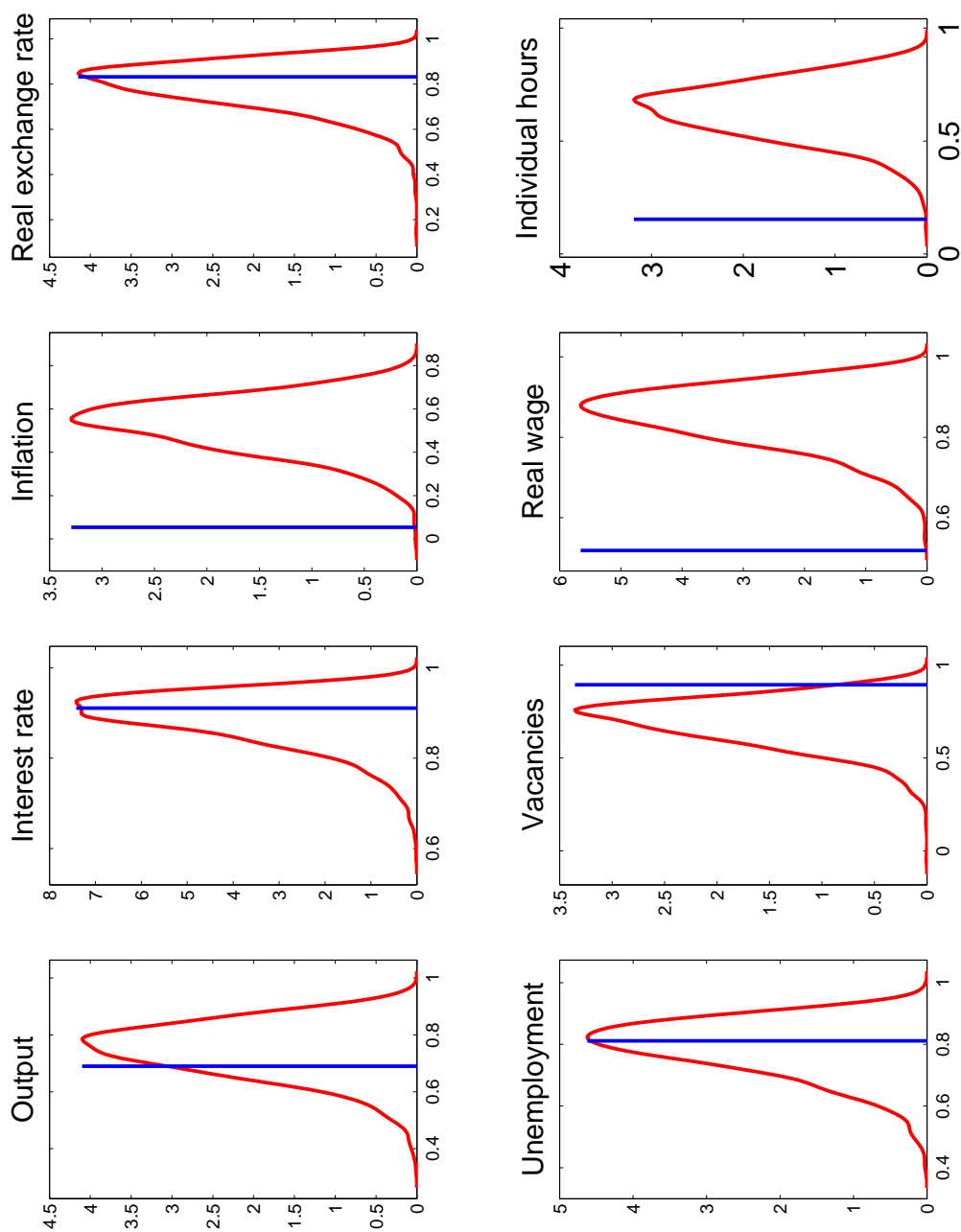


Figure 6
Impulse responses to a monetary policy shock

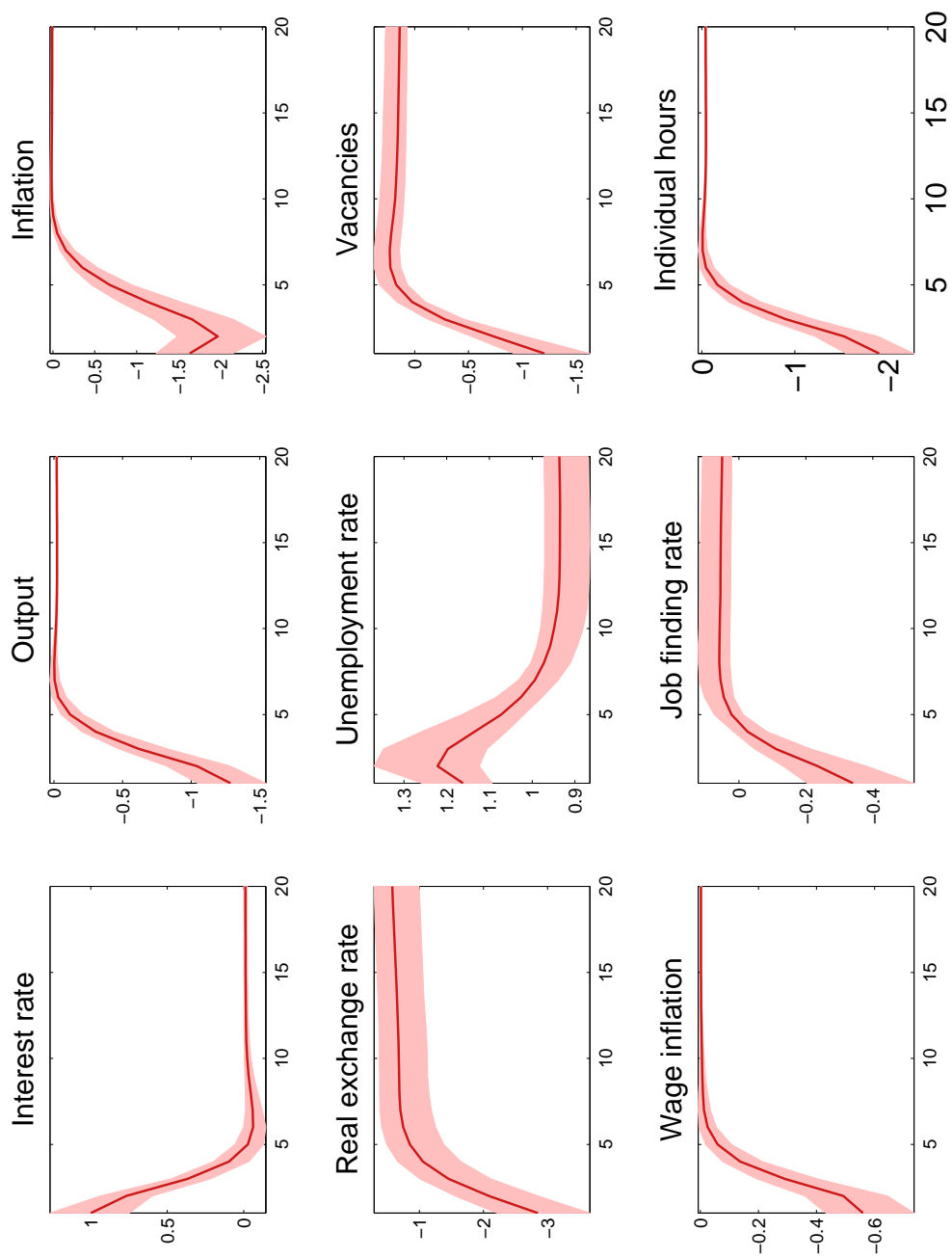


Figure 7
 Variance decomposition — Unemployment

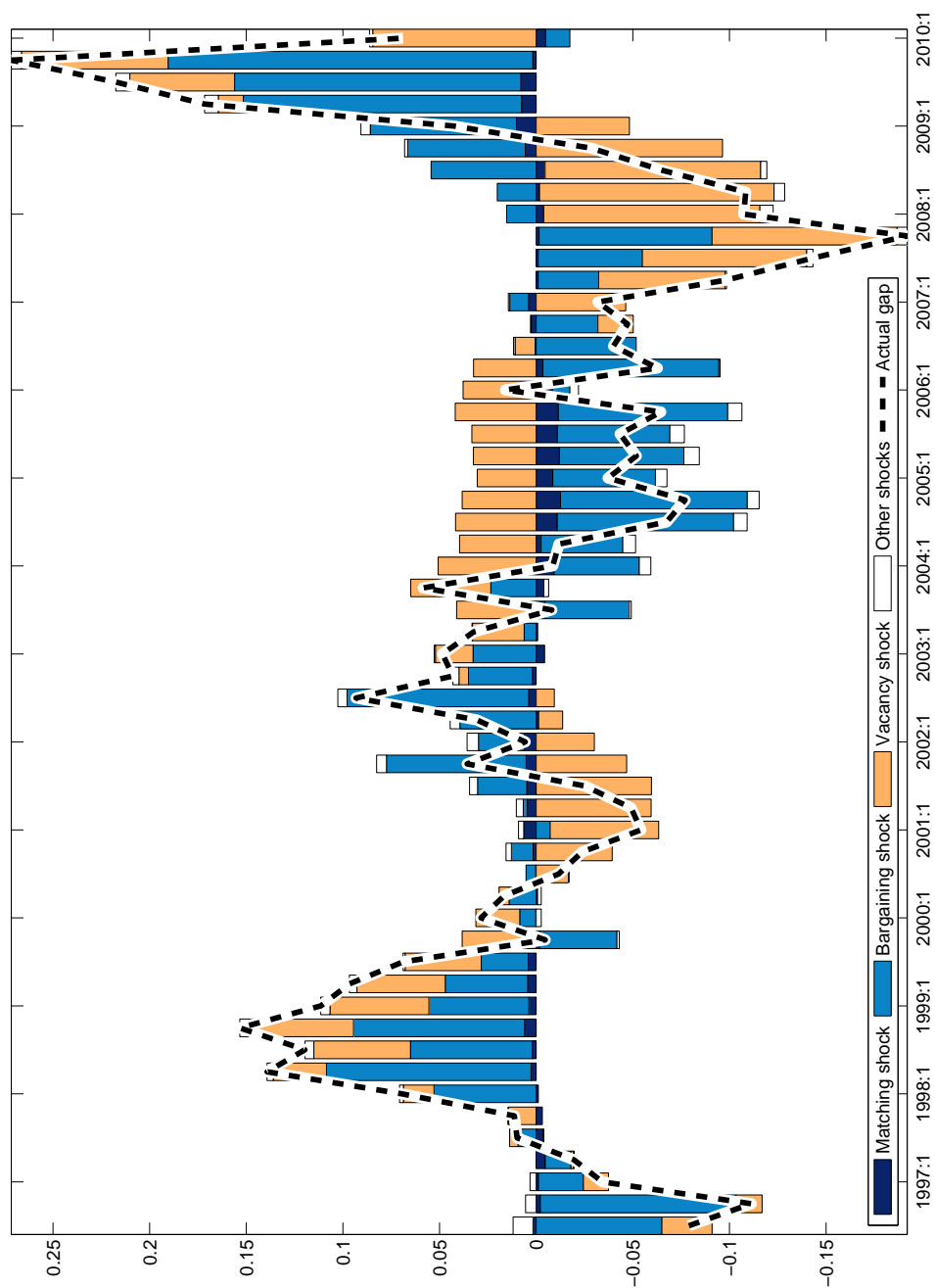


Figure 8
 Variance decomposition — Vacancies

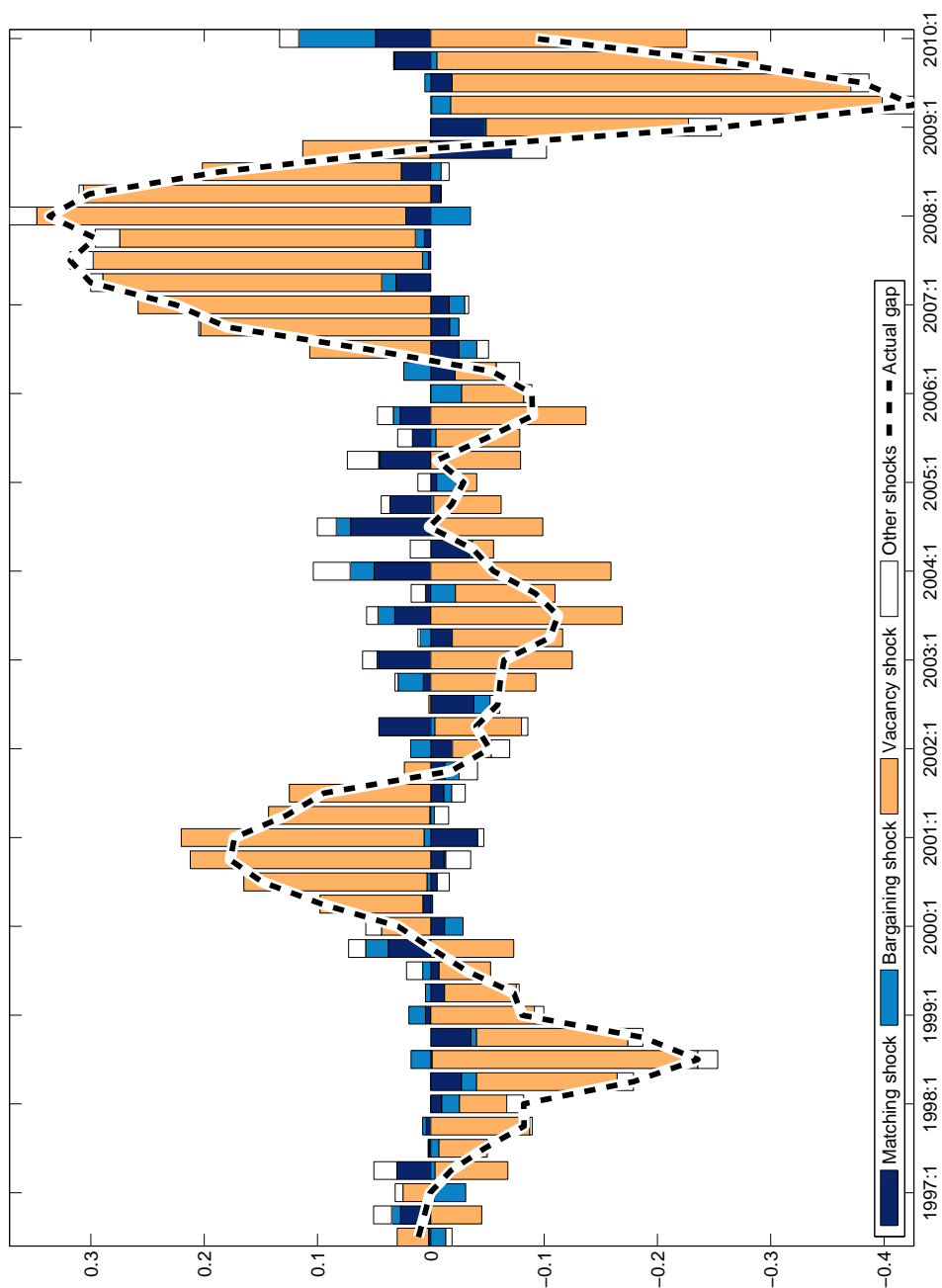


Figure 9
 Variance decomposition — Output

