An estimated New Keynesian policy model for Australia

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AN ESTIMATED NEW KEYNESIAN POLICY MODEL FOR AUSTRALIA*

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Abstract

An open economy New Keynesian policy model for Australia is estimated in this study. We investigate how important external shocks are as a source of macroeconomic fluctuations when compared to domestic ones. The results of our analysis suggest that the Australian business cycle and domestic inflation are most affected by domestic demand and supply shocks, respectively. However, domestic output also appears to be strongly affected by foreign demand shocks, and domestic inflation by exchange rate shocks. Domestic variables do not seem to be significantly affected by foreign supply and monetary policy shocks.

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1. Introduction

Macroeconomic policy in small open economies (SOEs) is often set with careful consideration of external conditions such as world demand, world interest rates, the terms of trade, the real exchange rate, capital flows, and other factors. This is largely due to the fact that changes in external conditions are commonly seen in the literature as one of the most important sources of macroeconomic fluctuations in SOEs. The aim of this study is to focus on the Australian economy and investigate how important external shocks are as sources of macroeconomic fluctuations when compared to domestic ones. Based on the parameter estimates of our economic model and the structural identification of domestic and foreign shocks that we employ, we are able to discuss some of the issues of concern to monetary policy makers such as, for example, which of the external shocks most attention should be paid to.

We utilise a two-block model that falls into the general class of New Keynesian policy models (NKPMs), involving optimising agents with rational expectations and various real and nominal rigidities (see Pagan, 2003, for an outline and comparison of various macroeconomic modelling approaches). We explicitly model the US economy, which we take as a proxy for the global economy, using a closed economy NKPM that is in structure very similar to the model recently estimated by Cho and Moreno (2006). Taking such an approach is advantageous as it allows for a model consistent, structural identification of the types of foreign shocks hitting the domestic economy.

New Keynesian models similar to ours have been fitted to a number of SOEs including Australia (see Justiniano and Preston, 2004; Lubik and Teo, 2005; Lubik and Schorfheide, 2007). Nevertheless, Lubik and Teo (2005) and Lubik and Schorfheide (2007) work with a group of SOEs and do not formulate an explicit model for the foreign economy. Only Lubik and Teo (2005) report somewhat detailed results for the Australian economy. Justiniano and Preston (2004), on the other hand, consider a two-block open economy model and report detailed results for a group of developed SOEs, including Australia. However, Justiniano and Preston (2004) focus on estimating the parameters of the structural model and do not address the responses of domestic variables to foreign shocks. Although our model's structure is similar to that of Justiniano and Preston (2004), it is much less restrictive as we focus on estimating the parameters of the system equations without imposing any cross-equation restrictions on the parameters in either of the two blocks. Such an approach has been advocated recently by Fukac *et al.* (2006). More specifically, we take as a reference point the two-block NKPM proposed by Svensson (2000), consisting of a domestic and world economy block.

The results of our analysis suggest that domestic and foreign demand shocks are the most influential in affecting business cycle fluctuations in Australia. Australian inflation, on the other hand, appears to be most sensitive to domestic supply and exchange rate shocks. The impact of domestic monetary policy shocks appears to be rather mild. Regarding foreign shocks in general, we find that world demand shocks and exchange rate shocks have the largest impact on the Australian economy, noticeably larger than domestic monetary policy shocks. Foreign supply and foreign monetary policy shocks do not appear to significantly affect domestic variables.

The remainder of the paper is structured as follows. Section 2 gives a detailed outline of the policy model we employ, discussing the evolution of the domestic and foreign variables in our system. In Section 3 we describe the data and methodology employed to estimate the parameters of the New Keynesian model introduced in Section 2. The parameter estimates and the transmission mechanism of domestic and foreign shocks to domestic variables are discussed in Section 4. Section 5 concludes the discussion.

2. The Policy Model

The NKPM that we employ is in its setup similar to that of Clarida *et al.* (1999). We extend the model to one of a small open economy (SOE), thereby allowing for the effects of global shocks to be transmitted into the domestic economy. The framework that we follow is analogous to the SOE New Keynesian models developed from first principles in, for example, Monacelli (2005), Bergin (2003), Clarida *et al.* (2001, 2002), McCallum and Nelson (2001), Obstfeld and Rogoff (2000) and Svensson (2000), making it redundant for us to go through its micro-foundation. As with many other SOE models, the core structure of our system consists of two blocks: a domestic block comprising an IS equation, a Phillips curve, a monetary policy rule and an uncovered interest parity (UIP) condition; and an exogenous world economy block.

A number of different approaches to modelling the world economy exist in the literature. For example, Svensson (2000) assumes that some foreign variables proxy the world economy, which themselves follow a simple autoregressive (AR) processes, while Lubik and Schorfheide (2007), Justiniano and Preston (2005) and Giordani (2004) use the US as a proxy for the world economy and formulate a small-scale closed economy NKPM for it. It is also possible to utilise a flexible vector autoregressive (VAR) model for the US, which is the approach taken by Justiniano and Preston (2004) or, alternatively, impose some structure on it, in order to be able to identify the shocks hitting the domestic economy. The latter approach is adopted by Dungey and Pagan (2000). Our preference is to adopt a small scale NKPM for the US that is very similar to the model that was recently employed by Cho and Moreno (2006).

2.1. The domestic economy

Let $E_t x_{t+1}$ denote the rational expectation forecast of x_{t+1} conditional on the information set available to the forecasting agent at time t. Aggregate supply (AS), i.e., the equation describing inflation dynamics in the domestic economy is modelled by the following '*hybrid*' Phillips curve:

$$\pi_t = \rho_\pi E_t \pi_{t+1} + (1 - \rho_\pi)\,\pi_{t-1} + \lambda_1 y_t + \lambda_2 q_t + \epsilon_{AS,t} \tag{1}$$

where π_t and y_t are respectively inflation and the output gap in the domestic economy, q_t is the real exchange rate and $\epsilon_{AS,t}$ is a stationary, but serially correlated, supply shock. The term hybrid relates to the fact that the Phillips curve is backward, as well as, forward looking in inflation. Allowing for an inertial effect by giving a non-zero weight to π_{t-1} in

Equation (1) was initially empirically motivated, but can also be derived from a staggered price setting mechanism, where a proportion of firms use a naïve, backward looking rule to forecast inflation. It thus arises as a consequence of a Calvo (1983) type price setting mechanism, with partial indexation to last period's inflation. An explicit derivation of the hybrid Phillips curve is given in, amongst others, Clarida *et al.* (2002), Christiano *et al.* (2001) and Smets and Wouters (2003). The empirical usefulness of the hybrid specification has been advocated in e.g. Rudd and Whelan (2005) and Lindé (2005). Notice also that the impact of the real exchange rate q_t on domestic inflation represents the first transmission channel of world shocks into the domestic economy. We prefer to use a levels real exchange rate specification, as opposed to lagged changes as employed in Giordani (2004, see page 717), which is more in line with the original formulation advocated in Svensson (2000).

The output gap is described by the following IS equation:

$$y_t = \rho_y E_t y_{t+1} + (1-\rho_y) y_{t-1} - \delta_1 \left(r_{t-1} - E_{t-1}\pi_t\right) + \delta_2 q_{t-1} + \delta_3 y_t^* + \epsilon_{IS,t} \tag{2}$$

where r_t is the monetary policy instrument, y_t^* is the US output gap, which is our proxy for world demand, and $\epsilon_{IS,t}$ is a serially correlated aggregate demand shock. One can see from Equation (2) that the output gap depends on its expected value one-period ahead and its lagged value, where the relative impact is determined by the size of ρ_y. The forward-looking term is due to households' inter-temporal optimising behaviour and the lagged term arises as a result of external consumption habit formation, or due to a costly adjustment of the capital stock (see, for example, Clarida *et al.*, 2002; Christiano *et al.*, 2001; Smets and Wouters, 2003, for more details).

The presence of the real exchange rate q_{t-1} and the foreign output gap y_t^* in (2) denotes the second and third transmission channel of foreign shocks into the domestic economy. The motivation for an open economy IS equation can be found in Monacelli (2005), Clarida *et al.* (2001), and Svensson (2000). Note that (2) assumes that the effect of the real interest rate $(r_{t-1} - E_{t-1}\pi_t)$ on domestic demand comes with a one period lag. This is contrary to the specification given in Cho and Moreno (2006), Monacelli (2005) and Justiniano and Preston (2004), who assume a contemporaneous impact of the real interest rate, but in line with that chosen by Giordani (2004), who fits an empirical SOE New Keynesian model to Canadian data. Traditionally, studies on the Australian economy have sought to specify a minimum two-period lagged effect of the real interest rate on output, see Gruen *et al.* (1997), Beechey *et al.* (2000) and Dungey and Pagan (2000). However, the recent study by Stone *et al.* (2005) allows the effect of the real interest rate to impact upon output starting with an one-period lag.

In the specification of the monetary policy (MP) reaction function, we follow the arguments put forth in Clarida *et al.* (2001) and Svensson (2000) that a Taylor-type rule that considers only the domestic output gap and domestic inflation is optimal even for an open economy, and that it is reasonably robust to different model structures. Empirical validation of this can be sought in, for example, Giordani (2004), who includes r_t^*, π_t^* and y_t^*, but nevertheless finds that only r_t^* receives a non-zero weight in the MP reaction function in his model for Canada. In the models estimated by Lubik and Schorfheide (2007) and Lubik (2005), changes in the nominal exchange rate were included in the MP reaction function of the central bank, however, no statistical evidence was found to suggest that the MP authority reacted to exchange rate fluctuations.[1] We thus decided to exclude foreign variables from the MP reaction function.

A forward-looking version of the Taylor rule is employed to emphasise the RBA's focus on future inflation when adjusting its MP instrument, taking the form

$$r_t = \rho_r r_{t-1} + (1 - \rho_r)\left(\psi_1 E_t \pi_{t+1} + \psi_2 y_t\right) + \epsilon_{MP,t} \tag{3}$$

where $\epsilon_{MP,t}$ is assumed to be distributed *i.i.d*. An *i.i.d* specification of the monetary policy shock is a common assumption in the literature, see Smets and Wouters (2003) and Del Negro *et al.* (2005). One can notice from the specification in (3) that the monetary authority responds to one period ahead expected inflation and the current output gap, while at the same time it adheres to a certain degree of inertia in r_t, making the response flexible and empirically justifiable.

To be able to close the model, the evolution of the real exchange rate and the foreign economy needs to be specified. We formulate the real exchange rate such that it evolves according to real UIP. The UIP condition is generally stated as an identity over the log of the exchange rate and interest rates, with the exchange rate being expressed as the ratio of domestic to foreign currency units. Since the model becomes stochastically singular if UIP is left as an identity in (4), it is necessary to either add a shock, or to compute the log-likelihood excluding the exchange rate equation. Giordani (2004), for example, opts for the latter, while we prefer the former (see also Justiniano and Preston (2004), Leu (2004) and McCallum and Nelson (2001), who adopt a similar approach). Equation (4) below describes how the real exchange rate evolves.

$$E_t \Delta q_{t+1} = \left(r_t - E_t \pi_{t+1}\right) - \left(r_t^* - E_t \pi_{t+1}^*\right) - \epsilon_{RER,t} \tag{4}$$

We allow $\epsilon_{RER,t}$ in (4) to be serially correlated, in order to accommodate findings in the related literature that UIP tends to hold over longer horizons of $1-2$ years (see the studies by Chinn and Meredith (2004) and Mark and Moh (2001) for more details regarding the empirical properties of UIP).

2.2. The foreign economy

The US economy, which is used as a proxy for the world economy, is modelled according to the NKPM that was recently employed by Cho and Moreno (2006). This model consists

[1] The RBA is known to have intervened in the foreign exchange market to eliminate exchange rate misalignments during turbulent periods. A detailed account of the RBA's intervention in the foreign exchange rate market is given in Becker and Sinclair (2004).

of the following three equations:

$$\begin{aligned}
\pi_t^* &= \rho_\pi^* E_t \pi_{t+1}^* + (1-\rho_\pi^*)\, \pi_{t-1}^* + \lambda^* y_t^* + \epsilon_{AS,t}^* \\
y_t^* &= \rho_y^* E_t y_{t+1}^* + (1-\rho_y^*) y_{t-1}^* - \delta^* (r_{t-1}^* - E_{t-1}\pi_t^*) + \epsilon_{IS,t}^* \\
r_t^* &= \rho_r^* r_{t-1}^* + (1-\rho_r^*) \left(\psi_1^* E_t \pi_{t+1}^* + \psi_2^* y_t^*\right) + \epsilon_{MP,t}^*
\end{aligned} \tag{5}$$

The specification of the closed economy model for the US is analogous to the one employed for the domestic economy, with the impact of foreign variables on domestic inflation and the output gap completely removed. Notice that the effect of the real interest rate on the output gap was set in line with the domestic economy model, i.e., with a one period lag, rather than with a contemporaneous effect as in the original formulation in Cho and Moreno (2006). Following a specification of the US block as in Equation (5) enables us to give a structural identification to the foreign shocks.

The model described by Equations (1) to (5) specifies the complete two-block structure that we consider, with the foreign block being exogenous to the domestic one. It should be pointed out here that we model the behaviour of the economy away from a deterministic steady-state growth path. That is, we follow the approach taken in Dungey and Pagan (2000) and demean and detrend all data – except the output series – via a regression on a constant and a time trend. The domestic and foreign output gaps are constructed by subtracting the HP-filtered permanent component from logged quarterly real GDP data (see the Data section for more details). Giordani (2004) has recently also pointed out that working with demeaned/detrended data avoids dealing with parameter instability and structural breaks which, he finds, largely affect the unconditional mean of the series being modelled.

3. Data and estimation

3.1. Data

The data series for the US are taken from the Federal Reserve Economic Data (FRED) database, available from http://research.stlouisfed.org/fred2/. The foreign interest rate series r_t^* is computed as the quarterly average of the monthly federal funds rate. The foreign inflation series π_t^* is constructed as $(CPI_t^*/CPI_{t-1}^* - 1)400$, where CPI_t^* is the US core CPI index. The foreign output gap y_t^* is obtained as the transitory component after applying the HP filter to logged quarterly real GDP data.

The data for Australia were taken from the Reserve Bank of Australia. The domestic interest rate r_t that we use is the quarterly average of the monthly cash rate.[2] The data series for domestic inflation π_t is the trimmed mean measure of inflation. The output gap for Australia was constructed analogously to the US output gap, using logged quarterly real non-farm GDP data.[3] The real exchange rate q_t is computed as 100 times the log difference between the quarterly average of the AUD/USD nominal exchange rate and the ratio of

[2]We thank one of the referees for kindly making the monthly cash rate data available to us.

[3]Note that non-farm GDP is used in our model as a proxy for output as we do not allow for weather related shocks in our model. We thank Adrian Pagan for clarifying this point to us.

Australian to US CPIs. An increasing value in q_t corresponds to a real depreciation of the domestic currency. The nominal exchange rate is obtained from the IMF's International Financial Statistics.

We use 1983:Q1 as the starting point for the HP-filtering of the logged real GDP data, up to 2005:Q4. This choice avoids some of the instabilities of the 1970s and the recessions of the early 1980s that both, the US and Australia, experienced. The US recession, according to NBER recession dates, bottomed out in 1982:Q4, while in Australia 1983:Q1 was the trough of the recession. The estimation period of our NKPM runs from 1984:Q1 to 2005:Q4, covering the entire post float period of the Australian dollar. Although the Australian dollar floated officially in December 1983, the exchange rate regime started to become more flexible in 1977, with the advent of a crawling peg. For that reason, one might consider an earlier point in time as the beginning of the sample period such as 1980:Q1, as, for example, Dungey and Pagan (2000) do. Nevertheless, to eliminate the possibility of a structural break in the transmission mechanism of foreign shocks into the Australian economy due to the new official exchange rate regime, we prefer to start the sample period in 1984:Q1. As an alternative, one could consider 1993:Q1 as the beginning of the sample period, i.e., after the introduction of inflation targeting in Australia, which is what Nimark (2006) does. However, this would further shorten the sample period available for estimation and is therefore not pursued.

3.2. Estimation

There exist several estimation methods in the literature to fit New Keynesian models to the data. One method that is often employed is the Generalised Method of Moments (GMM) (see, e.g., Galí and Gertler, 1999, and others). However, Lindé (2005) showed recently that GMM estimates of the parameters of a simple New Keynesian model are likely to be estimated imprecisely and with a bias. It has thus become common practice to estimate New Keynesian models using a full information Maximum Likelihood (ML) approach. One of the drawbacks of using ML is that parameters can take on corner solutions or theoretically implausible values. Additionally, it is often the case that the log-likelihood function is flat in certain directions of the parameter space and extremely hilly overall, so that without careful constraints on the parameters space it is difficult to numerically maximise the log-likelihood function (see the discussion in An and Schorfheide, 2005, for more details).

Rather than imposing constraints on the parameter space in ML estimation, it is more natural to add a probabilistic statement, or a prior belief, on the parameter space of the estimated model. This can be done easily within a Bayesian estimation approach which combines theoretical constraints and prior beliefs on the parameter space with the information contained in the data (see, e.g., Adolfson *et al.*, 2005). Our preferred approach to obtain parameter estimates and draw inferences on the model is therefore to use the Bayesian framework.

The Bayesian approach to estimating a NKPM with nominal rigidities consists of the following steps. Firstly, the linearised rational expectation model in (1) to (5) is put into state-space form and solved using the QZ solution algorithm of Sims (2002). The solved model has a VAR(2) structure, readily allowing us to compute the likelihood function. Combining the likelihood function of the solved model with the prior densities on the parameters then defines the posterior density. That is, given the priors $p(\theta)$, where θ is a vector containing the model parameters, the posterior density is proportional to the product of the likelihood function of the solved model and the priors:

$$p(\theta|\mathbf{Y}) \propto L(\theta|\mathbf{Y})\, p(\theta) \tag{6}$$

where $L(\theta|\mathbf{Y})$ is the likelihood function conditional on data $\mathbf{Y}$. Note that the priors that we use are mutually independent, so that $p(\theta)$ is constructed as the product of the individual priors on the structural parameters given in the first column of Table 1 and Table 3 for the US and domestic economy blocks respectively.

The posterior in (6) is generally a non-linear function of the structural parameters θ and is maximised using a numerical optimisation algorithm.[4] The values of the parameters at the posterior mode, together with the corresponding Hessian matrix are then used to start the random walk Metropolis-Hastings sampling algorithm to obtain draws from the entire posterior distribution. Proposals in the sampling algorithm are drawn from a multivariate normal distribution, where a scaling factor of 0.2 was used, resulting in an acceptance rate of 33%. See An and Schorfheide (2005) for the Metropolis-Hastings sampling algorithm and the role of the scaling factor in the sampler. We ran two chains of 1 million draws, where the first 50% of each chain were discarded as a burn-in sample.[5]

4. Discussion of results

It is evident from the two-block specification of our SOE New Keynesian model given by Equations (1) to (5) that the US block is a vital input into the complete structural open economy model for Australia. We find it therefore important to initially discuss some of the properties of the parameter estimates of the exogenous US block, before analysing the results for the domestic economy. Since the specification of the US block follows that of Cho and Moreno (2006), we largely compare our results to theirs. Note that the priors that we have chosen are set in line with the range of parameter values that are reported in Cho and Moreno (2006). We should also mention here that the log-likelihood function is extremely flat over ψ_1^*, ψ_2^*, $\rho_{\epsilon_{AS}}^*$ and $\rho_{\epsilon_{IS}}^*$, so that we have chosen to centre the priors on the ML estimates for those parameters. Overall, the priors we impose are mild.

4.1. The US economy model

Table 1 reports parameter estimates of the exogenous US block, specified by the Equations given in (5). In the column under heading 1 we show the parameters of interest and the

[4] We used a simulated annealing algorithm for this. Note that, as with ML estimation, it is the log of the posterior density that is maximised.

[5] We verify that the sampling algorithm converged successfully by monitoring standard multivariate convergence criteria due to Brooks and Gelman (1998), that is, we monitored the determinants of within-sequence and between-sequence covariance matrices of the iterates.

priors that were imposed on them. The column under heading 2 reports Bayesian posterior means and posterior 95% confidence intervals (CIs). Under the last two headings, i.e., 3 and 4, we report the range of parameter estimates that were obtained by Cho and Moreno (2006) and GMM estimates for comparison purposes. We used lagged values of y_t^*, π_t^* and r_t^* as instruments in the GMM estimation. Note that Cho and Moreno (2006) employ a number of alternative measures of the output gap and varying sample periods, resulting in a number of different parameter estimates. We therefore show the range of values they report, rather than focusing on one particular set of results. Also, GMM estimates are reported to verify the results of our system estimates. It is well known that system estimators can be inconsistent if one of the equations in the system is misspecified (see Johansen, 2004).

It is apparent from the results reported in Table 1 that our Bayesian estimates fall in the range of values reported in Cho and Moreno (2006). Looking over the GMM results, one can notice that they are close to our Bayesian system estimates, where all but λ^* and σ_{AS}^* fall in the 95% CI region. The Bayesian estimates of λ^* and σ_{AS}^* seem to be lower than their GMM counterparts. Since the GMM estimator can generate parameter estimates that produce an indeterminacy solution of the model, some disparities in the parameter estimates are likely to occur when compared to Bayesian or ML ones. Nevertheless, there appear to be no substantial differences between the GMM and Bayesian estimates, so that we can confidently dismiss any obvious system misspecification.

Examining the individual behavioural equations for the US block, one can notice that the effect of forward-looking inflation is somewhat stronger than the effect of the forward-looking output gap, as captured by the estimates of ρ_π^* and ρ_y^*. It is evident from the δ^* and λ^* parameter estimates reported in Table 1 that the output gap responds significantly to movements in the real interest rate and prices tend to accelerate as demand pressure and marginal cost increase. Our estimate of λ^* is much higher than that of Cho and Moreno (2006) and significantly positive, thereby accounting for substantial inflationary pressures as the output gap increases.

The US Fed appears to have reacted to inflation increases largely in line with predictions from a simple optimal rule, with the estimate of ψ_1^* at 1.61 being marginally lower than the range of $[1.64, 2.15]$ reported in Cho and Moreno (2006). As can be seen from the estimate of ψ_2^*, the weight that the US Fed puts on the output gap when deciding upon the appropriate stance of monetary policy is somewhat greater at 1.35 than the largest value of 1.14 reported in Cho and Moreno (2006). We attribute this to the different sample periods and data used in their study. As in Cho and Moreno (2006), we find it crucial to allow the AS shock to be negatively correlated in order to fit the empirical properties of the data. The absolute value of our estimate of $\rho_{\epsilon_{AS}}^*$ is, however, smaller at -0.22 than the estimate of -0.32 that is reported in Cho and Moreno (2006).

Since the US block is a vital input into our small open economy model for Australia, we find it important to assess how well the estimated NKPM fits the US data. In order to do so, we estimate an unrestricted VAR(2) model on the US variables and compare the log-likelihood of the VAR(2) to that of the reduced form NKPM. A second-order VAR represents a natural benchmark for comparison, because the solved NKPM has a VAR(2) reduced form. The log-likelihoods of the VAR(2) and the solved NKPM evaluated at the posterior means are -210.68 and -239.09, respectively. One can assess how strong the structural restrictions are that the NKPM imposes on the VAR by means of a standard $LR-$test. The $LR-$test statistic yields a value of 56.82. With 12 restrictions being imposed by the NKPM, this implies a $p-$ value of 0.00, indicating that these restrictions are rejected by the data.[6] A similar result is found in Cho and Moreno (2006) (see Panel C in Table 6 on page 1474).

Another way of assessing the theoretical restrictions that the NKPM imposes on the VAR model and the differing identification of structural shocks is to compare the impulse response functions (IRFs) of the NKPM to those generated from a VAR(2). A Cholesky decomposition is utilised to identify the $\epsilon^*_{AS,t}$, $\epsilon^*_{IS,t}$ and $\epsilon^*_{MP,t}$ structural shocks. The ordering of the variables in the VAR(2) is y^*_t, π^*_t and r^*_t. Such a triangular identification scheme of the structural shocks has been employed extensively in the macroeconomic literature, see Rudebusch and Svensson (1999), Rotemberg and Woodford (1997) and Leichter and Walsh (1999). The impulse responses derived from the estimated VAR(2) and the NKPM are plotted in Figure 1. The shaded regions in Figure 1 are approximate asymptotic 95% confidence intervals. As can be seen from the plots in Figure 1, the IRFs of the recursive VAR(2) and the NKPM model are very similar. Nevertheless, one important advantage that is evident from the IRFs in Figure 1 is that the NKPM does not produce any of the *puzzles* of the VAR(2). These are visible from Panels (a) and (b) in Figure 1 where the IRFs from the VAR(2), although being statistically insignificant, imply an atheoretical positive reaction of y^*_t and π^*_t to a US monetary policy shock.

A somewhat different approach to assess the model's fit to the data has been recently advocated by Breunig *et al.* (2003). Their approach entails examining how well the theoretical moments from the specified NKPM match the empirical sample moments in the data. This approach is termed a consistency check. The relevant moments that we consider involve the variances, the first to eighth order autocorrelation functions (ACFs) and cross-correlations of variables. A comparison of these moments, without any discussion or statistical testing, is shown in Table 2. It can be seen from the moment comparison reported in Table 2 that the NKPM can replicate the important features of the sample data rather well. The NKPM is, therefore, our preferred model for the US economy block.

4.2. The Australian economy model

The results for the domestic economy are presented in Table 3. The priors that we impose are again fairly mild and were centred around the parameter values advocated in Svensson (2000). Similar to the results for the US block, the log-likelihood function is quite flat over the ψ_1 and ψ_2 parameters. We therefore decided to centre the priors for these two parameters in line with those for the US block.[7] One can see from the results reported in Table 3 that the Bayesian and GMM estimates are largely consistent with one another. Discernible exceptions are, however, the estimates of ρ_y, ψ_1 and ψ_2. Under the GMM parameter setting of $\psi_1 = 0.89$ and $\psi_2 = 1.65$, the NKPM is not solvable because of ψ_1

[6] A 1% level of significance critical value for a $\chi^2(12)$ is 26.22.

[7] ML parameter estimates of ψ_1 and ψ_2 are, respectively 1.26 and 1.83. The impulse responses do not change noticeably when evaluated at the ML estimates.

being less than unity. This is a good example of how GMM can yield parameter estimates that do not exclude indeterminacy or unstable solutions. Although not reported here as it is not of primary interest to conduct inference on the GMM estimates, the standard errors from GMM estimation are fairly large. We can thus expect to find weak instrument problems, particularly when trying to instrument for the real exchange rate. We do not take these differences to be indicative of an obvious misspecification problem.

One can see from the results reported in Table 3 that, contrary to the finding for the US block, the estimate of ρ_y is higher than that of ρ_π. This suggests that forward-looking behaviour is more important for the determination of the output gap than in the formation of inflation. The estimate of the coefficient on the lagged output gap in the IS equation of 0.28 is notably lower than the values used in Dennis (2003) or estimated in Stone *et al.* (2005) of 0.75 and 0.84. There are probably two reasons for this. Firstly, Dennis (2003) and Stone *et al.* (2005) use an empirically motivated IS curve, i.e., one that does not include the expected future output gap. Secondly, the specification we employ includes a moving average error term that adds an additional degree of persistence to the output gap.

The impact of the real interest rate on the output gap measured by δ_1 is about six times larger than the impact of the real exchange rate (see the size of δ_2), but more than four times smaller than the impact of world demand on domestic output, as gauged by δ_3. Our estimate of the effect of the real cash rate on the domestic output gap of 0.017 is very close to the one estimated in Stone *et al.* (2005) of 0.021. Their estimate of the real exchange rate effect on the output gap is around 0.018 whilst ours is 0.002, about nine times smaller. However, their IS curve specification includes lagged changes in the exchange rate as well as lagged changes in the terms of trade, thus making it difficult to draw a direct comparison.

The impact of domestic demand pressure and increasing marginal cost on inflation, as captured by λ_1, is over ten times larger than the impact of the real exchange rate. Stone *et al.* (2005) use two different measures of inflation to quantify the impact of the output gap on prices. These are headline and underlying consumer price inflation. The coefficient estimates that they obtain are 0.09 and 0.019 respectively. Thus, our estimate of the output gap's impact on inflation of 0.016 is closer to their estimate when underlying consumer price inflation is used. Note that we employ a trimmed mean measure of inflation which is less volatile than headline inflation and therefore more comparable to underlying inflation.

The parameter estimates that we obtain for the simple monetary policy rule show that the interest rate is adjusted with a significant degree of inertia. This is captured by the size of ρ_r. Our estimate of the persistence in the cash rate is marginally lower at 0.67 than the 0.83 to 0.94 range reported in de Brouwer and Gilbert (2005). Also, the weights the RBA puts on inflation expectations and the output gap when adjusting its policy instrument are $\psi_1 = 1.68$ and $\psi_2 = 1.23$. The magnitudes of these estimates are in the range commonly reported in the literature for Australian data. For example, de Brouwer and Gilbert (2005) use GMM to estimate ψ_1 and ψ_2 to be in the range $[1.53, 2.36]$ and $[0.98, 1.96]$ (see the row labelled HP-final in Tables 2 and 3 in their paper). There appears to exist relatively little information about these two parameters in the data as the log-likelihood function is rather flat over the ψ_1 and ψ_2 coefficients. Nevertheless, impulse responses change only mildly with different values for ψ_1 and ψ_2.[8] These results are independent of the type of detrending method that is used to obtain the output gaps.

Comparing the estimates of the shocks it is evident that the real exchange rate shock is highly persistent and shows the largest variance. This is an expected outcome as exchange rate movements are notoriously difficult to explain (see Cheung *et al.*, 2003, among others). Out of the domestic shocks, the monetary policy shock appears to bear the highest variance. This most likely suggests a possible incomplete specification of the simple monetary policy rule that we adopt for Australia. Dennis (2003) elaborates on this topic extensively. He shows that simple rules that include forward looking terms are closer to an optimal policy rule than a simple Taylor rule that does not include forward looking terms. Following the suggestions of Dennis (2003), we have also included the change in the real exchange rate in the MP rule and re-estimated the model. Although the change in the real exchange rate appeared to be marginally significant, at the 10% level, we did not find any noticeable changes in the estimates of the remaining parameters of the model or the impulse responses. We also found that there was no decrease in the volatility of domestic variables simulated out of the fitted model. Our preference was therefore to follow the suggestions by Dennis (2003) and assign a simple reaction function to monetary policy, in which the real exchange rate effects the cash rate only through inflation expectations.

4.3. The transmission of domestic shocks

We now proceed to investigate the transmission mechanism of shocks hitting the domestic economy by inspecting the estimated impulse responses. We again compare the impulse responses from the NKPM to those obtained from a less restrictive VAR(2) model in order to provide a benchmark comparison. We impose lag exclusion and identifying restrictions on the VAR(2) that are similar to those utilised in the structural VAR (SVAR) model of Dungey and Pagan (2000) (see page 327 in their paper). Firstly, we restrict the US economy to be block exogenous to the Australian one, thereby only allowing lagged US variables to impact upon y_t^*, π_t^* and r_t^*. Secondly, we impose several exclusion restrictions of foreign lagged variables on current domestic variables. These are summarised for lags $i = 1, 2$ in the matrix given in (7) below.

$$\begin{array}{c|ccc} & y^*_{t-i} & \pi^*_{t-i} & r^*_{t-i} \\ \hline y_t & * & * & 0 \\ \pi_t & * & * & 0 \\ r_t & 0 & * & 0 \\ q_t & * & * & * \end{array} \tag{7}$$

An $*$ indicates that a specific variable is present, while 0 marks an exclusion. Note that there are no lag exclusion restrictions placed on the real exchange rate, so that all lagged variables impact upon q_t. Note also that there is no foreign inflation π^*_{t-i} in the model of Dungey and Pagan (2000). We therefore decided to leave the effect of π^*_{t-i} unrestricted.

[8] We have performed a sensitivity analysis with regards to this by comparing our Bayesian estimates to ML ones to verify this conclusion. These results are available from the authors upon request.

One other lag restriction that is imposed in line with those used in Dungey and Pagan (2000) is that r_{t-i} does not impact upon π_t for lags $i = 1, 2$.

Lastly, contemporaneous restrictions on the model are imposed to identify the shocks. These are summarised in (8) below.

$$\begin{array}{c|ccccccc} & y_t^* & \pi_t^* & r_t^* & y_t & \pi_t & r_t & q_t \\ \hline y_t & * & 0 & 0 & 1 & 0 & 0 & 0 \\ \pi_t & 0 & * & 0 & * & 1 & 0 & 0 \\ r_t & 0 & 0 & 0 & * & * & 1 & 0 \\ q_t & * & * & * & * & * & * & 1 \end{array} \tag{8}$$

The US block was again identified via a recursive structure as in Section 4.1. Dungey and Pagan (2000) use a real trade weighted index (RTWI) measure of the real exchange rate and restrict it to have no contemporaneous impact upon any domestic variables. This then translates in our model into the impact of q_t being restricted to zero. Also, since there is no foreign inflation in their model, we left the effect of π_t^* on π_t unrestricted, but set the effect of π_t^* on r_t and y_t to zero so that there is no immediate effect of US inflation on domestic output and the cash rate. A sensitivity analysis was carried out to see how strong these contemporaneous restrictions are. This was implemented by a comparison of the impulse responses from the SVAR(2) under the restrictions given in (8) to those coming from a Cholesky identification scheme. There were only marginal differences between these impulse responses, relating largely to the timing of the responses rather than their magnitudes.[9]

The impulse responses from the NKPM and SVAR(2) are shown in Figure 2. The shaded regions in Figure 2 are bootstrapped 95% confidence intervals for the SVAR(2) impulse responses. Dash-dotted lines denote the Bayesian posterior 95% confidence intervals for the NKPM impulse responses. We can see from the NKPM impulse responses that the domestic economy reacts instantly when hit by a positive demand shock, with output increasing significantly at impact, before slowly returning to its steady-state level after about 10 quarters. Such demand shocks can arise as a result of changes in consumers' inter-temporal preferences, consumers' preferences for leisure, government spending or capital adjustment costs (see Christiano *et al.*, 2001; Del Negro *et al.*, 2005). The response of inflation to a demand side shock peaks at around the fourth quarter after the shock and returns to its steady-state level after approximately 20 quarters. The response of inflation is of a similar magnitude as the response generated by the SVAR(2), albeit longer lasting. The interest rate increases considerably in response to a demand shock as the RBA tightens monetary policy in reaction to increasing inflationary expectations.

In response to an AS shock, which can be thought of as a price mark-up shock, the output gap decreases at impact, bottoming out after approximately 4 to 5 quarters. It then slowly returns to its steady-state level within about 25 quarters. The response of the output gap is not very pronounced at its trough, but is sustained for a number of periods. Notice here that, although insignificant, the SVAR(2) response moves in the wrong direc-

[9] The results of this comparison are available form the authors upon request. This exercise also provides a robustness check of whether foreign variables should be included in the MP reaction function.

tion, suggesting that a positive AS shock leads to a mild increase in output. The response of inflation to the AS shock is, as expected, more notable and peaks after two quarters. It also appears to last longer in the NKPM than the SVAR(2). The opposite response of output to an AS shock demonstrates the well known dilemma for policy makers of how to respond to such a shock. In our case the estimated response of the RBA is significantly positive, i.e., the interest rate rises in response to an AS shock, peaking after about 5 quarters and staying in effect for a number of quarters. The clear tightening of monetary policy by the RBA in response to the AS shock is attributable to the high and sustained response of inflation to this shock. The output gap responds instantly to an unexpected monetary policy tightening. This lasts for about 6 quarters. The response of inflation to a monetary policy shock is rather mild at impact, reaching its maximum after around 4 quarters, but with a sustained effect that lasts for approximately 12 quarters in total.

4.4. The transmission of foreign shocks

The first column of Figure 3 captures the responses of domestic variables to a foreign demand shock. A positive foreign IS shock causes an increase in the domestic output gap, with the maximum response at impact, lasting for almost 10 quarters. This positive foreign IS shock also results in an increase in domestic inflation, where the response of inflation peaks after 6 quarters and then slowly returns back to its steady-state level. The interest rate, therefore, increases as a result of this shock, as the RBA tightens its monetary policy in view of the widening output gap and increasing inflation. As can be seen in the second column of Figure 3, the foreign supply shock has only a limited impact on domestic variables. We can observe a very mild negative response of domestic output to the foreign AS shock. Domestic inflation increases also very mildly in response to the foreign AS shock. Monetary policy decisions appear to be largely set without any consideration of foreign supply shocks. This is implied by the small response of the MP instrument to the foreign AS shock. The third column of Figure 3 shows the impact of a foreign monetary policy shock on domestic variables. One can notice that the responses of all domestic variables to such a shock are, as with the foreign AS shock, rather contained. A positive foreign monetary policy shock has a mild negative effect on domestic output due to its negative impact on foreign demand and appreciating effect on the real exchange rate. The response of inflation to the foreign MP shock is only marginally positive, staying close to zero. The response of the domestic interest rate is also insignificant.

The small impact of foreign AS and MP shocks on domestic variables can be linked to the small role the real exchange rate plays in the determination of the domestic output gap and CPI inflation. This is largely due to the fact that foreign AS and MP shocks impact on the domestic economy only through the real exchange rate channel. Their impact is thus determined by the size of the δ_2 and λ_2 coefficients in the model. As reported in Table 3, the parameter estimates of these were rather small. The impact of foreign demand on domestic output is much more pronounced. We can see this from the magnitude of the estimate of δ_3. We should note here that the impact of foreign demand on the domestic economy is somewhat diminished through the real exchange rate channel, as the foreign real interest rate increases in response to a positive foreign output gap, and the exchange rate appreciates at time t in line with the UIP condition.

Although the exchange rate shock is estimated to be quite sizable when compared to other shocks in the system and highly persistent, its impact on domestic variables is moderate. We attribute this to the mild response of the Australian economy to real exchange rate movements represented by the relatively small estimates of δ_2 and λ_2. Still, there appears to be a significantly positive response of domestic output to a real exchange rate depreciation. Also, inflation increases significantly in response to a real exchange rate shock, reaching its peak after 5 quarters, before returning slowly back to its steady-state level. Since an unexpected real exchange rate depreciation increases domestic output and inflation, the RBA tries to offset the impacts of this shock by raising interest rates.

We conclude this section by summarising the relative importance of the individual shocks on the domestic economy. A convenient way to present this information is to use a (long-run) variance decomposition, showing the influence of all shocks in the system on each of the domestic variables. We present this information in matrix form in (9) below.

$$\begin{array}{c|ccccccc} & \epsilon_{IS,t} & \epsilon_{AS,t} & \epsilon_{MP,t} & \epsilon^*_{IS,t} & \epsilon^*_{AS,t} & \epsilon^*_{MP,t} & \epsilon_{RER,t} \\ \hline y_t & 71.59 & 8.82 & 0.86 & 15.79 & 0.03 & 0.16 & 2.75 \\ \pi_t & 1.98 & 51.19 & 0.34 & 19.26 & 0.03 & 0.07 & 27.13 \\ r_t & 26.75 & 19.84 & 11.14 & 24.03 & 0.01 & 0.04 & 18.19 \end{array} \tag{9}$$

In this matrix, the rows show the domestic variables whose variance is being decomposed, and the columns indicate which shocks contribute (in per cent) to this decomposition. For example, the first row shows the variance decomposition of the domestic output gap, where domestic demand shocks denoted by $\epsilon_{IS,t}$ contribute 71.59% to the variance of y_t, domestic supply shocks denoted by $\epsilon_{AS,t}$ contribute 8.82%, domestic monetary policy shocks labelled $\epsilon_{MP,t}$ contribute 0.86%, and so forth.

The variance decomposition in (9) indicates that the Australian output gap responds most to domestic IS shocks, which explain around 72% of its variance. Also, US demand shocks account for approximately 16% of the variation in y_t, with domestic supply shocks making up the third largest component at 9%. The influence of exchange rate shocks is small, accounting for about 3% of the variation in domestic output. These results are broadly in line with the findings in Dungey and Pagan (2000), (see pages 332 and 334 and figures 22 to 26), who decompose output into its shock components over time. The role of US demand shocks is somewhat bigger in Dungey and Pagan (2000) at the beginning of the sample, with the importance of domestic demand shocks growing over time. [10] Australian inflation is mainly influenced by domestic AS shocks, shocks to the real exchange rate, and foreign demand shocks, contributing respectively 51%, 27% and 19% to the variation in π_t. The decomposition of domestic interest rates appears to be rather equally dispersed between domestic demand and supply shocks, accounting for 27% and 20%, and foreign demand and real exchange rate shocks, making up 24% and 18% of the variation in r_t.

[10] Dungey and Pagan (2000) also include Tobin's Q ratios for Australia and the US and the terms of trade as variables in their SVAR model, with the latter two also being influential on domestic output.

5. Conclusion

A two-block open economy New Keynesian policy model was estimated for Australia. The exogenous rest-of-the world block in our model is approximated by the US economy. Using a structural model for the US block enabled us to identify and label foreign shocks within a model consistent framework and to isolate their impact on the Australian economy. The model employed for the Australian economy followed a similar structure to the one proposed by Svensson (2000), featuring three main transmission channels of foreign shocks into the domestic economy. Two of these impact upon domestic demand through exchange rate movements and changes in foreign demand, while the third one influences domestic CPI inflation directly through the effect of the exchange rate.

The results of our analysis suggest that domestic and foreign demand shocks and, to some extent, domestic supply shocks are the most influential in affecting the Australian business cycle. The effect of real exchange rate shocks on output is only mild. Inflation, on the other hand, appears to be most sensitive to movements in domestic supply shocks, shocks occurring to the real exchange rate and, to a lesser degree, foreign demand shocks. Shocks to the real exchange rate could involve terms of trade shocks or confidence shocks related to the Australian dollar. The impact of domestic monetary policy shocks on domestic inflation appears to be rather mild. The domestic interest rate is mainly influenced by domestic and foreign demand shocks, and domestic supply and real exchange rate shocks. When assessing the impact of foreign shocks, we find that US demand shocks and shocks to the real exchange rate have the largest impact on the Australian economy. These are noticeably larger than domestic monetary policy shocks. Foreign supply and foreign monetary policy shocks, on the other hand, do not appear to have a significant impact on domestic variables.

The policy implications of our results concern mainly the impact of world demand and exchange rate shocks on the Australian economy. Although domestic shocks are the most influential in affecting macroeconomic stability in Australia, we find some evidence suggesting that unexpected changes in foreign demand and the exchange rate also play an important role. The potential impact of the latter two shocks should thus be emphasised in debates concerning the appropriate stance of monetary policy in Australia.

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Tables and Figures

(1)		(2)		(3)	(4)
Parameters		Bayesian Posterior		Cho & Moreno (2006)	GMM
	Prior	Mean	95% CI	Range Reported	
ρ_π^*	$\mathcal{B}\,(0.6, 0.20)$	0.6571	[0.5980, 0.7751]	[0.5241, 0.5752]	0.7545
λ^*	$\mathcal{N}\,(0.01, 0.20)$	0.0341	[0.0181, 0.0583]	[−0.0002, 0.0023]	0.0806
ρ_y^*	$\mathcal{B}\,(0.5, 0.20)$	0.5214	[0.4740, 0.5466]	[0.4801, 0.5026]	0.4221
δ^*	$\mathcal{N}\,(0.01, 0.20)$	0.0031	[0.0013, 0.0049]	[0.0017, 0.0065]	0.0055
ρ_r^*	$\mathcal{B}\,(0.8, 0.20)$	0.8179	[0.7693, 0.8701]	[0.7761, 0.9023]	0.8609
ψ_1^*	$\mathcal{N}\,(1.65, 0.20)$	1.6162	[1.3166, 1.9425]	[1.6409, 2.1506]	1.8659
ψ_2^*	$\mathcal{N}\,(1.25, 0.20)$	1.3343	[1.0081, 1.6186]	[0.4007, 1.1366]	1.1380
$\rho_{\epsilon_{AS}}^*$	$\mathcal{N}\,(-0.22, 0.20)$	−0.2249	[−0.3829, −0.0161]	−0.3213	NA
$\rho_{\epsilon_{IS}}^*$	$\mathcal{N}\,(0.13, 0.20)$	0.1472	[0.0587, 0.2554]	0.3555	NA
σ_{AS}^*	$\mathcal{IG}\,(0.5, 0.30)$	0.8479	[0.7119, 1.0247]	[0.4585, 0.5123]	1.1956
σ_{IS}^*	$\mathcal{IG}\,(0.4, 0.30)$	0.2191	[0.1943, 0.4004]	[0.3460, 0.3951]	0.3042
σ_{MP}^*	$\mathcal{IG}\,(0.8, 0.30)$	0.4519	[0.4277, 0.5475]	[0.7085, 0.9918]	0.4950

Table 1: Parameter estimates of the exogenous U.S. block. The entries under heading (1) show the parameters of interest and the priors imposed on them. Under heading (2) the Bayesian Posterior mean and 95% confidence intervals are shown. Entries under (3) and (4) give the parameter estimates of Cho and Moreno (2006) and GMM ones respectively. $\mathcal{B}\,(a,b)\,,\mathcal{N}\,(a,b)$ and $\mathcal{IG}\,(a,b)$ are the Beta, Normal and Inverse Gamma densities respectively, with a and b being location and scale parameters. ρ_ϵ^* and σ^* are respectively the autocorrelation and standard deviation of the structural shocks.

The model equations are:

$$
\begin{aligned}
\pi_t^* &= \rho_\pi^* \mathbb{E}_t \pi_{t+1}^* + (1-\rho_\pi^*)\,\pi_{t-1}^* + \lambda^* y_t^* + \epsilon_{AS,t}^* \\
y_t^* &= \rho_y^* \mathbb{E}_t y_{t+1}^* + (1-\rho_y^*) y_{t-1}^* - \delta^* (r_{t-1}^* - \mathbb{E}_{t-1}\pi_t^*) + \epsilon_{IS,t}^* \\
r_t^* &= \rho_r^* r_{t-1}^* + (1-\rho_r^*)\left(\psi_1^* \mathbb{E}_t \pi_{t+1}^* + \psi_2^* y_t^*\right) + \epsilon_{MP,t}^*
\end{aligned}
$$

(1) Moments	(2) Sample			(3) Theoretical		
	y_t^*	π_t^*	r_t^*	y_t^*	π_t^*	r_t^*
σ^2	0.8541	1.4934	2.3223	0.8005	1.4059	2.3146
$ACF(1)$	0.8799	0.3891	0.9264	0.8677	0.4070	0.9319
$ACF(2)$	0.7285	0.2364	0.7891	0.7181	0.2838	0.8484
$ACF(3)$	0.5143	0.2776	0.6267	0.5842	0.1647	0.7578
$ACF(4)$	0.3325	0.0389	0.4669	0.4690	0.1048	0.6659
$ACF(5)$	0.1493	0.1098	0.3150	0.3716	0.0652	0.5767
$ACF(6)$	−0.0183	0.1491	0.1665	0.2903	0.0405	0.4929
$ACF(7)$	−0.1664	0.0966	0.0153	0.2230	0.0241	0.4161
$ACF(8)$	−0.2862	−0.0623	−0.1304	0.1681	0.0132	0.3470
$Corr(y_t^*, \pi_t^*)$		0.3208			0.3477	
$Corr(y_t^*, r_t^*)$		0.6785			0.6406	
$Corr(r_t^*, \pi_t^*)$		0.3119			0.3302	

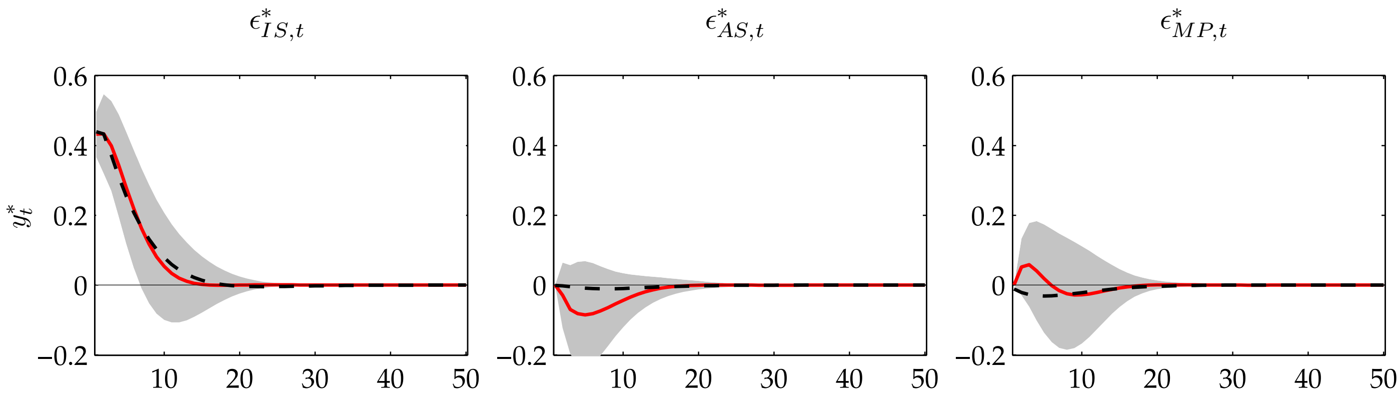
Table 2: Comparison of implied theoretical moments of the NKPM and empirical sample moments. ACF is the autocorrelations function. $Corr$ denotes standard correlation.

(1)		(2)		(3)
Parameter		Bayesian Posterior		GMM
	Prior	Mean	95% CI	
ρ_π	$\mathcal{B}(0.50, 0.20)$	0.4794	[0.4163, 0.5409]	0.4352
λ_1	$\mathcal{N}(0.01, 0.20)$	0.0162	[0.0061, 0.0232]	0.0048
λ_2	$\mathcal{N}(0.001, 0.20)$	0.0011	[0.0004, 0.0019]	0.0014
ρ_y	$\mathcal{B}(0.80, 0.20)$	0.7219	[0.6414, 0.7993]	0.5021
δ_1	$\mathcal{N}(0.015, 0.01)$	0.0171	[0.0016, 0.0266]	0.0024
δ_2	$\mathcal{N}(0.002, 0.10)$	0.0027	[0.0012, 0.0034]	-0.0002
δ_3	$\mathcal{N}(0.05, 0.10)$	0.0718	[0.0354, 0.1067]	0.0303
ρ_r	$\mathcal{B}(0.65, 0.20)$	0.6735	[0.6279, 0.7360]	0.7558
ψ_1	$\mathcal{N}(1.65, 0.20)$	1.6792	[1.5829, 1.7838]	0.8971
ψ_2	$\mathcal{N}(1.25, 0.20)$	1.2306	[1.0808, 1.3778]	1.6523
$\rho_{\epsilon_{IS}}$	$\mathcal{B}(0.60, 0.10)$	0.4522	[0.3114, 0.5793]	NA
$\rho_{\epsilon_{AS}}$	$\mathcal{B}(0.45, 0.20)$	0.7289	[0.7115, 0.7437]	NA
$\rho_{\epsilon_{RER}}$	$\mathcal{B}(0.70, 0.20)$	0.8818	[0.8365, 0.9121]	NA
σ_{IS}	$\mathcal{IG}(0.15, 0.20)$	0.1163	[0.0843, 0.1405]	0.4340
σ_{AS}	$\mathcal{IG}(0.10, 0.20)$	0.1848	[0.1602, 0.2085]	0.1834
σ_{MP}	$\mathcal{IG}(1.0, 0.20)$	0.8966	[0.7786, 1.0069]	0.8399
σ_{RER}	$\mathcal{IG}(4.0, 0.20)$	1.1623	[0.7577, 1.5973]	5.3501

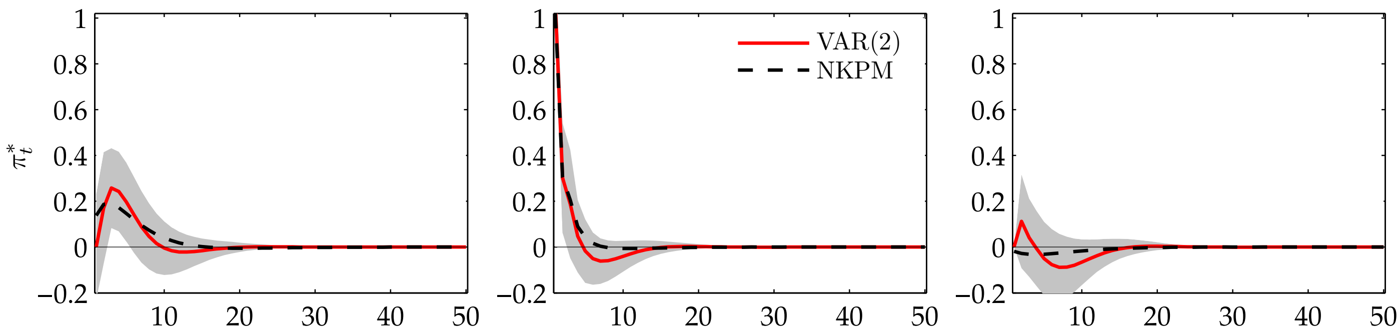
Table 3: Parameter estimates of the domestic block. The entries under heading (1) show the parameters of interest and the priors imposed on them. Under heading (2) the Bayesian Posterior mean and 95% confidence intervals are shown. Entries under (4) give GMM parameter estimates. $\mathcal{B}(a,b)$, $\mathcal{N}(a,b)$ and $\mathcal{IG}(a,b)$ are the Beta, Normal and Inverse Gamma densities respectively, with a and b being location and scale parameters. ρ_ϵ and σ are respectively the autocorrelation and standard deviation of the structural shocks.

The model equations are:

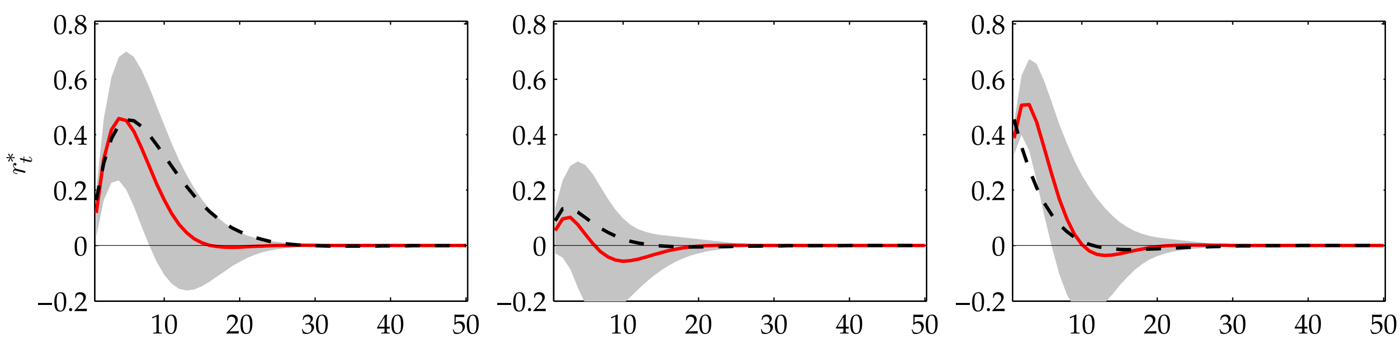
$$
\begin{aligned}
\pi_t^* &= \rho_\pi^* \mathbb{E}_t \pi_{t+1}^* + (1-\rho_\pi^*)\,\pi_{t-1}^* + \lambda^* y_t^* + \epsilon_{AS,t}^* \\
y_t^* &= \rho_y^* \mathbb{E}_t y_{t+1}^* + (1-\rho_y^*) y_{t-1}^* - \delta^* (r_{t-1}^* - \mathbb{E}_{t-1}\pi_t^*) + \epsilon_{IS,t}^* \\
r_t^* &= \rho_r^* r_{t-1}^* + (1-\rho_r^*)\left(\psi_1^* \mathbb{E}_t \pi_{t+1}^* + \psi_2^* y_t^*\right) + \epsilon_{MP,t}^* \\
\pi_t &= \rho_\pi \mathbb{E}_t \pi_{t+1} + (1-\rho_\pi)\,\pi_{t-1} + \lambda_1 y_t + \lambda_2 q_t + \epsilon_{AS,t} \\
y_t &= \rho_y \mathbb{E}_t y_{t+1} + (1-\rho_y) y_{t-1} - \delta_1 (r_{t-1} - \mathbb{E}_{t-1}\pi_t) + \delta_2 q_{t-1} + \delta_3 y_t^* + \epsilon_{IS,t} \\
r_t &= \rho_r r_{t-1} + (1-\rho_r)(\psi_1 \mathbb{E}_t \pi_{t+1} + \psi_2 y_t) + \epsilon_{MP,t} \\
\mathbb{E}_t \Delta q_{t+1} &= (r_t - \mathbb{E}_t \pi_{t+1}) - \left(r_t^* - \mathbb{E}_t \pi_{t+1}^*\right) - \epsilon_{RER,t}
\end{aligned}
$$



(a) Response of y^*_t to shocks in $\boldsymbol{\epsilon}^*_t$

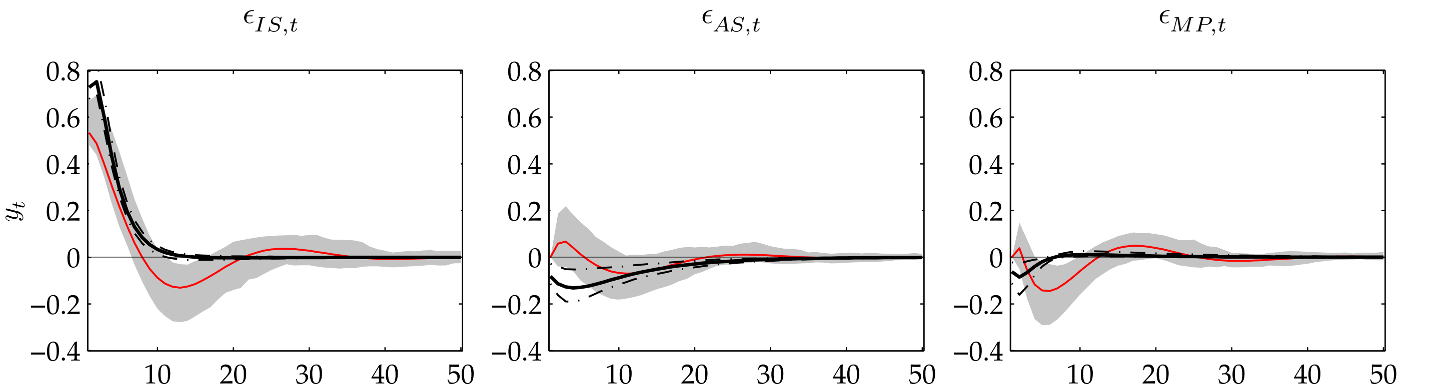


(b) Response of π^*_t to shocks in $\boldsymbol{\epsilon}^*_t$

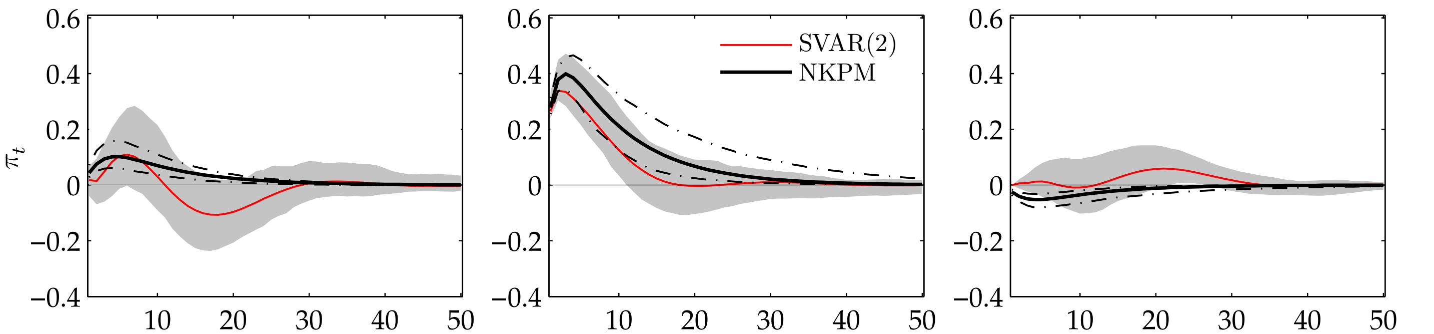


(c) Response of r^*_t to shocks in $\boldsymbol{\epsilon}^*_t$

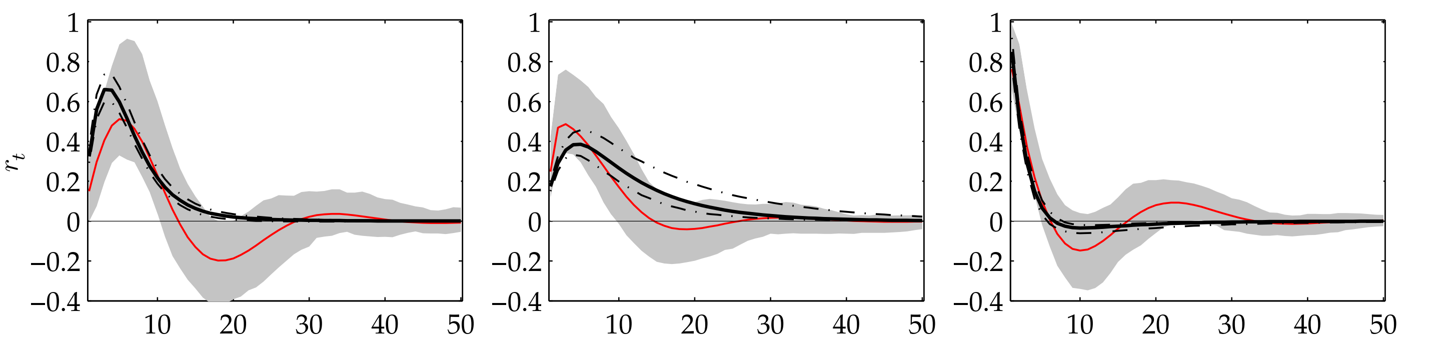
Figure 1: Comparisons of VAR(1) and NKPM impulse responses for the U.S. block. Shaded area is the approximate 95% confidence interval of the VAR(1).



(a) Response of y_t to shocks in $\boldsymbol{\epsilon}_t$

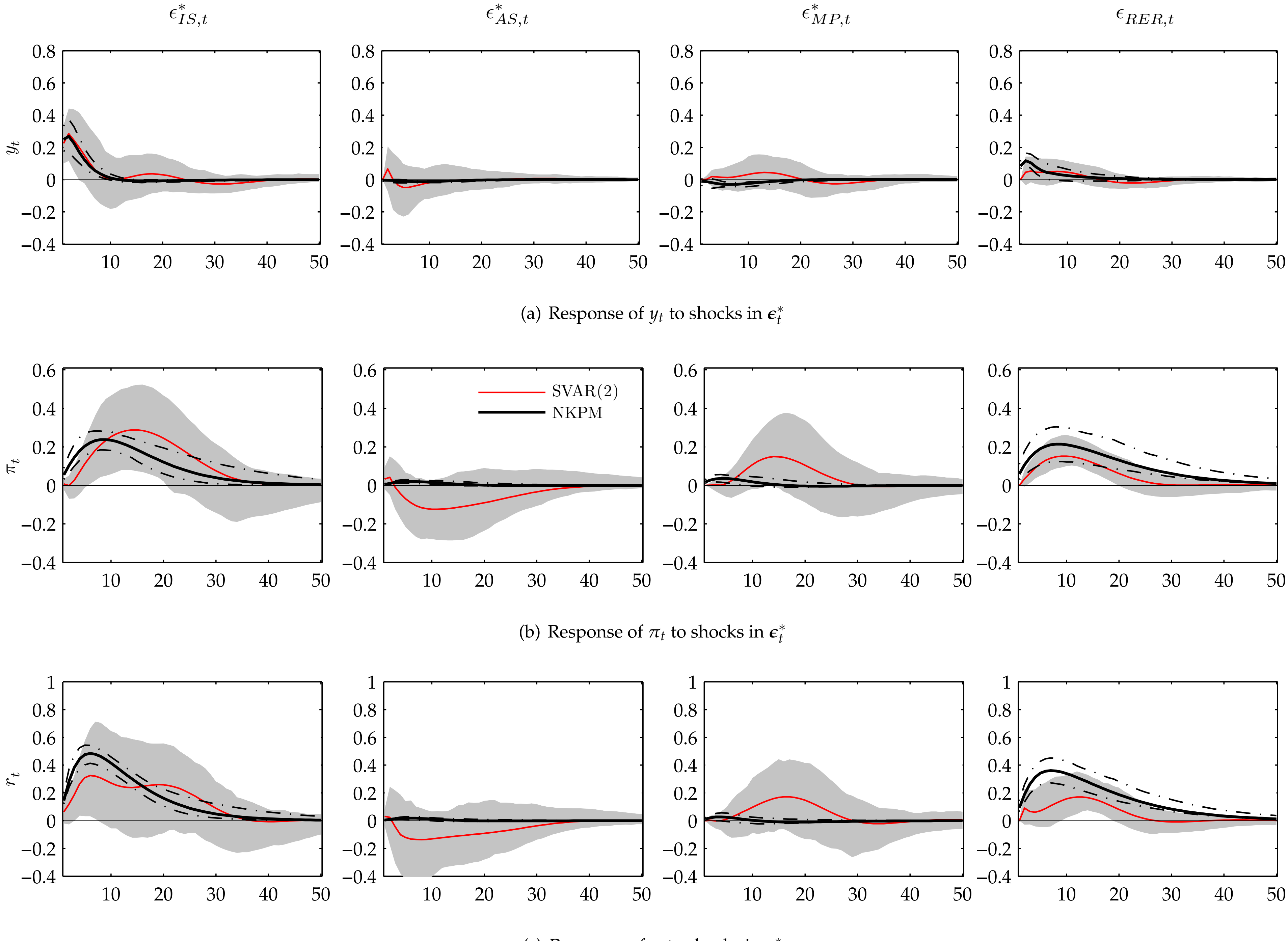


(b) Response of π_t to shocks in $\boldsymbol{\epsilon}_t$



(c) Response of r_t to shocks in $\boldsymbol{\epsilon}_t$

Figure 2: Comparison of domestic SVAR(2) and NKPM impulse responses to domestic shocks. Shaded areas denote bootstrapped 95% confidence intervals for the SVAR(2). Dash-dotted lines denote the Bayesian posterior 95% confidence intervals for the NKPM.



(a) Response of y_t to shocks in $\boldsymbol{\epsilon}^*_t$

(b) Response of π_t to shocks in $\boldsymbol{\epsilon}^*_t$

(c) Response of r_t to shocks in $\boldsymbol{\epsilon}^*_t$

Figure 3: Comparisons of domestic SVAR(2) and NKPM impulse responses to foreign shocks. Shaded areas denote bootstrapped 95% confidence intervals for the SVAR(2). Dash-dotted lines denote the Bayesian posterior 95% confidence intervals for the NKPM.