I. An Estimated Small Open Economy New-Keynesian Model of the Australian Economy[1]

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Abstract

This paper estimates a small open economy New-Keynesian model using data from Australia and the US economy with Full Information Maximum Likelihood method. Our estimated US structural parameters are in line with those of Giordani (2004) on Canadian data. For Australian parameters we find that the real exchange rate has little effect on output gap and inflation, whereas the foreign output gap has a significant effect on both of them. Moreover, our results show a prominent role for backward-looking behaviour for Australian inflation.

Keywords: Open Economy, New Keynesian model, FIML, Australia

JEL Classification: C22; E30; E50; F41; F42

1. Introduction

This paper presents an estimated small open economy (SOE) New-Keynesian model of the Australian economy. The New-Keynesian models are generally represented by three key equations: A Phillips curve representing dynamics of inflation, an IS/AD equation representing dynamics of output, and the monetary policy (MP) rule equation that describes how monetary policy reacts to macroeconomic variables of the economy.

Various theoretical and empirical studies on MP rules have focused on the closed economy (CE) version. However, an important extension of this model is to include them to the open economy. This paper estimates a SOE New-Keynesian model of the Australian economy. The estimated model is a modified version of Svensson's (2000)

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model. We estimate a simplified version of this model for the Australian economy with a block exogenous, rest of the world (ROW) economy (US).

Our results show that estimated structural parameters for US economy are in line with Giordani (2004). In this regard, our estimation shows that the IS and Phillips curve equations of US are prevalently backward-looking, though there is some important degree of forward-looking behaviour in the IS equation. Estimated parameters for the Australian economy show that real exchange rate has little effect on Australian output and inflation. We also find a predominantly backward-looking behaviour for Australian inflation.

The outline of the paper is as follows: Section 2 presents the basic structure of the model. Section 3 explains the solution and form of the solved model. Section 4 presents the results. Finally, conclusions are drawn in section 5.

2. The Model

2.1. The Small Open Economy

The New-Keynesian model, in its simplest form, composes of three equations (Clarida et al., 1999). The first one is a forward-looking version of an aggregate supply equation. Following Svensson (2000) and Giordani (2004), the Phillips curve of our model is partially forward-looking[3].

$$\pi_{t+1} = \alpha_\pi \overline{\pi}_t + (1-\alpha_\pi)\pi_{t+2|t} + \alpha_x x_{t+1} + \alpha_q (q_t - q_{t-1}) + \varepsilon_{t+1}^{CP} \quad (1)$$

where, for any variable ω, $\omega_{t+\tau|t}$ refers to the expectation of the variable ω_t, $[E_t(\omega_{t+\tau})]$ based on information available at time t. Furthermore, π_t denotes quarterly CPI inflation, $\overline{\pi}_t$ is annual inflation $[\overline{\pi}_t = (\pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3})/4]$, x_t is the (log) output gap, defined as $x_t = y_t - y_t^N$, where y_t is (log) real GDP and y_t^N is (log) real potential output; q_t is the (log) real exchange rate. The term ε_t^{CP} is a zero-mean $n.i.d.$ cost-push (CP) shock-: $\varepsilon_t^{CP} \sim nid(0, \sigma_{CP}^2)$.

Following Giordani (2004), the potential output is assumed to be an exogenous process that allows for technology spill-over from the ROW:

$$y_{t+1}^N = \rho_N y_t^N + \rho_{N^*} y_t^{N^*} + \varepsilon_{t+1}^N \quad (2)$$

where $y_t^{N^*}$ is ROW potential output, and ε_t^N is a zero-mean $n.i.d.$ technology shock: $\varepsilon_t^N \sim nid(0, \sigma_N^2)$. It is assumed that the technology shock is uncorrelated with the ROW technology shock.

[3] *Constants are omitted throughout the model.*

The second equation is the aggregate demand equation. Following Svensson (2000), an aggregate demand is determined as follows:

$$x_{t+1} = \beta_x x_t + (1-\beta_x)x_{t+2|t} - \beta_i(i_t - \pi_{t+1|t}) + \beta_{x^*} x^*_{t+1} + \beta_q q_{t+1|t} + \varepsilon^{AD}_{t+1} \tag{3}$$

where x^*_t is the (log) output gap, and i_t is the instrument of MP. All coefficients are constant and expected to be non-negative. The term ε^{AD}_t is a $n.i.d.$ zero-mean aggregate demand shock: $\varepsilon^{AD}_t \sim nid(0, \sigma^2_{AD})$.

It is assumed that the exchange rate fulfils the uncovered interest parity condition:

$$(i_t - \pi_{t+1|t}) - (i^*_t - \pi^*_{t+1|t}) = q_{t+1|t} - q_t \tag{4}$$

where i^*_t, and $\pi^*_{t+1|t}$ are the foreign nominal interest rate and one period ahead of foreign expectation of inflation, respectively.

The last equation in the New-Keynesian model is a MP. We take the short-term interest rate as the instrument of MP and following Giordani (2004) it is extended to include foreign variables:

$$i_{t+1} = \rho_i i_t + (1-\rho_i)(\gamma_x x_{t+1} + \gamma_\pi \overline{\pi}_{t+1} + \gamma_i i^*_{t+1} + \gamma_{x^*} x^*_{t+1} + \gamma_{\pi^*} \overline{\pi}^*_{t+1}) + \varepsilon^{MP}_{t+1} \tag{4.1}$$

where the term ε^{MP}_t is a zero-mean MP shock: $\varepsilon^{MP}_t \sim nid(0, \sigma^2_{MP})$.

In general, the New-Keynesian model brings these three equations together to characterise the dynamic behaviour of three key macroeconomic variables: output, inflation, and the nominal interest rate.

2.2. The Rest of the World

We assume that the ROW is the CE analogue of the SOE[4] (for a theoretical explanation see Galí and Monacelli, 2005). Hence, the model for the ROW has the same structure as a wide class of CE New-Keynesian models:

$$\pi^*_{t+1} = \alpha^*_\pi \overline{\pi}^*_t + (1-\alpha^*_\pi)\pi^*_{t+2|t} + \alpha^*_x x^*_{t+1} + \varepsilon^{CP*}_{t+1} \tag{5}$$

$$y^{N*}_{t+1} = y^{N*}_t + \varepsilon^{N*}_{t+1} \tag{6}$$

$$x^*_{t+1} = \beta^*_x x^*_t + (1-\beta^*_x)x^*_{t+2|t} - \beta^*_i(i^*_t - \pi^*_{t+1|t}) + \varepsilon^{AD*}_{t+1} \tag{7}$$

$$i^*_{t+1} = \rho^*_i i^*_t + (1-\rho^*_i)(\gamma^*_x x^*_{t+!} + \gamma^*_\pi \overline{\pi}^*_{t+1}) + \varepsilon^{MP*}_{t+!} \tag{8}$$

The model is forward-looking, yet it imposes several restrictions on contemporaneous responses of ROW variables to structural ROW shocks.

[4] *The exchange rate, SOE variables and shocks have no effect on ROW variables.*

3. The Solution and Form of the Solved Model

The model given above can be written as a system of dynamic expectational difference equations and solved in several different ways[5]. This paper uses the solution algorithm in Söderlind (1999), which is based on the Schur decomposition. Appling the solution algorithm explained in Söderlind (1999) shows that the law of motion for the ROW and for the SOE takes a Vector Autoregressive (VAR) form, where the ROW is block exogenous and all ROW shocks can be identified with recursive restrictions (Giordani, 2004).

The law of motion of the ROW has the following form[6]:

$$X^*_{t+1} = B^* X^*_t + C^* v^*_{t+1} \tag{9}$$

where $X^*_t = \{y^{N*}_t \quad x^*_t \quad \pi^*_t \quad i^*_t\}'$, and v^*_t is a 4×1 vector and $v^*_t \sim nid(0,\mathrm{I})$.

For the SOE, we partition the model solution. This partitioning is a necessary step when we are using full information maximum likelihood (FIML) method to estimate the model in next section. The law of motion of predetermined variables for the SOE is

$$Y_{t+1} = AX^*_{t+1} + BY_t + Cv_{t+1} \tag{10}$$

Assume that the forward-looking variables of the SOE include in a vector Z. The law of motion for forward-looking variables, Z, takes the following:

$$Z_{t+1} = H_1 Y_{t+1} + H_2 X^*_{t+1} \tag{11}$$

By stacking all the SOE variables, $X_t = \{Y'_t \quad Z'_t\}'$, equations (9), (10), and (11) imply that:

$$X_{t+1} = F_1 X_t + F_2 X^*_t + F_3 C^* v^*_{t+1} + F_4 C v_{t+1} \tag{12}$$

In this equation, all of the SOE variables, X_{t+1}, are a linear function of lags of themselves, X_t, lags of ROW variables, X^*_t, domestic and ROW shocks. Equations (9) and (12) are in fact a VAR model with the ROW block exogenous.

4. Estimation of the Model

In estimating the model it is assumed that all variables other than expectations and shocks are observable. This paper uses the US economy as a proxy for the ROW. This assumption does not mean that the US economy is the only important source of economic fluctuations on the Australian economy. Even though there are documented linkages between the two economies (see, Gruen and Shuetrim, 1994), as the US

[5] *Dennis (2005) makes an interesting review of different algorithm of solutions for RE models*

[6] *In solved form, we abandonment higher lags than one for presentation purposes.*

economy accounts for almost one-quarter of all the world's GDP, using this country as an indicator of the ROW is not unreasonable[7].

The SOE nature of Australia means that there is no feedback from Australia to the US. Hence, similar to Dungey and Pagan (2000), we assume that the Australian variables can not influence those in the US.

Quarterly Australian and US data are used to estimate the model from 1975 Q1 through 2006 Q4[8]. The empirical counterparts of the variables in the model are: real GDP, potential GDP, CPI, the federal fund rate (the short-term cash rate for Australia) and real exchange rate[9]. Output is measured by (log) chain volume measures of GDP. For the US, CPI are for all urban consumer, all items less food and energy with index 1982-84=100. For the Australia, CPI is measured for all groups with index 1989/90=100. For both two countries CPI is seasonally adjusted. Potential output series for US economy is built from measures of capacity utilization in the manufacturing sector. For the Australian economy, we do not have any good measurement of potential output, and we need to estimate it. As we are going to use FIML method to estimate the model, it is reasonable to use a measure of traditional *ad hoc* output gap[10]. The output gap is derived by calculating deviations of the log of real output from potential output. We apply Hodrick-Prescott (HP) filter to estimate potential output.

The results of FIML's point estimates are reported in Table 1. All US parameters have the expected sign. The IS and Phillips curve equations are prevalently backward-looking, though there is of some degree of forward-looking behavior in the IS equation. Our estimate of predominant backward-looking of Phillips curve and IS equation is in line with most of studies on US economy (see, e.g., Giordani, 2004; Lindé, 2005; Rudd and Whelan, 2005). Galí and Gertler (1999), and Galí et al. (2001, 2003 and 2005), however, show significant but small coefficients on lagged inflation and conclude that forward-looking behaviour is dominant in the Philips curve. Moreover, Kurmann (2005) uses a limited-information ML procedure to estimate a hybrid version of the New-Keynesian Phillips Curve, and obtains coefficient estimates very similar to the ones found in Galí and Gertler (1999). Batini et al. (2005), also show that inflation is highly forward-looking (they use GMM estimation method). However, Rudd and Whelan (2005), by documenting a serious problem on specification of Galí and Gertler's (1999) model show that Galí and Gertler's (1999) results are also consistent with a backward-looking Phillips curve.

Our estimate of β_i^* is in line with others (e.g., Giordani, 2004; Lindé, 2005). The estimate of α_π^*, however, is in line with Giordani (2004), and much larger than

7 *Brischetto and Voss (1999), Dungey and Pagan (2000), Kim and Sheen (2000) and Summers (2001) consider the US as an important component of the Australian economy in their model of the Australian economy as SOE*

8 *In order to get ride of the oil shocks, the sample starts from 1975Q1*

9 *All US data are from FRED. Australian data are from ABS, with the exception nominal exchange rate, from RBA*

10 *By using a FIML method Lindé (2005) finds that it does not matter for the results if we use both measures of output gap and real marginal costs.*

common estimates (see, e.g. Batini et al., 2005; and Lindé, 2005). Giordani (2004) points out some possible reasons for this difference in results. Our estimate for ρ_i^*, is 0.763 which is in the range reported by Kozicki (1999) and Amato and Laubach (1999). $\hat{\gamma}_\pi^*$ is higher than one, and in this regard it is in line with common estimates. Our estimation of $\hat{\gamma}_x^*$ is in line with common estimation of this parameter (see, e.g., Clarida, et al., 1999 and 2001).

The Australian parameters, $\hat{\alpha}_q$, $\hat{\beta}_q$, $\hat{\gamma}_{x^*}$, $\hat{\gamma}_{\pi^*}$ are found to be small, insignificant, and of the wrong sign. The insignificance of $\hat{\alpha}_q$, and $\hat{\beta}_q$ suggest that the real exchange rate has little effect on output and inflation. We then set all insignificant variables to zero to solve and re-estimate the model. Re-estimated parameters show that this has no substantial effect on any other parameters. In final estimation, $\hat{\beta}_{x^*}$ is 0.124. This estimation is in line with Beechey, et al. (2000). Insignificancy of $\hat{\alpha}_q$ and $\hat{\beta}_q$ on the one hand, and sizable estimated value for β_{x^*} on the other hand, imply that the foreign output gap is a very important variable in comparison with the real exchange rate and optimal MP should respond to the ROW business cycle. Our estimation for β_i is also small and insignificant. In a CE version of the New-Keynesian model for the Australian economy, we estimate a small and insignificant value for β_i as well.

Greater value of $\hat{\alpha}_\pi$ shows a backward-looking behaviour for Australian inflation. Our estimation of γ_π, is less than one, but the model is nevertheless stable. In order to get an idea about stability of the model, simulated data from estimated parameters are used to estimate the parameters of the Australian economy. The difference between standard deviation of simulated data and real data is very small for output gap, inflation and also interest rate. Notice that the model is stable even though γ_π<1. One possible reason for this stability is the large estimate value for γ_x. To investigate this possibility we choose two small values (0.001 and 0.341) for this parameter[11]. We then solve the model with these two fixed values for γ_x, separately. As the solved form has VAR form, we calculate eigenvalues of coefficient matrix in VAR form, M. It shows that with both of these small values the model is unstable, hence, it can be claimed that the large value of γ_x offsets the instability of the model caused by estimated value of $\gamma_\pi \langle 1$. We also set β_{i^*} to zero and solve the model. The estimated

[11] *Giordani (2004) estimates these two values for* γ_x *for SOE and CE with Canadian data, respectively.*

model with this restriction was also stable. Moreover, the parameter estimates show that, in the CE model, there is more evidence for forward looking behaviour in the AS and AD equations than the model where Australia is treated as a SOE. Our estimation for $\hat{\rho}_i$ is greater than what we estimate for the US economy. $\hat{\gamma}_i$ is less than one, implying that any changes in the US interest rate does not translate into one-to-one changes in the Australian interest rate. However, the Australian interest rate is still significantly affected by any movement of US interest rate. Finally, our estimation for ρ_N is approximately one, implying that any improvement in Australian productivity makes a one-to-one change to Australian potential output.

5. Conclusion

This paper estimates a SOE New-Keynesian model of the Australian economy. The structural parameters of the ROW, SOE, and CE are estimated using a modified version of Svensson (2000). The solution algorithm explained in Söderlind (1999) is used to solve the model. We then use FIML to estimate the solved model. Our estimated parameters for US economy are in line with Giordani (2004). In this regard we find that the IS and Phillips curve equations are prevalently backward-looking, though there is some degree of forward-looking behaviour in the IS equation. Our results also show a more prominent role for backward-looking behaviour for Australian inflation. While our results show that real exchange rate has little effect on output and inflation in Australian economy, US output gap has a significant effect on both of them.

Table 1

FIML's Point Estimates Results of the SOE New-Keynesian Model

US		AUSTRALIA	
parameters	point estimates	parameters	point estimates
β_x^*	0.769 (0.029)	β_x	0.889 (0.026)
β_i^*	0.060 (0.010)	β_i	0.006 (0.009)
		β_q	0^*
		β_{x^*}	0.124 (0.033)
α_π^*	0.717 (0.051)	α_π	0.924 (0.023)
α_x^*	0.235 (0.037)	α_x	0.513 (0.120)
		α_q	0^*
γ_x^*	0.737 (0.239)	γ_x	1.323 (0.530)
γ_π^*	1.365 (0.143)	γ_π	0.353 (0.171)

US		AUSTRALIA	
parameters	point estimates	parameters	point estimates
ρ_i^*	0.763 (0.037)	ρ_i	0.856 (0.028)
		γ_{i^*}	0.755 (0.196)
ρ_N^*	1^*	ρ_N	1.001 (0.094)
		ρ_{N^*}	0.002 (0.098)
σ_N^*	0.500	σ_N	0.128
σ_{AD}^*	0.520	σ_{AD}	0.767
σ_{CP}^*	1.289	σ_{CP}	2.260
σ_N^*	1.279	σ_{MP}	1.275

Note: Values in parentheses are standard deviations. Values with asterisks have been imposed.

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