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The Identification of Fiscal and Monetary Policy in a Structural VAR*

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Abstract

Jointly identifying the effects of both fiscal and monetary policy shocks in an open economy structural VAR poses identification challenges. The innovations in this paper are to combine the methods of identification via sign restrictions, cointegration and traditional exclusion restrictions within a system which explicitly accounts for both stationary and non-stationary variables. This incorporates the recent identification of permanent and temporary shocks by Pagan and Pesaran (2007). We show how to produce impulse responses and historical decompositions under these circumstances. The application is to the small open economy of New Zealand, where policy makers are actively considering the interaction between monetary and fiscal policies. The results show that over the last 20 years the influence of the fiscal policy stance on output has sometimes been substantial, and generally outweighs the contribution of monetary policy shocks.

Keywords: Identification, Fiscal policy, Monetary policy, SVAR, Permanent and transitory shocks, Sign restrictions

JEL Classification: E62, E63, C32, C50

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1 Introduction

After over a decade of preoccupation with both the importance and independence of monetary policy in macroeconomics there is now a resurgence of interest in how to model the potential interactions of monetary policy with fiscal policy shocks. While this has been led by policymakers concerned with co-ordination effects, advances in methodologies in empirical economics have also contributed. Although government policy makers have continued to run structural models incorporating fiscal effects, many researchers shifted to more data determined macroeconomic models encapsulated by the structural vector autoregression (SVAR) approach mooted by Sims (1980).

Identification of policy shocks in a SVAR occurs via three main streams of literature. The first is the traditional normalisation and restrictions on the contemporaneous relationships between variables. This has been widely applied to monetary policy (for example, Bagliano and Favero, 1998, for a review) and only recently to fiscal policy using institutional detail as an identification tool (Blanchard and Perotti, 2002). The second is the newer sign restriction literature, which imposes restrictions on the acceptable impulse responses to shocks for model identification (Faust, 1998 and Canova and de Nicoló, 2002); see also Fry and Pagan (2007) for a critique and some refinements adopted here. The third approach is to take account of the longer run properties, in one form as a VECM, or as an extension of the Blanchard and Quah (1989) methodology, or more recently in the recognition of the correspondence between SVARs and VECMs which allow the use of cointegrating relationships as a further tool of identification as in Pagan and Pesaran (2007). This has the attractive property of specifically allowing for both stationary and nonstationary variables in a system while also accounting for cointegrating relationships.

The contribution of this paper is the recognition that there are strengths and weaknesses in each of these approaches, but they can be effectively combined to accommodate the reality of the modelling problem confronting the policy maker.

The combined identification strategies are applied to model the interactions of fiscal and monetary policy and other important macroeconomic variables in the small open economy of New Zealand. The SVAR literature for the New Zealand economy is well developed and is drawn on for identifying the non-fiscal shocks of interest, while the sign restrictions method is applied to the fiscal policy shocks and the responses of the domestic variables to them. A minimal set of sign restrictions is used to identify the fiscal policy shocks to allow the data to freely determine the key variable responses to the fiscal shocks in line with the original intent of VARs put forth in Sims (1980).

These restrictions are applied in conjunction with information from the cointegrating relationships between the macroeconomic variables to model the long run, allowing for both permanent and transitory components. This follows the recent work of Pagan and Pesaran (2007) and the application in Dungey and Pagan (2007) for a model containing a mixture of stationary and non-stationary variables. The current paper is the first to combine these three techniques and allows us to make a more structured analysis of the New Zealand economy while still adhering to the VAR tradition of letting the data determine the dynamics in the economy, particularly for the less commonly modelled fiscal policy shocks.

The study of fiscal policy shocks and policy interactions in structural vector autoregression (SVAR) models is relatively limited but has largely built on the Blanchard and Perotti (2002) fiscal policy framework: for example Perotti (2002) for a range of OECD countries; Chung and Leeper (2007), and Favero and Giavazzi (2007) who also consider debt variables. Mountford and Uhlig (2005) use the Blanchard and Perotti fiscal variables but an alternative sign restriction based identification scheme. Canova and Pappa (2007) also utilise the sign restriction method for examining fiscal policy in a monetary union. The latter papers all focus on the US.[1]

New Zealand makes an interesting small open case-study for a number of reasons. First, New Zealand has been a policy making leader over the past few decades in both adopting inflation targeting in 1990 and the Fiscal Responsibility Act in 1994. Second, policymakers are actively considering interactions between fiscal and monetary policy (Finance and Expenditure Committee, 2007; Treasury and Reserve Bank of New Zealand (RBNZ), 2006; RBNZ, 2007).[2] Third, unlike many small open economies, New Zealand possesses a well-established SVAR modelling framework, which has resolved many of the issues in specification for other aspects of the economy; see particularly Buckle, Kim, Kirkham, McLellan and Sharma (2007) and references therein.

The rest of this paper proceeds as follows. Section 2 presents an overview of issues surrounding identification in VARs. A discussion of model identification via each of traditional restrictions, sign restrictions and long run restrictions is provided in Section 3, which also outlines issues surrounding the long run restrictions and mixed data types, and the methods to produce impulse responses and historical decompositions under these circumstances are derived. Section 4 presents the model including the

[1] Canova and Pappa (2007) also apply their model to Europe.

[2] An earlier review by Svensson (2001) recommended that monetary and fiscal policy not be coordinated to protect the independence of monetary policy, while the current RBNZ submission points to some of the difficulties for implementing monetary policy in a short-term stimulatory fiscal environment.

choice of permanent and transitory shocks imposed, as well as the traditional and sign restrictions. Section 5 presents the empirical results in terms of impulse response functions and historical decompositions. Section 6 discusses the relative influence of monetary and fiscal policy on the macroeconomy. Section 7 concludes with some suggestions for future developments.

2 Identification Problems in SVARs

VAR models have developed in a number of ways to solve the problem of identification in different circumstances.[3] The approaches can be broadly summarised as: i) traditional SVAR and VECM specifications; ii) the newer sign restriction methodology; and iii) the use of long term relationships as instruments in systems of mixed I(0) and I(1) data stemming from the work of Pagan and Pesaran (2007). Each approach has limitations. Researchers generally use just one of the three identification techniques in answering an empirical question. Here we show how a combination of all three types of identification methodology provides a practical solution to a more complex modelling problem. Combining the techniques avoids some of the limitations inherent in using a single identification method.

The most frequent approach to identification is the traditional SVAR, where there is some form of ordering and normalisation between the contemporaneous relationships between variables. Additional zero restrictions are often imposed on the coefficients in the system, usually with some theoretical justification. SVARs in this tradition are typically estimated in either levels or first differences, taking the view that the persistence will either be captured by parameter coefficients in the first case, or should be eliminated before estimation in the second case (that is, the data is transformed to a stationary form). Rather than making this transformation, VECM methods use this information as part of the identification process between cointegrated non-stationary variables.

Many of the SVAR and VECM models estimated in this manner show evidence of one or more of the so-called 'puzzles' in this literature. These include most prominently the price puzzle, the exchange rate puzzle and the liquidity puzzle. Pagan and Robertson (1998) particularly show that the liquidity puzzle relates directly to identification

[3]In some circumstances VAR methods are altogether inappropriate. Sometimes models cannot be written as a VAR (or at least a finite order VAR) in the first place or are unable to be recovered, or suffer from small sample problems; see Lippi and Reichlin (1994), Cooley and Dwyer (1995), Faust and Leeper (1997), Canova and Pina (2005), Fry and Pagan (2005), Chari et al (2005) and Fernandez-Villaverde et al (2007) amongst others for discussion.

problems.

Untangling some relationships in SVARs is also often difficult without further information. Fiscal policy provides a prominent example. The correlation between taxation revenue and government expenditure is high, and consequently a standard VAR or VECM has difficulty differentiating that an increase in taxes ought to be associated with a fall in GDP while an increase in government expenditure ought to be expansionary. One recent solution to this problem is based on institutional structures in Blanchard and Perotti (2002), Perotti (2002), Claus et al (2006), Chung and Leeper (2007) and Favero and Giavazzi (2007). Sign restrictions present an alternative approach. These were initially applied to models examining monetary policy (Faust, 1998; Canova and de Nicoló, 2002; Uhlig, 2005) and more recently extended to fiscal policy shocks by Mountford and Uhlig (2005), Canova and Pappa (2007) and Canova and Paustian (2007).

Sign restrictions formally incorporate criteria based on economic knowledge of empirical reactions in the economy, such as that output will rise in the face of a government expenditure shock, but fall with a positive taxation revenue shock. This method is often implemented intuitively by re-examining standard VAR models under alternative identification schemes (for example variable ordering in a simple system). The choice of a preferred model based on the signs of the impulse response functions in response to shocks is the foundation of the sign restriction technique. The sign restrictions method formalises this mechanism by examining numerous alternative identification schemes and considering only those where the impulses behave in an economically meaningful way. Techniques developed in Fry and Pagan (2007) show how to implement the sign restriction methodology to ensure that the identified model is coherent.

An advantage of the sign restrictions framework for problems such as fiscal policy identification is that contemporaneous relationships amongst the variables of the system are able to occur simultaneously. In the case of fiscal policy shocks, it is possible, but not imposed, for taxation to increase contemporaneously in response to a government expenditure shock, and in the same model for government expenditure to increase contemporaneously in response to a taxation shock (see Mountford and Uhlig, 2005). Hence experiments with the order of government expenditure and taxation shocks as in Claus et al (2006) are no longer necessary. It is also the case that it is simple to control for automatic and pure fiscal policy shocks.

As the dimension of the SVAR increases, the number of sign restrictions necessary increases dramatically if all shocks in the system are to be identified. Some papers identify a full suite of shocks using sign restrictions (Peersman, 2005), while others avoid this difficulty by identifying selected shocks, leaving the others unconstrained. For example, Mountford and Uhlig (2005) identify four shocks in an eight variate system, and Uhlig (2005) uses sign restrictions to identify monetary policy but takes an agnostic approach about its effects on output. Canova and Paustian (2007) show that it is however possible to be 'too' agnostic. On the other hand, it can be difficult to determine a full set of sign restrictions for identification as a system increases in size, as the patterns of signs stated to apply to each shock needs to be unique for the system to be properly identified.

A different method of identification proposed for VAR models is that of restrictions on the long run covariance matrix of the error terms. Most famously the Blanchard and Quah (1989) paper suggests an identification based on zero long run supply shocks. The inclusion of long run restrictions has become increasingly important, particularly when combined with the literature on cointegration.

At the same time as recognising alternative means of identification there has been an extensive move in the literature to allow recognition of the nature of the data in estimating VARs and this led directly to the VECM framework. Recently, Pagan and Pesaran (2007) have shown the direct analogy between a VAR in levels containing I(1) variables and an equivalent VECM representation. They developed a method to separately identify permanent and transitory shocks in a system of I(1) variables to produce a coherent SVAR system, effectively extending and generalising Blanchard and Quah (1989). This has the added benefit that the specification of the cointegrating vector makes available extra instruments for identifying the system. The two problems of identification and data properties are intrinsically related. It is often the case that the statistical properties of the desirable set of macroeconomic variables is of mixed nature, that is, includes both stationary and non-stationary data. Pagan and Pesaran (2007) demonstrate how to simultaneously incorporate both I(0) and cointegrating I(1) variables into a single system; see Dungey and Pagan (2007) for an example.

Combining identification using traditional SVAR restrictions with the Pagan and Pesaran (2007) framework allows the imposition of intertial restrictions while still allowing for long run relationships and mixed I(1) and I(0) variables in the system. Further including the sign restrictions method allows identification while being agnostic about the effects of fiscal shocks on most of the variables in the model. The empirical methodology is detailed in the next section with: i) a brief overview of traditional SVAR models; ii) an outline of the sign restrictions method adopted in this paper; and iii) a discussion of the treatment of the long run properties of the model accounting for long run cointegrating relationships, permanent and transitory shocks, as well as the bearing that the mix of I(0) and I(1) variables has on the modelling choices.

3 The Empirical Methodology

3.1 Traditional SVAR modelling

Define a SVAR(p) in n variables as

$$B_0 y_t = B(L) y_{t-l} + \varepsilon_t, \tag{1}$$

with corresponding VAR

$$y_t = A(L) y_{t-l} + v_t, \tag{2}$$

and

$$\widehat{v}_t = \widehat{B}_0^{-1} \widehat{\varepsilon}_t \tag{3}$$

being the relationship between the estimated VAR and SVAR residuals. The vector moving average form of the SVAR is

$$y_t = C\left(L\right) \varepsilon_t,$$

with $C\left(L\right) = C_0 + C_1 L + ...$, and $C_j = D_j B_0^{-1}$ being the impulse responses to the structural shocks ε_t, and D_j being the corresponding VAR impulse responses to a unit shock in v_t.

Typically, to identify this type of model, causal and/or inertial restrictions are imposed directly on the parameter matrices B_i. In the current paper this form of restriction in conjunction with the imposition of the long run component of the model described in Section 3.3 is the basis for the identification for all endogenous variables apart from the government expenditure and taxation component which is identified using sign restrictions.

3.2 Sign restrictions

Defining $\widehat{S}$ as containing the estimated standard deviations of the structural residuals along the diagonal and with zeros elsewhere,

$$\begin{aligned} \widehat{v}_t &= \widehat{B}_0^{-1} \widehat{S} \widehat{S}^{-1} \widehat{\varepsilon}_t \\ &= T \eta_t. \end{aligned} \tag{4}$$

T is an impact matrix, and η_t are the estimated shocks, where η_t has unit variances. The sign restrictions method produces an alternative set of shocks and an alternative impact matrix by choosing some orthonormal matrix Q which by definition has the properties $Q'Q = QQ' = I$. The original shocks can be redefined as a function of this orthonormal matrix

$$\begin{aligned} \widehat{v}_t &= TQ'Q\eta_t &(5)\\ &= T^*\eta_t^*, &(6)\end{aligned}$$

whereby the new set of estimated shocks η_t^* also has the property that their covariance matrix is I since $E\left(\eta_t^*\eta_t^{*\prime}\right) = QE\left(\eta_t\eta_t'\right)Q' = I$. Thus there is a combination of shocks η_t^* that has the same covariance matrix as η_t but which will have a different impact upon y_t through their impulse responses C_j^*. Intuitively, the initial arbitrary shocks are rotated to produce an alternative set of shocks while maintaining the desirable property that the shocks remain orthogonal.

There are an infinite number of candidates for Q which produce an orthogonal set of shocks, but which all have the same VAR representation. The impact matrix of the shocks is not required to follow a recursive pattern, although a recursive structure is an admissible decomposition. There are, however, many such rotations to consider, so economic concepts are used to narrow down the range of options of orthonormal matrices Q considered. This is the key to the implementation of the sign restriction method. As the naming convention implies, the sign restriction methodology restricts attention to rotations which produce shocks which satisfy an anticipated sign in responses of key variables. That is, information on the expected signs of responses to key economic variables is used to select the combinations of TQ' which make sense economically.

As it is the fiscal policy shocks to which the sign restriction methodology is applied, the matrix Q is constructed to only rotate the government expenditure and taxation shocks. Q is chosen based on the Givens rotation and is

$$Q = \begin{bmatrix} 1 & & & & & & & \\ & 1 & & & & & & \\ & & 1 & & & & & \\ & & & \cos(\theta) & -\sin(\theta) & & & \\ & & & \sin(\theta) & \cos(\theta) & & & \\ & & & & & 1 & & \\ & & & & & & \ddots & \\ & & & & & & & 1 \end{bmatrix}, \qquad (7)$$

where θ is chosen randomly from the uniform distribution and adopts a value between 0 and π. This choice of rotation matrix means that only the shocks to the fourth and fifth variables in this system (which will correspond with the government expenditure and taxation shocks in the application to New Zealand later in the paper) are rotated. It is clear that the shocks corresponding to the remaining variables remain those of the traditional SVAR system. Applying the sign restriction method to only two shocks and identifying the rest conventionally means that a system is estimated which is large enough to properly control for other shocks in the system, such as business cycle shocks.

Even with these restrictions in place, it is likely that there are many combinations of TQ' and D_j that produce impulse responses satisfying the required sign restrictions. Standard practice is for researchers to draw Q matrices until there are d number of impulses satisfying the set of economic restrictions stated.[4] The difficulty in the sign restriction method is in choosing which set of shocks is the correct set. Standard practice is to choose the median of the impulse response functions C_j^d, usually in association with impulses corresponding to chosen percentile bands.

Recent work in Fry and Pagan (2007) highlights some of the econometric problems in implementing the sign restriction methodology. A key issue is that taking the median response across the set of impulses no longer guarantees that the shocks of the system are orthogonal and that the impulses presented represent results from a mixture of models. To circumvent this problem and following Fry and Pagan (2007), a Q matrix is chosen so that the impulses selected are as close as possible to the median with the property of orthogonal shocks retained.[5] To implement this, the impulses are standardized and grouped into a vector $\phi^{d\prime}\phi^d$ for each of the d draws of Q. The expression $\phi^{d\prime}\phi^d$ is then minimised, and the corresponding Q^d matrix is used to calculate the impulse response functions. In this application $d = 1,000$.

3.3 Long run restrictions and mixed data types

Consider dividing the variable set y_t of the VAR(p) given in equation (1) into a set of I(1) variables denoted z_t, and I(0) variables denoted x_t. Greater orders of integration are prevented via the assumption that the eigenvalues of $B_0^{-1}B_i$ exist for all i, and lie inside the unit circle. For illustration consider the case where $p = 3$. In which case the

[4]The mechanics of identification differs across papers. Uhlig (2005) for example utilises a penalty function approach to choose between candidate impulses, Canova and de Nicoló (2002) employ grid search methods across Givens rotation matrices, Peersman (2005) randomly draws numbers between 0 and π from the uniform distribution in conjunction with Givens rotation matrices, and Rubio-Ramírez, Waggoner and Zha (2005) rotate by drawing householder rotation matrices.

[5]In the current application the shocks will not technically be orthogonal due to the zero restrictions imposed on the contemporaneous matrix in the SVAR part of the system. This is the case for all SVAR models with zero restrictions imposed in the contemporaneous part of the model. However, the results reported in this paper all come from the one model.

VAR(3) in levels of y_t can be rewritten as

$$B_0 \Delta y_t = -(B_0 - B_1 - B_2 + B_3) y_{t-1} - (B_2 - B_3) \Delta y_{t-1} - B_3 \Delta y_{t-2} + \varepsilon_t \tag{8}$$

with a corresponding reduced form of

$$\Delta y_t = -\Pi y_{t-1} + \Psi_1 \Delta y_{t-1} + \Psi_2 \Delta y_{t-2} + e_t \tag{9}$$

where $\Pi = B_0^{-1}(B_0 - B_1 - B_2 + B_3)$, $\Psi_1 = B_0^{-1}(B_3 - B_2)$, $\Psi_2 = -B_0^{-1} B_3$ and $e_t = B_0^{-1} \varepsilon_t$.

In the case where all variables in y_t are I(1) and there are cointegrating relationships between them such that the number of cointegrating vectors, r, is less than n, then the matrix Π will be rank deficient and the usual notation can be used to write that $\Pi = \alpha' \beta$ where α and β are of full rank. Then the system can be written as a VECM.

When the system contains fewer cointegrating vectors than I(1) variables it is useful to identify which of the shocks in the system are transitory, and which are permanent. Following Pagan and Pesaran (2007) we note that it is possible to write the y_t variables in a common trends representation

$$y_t = y_0 + F \sum_{j=1}^{t} B_0^{-1} \varepsilon_j + F^* \sum_{k=0}^{\infty} B_0^{-1} \varepsilon_{t-k}, \tag{10}$$

where

$$F = \beta_\perp \left[\alpha'_\perp \left(I_n - \Psi_1 - \Psi_2 \right)^{-1} \beta_\perp \right] \alpha_\perp^{-1} \tag{11}$$

and $\alpha'_\perp \alpha = 0$, $\beta'_\perp \beta = 0$, $F\alpha = 0$ and $\beta' F = 0$. If the first $(n-r)$ shocks are permanent then the structural shocks can be partitioned into two groups, the first of which have permanent effects, ε_{1j}, and the second which have only transitory effects in the system, ε_{2j} as follows:

$$y_t = y_0 + F B_0^{-1} \begin{pmatrix} \sum_{j=1}^{t} \varepsilon_{1j} \\ \sum_{j=1}^{t} \varepsilon_{2j} \end{pmatrix} + F^* \sum_{k=0}^{\infty} B_0^{-1} \varepsilon_{t-k}. \tag{12}$$

For the shocks in the second group, ε_{2j}, to be transitory then requires

$$F B_0^{-1} \begin{pmatrix} 0_{(n-r)\times r} \\ I_r \end{pmatrix} = 0 \tag{13}$$

which is equivalently

$$F B_0^{-1} \begin{pmatrix} 0_{(n-r)\times r} \\ I_r \end{pmatrix} = F\alpha = 0. \tag{14}$$

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

$$\begin{pmatrix} 0_{(n-r)\times r} \\ I_r \end{pmatrix} = B_0 \alpha = 0. \tag{15}$$

The right hand side of equation (15) can be multiplied by an arbitrary non-singular matrix S

$$\begin{pmatrix} 0_{(n-r)\times r} \\ I_r \end{pmatrix} = B_0 \alpha S = \alpha^* S = \begin{pmatrix} \alpha_1^* S \\ \alpha_2^* S \end{pmatrix}. \tag{16}$$

Satisfying this equation requires that $\alpha_1^* S = 0$, and consequently that $\alpha_1^* = 0$. The importance of this for the estimation of such a system is that it precludes the inclusion of error correction terms in structural equations which contain permanent shocks. This will provide extra instruments for identification, although that turns out to not be relevant in the overidentified system investigated in the current paper. The critical point for the current paper is in recognising that error correction terms do not enter structural equations where there are permanent shocks.

The extension of this system so that y_t includes I(0) variables is then relatively straightforward. Now there are $n+k$ variables, k of which are I(0). Augmenting the system above with a further k variables can be done in the same format as above by simply recognising that any I(0) variable which is represented as an AR(3) in levels

$$x_t = a_1 x_{t-1} + a_2 x_{t-2} + a_3 x_{t-3} + \varepsilon_t \tag{17}$$

can be equivalently transformed to

$$\Delta x_t = (a_1 + a_2 + a_3 - I) x_{t-1} - (a_2 + a_3) \Delta x_{t-1} - a_3 \Delta x_{t-2} + \varepsilon_t. \tag{18}$$

The logic of the system described above then extends to the I(0) variables by treating them as temporary shocks and including the lagged levels effect as in estimating the system, we christen these lagged levels effects as the adjustment mechanism term for the stationary variables, and it enters the system by defining

$$\beta = \begin{bmatrix} \beta_1 & 0 \\ 0 & -I_k \end{bmatrix}. \tag{19}$$

3.4 Analytical tools

3.4.1 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 an SVAR is useful, as developed in Dungey and Pagan (2007). The permanent components in the system maybe written as a Beveridge-Nelson decomposition as

$$\Delta \gamma = \eta_t, \tag{20}$$

where η_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

$$J = FB_0^{-1}. \tag{21}$$

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 (2007), 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. The correct transformation of the SVECM into a SVAR is

$$\begin{aligned} B_0\Delta\left(y_t - y_t^p\right) &= \alpha^*\beta'\left(y_{t-1} - y_{t-1}^p\right) + B_1\Delta\left(y_{t-1} - y_{t-1}^p\right) + B_2\left(y_{t-2} - y_{t-2}^p\right) \\ &\quad + B_2\Delta y_{t-2}^p + B_1\Delta y_{t-1}^p - B_0\Delta y_t^p + \varepsilon_t. \end{aligned} \tag{22}$$

Writing $\omega = \left(y_t - y_t^p\right)$ and premultiplying the coefficients appropriately by B_0^{-1} implies that the system can be written in moving average terms as

$$\Delta\omega_t = \alpha^*\beta'\omega_{t-1} + \widetilde{B}_1\Delta\omega_{t-1} + \widetilde{B}_2\Delta\omega_{t-2} - J\varepsilon_t + \widetilde{B}_1 J\varepsilon_{t-1} + \widetilde{B}_2 J\varepsilon_{t-2} + B_0^{-1}\varepsilon_t. \tag{23}$$

This can then be written as a moving average in ε_t to provide the standard expression

$$G(L)\,y_t = J(L)\,\varepsilon_t, \tag{24}$$

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

$$\frac{\partial y_{t+j}}{\partial\varepsilon_{kt}} = \frac{\partial\omega_{t+j}}{\partial\varepsilon_{kt}} + \frac{\partial y_{t+j}^p}{\partial\varepsilon_{kt}} = \frac{\partial\omega_{t+j}}{\partial\varepsilon_{kt}} + J. \tag{25}$$

3.4.2 Historical decompositions

Historical decompositions are a simple reorganisation of the information in the impulse response functions. They recognise that via the moving average form of any variable as given in equation (23) it is possible to attribute the change in any variable in the system at any given point in time to the cumulation of all previous shocks and initial conditions. Once it is evident that the current system can be written in the VMA form then this becomes the standard analytical tool. Effectively, write (23) as

$$\Delta\omega_t = \textit{initial conditions} + \sum_{i=0}^{t} C_i\varepsilon_{t-i} + J, \tag{26}$$

where the C_i are the impulse responses at each horizon. The distribution of the permanent effects over the time horizon of the decomposition is not explicit, and as we are interested in the changes at each point in time the effect of J is less interesting in this form of the analysis and can be largely ignored.

4 The Model

4.1 The data

The dataset is quarterly and consists of twelve individually linearly detrended endogenous variables in y_t

$$y_t = \{y_t^*, px_t, pm_t, g_t, tax_t, gne_t, debt_t, gdp_t, hpinf_t, inf_t, short_t, twi_t\}, \qquad (27)$$

where y_t consists of foreign output (y_t^*), the price of exports (px_t), the price of imports (pm_t), real government expenditure (g_t), real taxation revenue less transfers (tax_t), absorption (represented by real gross national expenditure) (gne_t) , the ratio of sovereign issued debt to GDP ($debt_t$), real GDP (gdp_t), house price inflation ($hpinf_t$), consumer price inflation (inf_t), the short term interest rate ($short_t$), and the trade weighted exchange rate for the New Zealand dollar (twi_t).[6] The sample period extends from 1983:2 to 2006:4 for a total of 95 observations.

All variables are in natural logarithms except for the interest rates and inflation rates which are in percentages.[7] Figure 1 presents a present a plot of the data for all variables including the exogenous variables of climate and the international interest rate.[8] Full definitions of the variables are given in Appendix 1. The majority of the New Zealand VAR literature uses a 3 lag specification. Here, the estimation is carried out in differences, as suggested in Section 3.2, using 2 lags in differences and a levels term to represent the corresponding 3 lags levels specification.

The fiscal variables are government expenditure, taxation revenue and the debt to GDP ratio. Government expenditure includes real total government consumption and real total government investment consistent with Blanchard and Perotti (2002) and Claus et al (2006) for New Zealand. Real net taxation revenue, denoted herein simply as taxation is total government revenue less transfer payments as in Claus et al (2006) and Mountford and Uhlig (2005). The debt to GDP ratio is included following

[6] Note that linear detrending is equivalent to the approach taken in many New Keynesian DSGE models, eg Lubik and Schörfheide (2005).

[7] Other fiscal SVAR models use either levels or per capita data. In this case per capita data essentially involves the use of a common detrending variable. Levels data aids our interpretation.

[8] For a more detailed preliminary data analysis consult Dungey and Fry (2008).

work showing the importance in avoiding the 'incredible debt to GDP ratios' which can occur in systems without this variable; see Favero and Giavazzi (2007) and Chung and Leeper (2007).

Consumer price inflation and house price inflation are treated as the annual inflation rates collected on a quarterly basis. The monetary policy instrument for New Zealand is represented by the 90 day bill yield, the Official Cash Rate is not available for the total sample period.

The starting point of the sample period is determined purely by the availability of data, and has been shown to work well in existing New Zealand studies. New Zealand implemented a number of important changes in macroeconomic policy during this period, including the adoption of formal inflation targeting in 1989, and the use of the Monetary Conditions Index (MCI) based on inflation and exchange rate movements as a reference for monetary policy decisions between 1994 and 1997.[9] On the fiscal policy side New Zealand experienced a period of rapidly rising debt over the 1980s, which led to a focus on debt reduction and the adoption of the Fiscal Responsibility Act in 1994 and the Public Finance Act in 1989 (amended in 2004), where the Government was charged with following principles of responsible fiscal management, including ensuring that Government debt be maintained at prudent debt levels.[10]

Table 1 presents the unit root tests on the (non detrended) data series. The series of interest are empirically of mixed order of integration. It is well-established that real output is an $I(1)$ process, viewed, for example in the New Keynesian DSGE literature as driven by a technological process subject to permanent shocks. Real government expenditure and taxation revenue are also statistically unable to reject the null hypothesis of a unit root using some common unit root tests and also existing evidence for New Zealand in Claus et al (2006). For the other variables it usually makes sense to treat interest and inflation rates as $I(0)$ processes. Although there is plenty of empirical evidence finding that both of these variables are $I(1)$, theoretical considerations on the nature of an $I(1)$ process strongly argue against them being $I(1)$. The autoregression parameter ρ for these two variables are 0.864 and 0.905 supporting this treatment.

One remaining difficulty is with the trade weighted index, the price of exports and the price of imports data. The trade weighted index is statistically $I(1)$ using both the Augmented Dickey-Fuller and Phillips-Perron tests as guides, while the evidence is mixed for the price of exports and the price of imports. All three are treated as

[9]Buckle et al (2007) find that accounting for the MCI period makes little difference to outcomes in their SVAR.

[10]Prudent is not defined, as the meaning of prudent is likely to change over time given economic structures and other factors.

$I(1)$ for the purposes of this paper. Application of the unit root tests to a longer time series on the price of exports and the price of imports supported this view.[11] Although there are some difficulties with viewing the trade weighted index as $I(1)$ that turns out to be a useful specification here – partly because as in Dungey and Pagan (2007), it allows a mechanism by which balance of payments adjustments can occur through the permanent effect, as otherwise there is no mechanism other than domestic income adjustment to shocks which change the demand or supply of the export sector. Secondly, the trade weighted index turns out to be an integral part of understanding the long term relationships between the variables in the system.

There are clearly many issues raised by the empirical properties of the data in terms of how to proceed with the modelling. In particular, the non-stationarity suggests the potential presence of cointegration between these variables. The issue which remains is the identification of the appropriate cointegrating vector(s) for use in equation (19). In the models developed both here and in Dungey and Pagan (2007) this is exogenously imposed by estimating the relationship from the underlying data and using those coefficients as the β matrix in the second step of estimating the VAR. The primary need is for this to be consistent with the underlying data in the model to obtain the expected long run responses for permanent shocks and zero long run responses for temporary shocks – broadly, if the cointegrating vector is inconsistent with the data then the model impulse responses will not produce long run coefficients consistent with the J matrix referred to in equation (21) and the effects of the permanent shocks on the non-cointegrating variables will be non-zero. This provides a useful diagnostic in designing the model.

Pagan and Pesaran (2007) suggest deciding which of the variables in the cointegrating vectors represent permanent shocks and which reflect temporary shocks can proceed by examining the significance of the ECM term from the cointegrating relationship in a VECM type specification. Although this provided an effective guide in Dungey and Pagan (2007) it was not as universally useful here. Simulations performed by the authors suggested that assigning the incorrect status of a temporary shock to a variable results in non-converging impulse responses in the model. In the current application both the Pagan and Pesaran (2007) diagnostic, and information from the eigenvalues of the Johansen test (larger eigenvalues are associated with permanent shocks) and a simple estimation of each cointegrating vector were employed to determine which of the variables in that vector could be viewed as temporary. It is straight forward to test this outside the final VAR and incorporate this classification into the final product.

[11] Additional tests are available on request.

In the empirical application there are 8 non-stationary variables and 3 cointegrating vectors, leaving 5 permanent shocks to be identified.[12] Following Dungey and Pagan (2007) the external sector shocks corresponding to international output, the price of exports and the price of imports are identified as a source of permanent shocks. The 2 shocks within the domestic economy that are viewed as permanent are then chosen to be those to *gne* and *gdp*. In the case of a government expenditure shock theoretically there should be some form of Ricardian equivalence, and with a temporary government expenditure shock it is not feasible to have a permanent tax shock without implying an unstable debt to GDP ratio. Neither is there desire for a permanent trade weighted index shock. Additionally, when testing the convergence of the SVAR these were the shocks in which the ECM term entered to give stability in the model.

Turning to the permanent shocks, recent New Keynesian literature often suggests that output can be driven by a common technology shock. Here, we suggest that there is evidence that there is some deviation between the world technology shock and New Zealand technology shock. There is evidence for different rates of trend growth in the international and New Zealand output series, although the evidence is less strong for a difference between GDP and absorption, but during the period there is substantial divergence between the paths of the two which may be responsible for the behaviour being found here. The domestic GDP shock can be regarded as something akin to either a domestic technology shock or a change in the rate of adoption of world or foreign technology. The absorption shock can be regarded as a change in preferences for imports over domestic goods. The behaviour of export and import prices shows that there is higher growth in export prices over the period than the price of imports. This divergence represents the increased foreign preference for commodity products over the period, and the general reduction in the world price of manufactures which make up imports. If the terms of trade were to be used in place of the two component series this would be akin to saying there has been a permanent shift in the terms of trade in the favour of New Zealand exports in this period.

Empirical examination of the cointegrating relationships amongst the non-stationary

[12] Using the Johansen test we identified 1 cointegrating vector from the maximum eigen value test and 3 using the trace test. On the basis of the eigen value test we tested for a cointegrating relationship between the $I(1)$ variables using the Engle Granger 2 step method and found evidence of the cointegrating relationships given in the text. One of the possible reasons for difficulties in establishing the relationships in the New Zealand framework between the variables is a potential structural break associated with the Fiscal Responsbility Act (1994) affecting the behaviour of the fiscal variables from 1994 onwards. We experimented with including a dummy variable in the cointegrating relationships involving government expenditure and tax to represent this change but it made no qualitative difference to the results presented here.

series using the Engle-Granger two-step procedure confirms a cointegrating vector between $\{\ g_t \quad tax_t \quad gne_t \quad gdp_y \quad twi_t \quad y_t^*\ \}$ and a further relationship between $\{\ twi_t \quad px_t \quad pm_t\ \}$. The results of these tests are summarised in Table 4. A further cointegrating vector [1 -1] between government expenditure and tax is chosen, essentially keeping the debt to GDP ratio stable.[13] Note, that the relationship between the first set of variables is consistent with sustainable fiscal policy, see for example footnote 6 of Favero and Giavazzi (2007) and Blanchard and Perotti (2002), although Blanchard and Perotti (2002) find limited evidence for cointegration between their taxation and government expenditure variables. The ECM terms constructed corresponding to these long run relationships are denoted $ecm1$, $ecm2$ and $ecm3$ respectively.

The lagged adjustment mechanism terms constructed for the stationary variables as shown in (17) are denoted $amdebt$, $amhpinf$, $aminf$ and $amshort$ corresponding to the relevant stationary variables.

4.2 Identification restrictions

The work of Buckle et al (2007) forms the basis of the traditional SVAR part of the hybrid approach to identification proposed here. The main modifications to the Buckle et al (2007) model include the incorporation of the fiscal (identified via sign restrictions) and debt variables, house price inflation and through the modelling of the long run. House price inflation represents the substantial asset price inflation in New Zealand in recent years. Table 3 summarises the structure of the SVAR of this paper. The dependent variables are contained in the columns. The traditional restrictions are denoted by $\circ$,$\bullet$ for the contemporaneous and lag relationships respectively. A +,- denotes a sign relationship with uc representing a relationship which is unconstrained in terms of the signs considered. These relationships are only applicable to the fiscal shocks in the system. A $\diamond$ signifies the incorporation of ECM or the adjustment mechanism terms as explanatory variables in a particular equation.

4.2.1 External sector

We modify the specification of Buckle et al (2007) to adopt a SVARX formation whereby climate and international interest rates are incorporated as exogenous vari-

[13]There is a substantial literature testing for fiscal sustainability as a cointegrating relationship between taxation revenue and government expenditure, with mixed results. Here we err on the side of imposing the more policy acceptable fiscal sustainability by imposing the cointegrating relationship between government expenditure and tax. The classic article setting forth the arguments for nonstationarity as a measure of sustainability is Hamilton and Flavin (1986). More recently Bohn (2007) has shown that cointegration is a sufficient but not necessary condition for fiscal sustainability.

ables and the external sector in consists of international output, export prices, import prices and the trade weighted index reflecting the small open economy assumption. International output and the price of exports and imports enter the system as simple AR(2) processes rather than interacting with each other as in Buckle et al (2007). Recent work on the similarly structured Dungey and Pagan (2000) model for Australia has shown little difference in the domestic economy's responses in the move from an SVAR including international economic variables and the small open economy assumption, to an SVARX where all international variables are exogenous to the domestic economy. The trade weighted index is assumed to respond to everything except for house price inflation in the system contemporaneously and at all lags, as well as the first and second ECM terms ecm_1 and ecm_2. The foreign interest rate (i^*) also enters exogenously.

4.2.2 Fiscal sector

The fiscal policy shocks of a government expenditure and a taxation shock are both identified through the sign restriction technique, which correspond to the fourth and fifth sets of impulse responses in the system denoted $\tau = 4, 5$. Prior to implementing the sign restriction method, government expenditure is regressed on the lags of the domestic variables, all adjustment mechanism terms corresponding to the stationary variables (excluding $amhpinf$) as well as $ecm1$.[14] Taxation is a function of the same variables with the exception that $ecm1$ is replaced by $ecm3$. The relevant rotation matrix is given in equation (7). To disentangle the impulses and to assign them to particular shocks, three levels of criteria are examined.

Criterion 1 The first criterion is purely sign based. For a positive Government expenditure shock (Gt), both government expenditure and GDP respond positively for j periods such that

$$\begin{aligned} C^{Gt,\tau}_{g,j} &\geqslant 0, \qquad \forall j \\ C^{Gt,\tau}_{gdp,j} &\geqslant 0, \qquad \forall j, \end{aligned} \tag{28}$$

for either of $\tau = 4$ or $\tau = 5$. The signs of the remaining impulses in τ are unconstrained and free to take on any sign as indicated by uc in Table 3. In the empirical example, $j = 4$, as in Mountford and Uhlig (2005).

[14] In the empirical implementation of the paper, the coefficients on the house price inflation series in the equations for government expenditure and taxation are constrained to be zero. Including these coefficients resulted in extreme volatility in the resulting impulse responses.

For a positive taxation shock (T), taxation rises and absorption falls for j periods following the shock where

$$\begin{aligned} C^{T,\tau}_{tax,j} &\geqslant 0, \qquad \forall j \\ C^{T,\tau}_{gne,j} &\leq 0, \qquad \forall j, \end{aligned} \tag{29}$$

for either of $\tau = 4$ or $\tau = 5$. Again, the signs of the remaining impulses in τ remain unconstrained.

Criterion 2 In certain draws, it is not possible to disentangle the two shocks using sign restrictions alone, and further disentanglement is needed. This occurs: (i) in the case of a government expenditure shocks occurring in impulses τ when the response of taxation in the same set of impulses is negative $\left(C^{Gt,\tau}_{tax,j} \leq 0, \forall j\right)$; (ii) in the case of a taxation shock in impulses τ where the response of government expenditure in the same set of impulses is positive $\left(C^{Gt,\tau}_{g,j} \geqslant 0, \forall j\right)$. It is not possible to uniquely label the impulses as government expenditure or a taxation shock, as the signs of the responses of the two shocks correspond with both combinations of signs previously postulated in (28) and (29).

Rather than also restricting the sign on taxation in response to a government expenditure shock, and the sign on government expenditure in response to a taxation shock quantitative information is used. If in a set of impulses τ, the magnitude of the response of government expenditure is greater than the magnitude of the response of taxation,

$$C^{\tau}_{g,j} > C^{\tau}_{tax,j}, \forall j, \tag{30}$$

the shock is a government expenditure shock. If it is the reverse case, then the set of impulses is considered a taxation shock. This magnitude restriction is similar to that of Peersman (2005) when disentangling supply and oil price shocks.

Criterion 3 Occasionally after criterion 2 is imposed there are cases where both sets of impulses ($\tau = 4$ and $\tau = 5$) appear to be the same shock (either both government expenditure or both taxation shocks). Rather than discarding these draws, the impulses are disentangled by examining the ratio of the absolute value of the contemporaneous response of government expenditure to the contemporaneous response of taxation in impulses τ. If, (where $\tau = 4, 5$ denote the fourth and fifth sets of impulses respectively)

$$abs\left(\frac{C^4_{g,1}}{C^4_{tax,1}}\right) \geqslant abs\left(\frac{C^5_{g,1}}{C^4_{tax,1}}\right), \tag{31}$$

then the fourth set of impulses is a government expenditure shock and the fifth set is a taxation shock and vice versa. If the two are equal, then it is assumed that the shock is a government expenditure shock.

4.2.3 Remaining domestic sector

Absorption represented by gne is assumed to be a function of both of the contemporaneous and lagged fiscal policy variables, and all lags of all of the variables in the system. Dummy variables corresponding to quarters 1986:4 and 1989:3 are included to capture two spikes in absorption coinciding with the quarters prior to announced increases to the GST rate (see Buckle et al, 2007).

The debt variable is dependent on each of the fiscal variables and absorption as an indicator of cyclical pressure, as well as it's own adjustment term $amdebt$. As in Chung and Leeper (2007) the presence of debt without a specific budget constraint is sufficient to avoid problems with debt to GDP ratios found in Favero and Giavazzi (2007), and additionally contributes to the stability of the system; see Fry and Pagan (2005) on the role of stock variables in VAR models.

GDP is a function of both of the contemporaneous and lagged fiscal policy variables, debt and absorption, as well as all lags of the short interest rate and the exchange rate. Exogenous variables include lags of foreign real output, and the contemporaneous and lagged climate variable. House price inflation is a function of contemporaneous and lagged domestic demand and output, lags of itself, it's own adjustment term $amhpinf$, inflation, and the interest rate.

The inflation equation encompasses a Phillips curve type specification, where contemporaneous and lagged domestic demand are key. Pass through effects from imported inflation are possible through the inclusion of the lagged exchange rate in the specification. Inflation is also a function of it's own adjustment mechanism term $aminf$. The exogenous variables include the two dummy variables discussed in relation to the absorption equation above, as well as lags of the climate variable.

The equation for the short interest rate contains only three variables. These are contemporaneous and lagged domestic demand and inflation and the lagged interest rate. Two adjustment terms corresponding to the stationary variables of inflation and itself enter into the equation as well.

5 Empirical Results

Impulse response functions and historical decompositions of the above system were estimated in Gauss 6.0. The analysis presents impulse response functions for one standard deviation shocks to the errors. Although there are many arguments for presenting one unit shocks or generalized impulse responses, the standard deviation form is chosen for consistency with the majority of the New Zealand literature. The sizes of the shocks for each error are given in Table 4. The log level variable shocks should be read in percentage terms, so that the shock to y^* for example is 0.729% and that to gdp is 0.597%. The inflation shock is 0.82783% p.a. and the short rate shock 98 basis points.

5.1 Dynamic interrelationships

Figure 2 presents the histogram of the thetas generating the impulse responses when the sign restrictions are satisfied. In general, they are relatively clustered. The bimodality evident represents the symmetry that is generated by the possibility of both positive and negative shocks (which are then normalised to be positive for the purposes of the impulse response analysis). The value of theta generating the optimal impulse response functions is 0.7625.

Table 5 presents statistics relating to the number of times each criterion is satisfied in the empirical example. On average, the set of fiscal policy shocks are identified in approximately every $69th$ draw. A total of $69,466$ draws of θ for the Q matrix were made to generate the $d = 1,000$ successful draws required. Overall, 678 shocks defined as government expenditure shocks are found in the fourth set of impulses, and 322 are found in the fifth set of impulses.

It appears that government expenditure shocks are more likely to be uncovered using examination of the signs of the impulse response functions alone. In the fourth set of impulses, ($\tau = 4$), $51,612$ government expenditure shocks were uncovered, and $61,506$ were found in the fifth set of impulses ($\tau = 5$). In contrast, a taxation shock was found in $16,896$ and $18,621$ cases in the two sets of impulses respectively.

Both government expenditure and taxation shocks simultaneously appear in each set of impulses in almost $16,896$ and $18,621$ cases for impulses $\tau = 4$ and $\tau = 5$ and respectively, indicating that the taxation shock is always associated with a positive increase in government expenditure (panel B). It is these impulse response functions that require further disentangling to determine if the shock is consistent with either a government expenditure or taxation shock. Panel B shows that for the case of $\tau = 4$ impulses, $16,574$ cases are government expenditure shocks, and 322 are taxations shocks. Comparison of the relative magnitudes of the response of the impulse response functions for government expenditure and taxation shows more taxation shocks being identified than government expenditure shocks. A similar proportion holds in the fifth set of impulses.

It is often the case that a Government expenditure shock is detected in both sets of impulses $\tau = 4$ and $\tau = 5$. This does not occur for the taxation shock. Panel C reports the disentanglement of these shocks, and shows that about 60 percent are associated with the fourth set of impulses, and about 40 percent with the fifth set of impulses.

As the system is relatively large, the impulse response functions presented correspond to shocks relating to policy variables, notably to government expenditure, taxation, the debt to GDP ratio and the interest rate. A more complete set of shocks is presented in Dungey and Fry (2008).

Shock to government expenditure Figure 3 gives the impulse responses for each of the eight domestic variables to a shock to government expenditure, with the behaviour of the shock itself shown in panel (a) of Figure 3. The temporary nature of the government expenditure shock as is reflected in the impulse responses shown in Figure 3. It is readily seen that the impact of the increased government expenditure is reflected in higher output (panel(e)), consistent with results in Blanchard and Perotti (2002), Perotti (2002) for a range of countries, and the preferred specification in Claus et al (2006). However, absorption falls initially. This result may reflect some of the debate about the nature of the private consumption response to higher government expenditure; as shown in Canova and Paustain (2007), the response in consumption seems to depend on the extent of non-ricardian agents in the economy, based on the theoretical framework of Gali et al (2007). The higher government expenditure results in a negative taxation response – that is taxation revenue falls, as it does in the majority of the results in Favero and Giavazzi (2007), who also include debt and feedbacks between debt and fiscal policy variables as we do here. The fall in absorption may be part of the mechanism for this via consumption tax revenue.

The debt stock rises by both the increase in government expenditure initially and the fall in taxation revenue, to a maximum of 1.4% one year after the shock. This is resolved in the longer term with a fall in government expenditure.[15] The fall in *gne* is echoed in a fall in inflation. While the response in the cash rate is initially positive, as a

[15] We have explored a number of alternative scenarios with the interactions of government expenditure shocks with *gne* and taxation but the addition of the long run restrictions in the model consistently results in a pattern similar to that given above (as compared with the levels estimation presented in a preliminary version of the model with sign restrictions and no long run restrictions imposed).

result of the higher *gdp* in panel (e), it quickly becomes negative stimulating a recovery in *gne* and higher inflation. The observed negative inflationary response is consistent with the existing US based studies of Chung and Leeper (2007), Mountford and Uhlig (2005) and most of the Favero and Giavazzi (2007) results. In these papers the interest rate declines in response to the government expenditure shock, although Mountford and Uhlig (2005) find an initial rise when the expenditure is delayed for a year (which becomes insignificant after the first quarter). In contrast, Canova and Paustain (2007) identify their government expenditure shock by a positive sign restriction whereby inflation rises in response to this shock. See also Perotti (2007) for the expansionary effect of a government expenditure shock.

The movement in the exchange rate, as in most of the scenarios explored here, reflects the changes in the real interest rate relative to unchanging international real interest rates. Although not shown, here the path for the real interest rate has a similar profile to the exchange rate shown in panel (i).

Shock to taxation The impulse responses for the taxation shock are shown in Figure 4. As with the government expenditure shock, taxation is a temporary shock in the model so all impulses return to the (zero) mean in the long run. This occurs after about 6 years, almost twice as long as the temporary shock applied in the deterministic specification of Claus et al (2006, Figure 2). The approximately 1 percent positive taxation shock (panel (b)) results in higher government expenditure (panel (a)), although the increase in taxation is sufficient to lower the debt to GDP ratio over the first 2 years of the impulse horizon (panel (d)).

While the higher taxation decreases absorption initially by 0.46%, there are increases in government expenditure and *gdp* (panels (c) and (e)). Although lower GDP would be expected the value here is very small and unlikely to be significant. This result is consistent with increased taxation through a consumption tax, resulting in lower absorption, and a redistribution of government spending through investment goods - something that may well be a suitable characterisation of the New Zealand economy over the sample period which includes both the introduction and increases in the rate of GST and a change in policy towards government investment expenditure over the period – the importance of government investment expenditure in variations in the analysis can be seen in Figure 5 which plots the log level of government consumption and government investment, scaled so that the initial observation is zero in each case. The variation in government investment is clearly evident. As in Hall and Rae (1998), if we scale these shocks, a decrease in taxation leads to a greater GDP effect than the equivalent increase in government expenditure.

Initially higher *gdp* results in a positive short term interest rate response (panel (h)), and this, coupled with the lower absorption in the first few quarters (panel (c)) is associated with lower inflation (panel (g)). The short term interest rate declines in response and inflation and absorption move back towards their long term values. The response in the *twi* (panel (i)) again reflects the real interest rate conditions in the scenario.

The inflation response is again one where mixed results occur in the literature. Favero and Giavazzi (2007) similarly find that inflation falls in response to a taxation shock and interest rates respond with a fall, while Mountford and Uhlig (2005) find a rise in prices. In the alternative experiments presented in Mountford and Uhlig, interest rates rise in the case where there is no delay in the implementation of the taxation shock, but fall when there is a 12 month delay. In both cases there is no recovery in the output variable to the taxation shock in their model. Perotti (2002) finds that the outcomes differ across countries.

Shock to the debt to GDP ratio A shock to the debt to GDP ratio in this model is a temporary shock, here shown as a temporary increase in the level of indebtedness as a proportion of output in Figure 6. The immediate effect is a decrease in government expenditure and a slightly delayed rise in taxation revenue in order to bring the ratio back towards its initial value (see panels (a) and (b)). The higher taxation and lower government expenditure results in continued lower *gdp*. Note that the effects of this 3.7% positive shock to the debt to GDP ratio, while it results in a 0.6% fall in government expenditure and 0.3% rise in taxation revenue at their respective minima and maxima has only a relatively small affect on absorption (*gne*) and *gdp*. Meanwhile, inflation has also emerged in the economy, leading to higher interest rates (panel (h)), which also acts to reduce the recovery in output. In this case both the fiscal and monetary policies seem to be working to decrease growth in their aims to both contain inflation and return to the previously pertaining debt/GDP equilibrium. This provides a very good reason to think carefully about the sources of shocks to a debt to GDP ratio. Forcing the shock to be temporary seems to have output costs.

Shock to the short term interest rate Shocks to short term interest rates in this model represent changes in monetary policy with temporary effects as is usual in the literature. The basic elements of this model behave as would be expected to a rise in the short term interest rate, with absorption and inflation falling (panels (c and f) of Figure 7), as in the Buckle et al (2007) SVAR for New Zealand. The *gdp* result is very small and more mixed, with the first few years having a very uncertain pattern before a positive outcome occurs for *gdp*. Note that the figure shown in panel (e) is typical of the cash rate impulse responses, in that they are extremely persistent and take quite a long time to return to the zero mean. One pleasing feature which results from imposing the Pagan and Pesaran (2007) distinction between temporary and permanent shocks in the model is that we are able to distinguish long lived effects of monetary policy decisions – without this other models including previous drafts of this model have found that the effects of monetary policy shocks can be dissipated within 18 months to 2 years – see for example Buckle et al (2007).

The interactions between the monetary policy shock and outcomes in the fiscal policy variables seem quite complex. Initially, taxation falls in line with lower output and absorption. However, both government expenditure and taxation revenue are also being affected by policy towards the debt to GDP ratio. The model is set up so that the effects on the debt to GDP ratio must ultimately be temporary. The uncertainty in the initial *gdp* response to the shock causes a problem in that there is a spike after 4 quarters which results in a rise in the debt to GDP ratio. However, the next impact is for lower *gdp*, lower government expenditure and higher taxation, all of which combine to create a lower debt to GDP ratio. The complexities of the policy interactions are more fully borne out in the discussion in Section 6.

5.1.1 Historical decomposition of GDP

Figure 8 shows the historical decomposition of *gdp* in the New Zealand economy over the sample. As might be expected the most important source of shocks lies with *gdp* itself. Shocks to absorption, *gne*, and international output shocks (y^*) are also important, as is inflation. Absorption shocks have an important role in offsetting the negative own shocks particularly during the recovery from the recession in the early 1990s and slowdown in the early 2000s period. Unfortunately, the influence of international output shocks seems to have been almost entirely negative for domestic *gdp* over this period, a result common to models of New Zealand.

The contribution of the policy variables are shown in greater detail in Figure 9. Taxation and government expenditure have had a more varied path. Before the Fiscal Responsibility Act in 1994 government expenditure shocks were more often contributing positively to output than negatively. From mid-1994 onwards, government expenditure shocks contributed negatively to output until late 1997 (just after the Asian financial crisis). They then returned to a positive effect which was sustained during the slowdown of the early 2000 period. Since about March 2003 government expenditure shocks have acted negatively on output. As in Claus et al (2006) the contributions of g and tax to gdp are roughly equivalent in their scale. In Section 6 where we control for feedback effects, a different picture emerges. The contribution of short term interest rates to output is largely negative post the early 1990s. Note that due to feedback effects this should not be interpreted as a pure monetary policy contribution, as will be discussed further below in Section 6.

Taxation shocks have generally been negative for output, as would be expected with the fiscal consolidation which has occurred over the period. Two periods of positive contribution stand out in the figures. The first is just post the increase in the rate of the GST in 1989 and leading into the early 1990s recession. The second is the most recent period from mid 2005. During the period prior to the Fiscal Responsibility Act when the debt to GDP ratio was climbing the effects of debt to GDP shocks are almost entirely negative for output. However, in more recent periods, as the debt to output ratio has become lower and more stable the relatively benign debt situation by world standards has resulted in shocks which are positive for domestic output.

5.1.2 Historical decomposition of inflation

Given that the target of monetary policy is inflation, the decomposition of inflation is of some interest. The historical decomposition of inflation, shown in Figure 10 shows that most of the inflationary shocks are own-shocks, which is consistent with results elsewhere. The other substantial influences are from absorption and the impact of international prices as represented through px, pm and the twi. A more interesting result is the historical decomposition of the short term interest rates, $short$, given in Figure 11. This shows that the major contributor to short term interest rates, other than own innovations, is domestic inflation. The Reserve Bank of New Zealand is clearly responding to domestic price conditions, and not international or asset price inflation (as represented here by house price inflation). It is also worth nothing that shocks to g and tax do not have a marked impact on either inflation or interest rate outcomes over the period compared with other influences.

6 The Influence of Monetary and Fiscal Policy

To build on what has already been uncovered we construct indices of the impact of monetary policy and fiscal policy on output in the New Zealand economy. To do this, we implicitly assume that policy shocks originate as pure shocks in the interest rate, which means isolating the feedback effects from the economy to these variables. Such an approach has been previously undertaken in Dungey and Pagan (2000) and Buckle et al (2007). Here the same logic is applied to government expenditure, taxation and debt to GDP shocks which in combination result in a total fiscal policy indicator. By estimating the VAR specification, but suppressing the feedback coefficients in calculating the historical decompositions it is possible to calculate the effect of the policy shocks on particular variables through the mechanism of a historical decomposition. To calculate the pure impact of monetary policy we first calculate an expression such as equation (26) but suppressing all coefficients except those on the lagged interest rate in the coefficient matrices. This gives an alternative decomposition for gdp, and the difference between these is the monetary policy effects from variables other than the interest rate, purged of feedback effects. This is then added to the pure interest rate impact to give the total monetary policy effect. The effects of government expenditure, taxation and debt policy are constructed similarly, and aggregated to form a total fiscal policy effect.

The contributions of monetary policy and fiscal policy to gdp over the sample period are shown as the mpi (monetary policy indicator) and fpi (fiscal policy indicator) in panel (a) of Figure 12. From September 1989 to June 1995 monetary policy is acting in a contractionary fashion. This is the period of the introduction of inflation targeting and monetary policy is clearly aimed at lowering inflation, but one consequence is that monetary policy is contractionary for gdp during a period of below average growth. Monetary policy is slightly expansionary from mid-1995 to June 1997, and then again resumed a contractionary stance. This latter episode is well-documented in the literature as associated with the period when the Reserve Bank of New Zealand based its anti inflationary target on a monetary conditions index (MCI) weighted equally across domestic inflation and exchange rate changes. A direct consequence was that to maintain the MCI policy stance during the East Asian crisis the Reserve Bank raised domestic interest rates in order to offset exchange rate movements, with unpleasant consequences for the real economy. In the figure the contractionary effect of monetary policy outlasts the MCI period and continues until mid-2003. For 2006 the mpi returned to a contractionary stance.

Fiscal policy clearly has a greater impact on gdp than monetary policy as shown in Figure 12. During the recession of the early 1990s and slowdown associated with the Asian crisis and drought in the late 1990s fiscal policy was broadly expansionary, in a counter cyclical manner. However, it does not always behave countercyclically. During the long recovery from the early 1990s when gdp is below average, fiscal policy is contractionary. And since mid-2005, in the midst of a period of sustained high growth in the New Zealand output the fpi shows an expansionary fiscal stance.

The contributions of the three components of the fpi can be seen in panel (b) of Figure 12. The first is the government expenditure index, the second is the taxation index and the third is the debt to GDP index. It is immediately apparent that the contributions of taxation policy have a high correlation with the overall fpi, the tax cuts introduced over the period 1997 and 1998 are apparent in the positive innovations to *gdp* over this period. The contractionary effects of government expenditure policy in the period following the Fiscal Responsibility Act are clearly evident from 1994 to 2000, followed by a small stimulatory impulse and then a return to a contractionary stance from 2001 onwards. The results of the Fiscal Responsibility Act and reduction in debt to GDP ratio are also evident in the *debt* indicator in the Figure. From about mid-1995 there is a positive stimulus to the economy from the enhanced prospects for future growth with a lower debt to GDP. This continues in the most recent period and is equally important in explaining the recent expansionary fpi reported in Panel A of the Figure. It is interesting to note that only for the period of 2000-2003 are each of the three components of the fpi acting in the same direction.

In the RBNZ (2007) submission to the review of the future of monetary policy implementation the Reserve Bank suggests that in the last few years of the sample period shown here, fiscal expenditure has been stimulatory (p.14 of their submission) and policy has contributed to cyclical fluctuations. The results here suggest for the period from mid-2005, that while government expenditure has not contributed to output pressure, this has been the case from net taxation and debt to GDP policy shocks. Potentially, the contribution of the debt to GDP ratio represents the greater confidence about the economy's ability to fund future growth with its currently historically relatively low debt to GDP ratio. The positive contribution of taxation shocks is a conglomerate of taxation receipts and transfer payments. Changes to the transfers system, and anticipation of lower income tax rates, are likely to be part of the explanation, and a further decomposition would be a useful future area for further research.

7 Conclusions

This paper showed how to use the comparative advantages of three different identification methods in SVARs to estimate models representing the types of policy issues of interest to national government, and in particular the interaction between fiscal and monetary policy shocks

The identification of monetary policy in VARs has received considerable attention in the academic literature, with that of fiscal policy less so. The innovation in this paper was to combine three existing methods of identification in SVARs into a single coherent model. Sign restrictions were used to separate government expenditure and taxation shocks, and combined with the rich work previously undertaken on traditional SVAR modelling for New Zealand (particularly Buckle et al, 2007) for the non-fiscal shocks. The third element is in formally modelling the long run by using information on cointegrating relationships between the macroeconomic variables, and accounting for both permanent and transitory components in the series for a model containing both I(0) and I(1) variables, building on the recent work of Pagan and Pesaran (2007) and Dungey and Pagan (2007). The cointegrating relationships are derived both empirically and theoretically. In modelling fiscal policy we also specifically incorporated debt, whose important role has been emphasized in the recent work of Chung and Leeper (2007) and Favero and Giavazzi (2007).

The application was to the small open economy of New Zealand. The case of New Zealand is an interesting one, as apart from being a policy innovator on a world scale in both monetary and fiscal policy, the issue of the interactions between the two policies has recently gained prominence in response to a parliamentary enquiry on the future of monetary policy in the economy. The paper focuses on the impact of the two policies on selected macroeconomic variables.

The model characterised the behaviour of output in New Zealand over the last 20 years, and showed that in general fiscal policy shocks have been larger than monetary policy, once the automatic feedback in each policy variable had been accounted for. In particular, taxation and debt policy shocks have been more substantial than both government expenditure and monetary policy shocks. Most of the behaviour in output arising over the sample period was clearly not a result of policy shocks; other influences, often own shocks, were dominant. However, a decomposition of monetary policy shocks showed that it mainly responded to inflationary shocks, providing a heartening validation of the conduct of monetary policy in New Zealand. The conduct of fiscal policy had both counter and pro-cyclical elements, and the three elements associated with government expenditure, taxation and debt policy were frequently acting in different directions.

References

[1] Bagliano, F.C. and C.A. Favero (1998), "Measuring Monetary Policy with VAR Models: An Evaluation", *European Economic Review,* 42, 1069-1112.

[2] 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.

[3] Blanchard, O. and D. Quah (1989), "The Dynamic Effects of Aggregate Demand and Supply Disturbances", *The American Economic Review*, 79, 655–673.

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

[5] Buckle, R.A., K. Kim, H. Kirkham, N. McLellan and J. Sharma (2007), "A Structural VAR Business Cycle Model for a Volatile Small Open Economy", *Economic Modelling*, 24, 990-1017.

[6] Canova, F. and G. de Nicoló (2002), "Monetary Disturbances Matter for Business Fluctuations in the G7", *Journal of Monetary Economics*, 49, 1131-1159.

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

[8] Canova, F. and M. Paustian (2007), "Measurement with Some Theory: Using Sign Restrictions to Evaluate Business Cycle Models", paper presented at the Reserve Bank of Australia Workshop, Monetary Policy in Open Economies, December 2007.

[9] Canova, F. and J. Pina (2005), "What VARs Tell Us About DSGE Models?", in C. Diebolt and C. Krystou (eds), *New Trends in Macroeconomics,* Springer Verlag, New York.

[10] Chari, V.V., Kehoe, P. and E. McGrattan (2005), "A Critique of Structural VARs Using Real Business Cycle Theory", Federal Reserve Bank of Minneapolis, working paper #631.

[11] 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.

[12] Chung, H. and E.M. Leeper (2007), "What Has Financed Government Debt?" manuscript.

[13] Claus, I., A. Gill, B. Lee and N. McLellan (2006), "An Empirical Investigation of Fiscal Policy in New Zealand", New Zealand Treasury Working Paper, 06/08.

[14] Cooley, T.F. and M. Dwyer (1995), "Business Cycles Without Much Theory: A Look at Structural VARs", *Journal of Econometrics*, *Journal of Econometrics,* 83, 57-88.

[15] Dungey, M and R.A. Fry (2008), "The Identification of Fiscal and Monetary Policy in a Structural VAR", New Zealand Treasury Working Paper, forthcoming.

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

[17] Dungey, M. and A.R. Pagan (2007), "Extending a Structural VAR Model of the Australian Economy", manuscript, University of Cambridge.

[18] Faust, J. (1998), "The Robustness of Identified VAR Conclusions about Money", *Carnegie-Rochester Series on Public Policy*, 49, 207-244.

[19] Faust, J. and E. Leeper (1997), "When do Long Run Identifying Restrictions Give Reliable Results", *Journal of Business and Economic Statistics*, 15, 345-353.

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

[21] Finance and Expenditure Committee (2007), Inquiry into the Future of the Monetary Policy Framework, Call for Submissions, New Zealand Parliament, http://www.parliament.nz/en-NZ/SC/SubmCalled/e/5/9/48SCFEInqfuturempf200707191-Inquiry-into-the-future-monetary-policy.htm

[22] Fernandez-Villaverde, J., Rubio-Ramirez, J., Sargent, T. and M. Watson (2007), "The ABCs (and Ds) of Understanding VARs, *American Economic Review,* 97, 1021-1026.

[23] Fry, R.A. and A.R. Pagan (2007), "Some Issues in Using Sign Restrictions for Identifying Structural VARs", NCER Working Paper #14.

[24] Fry, R.A. and A.R. Pagan (2005), "Some Issues in Using VAR's for Macroeconometric Research", CAMA Working Paper 19/05.

[25] Gali, J., J.D. López-Salido and J. Vallés (2007), "Understanding the Effects of Government Spending on Consumption ", *Journal of the European Economic Association*, 5, 227-270.

[26] Hall, V.B. and D. Rae (1998), "Fiscal Expansion, Monetary Policy, Interest Rate Risk Premia and Wage Reactions", *Economic Modelling*, 15, 621-640.

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

[28] Lippi, M. and L. Reichlin (2004), "VAR Analysis, Non Fundamental Representations, Blaschke Matrices", *Journal of Econometrics,* 63, 307-325.

[29] Lubik, T. and F. Schorfheide (2005), "A Bayesian Look at New Open Economy Macroeconomics", *NBER Macroeconomics Annual*, 20, 313–366.

[30] MacKinnon, J. (1996), "Numerical Distribution Functions for Unit Root and Cointegration Tests", *Journal of Applied Econometrics*, 11, 601-618.

[31] Mountford, A. and H. Uhlig (2005), "What are the Effects of Fiscal Policy Shocks", Discussion Paper 2005-039, SFB 649, Humboldt-Universitat, Berlin.

[32] Pagan, A.R. and M.H. Pesaran (2007), "On the Econometric Analysis of Structural Systems with Permanent and Transitory Shocks and Exogenous Variables", *Journal of Economic Dynamics and Control*, forthcoming.

[33] Pagan, A.R. and J. Robertson (1998), "Structural Models of the Liquidity Effect", *Review of Economics and Statistics*, 80, 202-217.

[34] Peersman, G. (2005), "What Caused the Early Millennium Slowdown? Evidence Based on Vector Autoregressions", *Journal of Applied Econometrics*, 20, 185-207.

[35] 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.

[36] Perotti, R. (2007), "In Search of the Transmission Mechanism of Fiscal Policy", NBER Working Paper #13143.

[37] Reserve Bank of New Zealand (2007), "Reserve Bank of New Zealand: Select Committee Submission, July 2007", Wellington, New Zealand.

[38] Rubio-Ramírez, J.F., D.F. Waggoner and T. Zha (2005), "Markov-Switching Structural Vector Autoregressions: Theory and Application", Working Paper 2005-27, Federal Reserve Bank of Atlanta.

[39] Sims, C.A. (1980), "Macroeconomics and Reality", *Econometrica*, 48, 1-48.

[40] Svensson, L. (2001), "Executive Summary of the Report to the Minister of Finance, by Professor Lars E.O. Svensson", *Reserve Bank of New Zealand Bulletin*, 64, 4-10.

[41] Treasury and Reserve Bank of New Zealand (2006), "Supplementary Stabilisation Instruments", Initial report to the Governor, Reserve Bank of New Zealand and Secretary to the Treasury, Wellington, New Zealand.

[42] Uhlig, H. (2005), "What are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure", *Journal of Monetary Economics*, 52, 381-419.

A Data Definitions

The sample period begins in 1983Q2 and extends to 2006Q4; all data were provided by the New Zealand Treasury.

A.1 Endogenous Variables:

Exchange rate: Logged nominal trade weighted index for New Zealand, average of 11 am observations from RBNZ (RTWI11am).

Export prices: Logged domestic current prices of New Zealand exports, export price index, all merchandise.

Foreign output: Logged real foreign output index from New Zealand Treasury, 2000Q1=100 made up of industrial output indices weighted by export value share. Until 1983Q1, the weights are a 4 quarter moving average of nominal exports. From 1983:2 onwards the weights are a 2 year moving average. Component countries are: Australia, Hong Kong, Japan, Germany, US, UK, Taiwan and South Korea.

Government debt: The log of 100 times the ratio of government debt to GDP. The debt data was interpolated from annual data using the method of Chow and Lin (1971) for the period to September 1994. See Dungey and Fry (2008) for further details.

Gross domestic product: Logged New Zealand real GDP(P) s.a. $NZ m., chain-volume expressed in 1995/96 prices.

Government expenditure: The logged sum of real government consumption and real government investment smoothed through the application of a moving average filter of the current and three lags of observations. The motivation for filtering in this manner lies in the apparent lumpiness of taxation and government expenditure. The original data has relatively high variance in quarterly terms, which is not seasonally related. In the VAR analysis this acts as though there are many 'surprises' in the data, implying many policy related changes. The moving average filter reduces this by effectively annualising the taxation collection and government expenditure.

Government consumption is central government consumption s.a. $NZm, chain volume series expressed in 1995/1996 prices.

Government investment is s.a. $NZ m., chain volume series expressed in 1995/1996 prices. The purchase of frigates in 1997 and 1998 are excluded from both the expenditure and taxation (GST) variables; see also Claus et al (2006). The series is also purged of investment by state owned enterprises.

Gross national expenditure: Logged real GNE s.a. $NZ m., chain-volume expressed in 1995/96 prices.

House price inflation: Annualised quarterly rate of the nominal house price index base of March 2000=100.

Import prices: Logged domestic current prices of New Zealand imports, import price index, total merchandise imports.

Inflation: Annualised quarterly rate calculated from the log difference of the New Zealand CPI - All groups, multiplied by 400.

Short term interest rate: New Zealand nominal 90 day bank bill yield, average 11 am rates.

Taxation: The log of real taxation minus real transfers. The series is deflated by the GDP(E) implicit price deflator s.a. based at 1995/1996=100 and smoothed through the application of a moving average filter of the current and three lags of observations, see the notes to Government expenditure.

Nominal taxation is total direct plus indirect taxation with intra-government GST removed, s.a. $NZ m.

Transfers are s.a. $NZ m.

A.2 EXOGENOUS VARIABLES:

Foreign interest rate: Nominal 90 day interest rate as used in Buckle et al (2007), nominal GDP weighted sum of US, Japanese, German and Australian interest rates, weights change with GDP each quarter.

Climate: Number of days of soil moisture deficit recorded in each quarter, as measured by National Institute of Water and Atmospheric Research. The variable has been adjusted by removing from each quarterly value the long-run average for that quarter, and is the same as that used in Buckle et al (2007).

Table 1:
Augmented Dickey-Fuller and Phillips-Perron unit root tests 1983Q2 to 2006Q4.*

	ADF test			PP test	
	t-stats.	p-values	ρ	t-stats.	p-values
$y*$	-2.463	0.346	0.930	-2.886	0.172
px	-3.506	0.045	0.862	-2.704	0.237
pm	-3.780	0.022	0.809	-2.829	0.191
g	-0.646	0.974	0.991	0.065	0.997
tax	-3.342	0.066	0.915	-1.787	0.703
gne	-2.386	0.384	0.927	-1.439	0.843
$debt$	-3.869	0.017	0.900	-3.171	0.097
gdp	-2.003	0.592	0.953	-1.273	0.888
$hpinf$	-3.218	0.088	0.842	-2.751	0.219
inf	-2.992	0.140	0.864	-2.555	0.302
$short$	-1.985	0.601	0.905	-2.254	0.454
twi	-2.920	0.161	0.869	-2.351	0.402

*Unit root tests are conducted on the non-detrended data and contain a constant and trend.
The lag length is set at 3 for each case reflecting the model.
The critical values are the McKinnon (1996) one sided.

Table 2:
Engle-Granger two-step cointegration tests 1983Q2 to 2006Q4.*

Variable	Coefficients in the cointegrating regressions								ADF p-values on residuals
	$y*$	px	pm	g	tax	gne	gdp	twi	
g	-0.692				0.304	1.480	-0.554	-0.172	0.132
g					1				n.a.
twi		-0.200	-1.016						0.000

*The ADF tests are performed on the errors of the cointegrating equations.

Table 3:
Structure of the SVAR.

$\circ$,$\bullet$ denote contemporaneous and lag relationships in terms of traditional restrictions respectively; +,-,uc, denote positive, negative and unconstrained sign restrictions respectively; $\diamond$ denote ECM and adjustment mechanisms respectively.

Explanatory variables	Dependent variables											
	y^*	px	pm	g	tax	gne	$debt$	gdp	$hpinf$	inf	$short$	twi
y^*	$\bullet$							$\circ,\bullet$				$\circ,\bullet$
px		$\bullet$										$\circ,\bullet$
pm			$\bullet$									$\circ,\bullet$
g				$+,\bullet$	$uc,\bullet$	$\circ,\bullet$	$\circ,\bullet$	$\circ,\bullet$				$\circ,\bullet$
tax				$uc,\bullet$	$+,\bullet$	$\circ,\bullet$	$\circ,\bullet$	$\circ,\bullet$				$\circ,\bullet$
gne				$uc,\bullet$	$-,\bullet$	$\circ,\bullet$	$\circ,\bullet$	$\circ,\bullet$	$\circ,\bullet$	$\circ,\bullet$	$\circ,\bullet$	$\circ,\bullet$
$debt$				$uc\bullet$	$uc,\bullet$		$\bullet$	$\circ,\bullet$				$\circ,\bullet$
gdp				$+\bullet$	$uc,\bullet$	$\bullet$	$\bullet$	$\bullet$	$\circ,\bullet$			$\circ,\bullet$
$hpinf$				uc	uc	$\bullet$			$\bullet$	$\circ,\bullet$		$\circ,\bullet$
inf				$uc,\bullet$	$uc,\bullet$	$\bullet$			$\bullet$	$\bullet$	$\circ,\bullet$	$\circ,\bullet$
$short$				$uc,\bullet$	$uc,\bullet$	$\bullet$			$\bullet$		$\bullet$	$\circ,\bullet$
twi				$uc,\bullet$	$uc,\bullet$	$\bullet$		$\bullet$		$\bullet$		$\circ,\bullet$
$ecm1$				$\diamond$								$\diamond$
$ecm2$												$\diamond$
$ecm3$					$\diamond$							
$amdebt$				$\diamond$	$\diamond$		$\diamond$					
$amhpinf$									$\diamond$			
$aminf$				$\diamond$	$\diamond$					$\diamond$	$\diamond$	
$amshort$				$\diamond$	$\diamond$						$\diamond$	

Table 4:

Sizes of one-standard deviation shocks to the model.

Variable	Size	Variable	Size
$y*$	0.00729	$debt$	0.03765
px	0.03176	gdp	0.00597
pm	0.03490	$hpinf$	1.94017
g	0.00536	inf	0.82783
tax	0.01080	$short$	0.98216
gne	0.01266	twi	0.01507

Table 5:
Statistics on the sign restriction draws.

Statistics and criteria		
Total number of successful draws		1,000
Total number of draws		69,466
Panel A: criterion 1		
impulses $\tau = 4$	Number of occurrences of a G shock	51,612
	Number of occurrences of a T shock	16,896
	Number of occurrences of a G and T shock	16,896
impulses $\tau = 5$	Number of occurrences of a G shock	61,506
	Number of occurrences of a T shock	18,621
	Number of occurrences of a G and T shock	18,621
Panel B: criterion 2		
impulses $\tau = 4$	total to be disentangled	16,896
	Number of occurrences of a G shock	16,574
	Number of occurrences of a T shock	322
impulses $\tau = 5$	total to be disentangled	18,621
	Number of occurrences of a G shock	17,943
	Number of occurrences of a T shock	678
Panel C: criterion 3		
Number of occurrences of a G shock in impulses $\tau = 4$ and $\tau = 5$		42,762
impulses $\tau = 4$	Number of occurrences of a G shock	26,091
impulses $\tau = 5$	Number of occurrences of a G shock	16,581
Number of occurrences of a T shock in impulses $\tau = 4$ and $\tau = 5$		0
impulses $\tau = 4$	Number of occurrences of a T shock	0
impulses $\tau = 5$	Number of occurrences of a T shock	0
Panel D: Final results		
impulses	G shock ($\tau = 4$), T shock ($\tau = 5$)	678
	G shock ($\tau = 5$), T shock ($\tau = 4$)	322

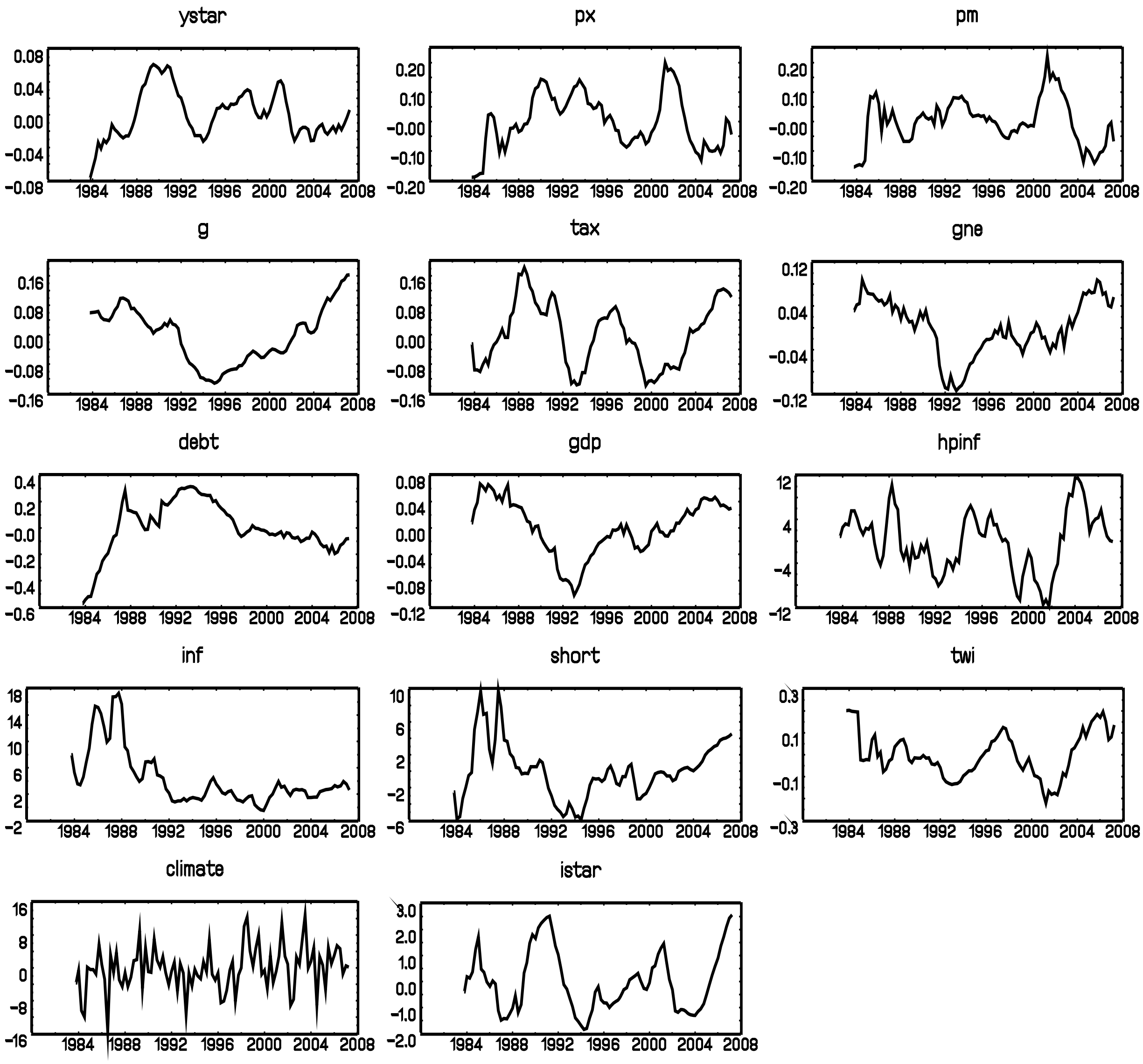

Figure 1: Plots of the New Zealand data. With the exception of the interest rates, inflation rates and the climate variable, the original data were detrended using a linear trend.

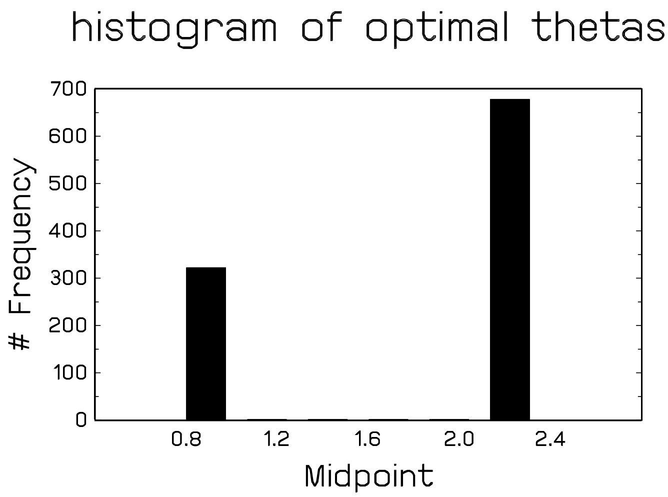

Figure 2: Distribution of the thetas used in generating the impulse responses.

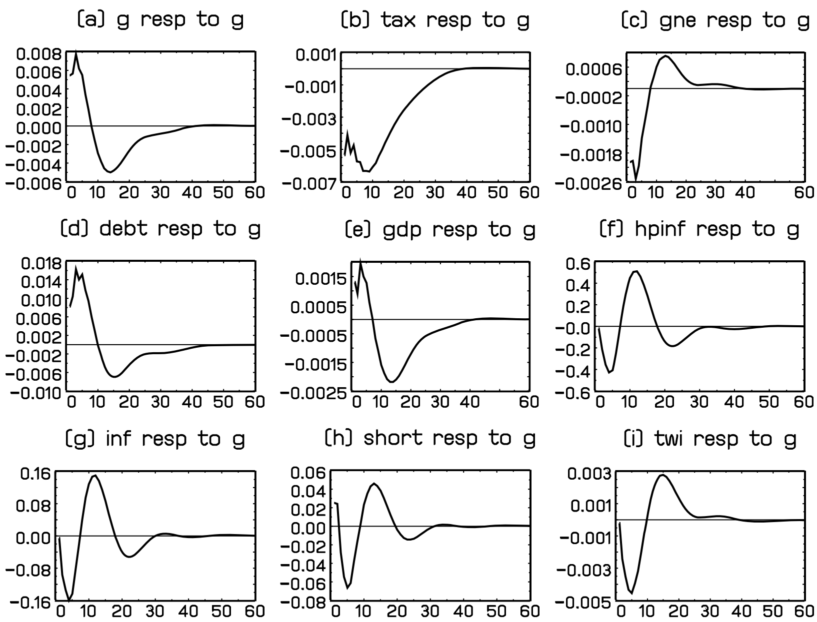

Figure 3: Impulse responses to a shock to government expenditure.

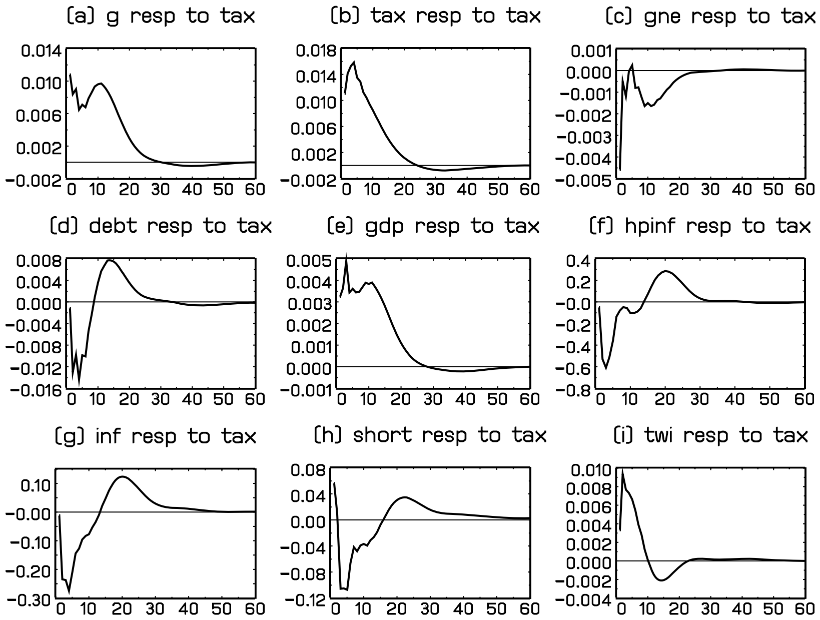

Figure 4: Impulse responses to a shock to taxation.

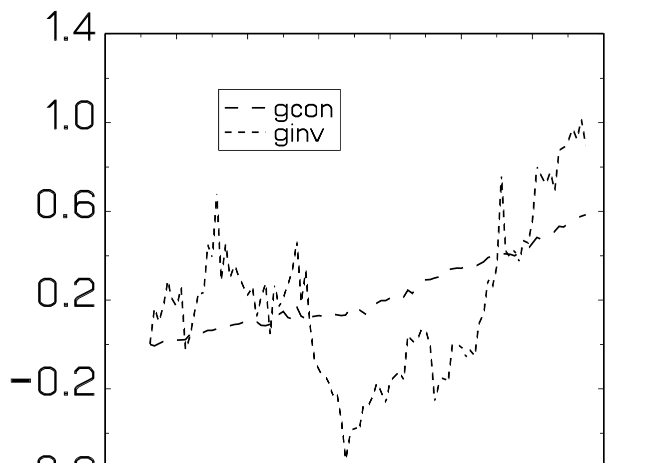

Figure 5: Government consumption and investment expenditure.

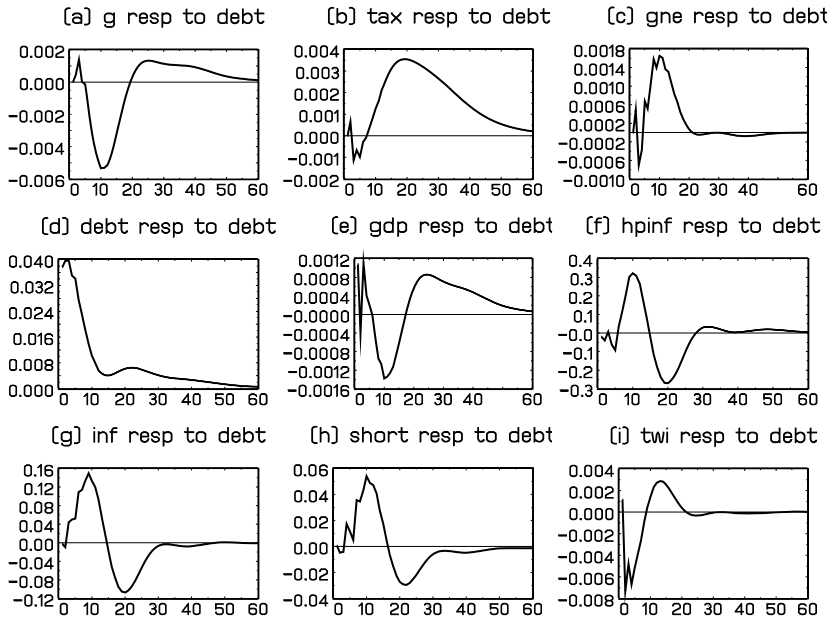

Figure 6: Impulse responses to a shock to the debt to GDP ratio.

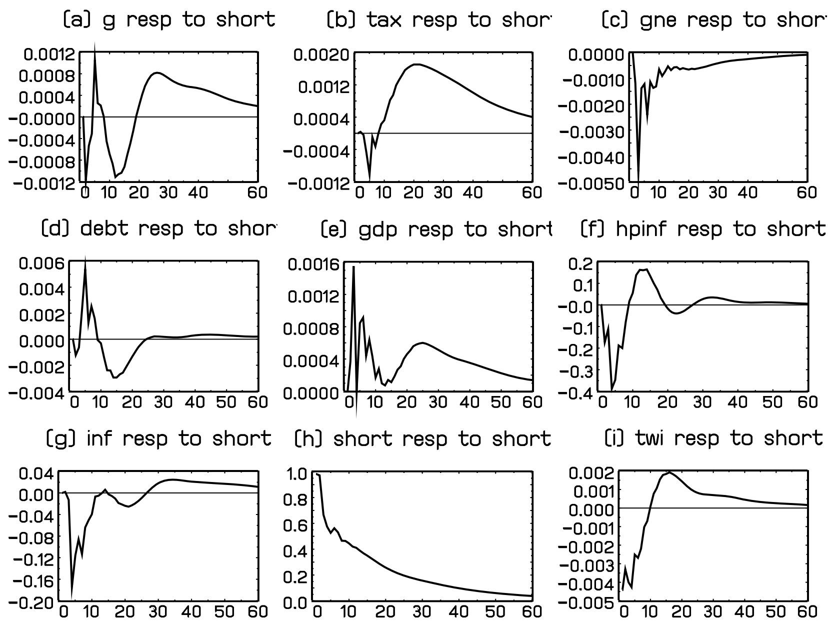

Figure 7: Impulse responses to a shock to the short interest rate.

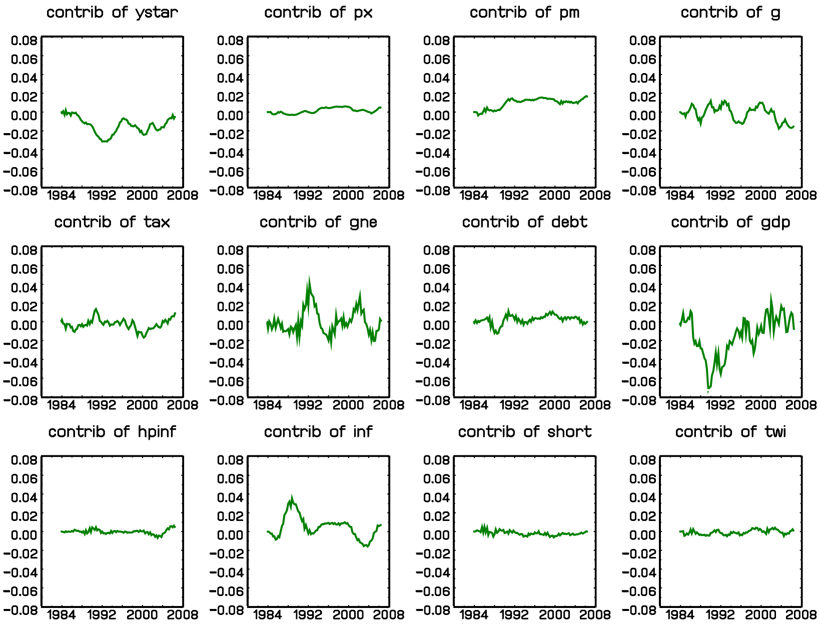

Figure 8: Historical decomposition of output (gdp).

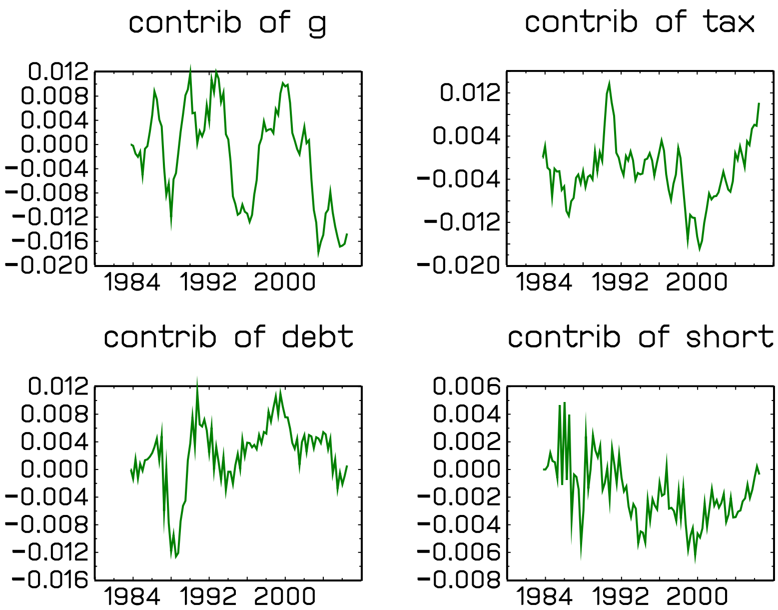

Figure 9: Historical decomposition of gdp by policy instruments.

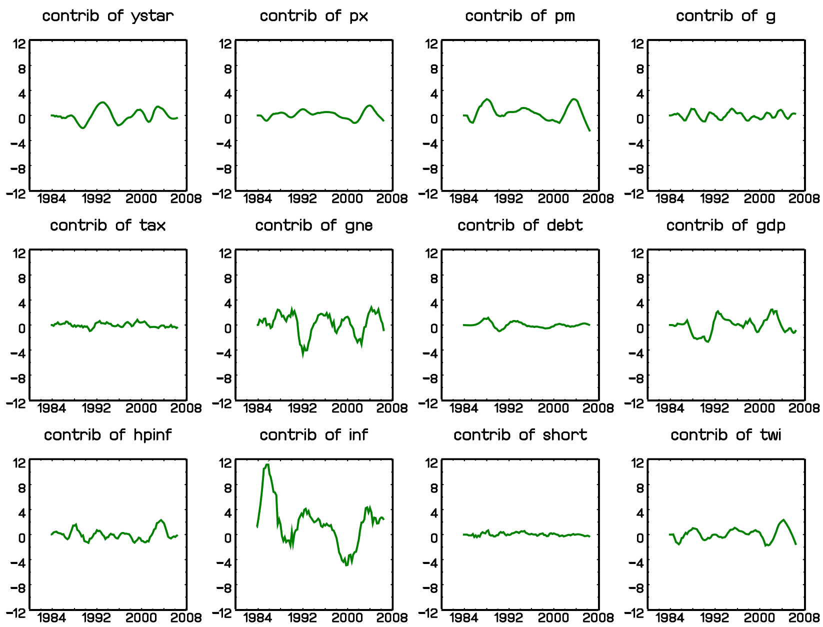

Figure 10: Historical decomposition of inflation.

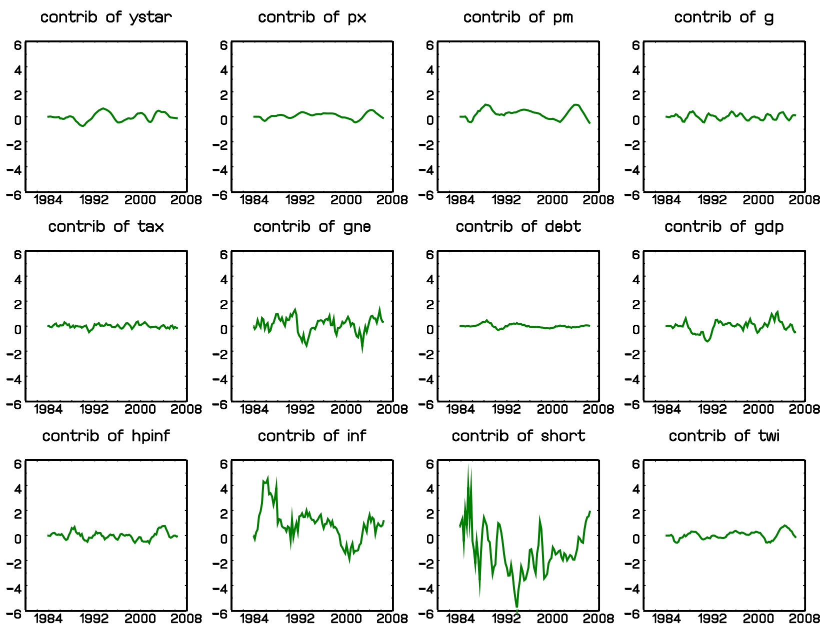

Figure 11: Historical decomposition of short term interest rates.

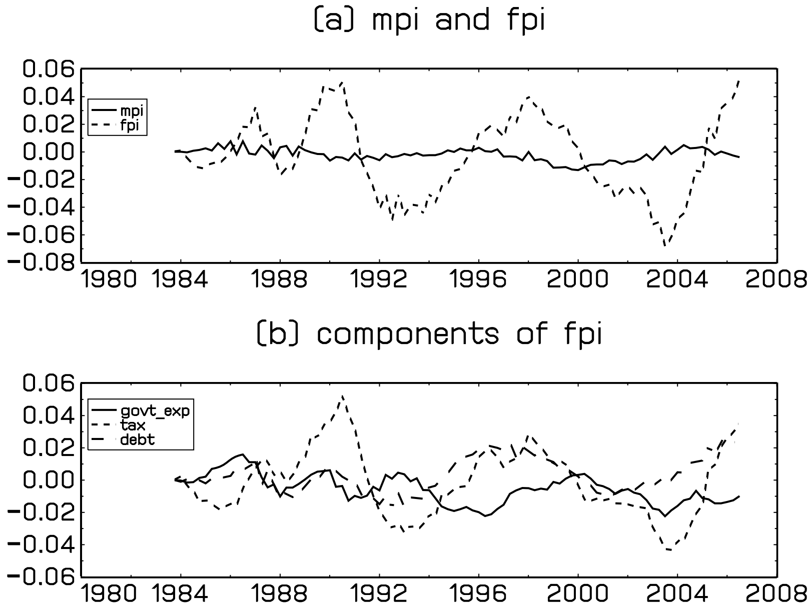

Figure 12: Monetary policy and fiscal policy indicators for GDP.