Fiscal and Monetary Policy in Australia: an SVAR Model[*]

Mardi Dungey[*%+] and Renée Fry[+%]
* University of Tasmania,
% CFAP, University of Cambridge
+ CAMA, Australian National University

August 13, 2010

Abstract

Monetary and fiscal policy actions are designed to influence economic outcomes. Their interactions may have important, and sometimes contradictory, impacts. This paper incorporates fiscal and monetary policy shocks into a small open economy SVAR model of the Australian economy, incorporating identification by combining sign restrictions, exclusion restrictions and cointegration, while directly recognising the mixed non-stationary and stationary nature of the relevant variables. The results over the period to 2006 show the impact of government expenditure and revenue shocks on output and debt particularly, indicating the changes in interest rates occuring in response to fiscal policy shocks. Contractionary monetary policy shocks result in reduced government revenue, but are also associated with reduced debt to GDP ratios. Ongoing work examines the contribution of policy responses to the behaviour of this economy during the Global Financial crisis.

1 Introduction

Fiscal and monetary policy actions have both had important roles to play in defending many economies from the ravages of the Global Financial Crisis (GFC) of 2007-08. In the case of Australia, a significant fiscal stimulus package of \$A42billion (approximately 4% of annual GDP) was launched in 2008 in an attempt to forestall a potential recession. At the same time, around the world monetary policy was eased, often dramatically. Australian cash rates (the announced target rate) were rising until March 2008 to peak at 7.25%. They remained at this level until they were dropped by 125 basis points over September and October meetings of the central bank in 2008. In a further 4 moves by the Reserve Bank of Australia the cash rate dropped substantially to 3% by April 2009. The feature of monetary policy in Australia during this time is that interest rates were not reduced below a nominal 3% rate, thereby not inducing negative real interest rates. This is in contrast to many economies around the world where nominal rates dropped either to, or very close to 0%, with substantially negative real interest rates evident in many developed economies, in particular the US and the UK.

Policy actions in the light of the GFC have restimulated interest in modelling fiscal policy and particularly the interaction between monetary and fiscal policy shocks. Prior to the crisis a small body of literature had emerged attempting to resolve the identification problems inherent in including government revenue and government expenditure variables in the data coherent structural vector autoregression (SVAR) framework which provides an empirical benchmark for modelling many economies.

The SVAR approach to macroeconomic modelling attempts to provide a data coherent representation of the major macroeconomic variables of an economy. The choices of variables to be included are often contentious. However, even more difficult are the choices required to identify these models, given that estimation of the full dynamics of relationships between any n variables in n equations is not possible. There are a number of identification

choices in the existing literature; in particular exclusion restrictions, which are a specific form of parameter restriction, long run restrictions, which effectively restrict combinations of parameters, cointegration restrictions and sign restrictions. Fry and Pagan (2010) stress that each form of parameter restriction has its own disadvantages, with currently little means other than researcher judgement for selecting between them.

Because each identification methodology has some advantages (and disadvantages) it seems most appropriate to capitalise on these. Dungey and Fry (2009) propose a mixture of parameter, cointegration and sign restrictions in order to identify both monetary and fiscal policy shocks for a small open economy. This paper similarly applies the combination of the three types of restrictions to modelling fiscal and monetary policy in Australia for the period leading up to the Global Financial Crisis.

The SVAR model of the Australian economy is based on Dungey and Pagan (2009) which extended Dungey and Pagan (2000). Dungey and Pagan (2009) is an 11 variable small open economy SVAR model to specifically account for the mixed stationary and non-stationary nature of the data, and to incorporate the cointegration relationships supported by the data, thus explicitly recognising differences between permanent and temporary shocks in the model. Short run exclusion restrictions are also used to identify the model. Both of these papers include only the monetary policy aspects of the Australian economy. The current paper introduces fiscal policy shocks.

Fiscal policy has been only a relatively recent addition to the SVAR literature. Blanchard and Perotti (2002) and Perotti (2002) first introduced the identification of government revenue and government expenditure shocks in a single SVAR model using institutional features of the data to separate the identification of the two types of shocks. Chung and Leeper (2007) and Favero and Giavazzi (2007) use calibrated elasticities to achieve their identification. More recently, the use of sign restrictions has become a more popular method of identifying fiscal policy; see for example Canova and Pappa (2008); and

Mountford and Uhlig (2009).

Combining these three methodologies in a practical application proves to be challenging. In particular, the sources for justifying individual restrictions must be justified Following much of the literature, the base SVAR model used here draws on insights from standard DSGE models to inform these choices. Monetary policy shocks are identified in this manner. The fiscal shocks are identified using sign restrictions and we explicitly include recognition of cointegrating relationships between the data. In this paper we specifically recognise a number of the difficulties explicit in the use of sign restrictions; in particular that the structural errors for the shocks identified with sign restrictions are not separable from the estimate of the impulse response function parameters, thus leading to implementation problems for calculating many of the traditional tools of VAR analysis; including forecast error variance decompositions, historical decompositions and confidence bands for impulse responses. In the final section we present some recent ideas for attacking some of those problems.

The rest of this paper proceeds as follows. Section 2 presents the three different identification restrictions used in estimating the fiscal and monetary policy VAR. Section 3 outlines the structure of the Australian monetary and fiscal policy VAR model (MF_SVAR), followed by a description of the data properties. Section 5 presents the estimation results and discussion while Section 6 concludes.

2 The Empirical Methodology

A standard VAR(p) for a vector of data Y_t can be written as,

$$B(L)Y_t = \varepsilon_t, \tag{1}$$

where $B(L) = B_0 - B_1 L - B_2 L^2 - \ldots - B_p L^p$.

Three forms of identification restrictions on this system are used in the application of this paper. The first is simple exclusion restrictions, which

3

restrict some elements of the coefficient matrices $B(L)$ to zero values. The second restriction is via cointegration. Regardless of the order of integration of the variables contained in Y_t equation (1) can be written in VECM form as

$$\Psi(L)\Delta Y_t = -\Pi Y_{t-1} + e_t, \tag{2}$$

where what is made particularly obvious by this representation is that in the case of r cointegrating relationships between the $n > r$ non-stationary variables in Y_t the matrix $\Pi = \alpha'\beta$ will be of reduced rank while α and β are of full rank. In the case where a number of the variables in Y_t are $I(0)$ this is simply included by recognising that any stationary variable in levels can be written as a sum of differences and a levels effect - so that where the levels effect is concentrated on the first lag of the variable the response to that variable is incorporated by a unit value for the appropriate β parameter.

The combination of $I(0)$ and $I(1)$ variables in a system where the number of cointegrating vectors is less than the number of non-stationary variables implies that there are both temporary and permanent shocks in the system. Specifically, in a system of k stationary variables and n non-stationary variables with $r < n$ cointegrating vectors, there will be $k + r$ temporary shocks and $n - r$ permanent shocks. In a common trends representation

$$\Delta Y_t = F(L)e_t = F(L)(B_0)^{-1}\varepsilon_t, \tag{3}$$

where $F(L) = I_{n+k} + F_1 L + F_2 L^2 + \dots$ and $F(1) = F$ is given by

$$F = \beta_\perp \left[\alpha'_\perp \Psi(L)\beta_\perp\right]\alpha_\perp^{-1}, \tag{4}$$

with $\alpha'_\perp \alpha = 0$, $\beta'_\perp \beta = 0$, $F\alpha = 0$ and $\beta'F = 0$. The matrix $\alpha'_\perp$ corresponds to the H matrix used in Levtchenova, Pagan and Roberston (1998) to partition permanent and temporary shocks. Pagan and Pesaran (2008) point out that if the first $(n - r)$ shocks are permanent then

$$\Delta Y_t = F(L)(B_0)^{-1}\begin{pmatrix}\varepsilon_{1jt} \\ \varepsilon_{2jt}\end{pmatrix}, \tag{5}$$

4

which implies that for the shocks in the second group, ε_{2jt}, to be transitory requires

$$FB_0^{-1} \left(\begin{array}{c} 0_{(n-r)\times r} \\ I_{r+k} \end{array} \right) = 0, \tag{6}$$

which is equivalently

$$FB_0^{*-1} \left(\begin{array}{c} 0_{(n-r)\times r} \\ I_{r+k} \end{array} \right) = F\alpha = 0. \tag{7}$$

Premultiplying by $B_0 F^{-1}$ leaves

$$\left(\begin{array}{c} 0_{(n-r)\times r} \\ I_{r+k} \end{array} \right) = B_0\alpha = 0. \tag{8}$$

The right hand side of equation (8) can be multiplied by an arbitrary non-singular matrix R

$$\left(\begin{array}{c} 0_{(n-r)\times r} \\ I_{r+k} \end{array} \right) = B_0\alpha R = \alpha R = \left(\begin{array}{c} \alpha_1 R \\ \alpha_2 R \end{array} \right). \tag{9}$$

To satisfy this equation requires that $\alpha_1 = 0$, with the direct consequence that structural equations which contain permanent shocks have a zero weight on the error correction terms in a structural equations, while temporary shocks are not restricted. In some systems this can provide an extra identifying instrument if required.

The final identification method used in this paper is that of sign restrictions. This methodology is particularly useful for identifying between government expenditure and revenue shocks, where theoretical restrictions provide an effective means of distinguishing between the impact of shocks which are not easily identified using purely empirical dynamics. The methodology proceeds from an initial estimate of the system without sign restrictions, which will represent one particular outcome of the model and produces estimates of the structural residuals, $\widehat{\varepsilon}_t$; We define $\widehat{S}$ as a diagonal matrix of these standard deviations with zero off-diagonal elements. The estimates of reduced form and structural residuals are related as follows:

$$\begin{aligned} \widehat{e}_t &= \widehat{B}_0^{-1}\widehat{S}\widehat{S}^{-1}\widehat{\varepsilon}_t \\ &= T\eta_t, \end{aligned} \tag{10}$$

5

where T is designated an impact matrix, and η_t are the estimated shocks with unit variances. Alternative specifications may also match the estimated reduced form residuals, the multiple models problem of Fry and Pagan (2010). That is the original shocks can be redefined as a function of an orthonormal matrix Q, where $Q'Q = QQ' = I$ such that

$$\widehat{e}_t = TQ'Q\eta_t \qquad (11)$$
$$= T^*\eta_t^*. \qquad (12)$$

Both η_t and η_t^* estimated shocks have an identity matrix for their covariance matrix, but will have different impulse responses impacting on Y_t. The rotations of the original shocks produce alternative sets of shocks which retain the property of orthogonality but produce alternative impulse responses. A popular choice for Q is the Givens rotation matrix, implemented in this paper, where the sign restrictions method is used only to identify two shocks. In larger systems of sign restrictions the Householder Transformation may provide a computationally more efficient method. The final choice of Q by the researcher is undertaken by selecting impulse responses with desired signs, thus the notation 'sign restrictions' for this form of identification. Ultimately, once Q has been chosen, the corresponding coefficient matrix can be defined as $B_0^* = (T^*S^{-1})^{-1}$, and $B_i^* = B_i$ for all $i \neq 0$. All of the cointegrating and exclusion restriction identification methods previously discussed can be applied to a system which incorporates sign restrictions to some or all of its components.

Impulse response functions To extract impulse response functions for a system of $I(1)$ and $I(0)$ variables with cointegrating relationships and a combination of permanent and temporary shocks a further reformulation of the VECM system to a SVAR is useful. The permanent components in the system may be written as a Beveridge-Nelson decomposition

$$\Delta\gamma = \zeta_t, \qquad (13)$$

6

where ζ_t is white noise. Then denote the permanent component of a series y_{it} as y_{it}^p which in general can be written as $y_{it}^p = J\gamma_{it}$ where

$$J = FB_0^{*-1}. \tag{14}$$

This consequently means that $\beta'J = 0$.

Using the permanent and temporary components of the system the VECM can be transformed into a so-called gaps SVAR form as in Dungey and Pagan (2009), who explicitly recognise that a number of existing models which use this do not specifically include the remaining lags of the permanent variables, thus missing an important aspect of the transformation. Denote the transitory component of the variables as $\omega_t = \left(y_t - y_t^P\right)$, the correct transformation of the SVECM into a SVAR is

$$B^*(L)\Delta\omega_t = \Pi\omega_{t-1} + \sum_{j=1}^{p-1} B_j^*\Delta y_{t-j}^P + \varepsilon_t. \tag{15}$$

Rearranging and recognising that $\Delta y_t^p = J\varepsilon_t$ means the system can be written as

$$\widetilde{B}(L)y_t = \Pi y_{t-1} + -\widetilde{B}(L)J\varepsilon_t + (B_0^*)^{-1}\varepsilon_t, \tag{16}$$

where $\widetilde{B}(L) = I_n - \widetilde{B}_1 L - \widetilde{B}_2 L^2 - \dots \widetilde{B}_p L^p$. Rewriting (16) as a moving average in ε_t provides the expression

$$G(L)y_t = J(L)\varepsilon_t, \tag{17}$$

and impulse responses are computed in the usual manner. The long run effects are apparent through the presence of the J matrix. The response in variable y at horizon j to a shock in ε_{kt} is represented as

$$\frac{\partial y_{t+j}}{\partial \varepsilon_{kt}} = \frac{\partial \omega_{t+j}}{\partial \varepsilon_{kt}} + \frac{\partial y_{t+j}^p}{\partial \varepsilon_{kt}} = \frac{\partial \omega_{t+j}}{\partial \varepsilon_{kt}} + J. \tag{18}$$

3   Fiscal Policy in a Small Open Economy SVAR

The basis of the identification of fiscal policy in conjunction with other important macroeconomic shocks in a small open economy presents several modelling challenges. The combination of techniques illustrated in Dungey and Fry (2009) and above are drawn upon for identification here for the case of Australia, with the work of Dungey and Pagan (2009) representing the basis of the macroeconomic model not related to the fiscal variables. The Dungey and Pagan (2009) framework is shown to produce sensible and interpretable empirical results, in particular with no evident price puzzle in the system.

A reasonable representation of an open economy macroeconomic model comprises equations representing the IS curve, a Phillips curve, the monetary policy reaction function and uncovered interest parity, all of which can be readily derived from various New Keynesian specifications, for example Justiano and Preston (2010), Lubik and Schorfheide (2007), and Gali and Monacelli (2005), and these relationships guide the formation of a major part of the SVAR for Australia and also that in Dungey and Pagan (2009). In addition, our model includes equations forming government expenditure, government revenue and the debt to GDP ratio relationships.

The variables in the SVAR model for Australia are summarized by $Y_t = \{y_t^*, s_t, i_t^* - \pi_t^*, q_t^*, x_t, \tau_t, g_t, q_t, \xi_t, d_t, y_t, \pi_t, r_t, \zeta_t\}$ where the first five terms represent influences on the Australian economy originating outside of the domestic economy, specifically overseas activity (US GDP), y_t^*, the terms of trade, s_t, incorporating the impact of commodity prices which is important in the Australian context, the real foreign interest rate, $i_t^* - \pi_t^*$, a proxy for international investment conditions in the form of a q-ratio for the US, q_t^*, and demand for Australian exports, x_t. The small open nature of the Australian economy means that each of these variables is modelled as influencing the Australian economy, but are not themselves directly influenced by Australian conditions.

The Australian economy is represented by government revenue defined as taxation revenue net of transfers, τ_t, government expenditure on consumption and investment g_t, a proxy for domestic investment conditions, q_t, domestic absorption, ξ_t, the government debt to GDP ratio, d_t, domestic output (GDP), y_t, domestic inflation, π_t, the domestic cash rate, r_t and finally the real exchange rate between the domestic and foreign economies, ζ_t.

The variables included in the SVAR for the key domestic equations are given in Table 1, where x represents contemporaneous relationships, and o represents higher order dynamics. Table 1 also reports the properties of each series in terms of the order of integration showing the mixed nature of the variables in the system. In the Sims-style approach to VAR modelling all data enter the VAR in levels, with the cointegrating relationships implicitly captured in the framework. However, more recently, the advantages of utilizing the information within the empirical properties of the data have become apparent, particularly in differentiating the long run relationships from the short-run dynamics and in specifying both permanent and temporary shocks (Pagan and Pesaran, 2008). Following this approach, cointegrating relationships and adjustment terms corresponding to the $I(0)$ variables are represented in Table 1 by an e.

The 14 variables in the model specification include 7 non-stationary variables $\{y_t^*, x_t, \tau_t, g_t, \xi_t, y_t, \zeta_t\}$. Testing supports the existence of three cointegrating vectors between the non-stationary variables and these are an expanded form of those in Dungey and Pagan (2009). The first cointegrating vector adds the fiscal variables τ_t and g_t to the first Dungey and Pagan cointegrating vector which now contains the relationship $\{y_t, y_t^*, x_t, \tau_t, g_t\}$. The second cointegrating vector is designed to ensure fiscal sustainability by allowing for cointegration between government revenue and government expenditure $\{\tau_t, g_t\}$. This structure is supported by Hamilton and Flavin (1986), although Quintos (1995) and Bohn (2007) who discuss fiscal sustainability and cointegration find that this relationship may not be crucial

9

with Quintos (1995) showing that cointegration is sufficient but not necessary and with Bohn (2007) removing sufficiency. However, it is found in this paper that cointegration between τ_t and g_t helps to induce stability into the model. The model introduces a further theoretically motivated, and empirically supported cointegrating vector between τ_t and g_t, although unlike in Dungey and Fry (2009) we do not impose a $[1, -1]$ structure on this relationship. The third cointegrating vector draws directly from Dungey and Pagan and is $\{y, \xi, \zeta\}$. The first and third vectors are normalized on y_t with the second normalized on tax τ_t.

Seven non-stationary variables and 3 cointegrating relationships implies that there are 4 permanent shocks in the system. Shocks to international GDP y_t^*, exports x_t, domestic absorption ξ_t, and GDP y_t, are considered to be permanent. In the Dungey and Pagan model domestic absorption was a temporary shock rather than permanent as is the case here. However, in this specification given that there must exist 4 permanent shocks, the remaining candidate variables are government revenue and expenditure τ_t and g_t and the exchange rate, ζ_t, but these are not particularly attractive for containing permanent shocks. All remaining shocks are temporary.

The fiscal sector of the model consists of government revenue τ_t, expenditure g_t and the debt to GDP ratio d_t. The g_t and τ_t dynamic relationships are unrestricted with respect to all domestic variables, but do not directly respond to, or affect, any internationally determined variables. To separate the shocks to government revenue and expenditure sign restrictions are implemented on the impulse responses of GDP and absorption to these shocks. In particular, the sign restrictions take the following form

$variable/shock$	ξ_t	y_t
τ_t	$-$	
g_t		$+$

which is to say that a positive government revenue shock is negatively related to absorption, and a positive government expenditure shock is positively

10

related to GDP. These restrictions are similar to those in Dungey and Fry (2009). These restrictions are implemented using a Givens rotation matrix

$$Q_{5,6} = \begin{bmatrix} I_5 & & & \\ & \cos(\theta) & -\sin(\theta) & \\ & \sin(\theta) & \cos(\theta) & \\ & & & I_7 \end{bmatrix}$$

rotating the revenue and expenditure variables and responses to them. However, this in itself is insufficient to identify the shocks with complete certainty, as the rotations may result in the impulse response functions reflecting the same shock in a draw twice. That is for example, a tax shock may occur in the impulse response functions relating to both the sixth and seventh shocks. Fry and Pagan (2010) refer to this as the multiple shocks problem. To counteract this problem and to ensure unique identification, if both shocks are identified but there is a duplicate of one shock meaning that one shock reflects both a tax and a government expenditure shock, then the superfluous duplicate shock is labelled as the shock that is not superfluous. There are no cases where both shocks are identified in both sets of impulses meaning that no decision rule was necessary in dealing with that scenario in the empirical application.

The third fiscal variable is the debt to GDP ratio, d_t, which is $I(0)$. While Blanchard and Perotti (2002) and Perotti (2002) simply use government revenue and expenditure to capture fiscal policy in their VAR model, Chung and Leeper (2007) show that such a system will be incorrect without the addition of a measure of government debt in the economy; see also Favero and Giavazzi (2007). Following from these results, the government debt to GDP ratio, d_t, is also included as an important component of fiscal policy for Australia. The debt to GDP ratio equation is similar to that of Dungey and Fry (2009) and also Karam and Pagan (2007). The latter paper, particularly, makes the point that the specification of the debt to GDP ratio should include the terms of trade as an explanatory variable, as a direct result of accounting for the effects of accumulating stocks of debt. The

debt to GDP ratio, d_t, is presumed to evolve in response to s_t, τ_t, g_t and y_t contemporaneously, and with dynamics governed by those variables and itself.

A particular feature of the model is the separate inclusion of absorption and GDP in the model framework, also included for New Zealand in Buckle et al (2007) and Dungey and Fry (2009), Canada in Karam and Pagan (2008) and Brazil and Chile in Catão and Pagan (2009). Empirically, this seems to improve the performance of the model by specifically allowing a role for current account imbalances, but it is also a more general version of representations of the theoretical IS curve where absorption is simply substituted with GDP in the IS equation.

The open economy IS curve follows a DSGE framework such as Monacelli (2005) where relaxing the law of one price allows a role for the exchange rate and by proxy the terms of trade in the IS relationship - although the specification does not specifically accommodate forward looking expectations found in most theoretical frameworks. The Phillips curve and monetary reaction functions are standard for a small open economy, with the inflation rate depending on domestic demand pressures via absorption, and commodity price influences through the terms of trade. Importantly we note that the monetary policy reaction function itself explicitly depends on the absorption gap, rather than level of absorption, and this is specifically accommodated using a Beveridge Nelson representation.

In addition to this standard framework, the role of wealth effects through the equity markets are explicitly recognised by the inclusion of the so-called Q-ratio variables, which represent specifically the ratio of the US S&P500 to the US CPI (q_t^*) and the ASX200 to the Implicit Price deflator for machinery and equipment in Australia (q_t). These two variables provide a direct representation of the role of investment in the economy, and were shown in Dungey and Pagan (2000) to improve model performance and were a key feature of Fry, Hocking and Martin (2008) in another SVAR for Australia focussing on

wealth effects. The exchange rate equation in a NK specification represents the UIP relationship. However, this is empirically unsupported, and hence an unrestricted dynamic relationship between the real exchange rate and all international and domestic variables is entertained in the model.

4 Data

The data for the baseline model of this paper are obtained from the same sources as Dungey and Pagan (2009), and are listed in the Appendix. The model takes the US economy as the benchmark for the international economy GDP and real 3 month interest rates, and represents the foreign investment conditions q_t^* as the ratio of the S&P500 index to the US CPIX. Early work with this model revealed little sensitivity of the results to alternative definitions of international economic conditions. Domestic output, absorption (GNE), short term interest rates and inflation are obtained from standard sources and are detailed more fully in Dungey and Pagan (2000, 2009). Of more interest here are the fiscal variables.

Government net taxation revenue, expenditure and debt figures were obtained directly from the Australian Commonwealth Treasury. The construction of these series specifically entailed construction of quarterly data for the revenue and expenditure series. While it would seem self-evident that fiscal data should be readily available for this type of modelling, in fact this is not the case. Common problems in constructing fiscal data for time series analysis include; insufficient frequency of data, the move from accrual to cash accounts, adjustments for large expenditures associated with defense or large projects, seasonal adjustment and lack of compatibility between component series. Perotti (2002) provides some evidence of the difficulties of data construction, and the consequences of dealing only with published series without adjustments. New Zealand, and now Australia, are two of the few countries where data are available on an appropriate basis. Both taxation and govern-

ment revenue data were smoothed by applying a 3 quarter moving average to account for the lumpiness of data collection.

The debt data is more complicated. Debt figures are available quarterly from the IFS from Quarter 2 1981 to Quarter 2 1988, while the OECD publish quarterly debt data from Quarter 3 1987 to June 2007. The Australian Bureau of Statistics publishes annual data on Australian Australian Government general government sector net debt over the sample period here. To obtain a consistent quarterly data series, the annual ABS data is interpolated using the Chow-Lin (1971) procedure, by using the IFS series as the point of interpolation in the first part of the sample, and by using the OECD data as the point of interpolation for the part of the sample not covered by the IFS data. Once the debt data is transformed into a quarterly series, it is then divided by nominal GDP for use in the model. The interpolated debt data is displayed in Figure 1 along with corresponding annual ABS series.

5   Empirical Results

The application of the three identification methods in the specification outlined above provides results for the impact of shocks labelled as originating in various parts of the model on the endogenous variables. In particular, this paper is focussed on the impact of government expenditure, government revenue and monetary policy shocks. It is usual to label shocks to the residuals in the monetary reaction function as shocks to monetary policy, and that practice is followed here. However, interpreting shocks to government revenue and expenditure shocks are slightly more difficult as it is not possible to directly identify the structural residuals from the modelling procedure, see Fry and Pagan (2010). As the identification is implemented by sign restrictions on the impulse response functions there is nothing to directly identify the residuals from the parameter estimates in these cases. An implication of this is that the shocks are labelled as 1 standard deviation shocks, but there

is no information available as to the scale of that standard deviation. Additionally, this means it is not possible to construct confidence bands from bootstraps of the model, nor provide a traditional forecast error variance decomposition or historical decomposition - all of which depend on knowledge of the parameterisation and/or identification of the errors (or at least the variance of those errors). Consequently in what follows, emphasis is put upon the impulse response function analysis. The shocks reported for variables other than the government expenditure and government revenue shocks are 1 unit shocks, while the g_t and τ_t, shocks are 1 standard deviation, but without any proper measure of what the standard deviation of those shocks are at this point.

5.1 Impulse Responses to Shocks from Exogenous Variables

Selected impulse responses to shocks from exogenous variables are illustrated in Figure 2. A shock to foreign output, y_t^* is permanent in the model and results in a permanent rise in domestic output, y_t, and an associated, but temporary, increase in domestic interest rates to reduce the potential inflationary consequences. As real interest rates increase initially this results in an appreciation of the exchange rate, but ultimately the exchange rate settles at a lower level.

A shock to the terms of trade, s_t increases absoprtion due to the impact of higher incomes for Australians, and the increased demand results in increased taxation revenue with a commensurate sustained decrease in the debt to GDP ratio over the first 7 years after the shock, which is directly associated with a decrease in debt (as GDP does not rise in this period).

Shocks to the foreign financial variables are similar to those previously reported in Dungey and Pagan (2009) for the domestic economy.

The permanent shock to exports, temporarily increase q_t, and permanently increase absorption, ξ_t, and GDP, y_t.(The time at which the level of

15

the permanent effect is established in the model is long giving the appearance that some of these impulses are exploding, but the model is stable and these long response times are a feature of these models).

5.2 Impulse Responses to Shocks From Domestic Variables

This section presents results on the non-policy variables from the domestic economy, but omits the difficult to interpret exchange rate shock.

Real equity price, q_t, shocks

Absorption and GDP are both positively impacted by shocks to the real equity price, q_t, with the effect on GNE being around twice that on GDP, see the first column of Figure 3. This is reflected in an increase in the taxation revenue generated, and a subsequent increase in government expenditure, although for most of the first 8 years increased taxation revenues are sufficient to offset increased expenditure, see the debt to GDP ratio in Figure 3e). The initial inflationary response to increased wealth effects is short and sharp, provoking a quick reaction on the part of the monetary authority with higher cash rates - resulting in higher real interest rates and an appreciation in the currency which dissipates in a few years as shown in Figure 3i).

Absorption, ξ_t, shocks

The permanent shock to ξ_t, increase both absorption and GDP, with the consequence that automatic stabilizers mean that taxation revenue rises and government expenditure falls, leading to a decline in the debt to GDP ratio, see the second column of Figure 3. Inflationary tendencies arising from the increase in absorption are quickly stifled by higher interest rates, but in this case the real interest rate falls and a depreciation of the currency.

Debt to GDP, d_t, shocks

The shock to the debt to GDP ratio has relatively short-lived effects on the economy compared with other shocks examined in the paper. It is somewhat difficult to interpret, as an increase in the debt to GDP ratio could occur

through an increase in debt, with GDP fixed, or a decrease in GDP with debt fixed, or some combination of these events. The impact of the shock on GDP and absoprtion are very small and initially negative, becoming positive at about 18 months after the shock. suggesting that the initial shock is sourced through increased debt rather than decreased GDP. Once activity begins to increase, there is increased taxation revenue, τ_t, and a decrease in government expenditure, g_t, contributing to reducing the debt to GDP ratio. The outcome supports the notion that there is some delay in reducing debt to GDP ratios in economic management.

GDP, y_t, shocks

Shocks to GDP are permanent in this model. In this case the higher GDP results in a decline in government expenditure, see the first column of Figure 4. However, it also decreases absorption and has decreased taxation revenue, resulting in an increased debt to GDP ratio. Because GDP has a negative response to its own shock for a greater than 3 year horizon it takes some time for the declines in government expenditure induced in the model to sufficiently exceed the declines in taxation revenue and return the debt to GDP ratio to equilibrium. Inflation rises initially, but is quickly tackled with short-lived higher interest rates, before easing in response to the declines in activity.

Inflation, π_t, shocks

Inflationary shocks in the model result in declines in absorption, output and investment conditions, q_t. The government expenditure automatic sta-biliser results in an increase in g_t in the first 3 years, but as the debt to GDP ratio increases after this horizon, g_t subsequently declines. In spite of this, taxation revenue increases for a short period. This presumably reflects the nominal structure of the taxation structure, whereby increased prices result in short-term gain to revenue until there is appropriate adjustment of brack-ets and thresholds. The more puzzling response to this shock is the lack of strong positive rise in the interest rate, r_t, to reflect the monetary pol-

17

icy response to the inflationary shock. There is some evidence of a positive response with slight delay, but this is not a sustained response.

5.3   Impulse responses to shocks from policy variables

Impulse responses for the shocks to the three policy variables are shown in the three columns of Figure 5. The first column represents g_t shocks, the second column represents τ_t shocks and the final column the monetary policy shocks.

Government expenditure, g_t, shocks

The immediate effect of a government expenditure shock is to induce a much larger rise in government revenue, thus resulting in a fall in the debt to GDP ratio over the first 5 years after the rise in debt to GDP immediately following the initial shock; Figure 5e). This is clearly the response of the sustainable fiscal policy condition at work in the model. The increase in g_t increases both GDP and absorption. The absorption effect is considerably larger, but given that the model shows a response of lower inflation and an appreciated domestic currency this is consistent with government expenditure in investment and infrastructure rather than direct consumption.

Government net revenue, τ_t, shocks

A government revenue shock, which we can think of as a higher taxation take, is used to reduce the debt to GDP ratio in the model; Figure 5n). Both absorption and GDP decline initially. The immediate consequence for the financial markets in the model is higher real equity prices, shown in Figure 5l) despite the initial decrease in GDP. GDP subsequently picks up, although the increase in short term interest rates is not sufficient to overcome the higher inflation in the first 3 years after the shock, contributing to a depreciated domestic currency.

Interest rate, r_t, shocks

Shocks to interest rates in the model specification have a first period price puzzle, and then act to counter inflationary pressures until the 18 month

mark, as shown in Figure 5y). Subsequently there is strong evidence of price puzzle in that the higher interest rates are associated with increased inflation in the model. This is unlike previous specifications of this model, and deserves further investigation to determine exactly which of the changes made to the specification are contributing to the price puzzle result. The candidate explanations are (i) the introduction of the government expenditure, government revenue and debt to GDP ratio variables (ii) the extension of the cointegrating relationships in the model (iii) modelling both absorption and GDP shocks as permanent. The combination of these three changes requires further unravelling to determine which of them are the contributor to the change in monetary policy shock behaviour observed here. Other responses to the cash rate shock are as expected, with decreases in absorption and GDP and a rise in real equity prices, but a decline in both the government revenue and government expenditure, resulting in a decline in the debt to GDP ratio, as the decline in government expenditure exceeds that of the decline in taxation - meaning that the automatic stabilisers are not acting in the anticipated manner in response to this shock. This aspect of the model provides ample scope for future developments.

6   Conclusion

At this point this research agenda has achieved a model which captures permanent and transitory shocks for a small open economy, in this case Australia, while taking account of the mixed stationary and non-stationary nature of the data which one would wish to include in such a specification. In particular, the paper focuses on the identification of macroeconomic policy shocks, including government expenditure, government revenue and monetary policy shocks. Identification is achieved by a combination of exclusion restrictions, cointegration relationships and sign restrictions. In particular sign restrictions are used to identify government expenditure and revenue

shocks. The model is also augmented with debt following research supporting the crucial role of this variable in achieving stable modelling outcomes. The estimated empirical outcomes indicate that the three types of macroeconomic policy shocks can be successfully identified. Government expenditure and revenue shocks have results which are consistent with theoretically anticipated effects on other segments of the economy, with evidence of automatic stabilisers and adjustment to sustainable debt to GDP conditions. However, unlike a specification without fiscal policy variables, this model does not provide clear evidence of the expected monetary policy reaction to higher inflation - and price puzzle occurs around the 2 year horizon. Resolving this issue is one aspect for the further development of this framework.

Some pressing methodological challenges remain in this application, associated with the recent criticisms of sign restriction based identification in Fry and Pagan (2010). Most importantly, the lack of identification of the reduced or structural form residuals for the government expenditure and revenue shocks hampers the production of confidence bands and historical decompositions. Current work in progress is focussed on attempting to resolve this problem. With those tools it will then be possible to extend the work to examine whether the Australian economy escaped the worst ravages of the Global Financial Crisis due to good economic policy management through offsetting internationally sourced shocks with domestic policy tools, or whether in fact good luck prevailed and the economy was sheltered from the full extent of international shocks.

References

[1] Blanchard, O. and R. Perotti (2002), "An Empirical Characterisation of the Dynamic Effects of Changes in Government Spending and Taxes on Output", *The Quarterly Journal of Economics*, 117, 1329-1368.

[2] Bohn, H. (2007), "Are Stationarity and Cointegration Restrictions Really Necessary for the Intertemporal Budget Constraint?", *Journal of Monetary Economics*, 54, 1837-1847.

[3] Canova, F. and E. Pappa (2007), "Price Differentials in Monetary Unions: The Role of Fiscal Shocks", *The Economic Journal*, 117, 713-737.

[4] Catão, L. and Pagan, A. (2010), "The Credit Channel and Monetary Transmission in Brazil and Chile: A Structured VAR Approach", NCER Working paper #53.

[5] Chow, G.C. and A. Lin (1971), "Best Linear Unbiased Interpolation, Distribution, and Extrapolation of Time Series by Related Series", *The Review of Economics and Statistics*, 53, 372-375.

[6] Chung, H. and E.M. Leeper (2007), "What Has Financed Government Debt?", NBER Working Paper 13425.

[7] Dungey, M. and R. Fry (2009), "Identifying Fiscal and Monetary Policy in a Small Open Economy VAR", *Economic Modelling*, 26, 1147-1160.

[8] Dungey, M. and A.R. Pagan (2010), "Revisiting a SVAR Model of the Australian Economy", *Economic Record,* 85, 1-20.

[9] Dungey, M. and A.R. Pagan (2000), "A Structural VAR Model of the Australian Economy", *Economic Record*, 76, 321-342.

[10] Favero, C.A. and F. Giavazzi (2007), "Debt and the Effects of Fiscal Policy", NBER Working Paper 12822.

[11] Fry, R.A., J. Hocking and V.L. Martin (2008), "The Role of Portfolio Shocks in a SVAR Model of the Australian Economy", *Economic Record*, 264, 17–33.

[12] Fry, R. and A.R. Pagan (2010), "Sign Restrictions in Structural Vector Autoregressions: A Critical View", *CAMA Working Paper 22/2010* , Australian National University.

[13] Gali, J. and T. Monacelli (2005), "Monetary Policy and Exchange Rate Volatility in a Small Open Economy", *Review of Economic Studies*, 72, 707-734.

[14] Giordani, P. (2004), "Evaluating New-Keynesian Models of a Small Open Economy", *Oxford Bulletin of Economcs and Statistics*, 66, 713-733.

[15] Hamilton, J. and M. Flavin (1986), "On the Limitations of Government Borrowing: A Framework for Empirical Testing", *American Economic Review*, 76, 808-819.

[16] Justiniano, A. and B. Preston (2010), "Monetary Policy and Uncertainty in an Empirical Small Open Economy Model", *Journal of Applied Econometrics*, 25, 93-128.

[17] Karam , P. and Pagan, A. (2008), "A Small Structural Monetary Policy Model for Small Open Economies with Debt Accumulation", *IMF Working Paper* WP/08/64.

[18] Levtchenkova, S., A.R. Pagan and J. Robertson (1998), "Shocking Stories", *Journal of Economic Surveys*, 12, 507-526.

[19] Mountford, A. and H. Uhlig (2009), "What are the Effects of Fiscal Policy Shocks", *Journal of Applied Econometrics*, 24, 960-992.

[20] Pagan, A.R. and M.H. Pesaran (2008), "Econometric Analysis of Structural Systems with Permanent and Transitory Shocks", *Journal of Economic Dynamics and Control*, 32, 3376-3395.

[21] Perotti, R. (2002), "Estimating the Effects of Fiscal Policy in OECD Countries", European Network of Economic Policy Research Institutes, Working Paper No. 15, October 2002.

[22] Quintos, C. (1995), "Sustainability of the Deficit Process with Structural Shifts", *Journal of Business and Economic Statistics*, 13, 409-417.

Table 1: Summary of the key SVAR relationships. A x represents a contemporaneous relationship, an o a dynamic relationship, and e a cointegrating relationship or an adjustment term corresponding to the $I(0)$ variables.

Explanatory variables		Data properties	Key equations Fiscal sector		
			Revenue (τ_t)	Expenditure (g_t)	Debt ratio (d_t)
US GDP	y_t^*	$I(1)$			
Terms of trade	s_t	$I(0)$			xoa
US real interest rate	r_t^*	$I(0)$			
US Q ratio	q_t^*	$I(0)$			
Real Exports	x_t	$I(1)$			
Govt. revenue	τ_t	$I(1)$	o	xo	xo
Govt. expenditure	g_t	$I(1)$	o	o	xo
GNE	ξ_t	$I(1)$	o	o	
Aust Q ratio	q_t	$I(0)$	oa	oa	xo
GDP	y_t	$I(1)$	o	o	o
Debt to GDP ratio	d_t	$I(0)$	oa	oa	oa
Inflation	π_t	$I(0)$	oa	oa	
Cash rate	r_t	$I(0)$	oa	oa	
Real TWI	ζ_t	$I(1)$	o	o	
Cointegrating relationships					
1. $\{y_t^*, x_t, \tau_t, g_t, \xi_t, y_t, \zeta_t\}$		$I(0)$			
2. $\{\tau_t, g_t\}$		$I(0)$	a	a	
3. $\{y_t, y_t^*, x_t, \tau_t, g_t\}$		$I(0)$	a	a	a

Table 1 continued: Summary of the key SVAR relationships. A x represents a contemporaneous relationship, an o a dynamic relationship, and e a cointegrating relationship or an adjustment term corresponding to the $I(0)$ variables.

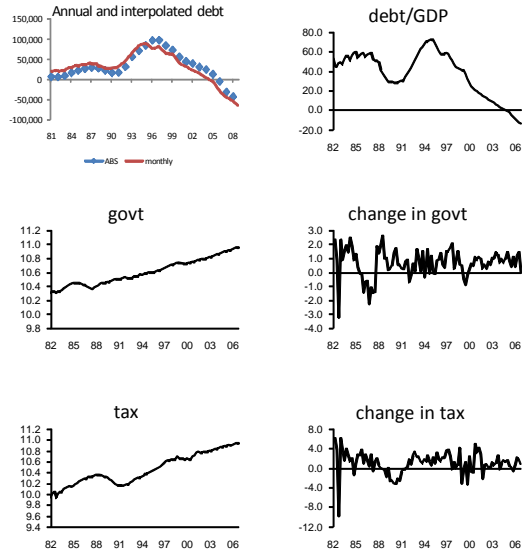| Explanatory variables		Data properties	Q ratio (q_t)	IS curve (ξ_t)	GDP identity (y_t)	Phillips curve (π_t)	Monetary reaction fn (r_t)	Exchange rate (ζ_t)
US GDP	y_t^*	$I(1)$			xo			xo
Terms of trade	s_t	$I(0)$		xoa	xo	xo		xo
US real interest rate	r_t^*	$I(0)$						xo
US Q ratio	q_t^*	$I(0)$						xo
Real Exports	x_t	$I(1)$						xo
Govt. revenue	τ_t	$I(1)$		xo	xo			xo
Govt. expenditure	g_t	$I(1)$		xo	xo			xo
GNE	ξ_t	$I(1)$		xo		xo	xo	xo
Aust Q ratio	q_t	$I(0)$		xo				xo
GDP	y_t	$I(1)$			xo			xo
Debt to GDP ratio	d_t	$I(0)$		oa				xo
Inflation	π_t	$I(0)$		o		xo	xo	xo
Cash rate	r_t	$I(0)$		o			xo	xo
Real TWI	ζ_t	$I(1)$		o		o	o	xo
Cointegrating relationships								
1. $\{y_t^*, x_t, \tau_t, g_t, \xi_t, y_t, \zeta_t\}$		$I(0)$						
2. $\{\tau_t, g_t\}$		$I(0)$						
3. $\{y_t, y_t^*, x_t, \tau_t, g_t\}$		$I(0)$		a				

Figure 1: Debt data, the debt to GDP ratio and levels and quarterly percentage changes for log government expenditure, g_t, and taxation revenue, τ_t.
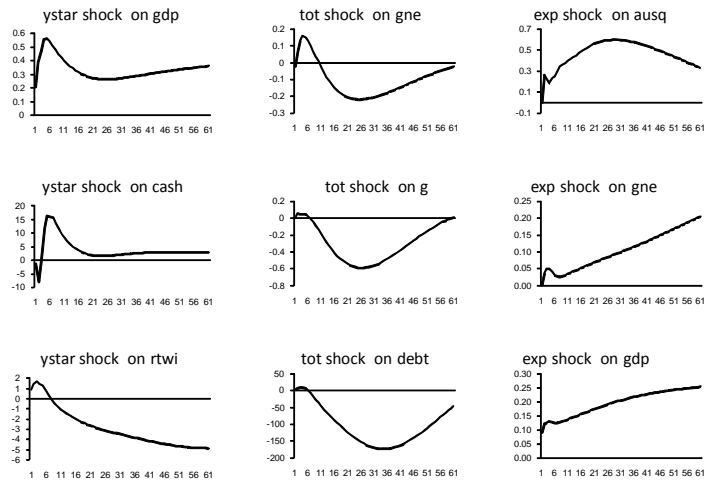

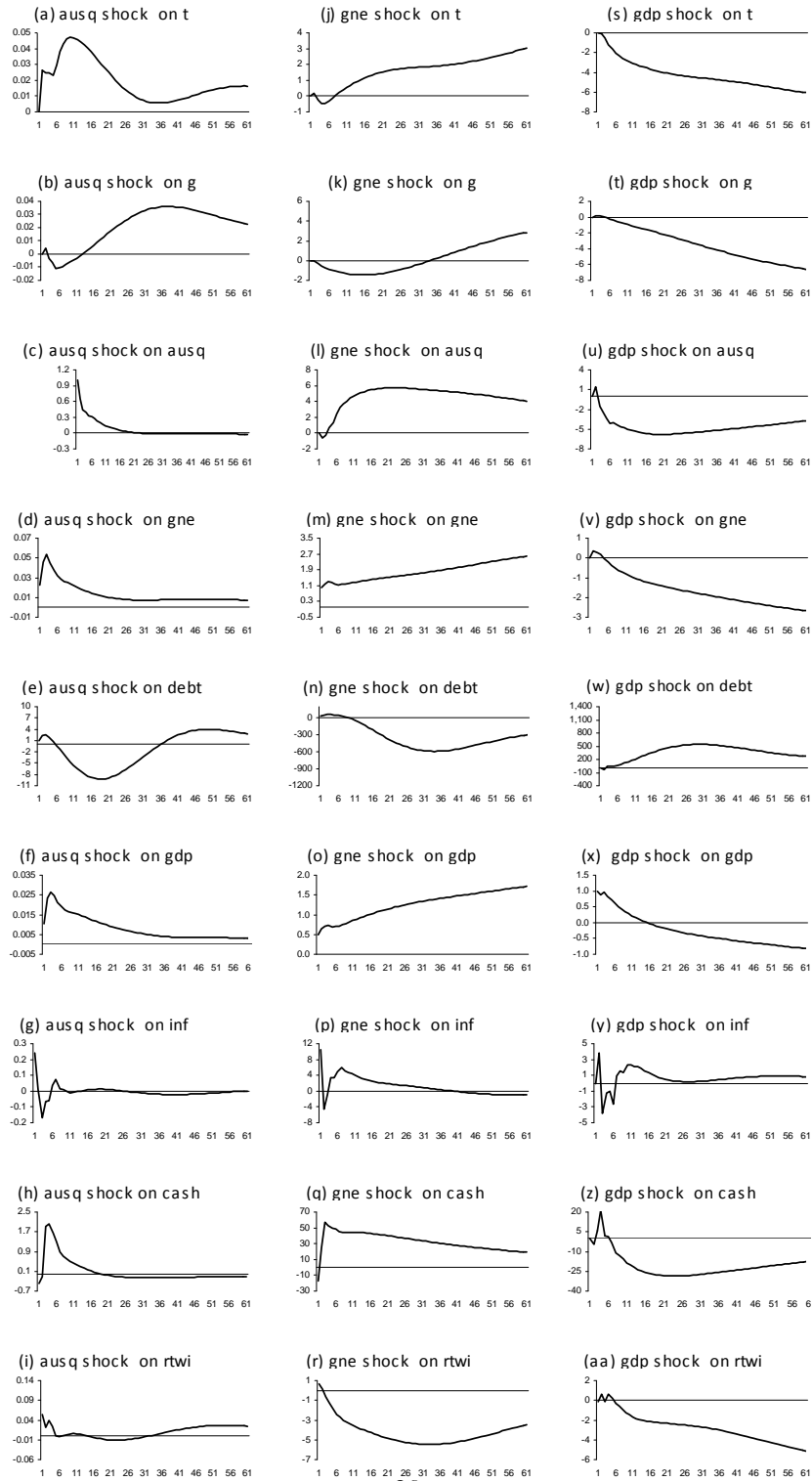Figure 2: Selected impulse responses to shocks to exogenous variables.

25

Figure 3: Impulse responses of domestic economy variables to shocks to Australian investment conditions, q_t, absorption, ξ_t, and GDP, y_t.
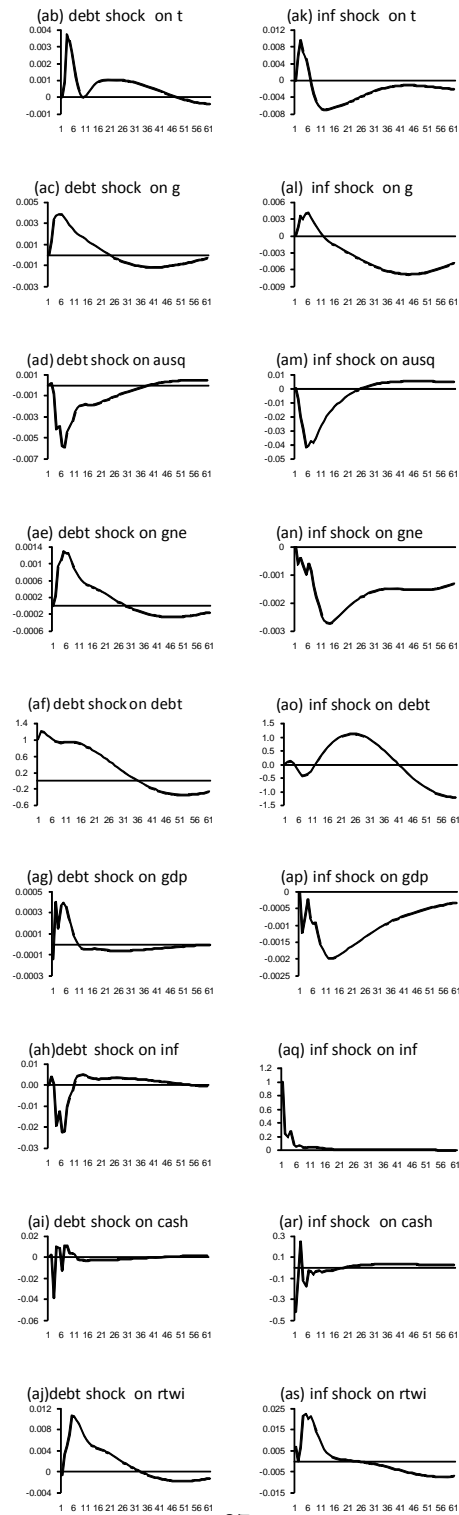
27

Figure 4: Impulse responses of domestic economy variables to shocks to the
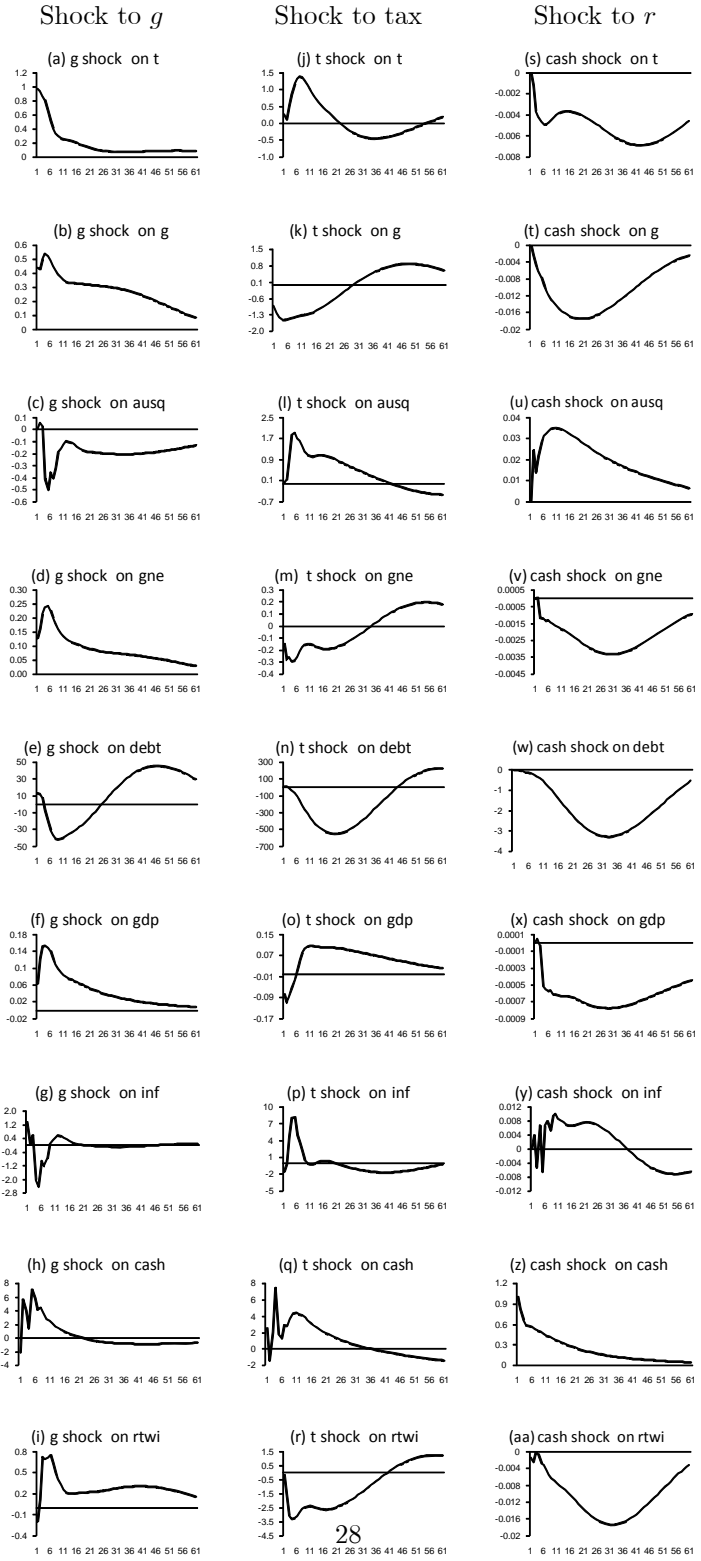debt/GDP ratio and inflation.

Figure 5: Impulse responses to 1 standard deviation fiscal policy shocks and 1 unit monetary policy shocks.

Appendix: Data Definitions

Variable	Description	Source
y_t^*	Real US GDP, s.a.	Datastream USGDP...D
s_t	Australian terms of trade	ABS National Accounts
r_t^*	US 90 day interest rate	Datastream USESTBIL quarterly average
π_t^*	US CPI Inflation	Datastream USI64...F
q_t^*	US Q ratio	Datastream Dow Jones USJINDUS divided by the USCPI from
x_t	Real exports, s.a.	Datastream AUEXPGSVD
q_t	Australian Q ratio	All Ordinaries Index Datastream AUSHRPRCF divided by the implicit price deflator for plant and equipment from AUSSTATS A20303942V
ξ_t	Real GNE, s.a.	Datastream AUGNE...D
y_t	Real GDP, s.a.	Datastream AUGDP...D
π_t	CPI inflation	Spliced CPI from ABS with the RBA Aquisitions series for the period when CPI included mortgate interest rate costs.
r_t	11 am cash rate	Datastream AUUOFFL quarterly average
ζ_t	Real TWI	Datastream AUXTW..R quarterly average