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

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Abstract

The problem of economic management depends on the interactions between monetary policy, fiscal policy and other shocks affecting the economy. This paper presents a new methodology to disentangle fiscal and monetary policy shocks in a VAR framework. The method combines identification via sign restrictions, cointegration and traditional exclusion restrictions within a system which explicitly models stationary and non-stationary variables and accounts for both permanent and temporary shocks. The usefulness of the approach is demonstrated on a small open economy 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.

1 Introduction

For any country the problem of economic management depends on the interactions of monetary policy, fiscal policy and shocks to the economy. This paper contributes a new methodology for disentangling these effects empirically in a structural vector autoregression framework (SVAR).

Empirical macroeconomic modelling is often undertaken in a SVAR, where identification of policy shocks usually occurs in one of three ways.[1] The first is through traditional normalisation and restrictions on the contemporaneous relationships between variables. This is widely applied to monetary policy (for a review see Bagliano and Favero, 1998) and only recently to fiscal policy using institutional detail and calibrated elasticities as identification tools (Blanchard and Perotti, 2002; Perotti, 2002; Chung and Leeper, 2007; and Favero and Giavazzi, 2007). The second is the newer sign restriction identification method which imposes restrictions on the choice of impulse responses to shocks considered acceptable from the possible choice of orthogonal systems (Faust, 1998; Canova and de Nicoló, 2002; and Mountford and Uhlig, 2005). The third approach is to take account of the longer run properties of the model, in one form as a vector error correction model (VECM), or as an extension of the Blanchard and Quah (1989) methodology, or in the recognition of the correspondence between SVARs and VECMs, see Jacobs and Wallis (2007), which allow the use of cointegrating relationships as a tool of identification as in Pagan and Pesaran (2008).

Here the approach is to build a model containing fiscal, monetary and other macroeconomic variables drawing on elements of these three identification methods. Short-run restrictions on the non-fiscal variables are provided via the existing traditional SVAR restrictions. The fiscal policy shocks are identified using a minimal set of sign restrictions, leaving other relationships to be data determined.[2] 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 and 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 while still adhering to the VAR tradition of letting the data

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[1]In some circumstances VAR methods are inappropriate. Sometimes models cannot be written as 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); Fernandez-Villaverde et al (2007); and Leeper, Walker and Yang (2008) amongst others for discussion.

[2]Leeper, Walker and Yang (2008) suggest that non-fiscal policy shocks are not well identified by sign restrictions.

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 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. More recently, Chung and Leeper (2007) and Favero and Giavazzi (2007) build on Blanchard and Perotti and show the importance of accounting for the level of government debt. 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.[3]

The application in this paper is to the small open economy of New Zealand, one of the few countries which has coherent fiscal data available for modelling.[4] New Zealand was the first country to adopt inflation targeting, in 1990, and consequently has the longest available time series for a small open economy in an inflation targeting structure. It also adopted a Fiscal Responsibility Act in 1994. Further, policy attention in New Zealand is currently focussed on the interactions between fiscal and monetary policy (Finance and Expenditure Committee, 2007). There is a well-established SVAR modelling framework for New Zealand, which has resolved many non-fiscal related model specification issues, and we draw on this for the short-run restrictions for non-fiscal variables; see particularly Buckle, Kim, Kirkham, McLellan and Sharma (2007) and references therein.

The rest of this paper proceeds as follows. Section 2 presents a coherent VAR framework in which three types of identification restrictions are simultaneously applied and illustrates how to obtain impulse response functions and historical decompositions in this framework. Section 3 outlines the variables and data properties for the New Zealand example, characterising the stationarity and cointegration results necessary to apply the modelling framework. The specification of the model is described in Section 4 and the results presented in Section 5 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.

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

[4]Common problems with time series of fiscal data are moves from accrual to cash accounts within recent sample periods, lack of seasonally adjusted data, insufficient frequency of data (many series are simply annual), adjustments for large defence expenditure items, consistent debt data and compatability of component series - see Blanchard and Perotti (2002) for their approach to US data.

2 The Empirical Methodology

This section shows how to nest three identification methods in the same VAR. These are specifically, the traditional short-run restrictions, sign restrictions and long-run restrictions. Both permanent and transitory shocks are identified following Pagan and Pesaran (2008).

Consider a standard $\text{VAR}(p)$ where the data y_t are expressed in levels,

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

where $B(L) = B_0 - B_1 L - B_2 L^2 - \ldots - B_p L^p$. Usually identification proceeds through restrictions on B_0 and $\Omega = E(\varepsilon_t \varepsilon_t')$ matrices or in the case of Blanchard and Quah (1989) restrictions on long run impact effects. Sign restrictions provide a further alternative. Defining $\widehat{S}$ as containing the estimated standard deviations of the structural residuals along the diagonal with zeros elsewhere, the relationship between the estimated reduced form and structural errors is

$$
\begin{aligned}
\widehat{e}_t &= \widehat{B}_0^{-1}\widehat{S}\widehat{S}^{-1}\widehat{\varepsilon}_t \\
&= T\eta_t,
\end{aligned}
\tag{2}
$$

where $\widehat{B}_0^{-1}$ is the estimated matrix of contemporaneous coefficients, T is designated an impact matrix, and η_t are the estimated shocks where η_t has unit variances. The original shocks can be redefined as a function of an orthonormal matrix Q, in this paper the Given's rotation matrix, which by definition has the properties $Q'Q = QQ' = I$ such that

$$
\begin{aligned}
\widehat{e}_t &= TQ'Q\eta_t \tag{3} \\
&= T^*\eta_t^*. \tag{4}
\end{aligned}
$$

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^*. The initial arbitrary shocks are rotated to produce an alternative set of shocks while maintaining the desirable property that the shocks remain orthogonal. The choice of Q is determined by examination of the signs of the impulse response functions. Defining $B_0^* = (T^*)^{-1}$, and $B_i^* = B_i$ for all $i \neq 0$, the $\text{VAR}(p)$ can be rewritten as

$$B^*(L)y_t = \varepsilon_t, \tag{5}$$

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

The VAR(p) expressed in either equation (1) or (5) depending on whether sign restrictions are imposed, can be written in a corresponding reduced form in differences as follows, (for convenience the notation from now on assumes the imposition of sign restrictions, but to remove them simply impose $B^*(L) = B(L)$):

$$\Psi(L)\Delta y_t = -\Pi y_{t-1} + e_t, \tag{6}$$

where $e_t = B_0^{*-1}\varepsilon_t$ and, $\Psi(L) = (I_n - \Psi_1 - \Psi_2 - ...\Psi_{p-1})$ and Ψ_j are the appropriate transformation of the structural parameters.[5] In the case where all variables in y_t are I(1) and there are $r < n$ cointegrating relationships between them, the matrix Π will be rank deficient and in the usual notation $\Pi = \alpha'\beta$ where α and β are of full rank.[6]

The inclusion of I(0) variables in y_t is relatively straightforward by simply recognising that the k I(0) variables are treated in exactly the same way as the n I(1) variables, but with the matrix β on the lagged levels effects (y_{t-1}) defined as

$$\beta = \left[\begin{array}{cc} \beta_n & 0 \\ 0 & -I_k \end{array} \right]. \tag{7}$$

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; see Levtchenkova, Pagan and Robertson (1998) and Jacobs and Wallis (2007). By definition all shocks corresponding to the I(0) variables are transitory. In a common trends representation

$$\Delta y_t = F(L)e_t = F(L)\left(B_0^*\right)^{-1}\varepsilon_t, \tag{8}$$

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

$$F = \beta_\perp \left[\alpha'_\perp \Psi(L)\beta_\perp \right] \alpha_\perp^{-1}, \tag{9}$$

with $\alpha'_\perp \alpha = 0$, $\beta'_\perp \beta = 0$, $F\alpha = 0$ and $\beta'F = 0$. The matrix $\alpha'_\perp$ corresponds to the H matrix used in Levtchenova, Pagan and Roberston (1998) to partition permanent and temporary shocks. Here we can say more about its properties following Pagan and Pesaran (2008). If the first $(n-r)$ shocks are permanent then

$$\Delta y_t = F(L)\left(B_0^*\right)^{-1} \left(\begin{array}{c} \varepsilon_{1jt} \\ \varepsilon_{2jt} \end{array} \right), \tag{10}$$

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

$$F B_0^{*-1} \left(\begin{array}{c} 0_{(n-r)\times r} \\ I_{r+k} \end{array} \right) = 0, \tag{11}$$

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[5]For example, in the case of a VAR(3) in levels the appropriate transformations are $\Pi = (B_0^*)^{-1}(B_0^* - B_1^* - B_2^* + B_3^*)$, $\Psi_1 = (B_0^*)^{-1}(B_3^* - B_2^*)$ and $\Psi_2 = -(B_0^*)^{-1}B_3^*$.

[6]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.

which is equivalently

$$FB_0^{*-1} \begin{pmatrix} 0_{(n-r) \times r} \\ I_{r+k} \end{pmatrix} = F\alpha = 0. \tag{12}$$

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

$$\begin{pmatrix} 0_{(n-r) \times r} \\ I_{r+k} \end{pmatrix} = B_0^* \alpha = 0. \tag{13}$$

The right hand side of equation (13) can be multiplied by an arbitrary non-singular matrix R

$$\begin{pmatrix} 0_{(n-r) \times r} \\ I_{r+k} \end{pmatrix} = B_0^* \alpha R = \alpha^* R = \begin{pmatrix} \alpha_1^* R \\ \alpha_2^* R \end{pmatrix}. \tag{14}$$

Satisfying this equation requires that $\alpha_1^* R = 0$, 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, but the error correction terms enter where there are transitory shocks. This provides extra instruments for identification, although this turns out not to be relevant in the overidentified system investigated in the current paper. For the stationary variables, the error correction terms can be thought of as additional adjustment mechanisms.

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

$$\Delta \gamma = \zeta_t, \tag{15}$$

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

$$J = FB_0^{*-1}. \tag{16}$$

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 (2008), who explicitly recognise that a number of existing models which use this do not specifically include the remaining lags of the permanent variables, thus missing an important aspect of the transformation. Denote the transitory component of the variables as $\omega_t = \left(y_t - y_t^P \right)$, the correct transformation of the SVECM into a SVAR is

$$B^*(L)\Delta \omega_t = \Pi \omega_{t-1} + \sum_{j=1}^{p-1} B_j^* \Delta y_{t-j}^P + \varepsilon_t. \tag{17}$$

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

$$\widetilde{B}(L)y_t = \Pi y_{t-1} + -\widetilde{B}(L)J\varepsilon_t + (B_0^*)^{-1}\varepsilon_t, \qquad (18)$$

where $\widetilde{B}(L) = I_n - \widetilde{B}_1 L - \widetilde{B}_2 L^2 - \dots \widetilde{B}_p L^p$. Rewriting (18) as a moving average in ε_t provides the expression

$$G(L)y_t = J(L)\varepsilon_t, \qquad (19)$$

and impulse responses are 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} is represented as

$$\frac{\partial y_{t+j}}{\partial \varepsilon_{kt}} = \frac{\partial \omega_{t+j}}{\partial \varepsilon_{kt}} + \frac{\partial y_{t+j}^p}{\partial \varepsilon_{kt}} = \frac{\partial \omega_{t+j}}{\partial \varepsilon_{kt}} + J. \qquad (20)$$

Historical decompositions   Historical decompositions are a reorganisation of information in the impulse response functions. From the moving average form of any variable as given in equation (18), 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. From (18) this has the form

$$\Delta \omega_t = initial\ conditions + \sum_{i=0}^{t} C_i \varepsilon_{t-i} + J, \qquad (21)$$

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 the changes at each point in time are of interest, the effect of J in this form of the analysis is largely ignored.

3   The Data

The data consist of 12 individually linearly detrended endogenous variables in y_t ordered as

$$y_t = \{y_t^*, px_t, pm_t, g_t, tax_t, gne_t, debt_t, gdp_t, hpinf_t, inf_t, short_t, twi_t\}, \qquad (22)$$

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).[7]

Data are available from 1983:2, and the current dataset extends to 2006:4. 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.[8] 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. All variables are in natural logarithms except for the interest rates and inflation rates which are in percentages.[9] Figure 1 presents a present a plot of the data for all variables including the exogenous variables of climate and the international interest rate. Full definitions of the variables are given in Appendix 1.

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 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).

The data are of mixed order of integration, see Dungey and Fry (2007) for the complete set of unit root tests. Foreign and domestic output, government expenditure and taxation revenue are $I(1)$ processes. House price and consumer price inflation and interest rates are treated as $I(0)$. The trade weighted index is statistically $I(1)$ using both the Augmented Dickey-Fuller and Phillips-Perron tests as guides, while

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[7]Note that linear detrending is equivalent to the approach taken in many New Keynesian DSGE models (see Lubik and Schörfheide, 2005). In contrast Buckle et al (2007) use an HP filter to detrend, however it is not clear how to retain the long run cointegrating relationships in this case.

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

[9]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, particularly when comparing fiscal and monetary policies.

the evidence is mixed for the price of exports and the price of imports. All three are treated as $I(1)$ 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 supports this view. Although there are some difficulties with viewing the trade weighted index as $I(1)$ this turns out to be a useful specification here, partly because as in Dungey and Pagan (2008), it allows a mechanism by which balance of payments adjustments can occur, 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.

Of the 12 variables, 8 are non-stationary, and there are 3 cointegrating vectors.[10] Empirical examination of the cointegrating relationships amongst the non-stationary series using the Engle-Granger two-step procedure confirms a cointegrating vector between $\left\{ \begin{array}{cccccc} g_t & tax_t & gne_t & gdp_y & twi_t & y_t^* \end{array} \right\}$ and a further relationship between $\left\{ \begin{array}{ccc} twi_t & px_t & pm_t \end{array} \right\}$. The results of these tests are summarised in Table 1. A further cointegrating vector [1 -1] between government expenditure and tax is chosen, essentially keeping the debt to GDP ratio stable.[11] 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.

4 Empirical Specification

The model is identified by imposing restrictions directly on the B_i, α and β matrices described in Section 2 given the properties of the integration of the data and the

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[10] 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 between the variables in the New Zealand framework 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.

[11] 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.

cointegrating relationships established in Section 3. The restrictions on the B_i matrices broadly follow the traditional SVAR restrictions of Buckle et al (2007). The main modifications to the Buckle et al (2007) model include the incorporation of the fiscal and debt variables and house price inflation, as well as the modelling of the long run, and the adoption of a SVARX form, where climate and international interest rates are incorporated as exogenous variables. The structure of the contemporaneous restriction matrix, B_0, is given by

$$
B_0 = \begin{bmatrix}
1 & & & & & & & & & & & \\
& 1 & & & & & & & & & & \\
& & 1 & & & & & & & & & \\
& & & 1 & & & & & & & & \\
& & & b_{5,4} & 1 & & & & & & & \\
& & & b_{6,4} & b_{6,5} & 1 & & & & & & \\
& & & b_{7,4} & b_{7,5} & b_{7,6} & 1 & & & & & \\
b_{8,1} & & & b_{8,4} & b_{8,5} & b_{8,6} & b_{8,7} & 1 & & & & \\
& & & & & b_{9,6} & & b_{9,8} & 1 & & & \\
& & & & & b_{10,6} & & & b_{10,9} & 1 & & \\
& & & & & b_{11,6} & & & & b_{11,10} & 1 & \\
b_{12,1} & b_{12,2} & b_{12,3} & b_{12,4} & b_{12,5} & b_{12,6} & b_{12,7} & b_{12,8} & b_{12,9} & b_{12,10} & b_{12,11} & 1
\end{bmatrix},
$$

(23)

where the first three diagonal elements correspond to the international variables, y_t^*, px_t and pm_t which enter the system as an AR(2) processes. The fourth and fifth equations correspond to the fiscal variables, the identification of which will be discussed further below.

Absorption represented by gne is the sixth variable in the system and is assumed to be a function of both of the contemporaneous and lagged fiscal policy variables, and all lags of the variables in the system (the B_i $i > 0$ matrices are not shown here for brevity, as they correspond with those in Buckle et al (2007) with the addition of the fiscal, debt and house price inflation equations, the full specification is available in Dungey and Fry (2007). 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 enters as the seventh variable in the system and is contemporaneously dependent on each of the fiscal variables and absorption (gne_t) as an indicator of cyclical pressure. 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.

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Domestic GDP is modelled as a function of the contemporaneous and lagged fiscal policy variables, debt and absorption, as well as all lags of the short interest rate and exchange rate. It also responds to the contemporaneous and lagged exogenous variables of foreign output, y_t^* and the climate variable.

House price inflation is included as a control for asset price behaviour in New Zealand. It is modelled as a function of contemporaneous and lagged domestic demand and output, its own lags, lagged inflation and the interest rate. Consumer price inflation itself encompasses a Phillips curve type specification, where contemporaneous and lagged domestic demand are key. Pass through effects from imported inflation are accounted for through the inclusion of the lagged exchange rate. The two GST dummies variables discussed in relation to the absorption equation above, as well as lags of the climate variable are also included.

The short interest rate adopts a Taylor rule form, containing contemporaneous and lagged domestic demand and inflation and the lagged interest rate. The exchange rate responds to all variables in the model, with the exception of house price inflation, given that the housing stock is an essentially non-internationally tradeable commodity.

While a traditional SVAR identification such as outlined so far has been successfully applied to modelling monetary policy, untangling fiscal policy is more difficult; see Blanchard and Perotti (2002). 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.[12] The solution adopted here is to specifically incorporate the direction of these hypothesized fiscal relationships using the sign restrictions methodology; see for example Mountford and Uhlig (2005) and Canova and Pappa (2007).[13] This method has the advantage that the same model can incorporate contemporaneous taxation increases in response to a government expenditure shock, and contemporaneous government expenditure increases in response to a taxation shock (see Mountford and Uhlig, 2005). By using sign restrictions only on the two fiscal shocks, it is possible to remain agnostic, but not 'too' agnostic, about effects on other variables; contrast Uhlig (2005) and Canova and Paustian (2007).[14] Recall

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[12]The specification in Muscatelli, Tirelli and Trecroci (2004) uses the budget deficit as a measure of fiscal stance to avoid the problem with separately identifying taxation revenue and government expenditure.

[13]Blanchard and Perotti (2002) solve this problem using institutional details; see also Perotti (2002), Claus et al (2006), Chung and Leeper (2007) and Favero and Giavazzi (2007).

[14]As the dimension of the SVAR increases, the number of sign restrictions increases dramatically if all shocks are to be identified, making large systems difficult to identify using only this method. Peersman (2005) provides an example of a such a system.

that

$$B_0^* = (T^*)^{-1} = \left(B_0^{-1}SQ\right)^{-1} \tag{24}$$

where S is a diagonal matrix of the structural standard deviations, in the current case B_0 is as described in equation (23), and Q is defined as a Givens matrix as follows:

$$Q = \begin{bmatrix} I_3 & & \\ & \cos(\theta) & -\sin(\theta) \\ & \sin(\theta) & \cos(\theta) \\ & & & I_7 \end{bmatrix}. \tag{25}$$

θ is chosen randomly from the uniform distribution and adopts a value between 0 and π. The sign restriction method is applied to only two shocks and the remainder of the shocks are identified conventionally, as (23).

There are an infinite number of candidates for Q which produce an orthogonal set of shocks, but which all have the same VAR representation. As the naming convention implies, the sign restriction method restricts attention to rotations which produce shocks satisfying an anticipated sign in responses of key variables. Standard practice is for researchers to draw Q matrices until there are d number of impulses satisfying the set of economic restrictions stated.[15] The median of the impulse response functions C_j^d are then chosen, usually in association with impulses corresponding to specified percentile bands.

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.[16] 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 $d = 1,000$.

To disentangle the impulses and to assign them to particular shocks, three levels of criteria are examined.

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[15]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 matrices.

[16]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 have the advantage that they all come from the one model.

Criterion 1: pure sign criterion 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

$$C_{g,j}^{Gt,\tau} \geqslant 0, \qquad \forall j \tag{26}$$
$$C_{gdp,j}^{Gt,\tau} \geqslant 0, \qquad \forall j,$$

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. In the empirical example, $j = 1$.

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

$$C_{tax,j}^{T,\tau} \geqslant 0, \qquad \forall j \tag{27}$$
$$C_{gne,j}^{T,\tau} \leq 0, \qquad \forall j,$$

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

Criterion 2: magnitude restriction In certain draws, it is not possible to disentangle the two shocks using (26) and (27) alone. 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 $\left(C_{tax,j}^{Gt,\tau} \leq 0, \forall j\right)$; (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 $\left(C_{g,j}^{Gt,\tau} \geqslant 0, \forall j\right)$. The next criterion is that 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,

$$C_{g,j}^{\tau} > C_{tax,j}^{\tau}, \forall j, \tag{28}$$

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: relative magnitude restriction 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)

$$abs \left(\frac{C^4_{g,1}}{C^4_{tax,1}} \right) \geqslant abs \left(\frac{C^5_{g,1}}{C^4_{tax,1}} \right), \tag{29}$$

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.

Long run restrictions   Amongst the 8 non-stationary variables there are 3 cointegrating relationships leaving 5 permanent shocks to be identified. Following Dungey and Pagan (2008) 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 remaining 2 permanent shocks within the domestic economy are chosen to be those corresponding to *gne* and *gdp*.[17] When testing the convergence of the SVAR these were the shocks in which the ECM term entered to give stability in the model, see Pagan and Pesaran (2008).

Identifying permanent shocks in both foreign and domestic *gdp* suggests some deviation between the world technology shock and a New Zealand technology shock. There is evidence for different rates of trend growth in the international and New Zealand output series. The evidence is less strong for a difference between GDP and absorption, but during the sample period there is substantial divergence between the paths of the two which may be responsible for the behaviour being found here. 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. This is akin to allowing for a permanent shift in the terms of trade in the favour of New Zealand exports in this period.

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[17]There is a strong case for the *g* and *tax* shocks to be transitory. In the case of a government expenditure shock Ricardian equivalence should hold. With a temporary government expenditure shock it is not feasible to have a permanent tax shock without implying an unstable debt to GDP ratio.

Given this specification, the β of (7) is

$$
\beta = \begin{bmatrix}
\beta_{1,1} & & & & & & & & & & & \\
& \beta_{2,2} & -1 & & & & & & & & & \\
& \beta_{3,2} & & & & & & & & & & \\
-1 & & & & & & & & & & & \\
\beta_{5,1} & & 1 & & & & & & & & & \\
\beta_{6,1} & & & & & & & & & & & \\
& & & & -1 & & & & & & & \\
\beta_{8,1} & & & & & & & & & & & \\
& & & & & -1 & & & & & & \\
& & & & & & -1 & & & & & \\
& & & & & & & -1 & & & & \\
\beta_{12,1} & & -1 & & & & & & & & &
\end{bmatrix}, \tag{30}
$$

whilst α' is

$$
\alpha' = \begin{bmatrix}
\alpha_{4,1} & & & \alpha_{4,4} & & \alpha_{4,6} & \alpha_{4,7} \\
& \alpha_{5,2} & & \alpha_{5,4} & & \alpha_{5,6} & \alpha_{5,7} \\
& & & & & & \\
& & & \alpha_{7,4} & & & \\
& & & & \alpha_{9,5} & & \\
& & & & & \alpha_{10,6} & \\
& & & & & \alpha_{11,6} & \alpha_{11,7} \\
\alpha_{12,1} & & \alpha_{12,3} & & & &
\end{bmatrix}. \tag{31}
$$

5   Empirical Results

To illustrate the role of policy variables impulse response functions for monetary and fiscal policy variables and historical decompositions of the policy target variables, inflation and output are presented below. The model is estimated in Gauss 6.0, with on average, the set of fiscal policy shocks identified in every $69th$ draw. The analysis presents impulse response functions for one standard deviation shocks to the errors, the sizes of the shocks are presented in Table 2. A more complete set of shocks is presented in Dungey and Fry (2007).

Monetary policy shocks   Monetary policy shocks are represented as temporary short term interest rate shocks as is usual in the literature. The model behaves as is expected, with a rise in the short term interest rate resulting in falls in absorption and

inflation (see Figure 2). The budget deficit (taxation less government expenditure) response is in the opposite direction to that of the short term interest rate, echoing the substitutability result in Muscatelli, Tirelli and Trecroci (2004). The relatively long lived effects of monetary policy decisions are apparent in the figures. This result arises from the imposition of the Pagan and Pesaran (2008) distinction between temporary and permanent shocks, without this other models (including previous drafts of this model) find that the effects of monetary policy shocks can dissipate within 18 months to 2 years; see for example Buckle et al (2007). The movement in the exchange rate (not shown) as in most of the scenarios explored here, reflects the changes in the real interest rate relative to unchanging international real interest rates.

Fiscal policy shocks Figure 3 gives the impulse responses for seven of the domestic variables to temporary shocks originating in government expenditure (column 1), taxation revenue (column 2) and the debt to GDP ratio (column 3).

The impact of the increased government expenditure is reflected in higher output (panel e), consistent with results in Blanchard and Perotti (2002), Perotti (2002, 2007) for a range of countries, and the preferred specification in Claus et al (2006). However, absorption falls initially (panel c). 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 higher government expenditure results in a fall in taxation revenue (panel b), as it does in the majority of the results in Favero and Giavazzi (2007). The fall in absorption may be part of the mechanism for this via consumption tax revenue. The debt variable rises (panel d) and is resolved in the longer term by lower government expenditure. Inflation (panel f) falls, 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 expenditure is delayed for a year. Here, interest rates initially rise (panel g) associated with the higher *gdp* but quickly become negative stimulating a recovery in *gne* and higher inflation.[18]

The temporary taxation shock results in higher government expenditure (panel h), although the increase in taxation is sufficient to lower the debt to GDP ratio over the first 2 years of the impulse horizon (panel k). This result is consistent with increased taxation through a consumption tax, resulting in lower absorption, and a redistribution

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[18]Canova and Paustain (2007) identify their government expenditure shock by a positive sign restriction whereby only draws where inflation rises in response to a government expenditure shock are retained.

of government spending through investment goods. This is 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. As in Hall and Rae (1998), a comparison of the results in columns 1 and 2 show that a decrease in taxation leads to a greater GDP effect than the equivalent increase in government expenditure. The taxation shock is associated with lower inflation (panel m). 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 current model, the short term interest rate declines in response to lower inflation.

The immediate effect of a temporary shock to the debt to GDP ratio 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 (panels o and p). The higher taxation and lower government expenditure combine for continued lower *gdp* (panel s). The effects of this 3.7% positive shock to the debt to GDP ratio, while resulting 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 effect on absorption (*gne*) and *gdp*. The emergence of inflation (panel t) leads to higher interest rates (panel u), which act 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. The interactions between the fiscal and monetary policy shocks are more fully explored in Section 6.

Historical decompositions of inflation, the interest rate and GDP Figure 4 presents the historical decomposition of inflation over the sample period, with each panel showing the contribution of a particular shock to inflation. Inflation is determined mainly by own-shocks, although each of absorption, export and import prices and the exchange rate also have a discernible effect.

The historical decomposition of the short term interest rate, *short*, is given in Figure 5. This shows that the major contributor to the short term interest rate, 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

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over the period compared with other influences.

The historical decomposition of gdp is shown in Figure 6. The most important source of shocks lies with gdp itself, followed by shocks to absorption, gne, and international output, y^*. Absorption shocks have an important role in offsetting negative own shocks particularly during the recovery from the recession in the early 1990s and slowdown in the early 2000s period.

The contribution of the policy variables to gdp are shown in greater detail in Figure 7. The government expenditure shocks are approximately counter-cyclical. They make positive contributions to output prior to the Fiscal Responsibility Act in 1994, and in the post-Asian crisis period and during the slowdown of 2000. Since about March 2003 government expenditure shocks act negatively on output. As in Claus et al (2006) the contributions of g and tax to gdp are roughly equivalent in their scale. The contribution of the short term interest rate to output is largely negative post the early 1990s. In Section 6 where feedback effects to policy variables are controlled for, a different picture emerges.

Taxation shocks generally contribute negatively to output, as is expected with the fiscal consolidation occurring over the period. Two periods of positive contribution stand out in the figures. The first is immediately post the increase in the rate of the GST in 1989. The second is the most recent period from mid 2005. Prior to the Fiscal Responsibility Act, when the debt to GDP ratio is climbing, the effects of debt to GDP shocks are almost entirely negative. In more recent periods, a more benign debt outlook contributes positively to output.

6 The Influence of Monetary and Fiscal Policy

The dynamics of the model represented in the impulse response functions and the historical decompositions consist of a combination of both direct and indirect effects of policy variables in response to shocks. To isolate the pure policy effects from those which arise from the result of feedback of policy responses through to other variables in the economy, the coefficients of the non policy variable lags in an equation are set to zero, and the decompositions recalculated. This allows the construction of indices of the impact of monetary and fiscal policy shocks from the historical decomposition; see for example Dungey and Pagan (2000) and Buckle et al (2007). The difference between the historical decompositions of gdp with and without feedback effects in the interest rate equation is a measure of the impact of monetary policy on the economy, and when added to the direct impact of interest rate shocks forms a monetary policy

indicator (mpi). The effects of government expenditure, taxation and debt policy are constructed similarly, and aggregated to form fiscal policy indicators for government expenditure gpi, taxation revenue, tpi, and debt, dpi.

The contributions of pure monetary and fiscal policy to gdp over the sample period are shown in Figure 8. The mpi clearly makes a much smaller contribution than the fiscal policy indicators. From September 1989 to June 1995 monetary policy acts 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 resumes 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 returns to a contractionary stance.

The combination of the fiscal policy indicators is counter cyclical during each of the recession of the early 1990s, the slowdown associated with the Asian crisis and the drought in the late 1990s. However, this is not always the case. Fiscal policy is contractionary during the long recovery of the early 1990s and from mid-2005, in the midst of a period of sustained high growth in the New Zealand output, the tpi and the dpi in particular shows an expansionary fiscal stance. Only for the period of 2000-2003 are each of the three fiscal policy indicators acting in the same direction. The tax cuts introduced over the period 1997 and 1998 are apparent in the positive innovations from tpi over this period. The results of the Fiscal Responsibility Act and reduction in debt to GDP ratio are also evident in the dpi 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 ratio.

The combination of shocks which make up the GDP historical decomposition (Figure 6) suggest that the mpi and fiscal policy indicators are complementary in the sense of Muscatelli, Tirelli and Trecroci (2004) only during the period of December 1991 to September 1994; further the complentarity comes from the tpi, a refinement not available in their analysis. 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 is stimulatory (p.14 of their submission) and contributes to cyclical fluctuations. The results here suggest for the period from mid-2005, net taxation and debt to GDP policy shocks are contributing to output pressure, while government expenditure shocks are not. 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.[19]

7   Conclusions

This paper has contributed a new approach to the empirical estimation of the interactions between monetary policy, fiscal policy and other economic shocks using a SVAR framework. The strengths of three different identification methods were exploited within a single modelling framework with an application to a small open economy. The existing traditional short-run coefficient restrictions were used to identify non-fiscal shocks. Sign restrictions were used to separate government expenditure and taxation shocks. The third element was to formally model the long run via the cointegrating relationships between the macroeconomic variables, and account for both permanent and transitory shocks in a model with both stationary and nonstationary data.

The methodology was illustrated by an application to New Zealand, the economy with the longest history of inflation targeting and a well-constructed fiscal data set. Additionally, New Zealand is currently considering the structure of its macroeconomic policy making, and specifically the interactions between monetary and fiscal policy. The model incorporated elements of previous SVAR modelling for this economy in the short-run coefficient restrictions, building on Buckle et al (2007). New features included the incorporation of the fiscal and debt variables, and the adoption of a SVARX form, where climate and international interest rates are incorporated as exogenous variables. The important role of debt in empirical models of fiscal policy has been emphasized in the recent work of Chung and Leeper (2007) and Favero and Giavazzi (2007). An important addition to the model was incorporating the long run behaviour, where the cointegrating relationships were derived from both the empirical characteristics of the

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[19]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.

data and theoretical concepts regarding fiscal sustainability.

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 shocks. Taxation and debt policy shocks have been more substantial than government expenditure 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. With respect to the current debate in New Zealand, the results showed that at the end of the sample period, net taxation policy was contributing to higher demand, while government expenditure policy was not. A useful avenue for future research would be to separate the effects of taxation and transfers from the net tax variable.

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A Data Definitions

All data are provided by the New Zealand Treasury, further details are available in Dungey and Fry (2007).

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, as in Buckle et al (2007).

Exchange rate: Nominal trade weighted index, average of 11 am observations from RBNZ (RTWI11am).

Export prices: Domestic current price export price index, all merchandise.

Foreign interest rate: Time varying GDP-weighted 90 day interest rate consisting of US, Japanese, German and Australian interest rates.

Foreign output: Real foreign output index from New Zealand Treasury, 2000Q1=100 made up of industrial output indices weighted by export value share.

Government debt: 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.

Government expenditure: Real central government consumption plus real government investment (both s.a. $NZm, chain volume in 1995/1996 prices) smoothed through the application of a moving average filter of the current and three lags of observations. The series are purged of purchases of frigates in 1997 and 1998 and investment by state owned enterprises.

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

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

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

Import prices: Domestic current price import price index, total merchandise imports.

Inflation: Annualised quarterly rate of the New Zealand CPI - All groups.

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

Taxation: Real taxation (direct plus indirect taxation with intra-government GST removed) minus real transfers (both are s.a. $NZm). 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.

Table 1:
Engle-Granger two-step cointegration tests 1983Q2 to 2006Q4.*

Variable	Coefficients in the cointegrating regressions								test statistics on residuals
	y^*	px	pm	g	tax	gne	gdp	twi	
g	-0.692				0.304	1.480	-0.554	-0.172	-2.487
g				1					n.a.
twi		-0.200	-1.016						-4.419

*The ADF tests are performed on the errors of the cointegrating equations.
The MacKinnon (1996) 5% critical value is -1.944.

Table 2:

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
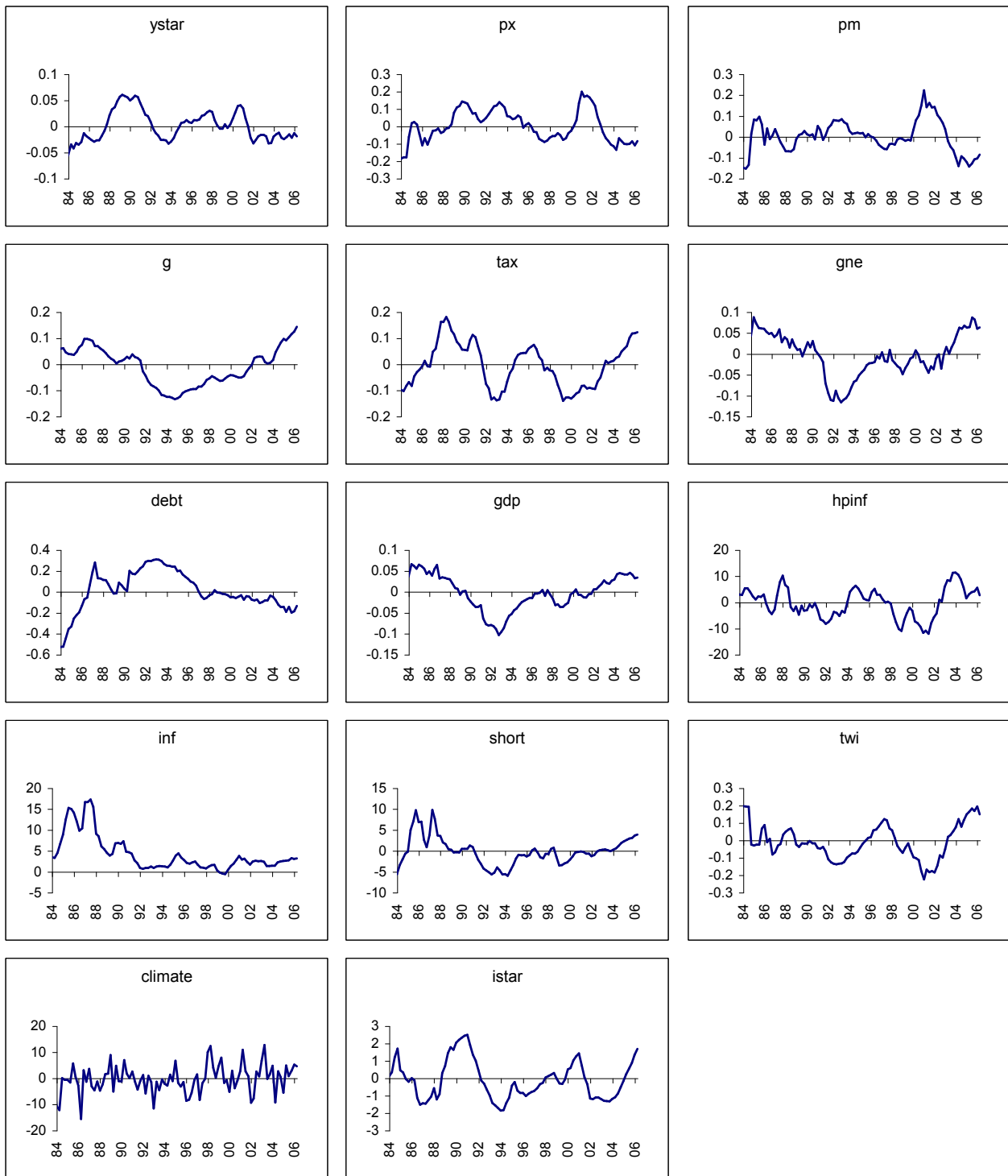
Figure1 : Plots of the New Zealand data. With the exception of the interest rates, inflation rates and the climate variable, the original data were detrended using a linear trend.
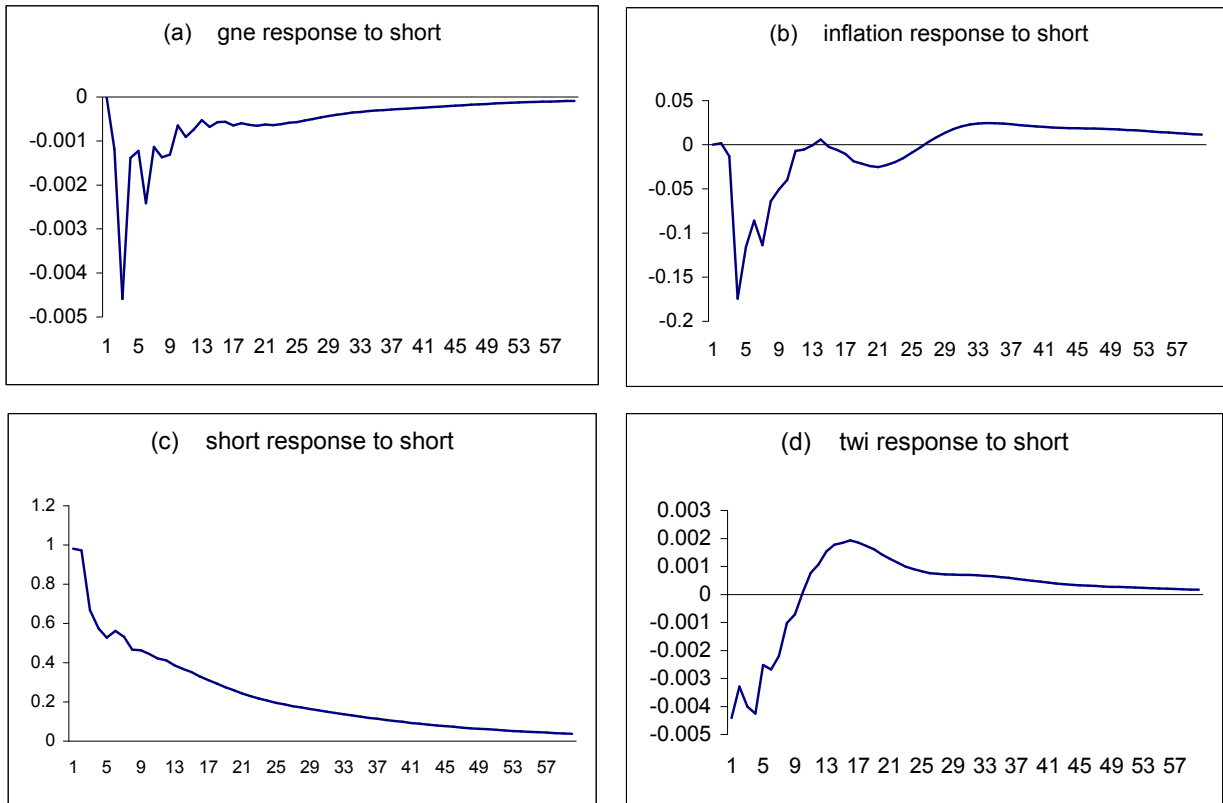
Figure 2: Impulse responses to a shock to the short interest rate
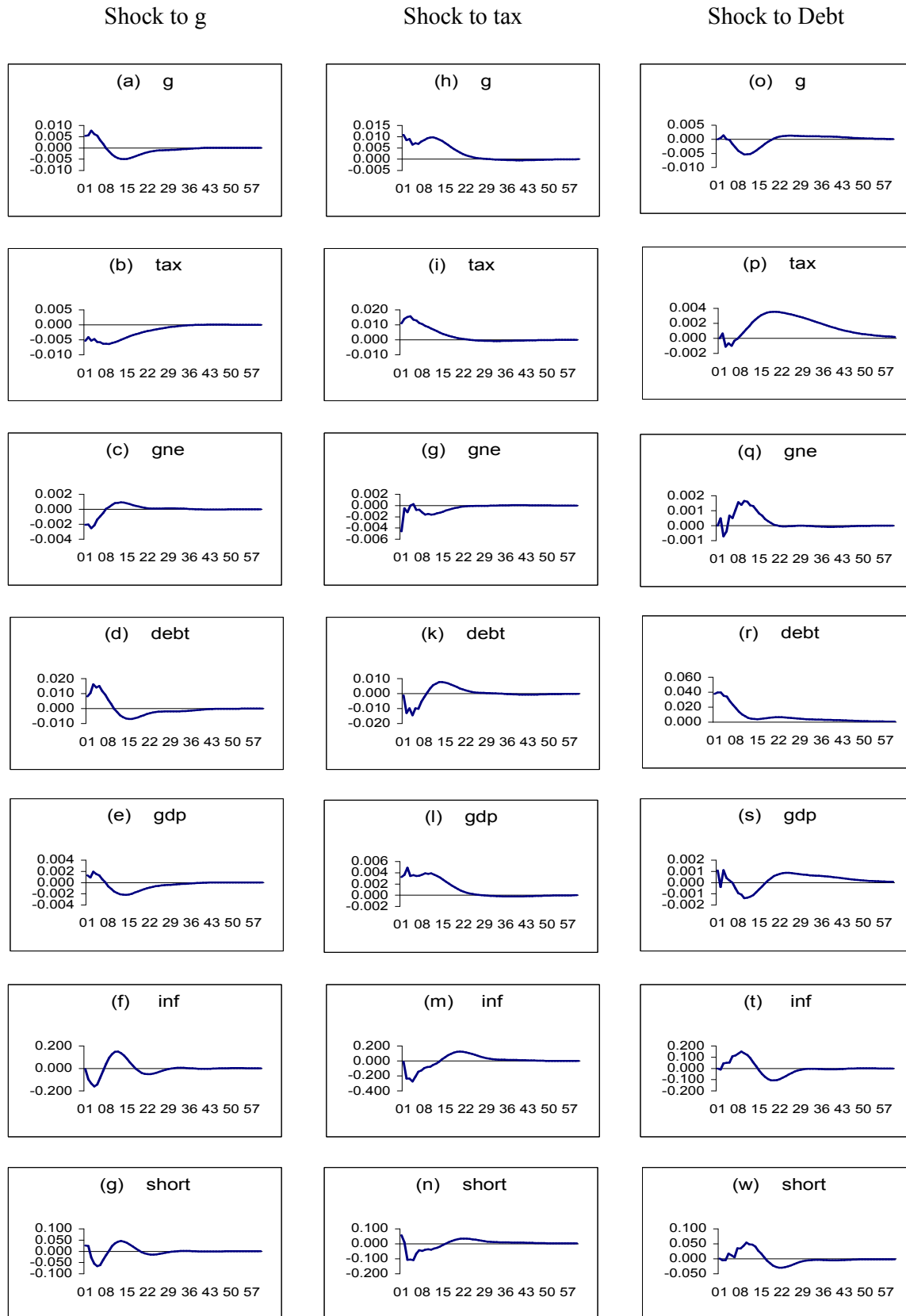
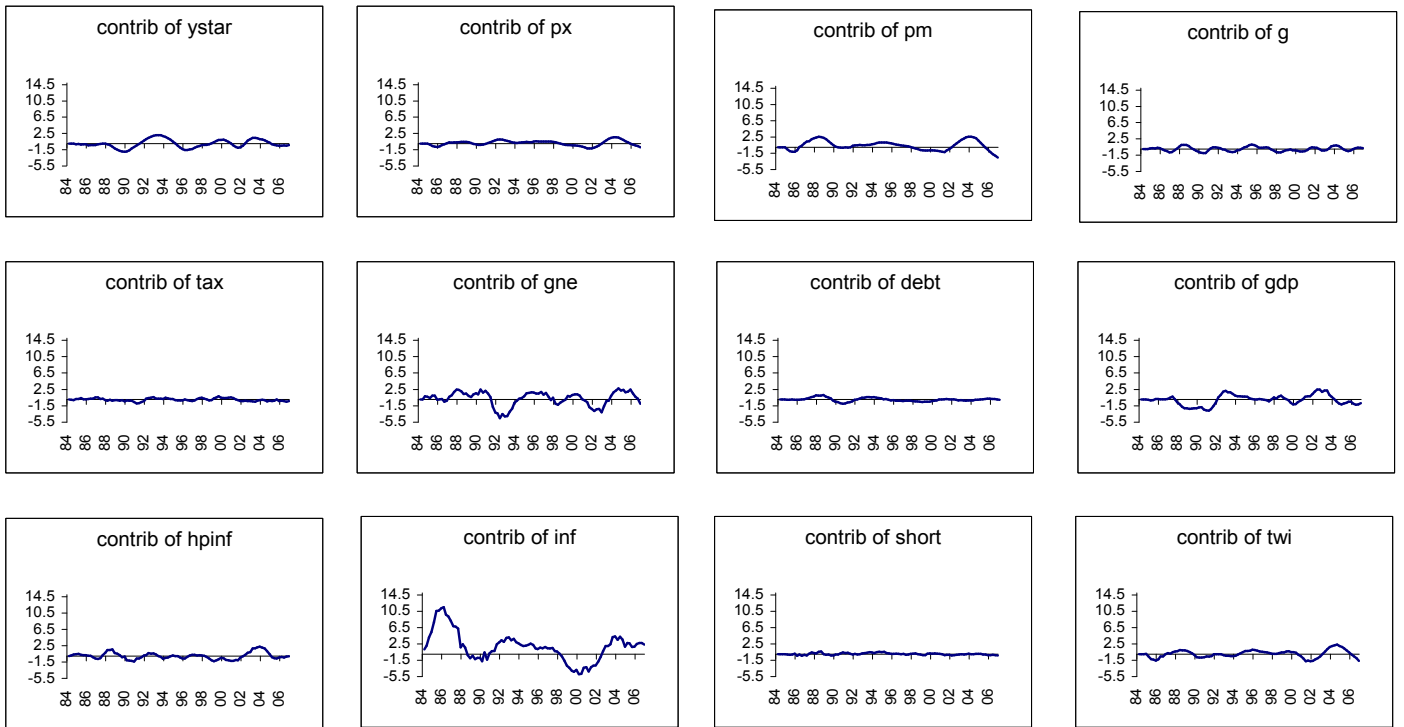Figure 3: Impulse Responses to a Shock to g, tax and debt

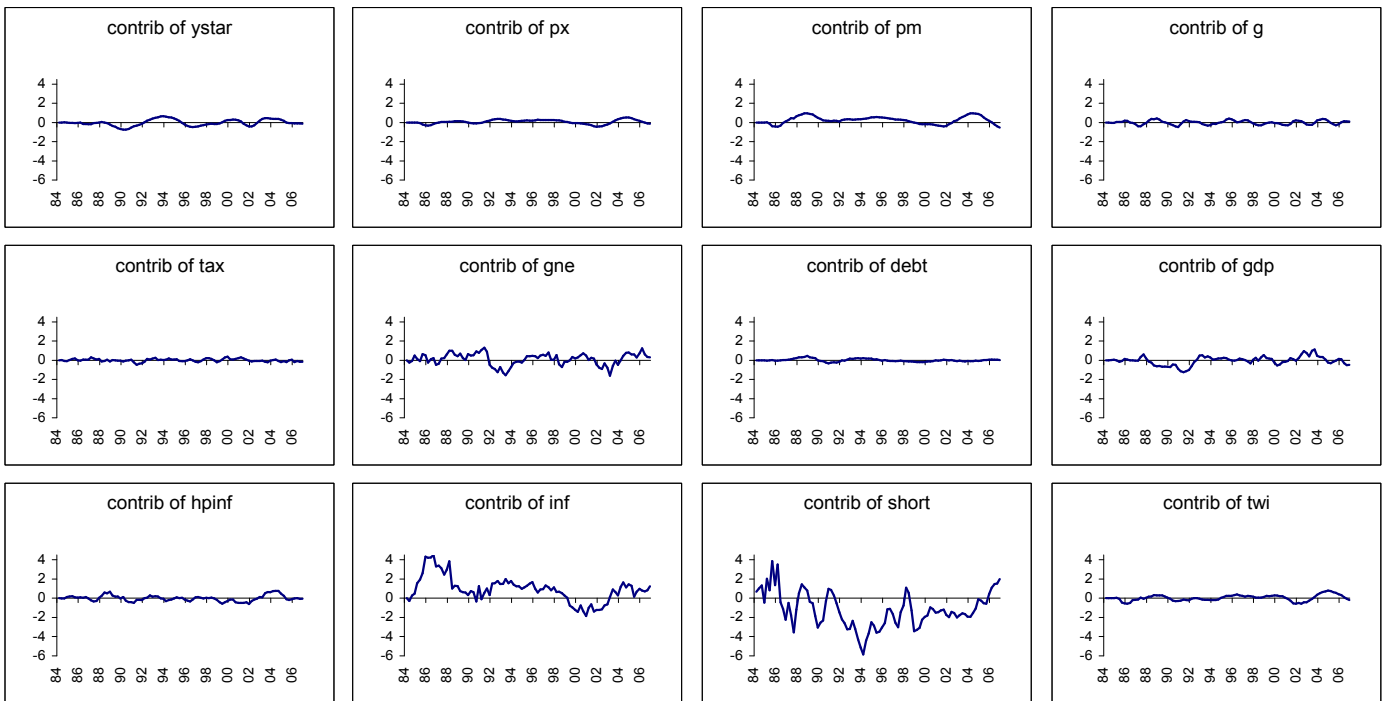Figure 4: Historical decomposition of inflation

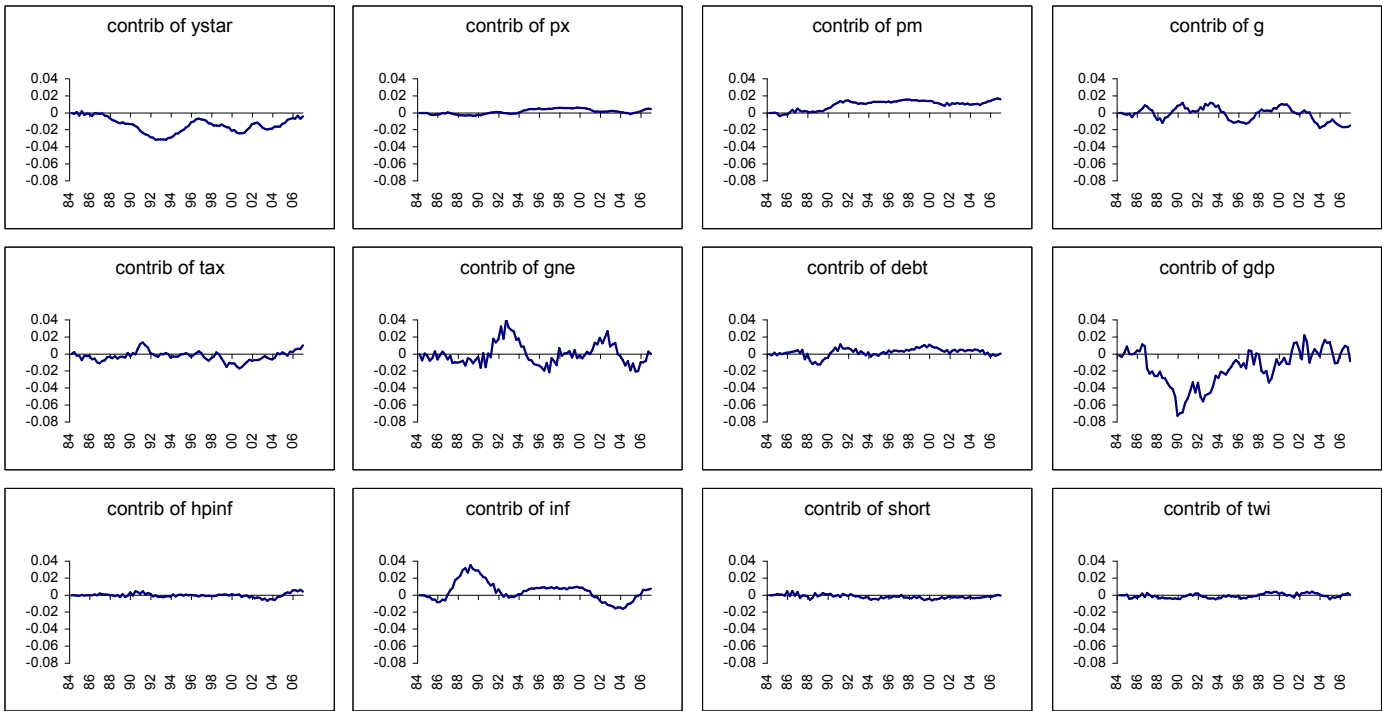Figure 5: Historical decomposition of short term interest rates.
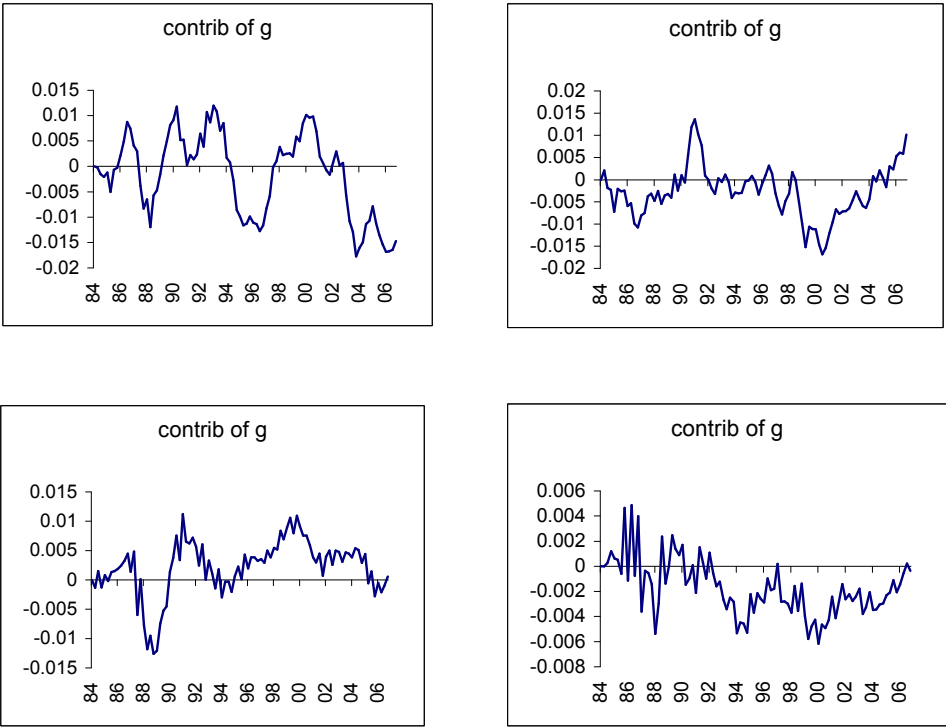
Figure 6: Historical decomposition of output (GDP).
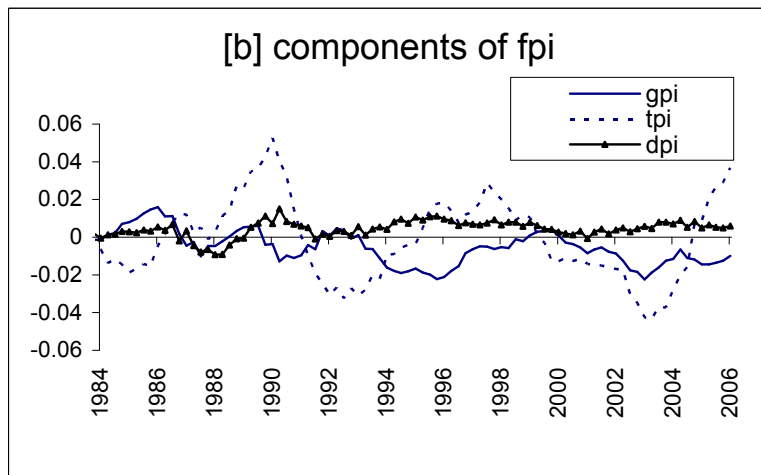

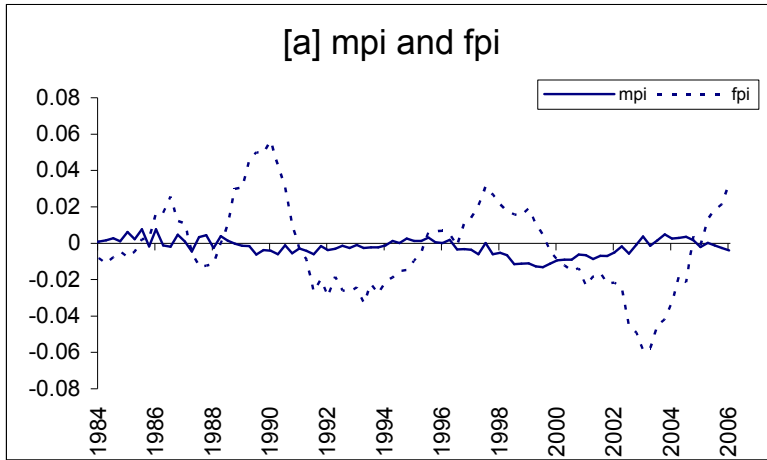
Figure 7: Historical decomposition of GDP by policy instruments

Figure 8: Monetary policy and fiscal policy indicators for GDP.