Explaining some Puzzles in the Estimated Response of New Zealand GDP to Fiscal Shocks[*]

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In this paper, we explore the reasons why previous time-series analyses of fiscal policy shocks in NZ have produced 'perverse' results, with positive shocks to tax receipts boosting GDP and positive shocks to government spending reducing GDP. We find that the real exchange rate has a crucial role to play in the transmission of fiscal shocks, and this can explain the perverse government spending result. The ‘tax puzzle’ may reflect a failure to account for a correlation between tax revenue and productivity.

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[*] The views expressed in this paper do not necessarily represent those of the New Zealand Treasury.

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1. Introduction

Standard textbook macroeconomic theory contains some straightforward predictions regarding the impact of unanticipated government spending and tax changes on aggregate output. In a Keynesian model with sticky wages and an upward-sloping short-run aggregate supply curve, a positive spending shock will boost aggregate demand, inducing an expansion of output (and some inflation). A positive tax shock will depress aggregate demand, having the opposite effect. In a Real Business Cycle model the predicted effects of the shock are similar, but for entirely different reasons. With Ricardian Equivalence, a rise in current spending induces an anticipation of future tax rises. Intertemporally optimising households will respond by cutting present consumption and leisure, spreading the cost of the anticipated future tax rise over several periods. With flexible prices, the fall in domestic consumer demand will not affect output, but the increase in labour supply will: again, aggregate output expands. A rise in current taxes induces an anticipation of future tax cuts, which has the opposite effect.

Given this agreement between alternative macroeconomic models which differ radically in other ways, we might expect macro-econometric analysis of New Zealand data to produce some unambiguous results. This is not the case; the evidence in favour of the standard theoretical predictions is very weak. In this paper, we review the evidence and discover some explanations for some of the apparently perverse econometric results.

2. The Existing Evidence

The two main sources of evidence on the effect of fiscal policy shocks in New Zealand are Claus *et al*. (2006) and Dungey and Fry (2009). The results of Claus *et al*.

are based on a three-variable Vector Autoregressive (VAR) model:[1]

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

Here, z_t is a vector of three quarterly variables: real government spending, real tax revenue (net of transfers) and GDP;[2] ε_t is a vector of reduced-form residuals. $B(L)$ is a p^{th} order matrix polynomial in the lag operator L, that is,

$$B(L)_t = I - B_1L - B_2L^2 - \ldots - B_pL^p \tag{2}$$

In order to ensure that the system is stationary, the variables are de-trended. Two alternative forms of de-trending are considered: a Hodrick-Prescott Filter and taking first differences of the variables. In order to extract structural shocks to each variable (u_t) from the reduced-form residuals (ε_t), Claus *et al.* follow Blanchard and Perotti (2002), noting that:

$$\varepsilon_t{}^g = \alpha_1 \cdot \varepsilon_t{}^y + \alpha_2 \cdot u_t{}^r + u_t{}^g$$

(3)

$$\varepsilon_t{}^r = \beta_1 \cdot \varepsilon_t{}^y + \beta_2 \cdot u_t{}^g + u_t{}^r \tag{4}$$

$$\varepsilon_t{}^y = \gamma_1 \cdot \varepsilon_t{}^r + \gamma_2 \cdot \varepsilon_t{}^g + u_t{}^y \tag{5}$$

where the g superscript denotes shocks to government spending, the r superscript shocks to tax revenue, and the y superscript shocks to GDP. The parameters α_1 and β_1 capture the immediate response of government spending and tax revenue to

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[1] We have altered the notation slightly.

[2] There is also a version of the Claus *et al.* model with four variables, when government transfers are included as a separate variable. The results from the four-variable VAR are similar to those from the three-variable VAR.

unanticipated movements in GDP. In a quarterly model, it can be argued that it is implausible for these immediate responses to reflect any change in government policy following changes in economic activity. The only plausible responses are automatic ones resulting from predetermined tax and spending rules. External information on government spending and tax elasticities can then be used to impose values for α_1 and β_1 on equations (3-4) and thus extract the structural shocks to the fiscal variables from the reduced-form residuals. (In the Claus *et al*. paper, these values are $\alpha_1 = 0$ and $\beta_1 = 1$.) Identification of the fiscal shocks also requires values for α_2 and β_2. In the absence of any theoretical justification for imposing values on these parameters, two alternative approaches are used: assuming that government spending is weakly exogenous to tax revenue, set $\alpha_2 = 0$ and estimate β_2 on the data; or, assuming that tax revenue is weakly exogenous to government spending, set $\beta_2 = 0$ and estimate α_2 on the data. Finally, cyclically adjusted values of $\varepsilon_t{}^g$ and $\varepsilon_t{}^r$ are used as instrumental variables to estimate γ_1 and γ_2, so the system is fully identified.

Figure 1 reproduces some of the estimated responses to fiscal shocks in the Claus *et al*. paper. For the versions of the model with de-trending by taking differences, the results are broadly consistent with standard theory, although the effects are not that large, and not persistent. A positive spending shock leads to a significantly higher level of GDP in quarters 1-2 following the shock. A positive tax shock leads to a significantly lower level of GDP in quarter zero. For the version of the model with the Hodrick-Prescott Filter, the results are more puzzling. A positive spending shock leads to no significant increase in GDP; in fact, GDP is significantly *below* trend up to six quarters following the shock. The positive tax shock still depresses GDP in quarter zero, but then there is a significant *increase* in GDP above trend that lasts up to quarter 4.

Because the different methods of de-trending do not correspond to any particular theoretical macroeconomic model, it is difficult to interpret the differences between the two versions of the econometric model. One alternative modelling approach is to refrain from de-trending the data and to model the long-run relationships between the variables explicitly using cointegration analysis. This is the approach taken by Dungey and Fry (2009). The Dungey and Fry model differs from the Claus *et al*. model in two other substantial ways: it includes several other macroeconomic variables (such as foreign GDP, export and import prices, and interest rates), and fiscal shocks are identified using an entirely different method. Government spending shocks are identified using a sign restriction: for a positive government spending shock, it is assumed that both government spending and GDP must be no lower in the first quarter following the shock. Tax revenue shocks are identified in a similar way: it is assumed that for a positive tax shock, tax revenue must be no lower and domestic absorption no higher in the first quarter following the shock.

Figure 2 reproduces some of the impulse responses from the Dungey and Fry paper. It can be seen that a positive government spending shock initially raises GDP (this effect is imposed on the model), but then GDP falls, and the cumulated effect of the shock on GDP is negative. A positive tax revenue shock raises GDP above its steady-state level, where it remains for several years.

In several econometric models that have been fitted to New Zealand data, the effects of fiscal policy shocks do not have the anticipated sign. In this paper, we pursue this puzzle in two ways. Firstly, we explore whether the results in the original Claus *et al*. VAR are robust to the extension of the sample to incorporate more recent data. Secondly, we use another type of VAR to suggest some reasons why a standard econometric model produces such unexpected results.

3. Fiscal VARs Using More Recent Data

3.1 A three-variable fiscal VAR

Firstly, we consider the three-variable VAR of Claus *et al*. (2006). The original results are based on a sample that runs from 1982q3 to 2004q3. We extend the sample to 2008q1, just before the onset of the Global Financial Crisis.[3] In one exercise, we fit the Claus *et al*. model to all data for 1982q3-2008q1; in a second exercise, we fit the model to data for 1990q4-2008q1, the period of monetary stability and low inflation following the Reserve Bank of New Zealand Act in December 1989. In each exercise, there are two measures of tax revenue (real gross taxes, or taxes net of transfers) and two corresponding measures of government expenditure (real spending plus transfers, or just spending). This exercise is performed using both differencing and a Hodrick-Prescott Filter to de-trend the data. Restricting our attention to the responses to shocks when the shocked variable is strictly exogenous,[4] we have $2 \times 2 \times 2 \times 2 = 16$ response profiles, which appear in Figures 3-6.

Figure 3 shows the four alternative responses of the log-level of GDP to a 1% tax shock when differencing is used to de-trend the data (two different sample periods × two tax measures). The figure reveals a wide diversity of estimated responses, varying from a persistent 0.25% fall in GDP (the longer sample period with gross taxes) to a persistent 0.25% rise in GDP (the shorter sample period with net taxes). Using differencing to de-trend the data produces estimates that are highly sensitive to

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[3] With several of the models we consider, adding data from mid-2008 to the end of 2010 substantially reduces the precision of the parameter estimates. Macroeconomic conditions during the period of the Global Financial Crisis have been highly atypical, and a conclusive analysis of the New Zealand economy during this period awaits the availability of some post-crisis time-series data.

[4] The impulse responses with the alternative exogeneity assumptions are very similar.

the sample used and the way that taxes are measured. By contrast, Figure 4, which shows the responses to a tax shock of GDP relative to its Hodrick-Prescott trend, exhibits much less variation.[5] In all cases, a negative response of GDP in quarter zero is followed by a positive response in quarters 2-8. The magnitude of the response varies somewhat, but the overall pattern is the same in all cases. The estimate of initial impact of the shock is based on the correlation of the residuals ε_t (with some identifying restrictions), and the subsequent response profile depends on the $B(L)$ parameters. When a Hodrick-Prescott Filter is used, neither the residual correlations nor the VAR parameters are highly sensitive to the way that taxes are measured or the sample period chosen. In the absence of any *a priori* criterion for selecting a particular model of tax shocks, the versions with a Hodrick-Prescott Filter at least produce consistent results. In these results, a positive tax shock eventually leads to a rise in GDP, and the cumulative effect of the shock on GDP is positive. The puzzle remains.

A similar pattern appears in Figures 5-6, which show the responses of GDP to a government spending shock. Figure 5 is based on data that have been de-trended using first differences, and Figure 6 is based on data that have been de-trended using a Hodrick-Prescott Filter. Again, the model using differenced variables produces impulse responses that are highly sensitive to the way that spending is measured and the sample period used. The model using the Hodrick-Prescott Filter shows much less heterogeneity; in this model, a positive spending shock leads to a dip in GDP between

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[5] The GDP measures used in Figures 3-4 (log-levels and de-trended log-levels respectively) are designed for easy comparison of each figure with the original Claus *et* al. results. For comparison between figures, it could be argued that Figure 3 should show GDP growth responses. Such a figure also shows more heterogeneity in the different responses than in Figure 4.

the first and eighth quarter following the shock. Again, the puzzle remains.

3.2 A large fiscal VAR with minimal theoretical restrictions

3.2.1 Model structure

In order to explore the channels through which fiscal shocks might generate the unexpected responses in GDP, we first of all expand the Claus *et al*. VAR to incorporate a wider range of macroeconomic variables. In this expanded VAR, we model the long-run relationships between the variables, so that we do not need to commit to a particular de-trending method. In this respect, our model resembles that of Dungey and Fry. However, we do not wish to impose any particular sign on the responses to fiscal shocks, and our model incorporates a minimal number of identifying restrictions.

The model comprises the following quarterly variables. Those marked (¶) are extensions of series described in Buckle *et al*. (2007) up to 2010q3; those marked (§) are extensions of series described in the Claus *et al*. and Dungey and Fry papers.[6] Variables marked (‡) are provided by the Reserve Bank of New Zealand, downloaded from www.rbnz.govt.nz on 06/01/2011; further details are available on request.

- Domestic real GDP (y_t).¶
- A trade-weighted index of foreign real GDP (y_t*).¶
- The domestic price level (p_t).¶
- A trade-weighted index of the foreign price level (p_t*).‡
- The domestic nominal 90-day interest rate (i_t).¶
- A trade-weighted index of the foreign nominal 90-day interest rate (i_t*).¶

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[6] We find that it makes little difference whether transfers are subtracted from tax revenue or added to government spending. The results below are based on the latter approach.

- The nominal trade-weighted exchange rate expressed in terms of the relative value of the New Zealand Dollar (e_t). A rise in e_t constitutes a domestic currency appreciation.[‡]
- The domestic nominal M0 money stock (m_t) [‡]
- Real government spending (g_t).[§]
- Real tax revenue (r_t).[§]
- The rate of growth of the international petroleum price (π_t^{OIL}). This variable is constructed from the petroleum price index incorporated in the New Zealand Trade statistics provided by Statistics New Zealand and downloaded from www.statistics.govt.nz on 06/01/2011.
- An index of New Zealand climatic variations (c_t).[¶]

All variables are expressed in logarithms except the interest rates and oil price inflation. In the model, the money stock and the exchange rate are expressed in real terms, that is, $[m_t - p_t]$ and $[e_t + p_t - p_t^*]$, and the behavior of the nominal variables is implicit. For reasons discussed later, tax revenue is expressed as a fraction of GDP, that is, $[r_t - y_t]$. Since New Zealand is a very small open economy, the foreign variables and the international oil price are taken to be strictly exogenous, as is the climate. In this respect, the model differs from models of larger economies, such as Garratt *et al*. model. The dependent variables in the VAR are as follows: y_t, $[m_t - p_t]$, g_t, $[r_t - y_t]$, $[p_t - p_{t-1}]$ (that is, domestic inflation, henceforth π_t), i_t and $[e_t + p_t - p_t^*]$. The exogenous variables are as follows: y_t^*, i_t^*, π_t^{OIL} and c_t.

The seven dependent variables are illustrated in Figure 7, which shows all available data (1982q2-2010q3). The parameters of a model fitted to data beginning in the high-inflation, low-growth 1980s are significantly different from those of a model fitted to data beginning in the low-inflation, high growth 1990s. Our sample period (not including lags) is 1990q4-2008q1. This sample also excludes the period of the Global Financial Crisis.

At least one lag of each variable is included in the unrestricted reduced-form VAR. Otherwise, the lag order of each variable is chosen to minimise the Schwartz Bayesian Information Criterion. The application of this criterion leads to two lags of g_t, $[r_t - y_t]$ and i_t, and one lag of the other variables. The model is as follows:[7]

$$\begin{bmatrix} y_t \\ m_t - p_t \\ g_t \\ r_t - y_t \\ \pi_t \\ i_t \\ e_t + p_t - p_t^* \end{bmatrix} = B_0 \begin{bmatrix} Q_t^1 \\ Q_t^2 \\ Q_t^3 \\ Q_t^4 \\ t \end{bmatrix} + B_1 \begin{bmatrix} y_{t-1} \\ m_{t-1} - p_{t-1} \\ g_{t-1} \\ r_{t-1} - y_{t-1} \\ \pi_{t-1} \\ i_{t-1} \\ e_{t-1} + p_{t-1} - p_{t-1}^* \end{bmatrix} + B_2 \begin{bmatrix} g_{t-2} \\ r_{t-2} - y_{t-2} \\ i_{t-2} \end{bmatrix} + C_0 \begin{bmatrix} y_t^* \\ i_t^* \\ \pi_t^{OIL} \\ c_t \end{bmatrix} + C_1 \begin{bmatrix} y_{t-1}^* \\ i_{t-1}^* \\ \pi_{t-1}^{OIL} \\ c_{t-1} \end{bmatrix} + U_t \qquad (6)$$

Here, B_0 is a 7 × 5 parameter matrix, B_1 is a 7 × 7 parameter matrix, B_2 is a 7 × 3 parameter matrix, C_0 and C_1 are 7 × 4 parameter matrices, and U_t is a 7 × 1 matrix of reduced-form residuals for quarter t. The Q_t variables are quarterly dummies.[8]

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[7] There are three substantial differences between this model and that of Garratt *et al*. (2003): firstly, the strict exogeneity of the international variables, New Zealand being a very small open economy; secondly, the addition of fiscal variables and absence of a restriction to identify monetary policy shocks (which are not of interest in this paper); thirdly, the stationarity of interest rates. One possible explanation for the difference with regard to stationarity is that we are looking at a much longer period of monetary stability, since the independence of the Reserve Bank of New Zealand predates that of the Bank of England by eight years, and our sample extends later into the 2000s. It means that in our model there are no cointegration restrictions corresponding to a Fisher Equation and an interest parity condition. Finally, unlike Garratt *et al*., we can reject the restriction that domestic GDP is proportional to foreign GDP in the long run, and such a restriction is not imposed on the model.

[8] There is no significant autocorrelation in U_t. However, a Jarque-Bera test rejects the null that the residuals are normally distributed. The reason is a spike in $[m_t - p_t]$ in 1999q3-1999q4, which can be seen in Figure 1. The unusually high demand for liquidity at this time probably reflects worries

Two types of restrictions are imposed on the model. Firstly, there are some cointegration restrictions, because not all of the variables in the model are stationary. Secondly, there are restrictions to identify the effect of fiscal shocks. In Appendix 1, we discuss stationarity and cointegration tests for the variables. The null of non-stationarity can be rejected for three of the dependent variables, π_t, i_t, $[e_t + p_t - p_t^*]$, and three of the exogenous variables, i_t^*, π_t^{OIL} and c_t. The other variables, y_t, $[m_t - p_t]$, g_t, $[r_t - y_t]$ and y_t^*, appear to be difference-stationary, but with four cointegrating vectors. Since y_t^* is strictly exogenous, there is no need for any cointegration restriction in the equations for y_t, $[m_t - p_t]$, g_t and $[r_t - y_t]$. The equations for the stationary dependent variables, π_t, i_t and $[e_t + p_t - p_t^*]$, do embody some cointegration restrictions. These restrictions are imposed before estimation, by first of all reformulating the first four rows of equation (6) as follows.

$$\begin{bmatrix} \Delta y_t \\ \Delta[m_t - p_t] \\ \Delta g_t \\ \Delta[r_t - y_t] \end{bmatrix} = \breve{B}_0 \begin{bmatrix} Q_t^1 \\ Q_t^2 \\ Q_t^3 \\ Q_t^4 \\ t \end{bmatrix} + \breve{B}_1 \begin{bmatrix} y_{t-1} \\ m_{t-1} - p_{t-1} \\ g_{t-1} \\ r_{t-1} - y_{t-1} \\ \pi_{t-1} \\ i_{t-1} \\ e_{t-1} + p_{t-1} - p_{t-1}^* \end{bmatrix} + \breve{B}_2 \begin{bmatrix} \Delta g_{t-1} \\ \Delta[r_{t-1} - y_{t-1}] \\ i_{t-2} \end{bmatrix} + \breve{C}_0 \begin{bmatrix} \Delta y_t^* \\ i_t^* \\ \pi_t^{OIL} \\ c_t \end{bmatrix} + \breve{C}_1 \begin{bmatrix} y_{t-1}^* \\ i_{t-1}^* \\ \pi_{t-1}^{OIL} \\ c_{t-1} \end{bmatrix} + \breve{U}_t \qquad (7)$$

Equation (2) is fitted to the data, and then the following equilibrium correction terms are constructed:

$$\begin{bmatrix} ecm_t^y \\ ecm_t^m \\ ecm_t^g \\ ecm_t^r \end{bmatrix} = \overset{\frown}{B}_1 \begin{bmatrix} y_t \\ m_t - p_t \\ g_t \\ r_r - y_t \end{bmatrix} + \hat{C}_1 y_t^* \qquad (7a)$$

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about the Millennium Bug. Dummy variables for 1999q3 and 1999q4 can be added to the model; this makes no substantial difference to the estimated values of the equation (1) parameters.

Here, $\overset{\frown}{B}_1$ consists of first four columns of $\breve{B}_1$, and $\hat{C}_1$ consists of the first column of $\breve{C}_1$. Equations for the three stationary variables are then fitted to the data follows.[9]

$$\begin{bmatrix} \pi_t \\ i_t \\ e_t + p_t - p_t^* \end{bmatrix} = \tilde{B}_0 \begin{bmatrix} Q_t^1 \\ Q_t^2 \\ Q_t^3 \\ Q_t^4 \\ t \end{bmatrix} + \tilde{B}_1 \begin{bmatrix} ecm_{t-1}^y \\ ecm_{t-1}^m \\ ecm_{t-1}^g \\ ecm_{t-1}^r \\ \pi_{t-1} \\ i_{t-1} \\ e_{t-1} + p_{t-1} - p_{t-1}^* \end{bmatrix} + \tilde{B}_2 \begin{bmatrix} \Delta g_{t-1} \\ \Delta[r_{t-1} - y_{t-1}] \\ i_{t-2} \end{bmatrix} + \tilde{C}_0 \begin{bmatrix} \Delta y_t^* \\ i_t^* \\ \pi_t^{OIL} \\ c_t \end{bmatrix} + \tilde{C}_1 \begin{bmatrix} i_{t-1}^* \\ \pi_{t-1}^{OIL} \\ c_{t-1} \end{bmatrix} + \tilde{U}_t \qquad (7b)$$

The fiscal shocks are again identified in the manner of Blanchard and Perotti (2002). However, the original identification scheme described above applies to a VAR that includes only three variables: government spending, tax revenue and GDP. Our expanded model also includes inflation and interest rates, and while it is unlikely that these have an immediate direct effect on real government spending, they might affect tax revenue, for example by influencing consumer spending and indirect taxes, or through fiscal drag. Heinemann (2001) estimates the effect of inflation on different types of tax revenue relative to GDP in a panel of countries including New Zealand. The following inflation coefficients are reported: personal income tax, 0.134; corporate income tax, –0.800; indirect taxes, 0.173. New Zealand Treasury quarterly tax receipt data indicate that over the sample period, the share of these three types of tax in total revenue are 45.8%, 14.9% and 36.0% respectively. Using Heinemann's estimates, this implies an overall inflation tax elasticity of 0.004. On this basis, we will assume that unanticipated changes in total tax revenue relative to GDP are independent of unanticipated movements in inflation. (This is the reason for including

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[9] It is also possible to fit equations (7-7*b*) simultaneously using a Maximum Likelihood estimator. However, it turns out that the log-likelihood function is very flat and so the parameter estimates are very imprecise.

[$r_t - y_t$] in the VAR instead of r_t.) With regard to the interest rate elasticity, we draw on two pieces of evidence. Firstly, Goh and Downing (2002) present a model of quarterly New Zealand consumer expenditure in which the estimated short-run interest elasticity is 0.000. Household purchases, and therefore indirect tax revenue, are independent of the interest rate in the short run. Moreover, shocks to interest rates have no significant impact on GDP (Buckle *et* al., 2007), so the ratio of indirect tax revenue to GDP will be independent of the interest rate in the short run. Secondly, New Zealand Treasury quarterly tax receipt data indicate that over the sample period, direct taxes on interest income account for only 4.8% of total tax revenue. On this basis, we will assume that unanticipated changes in total tax revenue are independent of unanticipated changes in the interest rate.

3.2.2 Tax shocks in the model

Fitting the model to the data and imposing the Blanchard-Perotti identifying restrictions produces impulse response profiles for a tax revenue shock illustrated in Figure 8. This figure shows the impulse response profiles for all seven of the dependent variables in the model following a unit shock to tax revenue. The figure also includes impulse responses for the nominal exchange rate e_t implicit in the real exchange rate and inflation responses. The black lines in the figure indicate the estimated responses under the assumption that tax revenue ($r_t - y_t$) is weakly exogenous to government spending (g_t), and the grey lines the estimated responses under the assumption that g_t is weakly exogenous to [$r_t - y_t$]. There is little difference between the two sets of responses. The dashed lines in the figure mark out the 95% confidence interval for each response, based on 10,000 bootstrap replications.

There are two statistically significant impulse responses. An unanticipated 1% rise in tax revenue leads to a rise in GDP that peaks at around 0.1-0.15%, and a real and nominal exchange rate appreciation of around 0.3-0.4%.

Why would an unanticipated rise in tax revenue be associated with an exchange rate appreciation and more economic growth? One possible explanation is that the rise in tax revenue is associated with a rise in productivity: a positive productivity shock should in theory generate the GDP and exchange rate responses in Figure 8. The absence of quarterly productivity data precludes the inclusion of a productivity variable in the VAR. However, the correlations between annual tax revenue and labour productivity data are suggestive. Taking the log of the index of annual industrial labour productivity for 1984-2010 from the Statistics New Zealand database (x_t) and annual averages for $[r_t - y_t]$, we can fit the following OLS regression equation (with t-ratios in parentheses):[10]

$$\Delta x_t = \underset{(2.75)}{0.773} - \underset{(2.72)}{0.096} \cdot x_{t-1} + \underset{(1.97)}{0.041} \cdot [r_{t-1} - y_{t-1}]$$

The R^2 is 0.26. The t-ratios should be viewed with some caution, since the variables are probably not stationary, but there does appear to be a positive correlation between labour productivity and tax revenue as a share of GDP. The mechanisms underlying such a correlation remain to be investigated, but there is reason to doubt that the responses in Figure 8 represent the direct consequence of an unanticipated rise in taxes.

3.2.2 Government spending shocks in the model

Figure 9 illustrates the responses to a unit shock to government spending (g_t). Again, there are two sets of response profiles corresponding to the different assumptions about the weak exogeneity of taxes relative to government spending, and again the

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[10] There is no significant linear time trend in the productivity data.

error bars mark the 95% confidence intervals.

The figure shows that following a shock to government spending, there is no significant response in money demand, tax revenue or inflation. The most marked immediate response is in the real exchange rate, a 1% shock to government spending leading to a 0.5% appreciation. Given the absence of a significant domestic price response, there is a nominal exchange rate appreciation of a similar magnitude. This appreciation is consistent with both a Keynesian model and a Real Business Cycle model.[11] There is also a significant response in the domestic interest rate, a 1% shock to government spending leading to a fall of 0.1 percentage points. That nominal interest rates are lower during a period of exchange rate appreciation suggests that some interest parity condition is at work, although the fall in the interest rate is not exactly proportional to the appreciation.

There is no significant immediate response in domestic GDP. In a Real Business Cycle interpretation of the model, this implies that the elasticity of labour supply is very low, and that consumers are responding to higher future expected tax rates by reducing consumption rather than by working harder. In a Keynesian interpretation of the model, it implies that the short-run aggregate supply curve is very inelastic. Moreover, as in the smaller VAR, GDP begins to *fall* in the months following the shock, and by the third quarter, this effect is statistically significant. A 1% shock to government spending in quarter t entails a level of GDP that is about 0.15% lower in quarter $t+3$.

The fall in GDP combined with a real exchange rate appreciation suggests that there is a Dutch Disease effect at work. In theory, a fall in the relative price of traded

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[11] However, they differ from the results for most other countries; see for example Monacelli and Perotti (2010).

goods does not *necessarily* entail lower output, but if the traded goods production sector is relatively capital-intensive, then the real exchange rate appreciation will tend to depress investment. Eventually, this will reduce the physical capital stock, entailing lower domestic production. However, with a constant savings rate, net foreign assets will increase (through a trade surplus) and net overseas investment income will eventually be higher. Fielding (2011) pursues this line of argument, combining the modelling framework in equation (7) with a model of the different components of GDP other than government spending (household consumption, business investment and net exports). The impulse responses for the GDP components are shown in Figure 9a. The figure shows that the real exchange rate appreciation following the spending shock is indeed associated with a reduction in private sector investment and a movement towards trade surplus, while there is no significant response in household consumption.

3.3 A large fiscal VAR with more theoretical restrictions

Another type of large VAR that has been fitted to New Zealand data is presented in Buckle *et al*. (2007). In this VAR, the data are de-trended using a Hodrick-Prescott Filter, and the long-run relationships between the variables are not modelled; in this respect it resembles the smaller Claus *et al*. VAR. The Buckle *et al*. VAR is also fully identified using a Cholesky Decomposition that orders the variables in terms of weak exogeneity. In this section, we explore the results of a VAR using the same data as in the previous section, but with de-trending and Cholesky Decomposition of Buckle *et al*.[12] The ordering of the variables is as follows.

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[12] The model here is not identical to that of Buckle *et al*., which includes no fiscal variables or real exchange rate. Also, we do not impose the over-identifying restrictions used in the Buckle *et al*. model.

1. Climate (c_t)
2. Foreign GDP (y_y*)
3. Oil price inflation (π_t^{OIL})
4. Foreign interest rates (i_t*)
5. Tax revenue as a share of GDP ($r_t - y_t$)
6. Government spending (g_t)
7. Domestic interest rates (i_t)
8. Domestic GDP (y_t)
9. Domestic inflation (π_t)
10. Real money demand ($m_t - p_t$)
11. The real exchange rate ($e_t + p_t - p_t$*)

This ordering incorporates a ‘foreign block’ (2-4), a ‘policy block’ (5-7) and a ‘domestic block’ (8-11). Switching the ordering within blocks makes no substantial difference to the results. The reduced-form VAR includes two lags of all variables, and the same deterministic components as in equation (7).

Figure 10 shows the impulse responses for a one standard deviation shock to tax revenue ($r_t - y_t$), and Figure 11 the impulse responses for a unit shock to government spending (g_t). Figure 10 shows an increase in GDP similar to that in Figure 8, and Figure 11 a dip in GDP similar to that in Figure 9, although with the Cholesky Decomposition the latter is not significant at the 5% level. Both Figure 10 and Figure 11 show a significant real exchange rate appreciation similar to the appreciation in Figures 8 and 9. In Figures 10 and 11, as in Figure 8 and 9, there is no significant domestic inflation response. In this sense, the results for the VAR with a Cholesky Decomposition are broadly consistent with those for the VAR in the previous section, although the GDP impulse responses are less precisely estimated in the former.

4. Conclusion

Fitting a variety of fiscal VARs to recent New Zealand data confirms some anomalous results that appear in earlier papers. Positive shocks to government spending tend to depress output in the medium term, and positive shocks to tax revenue appear to boost output.

The explanation for the effect of government spending effect on output lies in the response of the real exchange rate. Shocks to government spending have a large and persistent effect on relative prices, positive shocks causing a real appreciation. This exchange rate appreciation is accompanied by a fall in investment, and in the medium term the capital stock is diminished. The tax revenue effect may only be apparent, reflecting a correlation between tax receipts and labour productivity. The mechanisms underlying this correlation are yet to be analysed.

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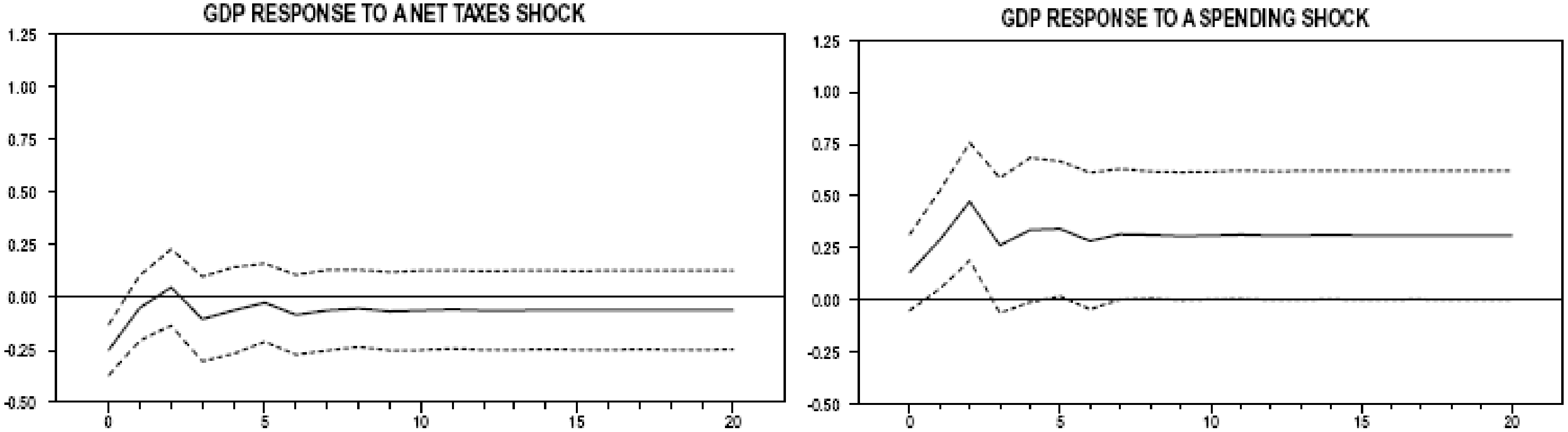
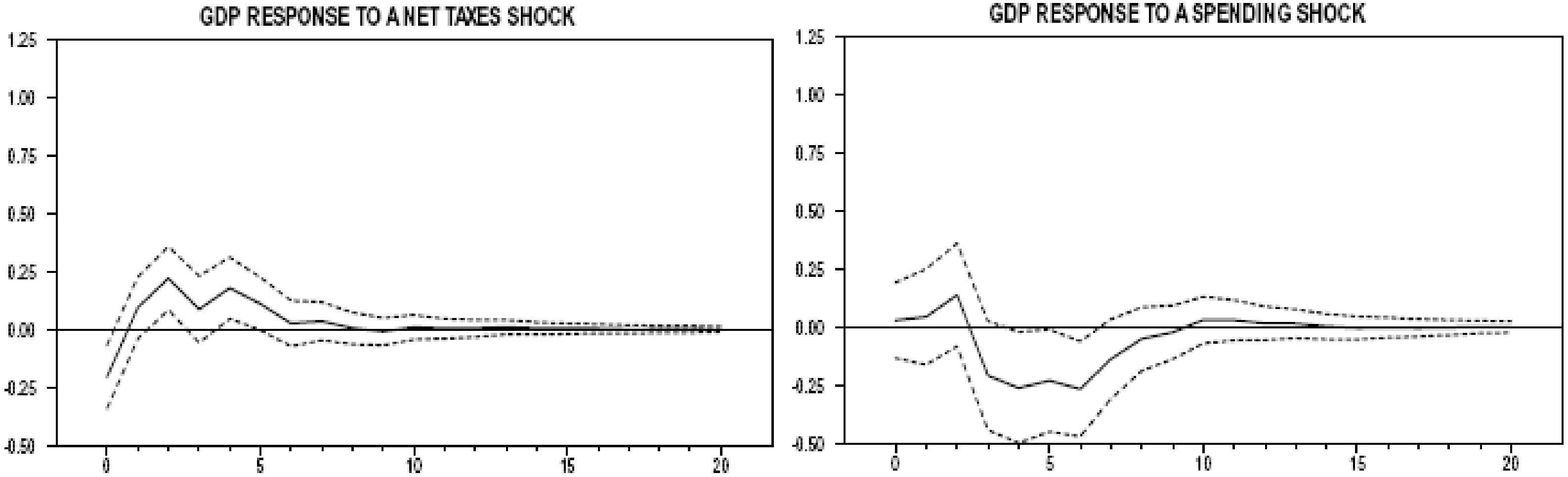
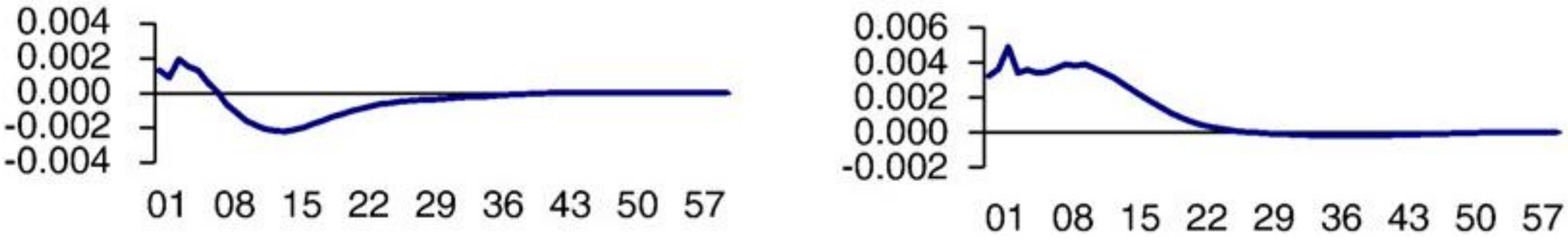


(i) GDP responses using first differences to de-trend the data



(ii) GDP responses using a Hodrick-Prescott Filter to de-trend the data

Figure 1: The effect of 1% fiscal shocks on GDP in Claus *et al*. (2006). Responses are percent changes in the quarters following the shock.



(i) GDP response to a government spending shock *(ii) GDP responses to a tax shock*

Figure 2: The effect of one standard deviation fiscal shocks on GDP in Dungey and Fry (2009).

Responses are unit changes in the quarters following the shock.

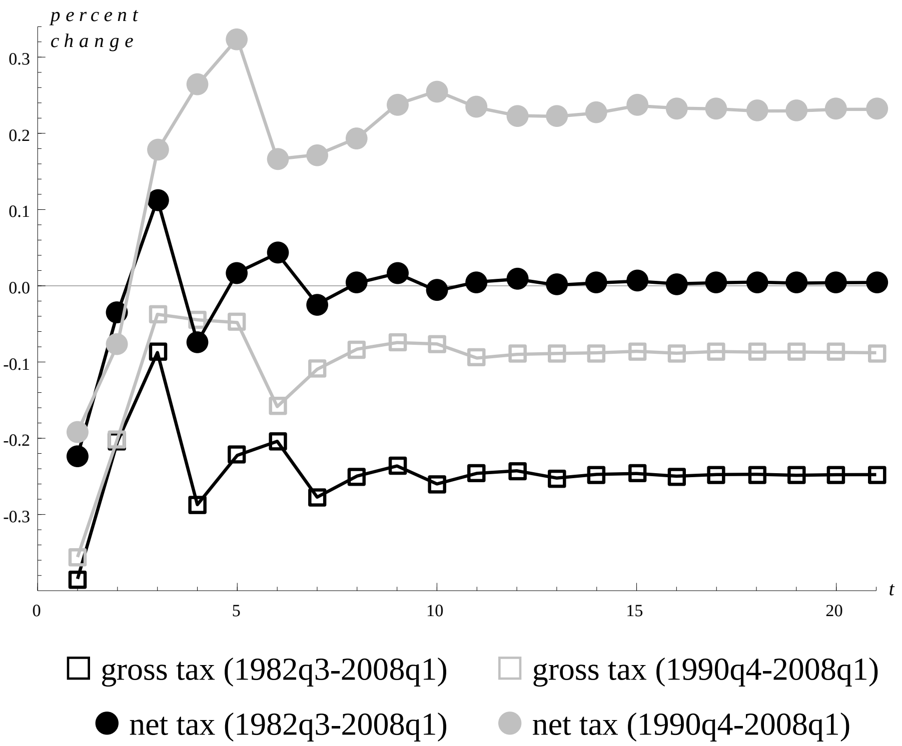


Figure 3: Responses to a 1% tax revenue shock in the three-variable VAR with differenced variables

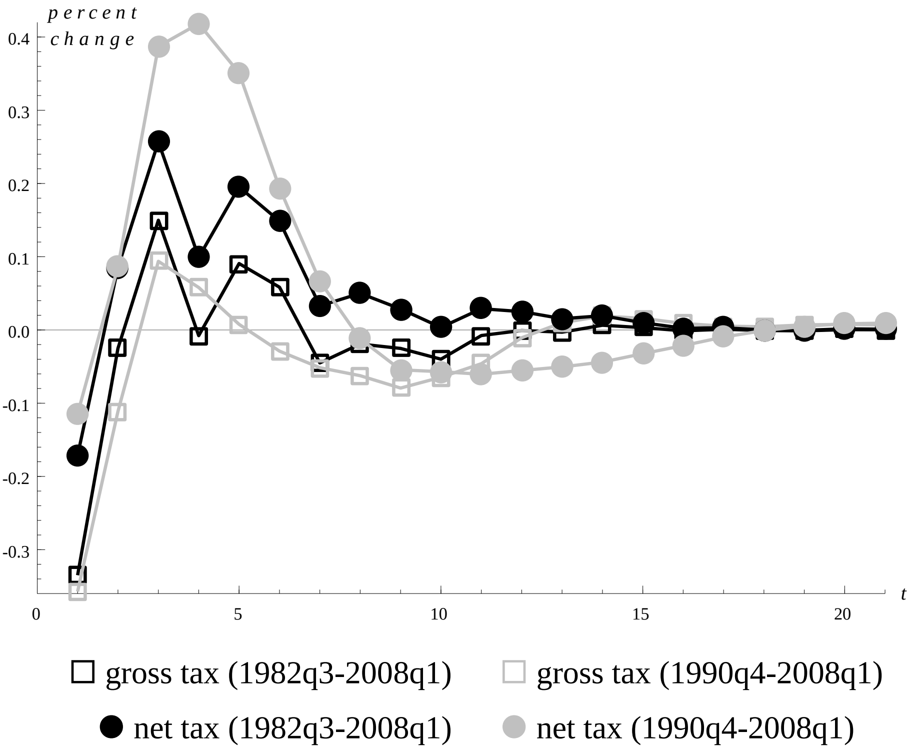
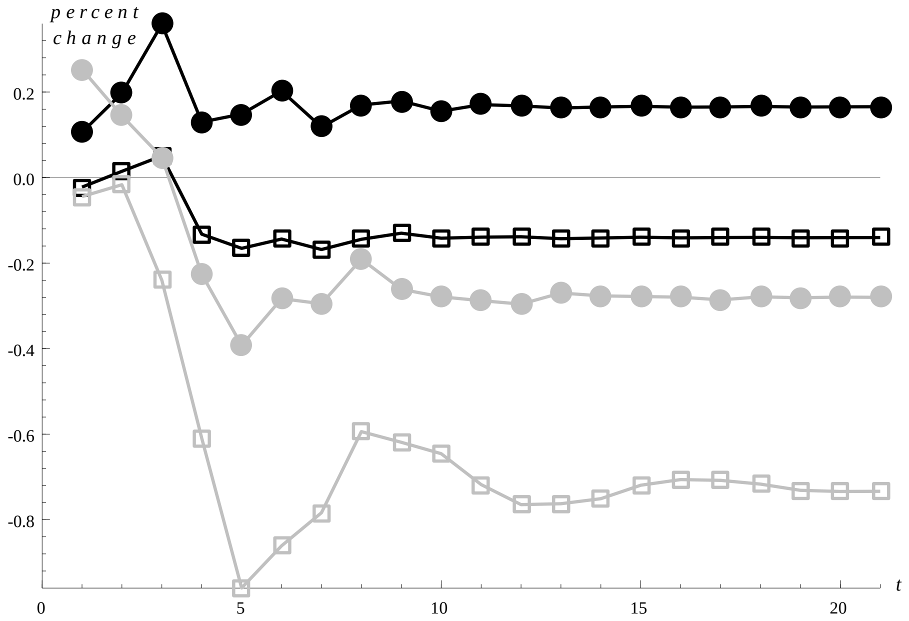


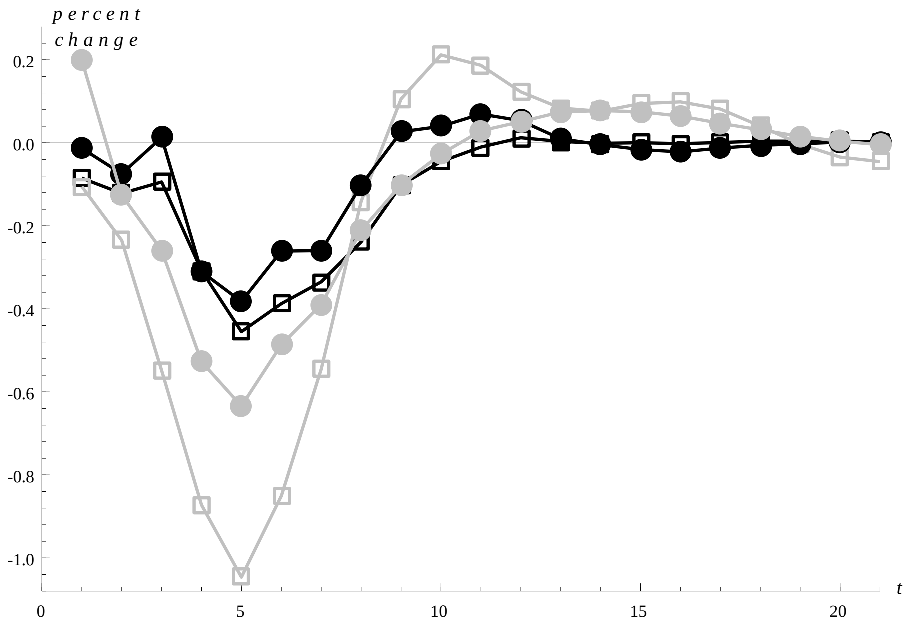
Figure 4: Responses to a 1% tax revenue shock in the three-variable VAR with filtered variables



☐ spending + transfers (1982q2-2008q1) ☐ spending + transfers (1990q4-2008q1)

● spending (1982q2-2008q1) ● spending (1990q4-2008q1)

Figure 5: Responses to a 1% government spending shock in the three-variable VAR with differenced variables



☐ spending + transfers (1982q2-2008q1) ☐ spending + transfers (1990q4-2008q1)

● spending (1982q2-2008q1) ● spending (1990q4-2008q1)

Figure 6: Responses to a 1% government spending shock in the three-variable VAR with filtered variables

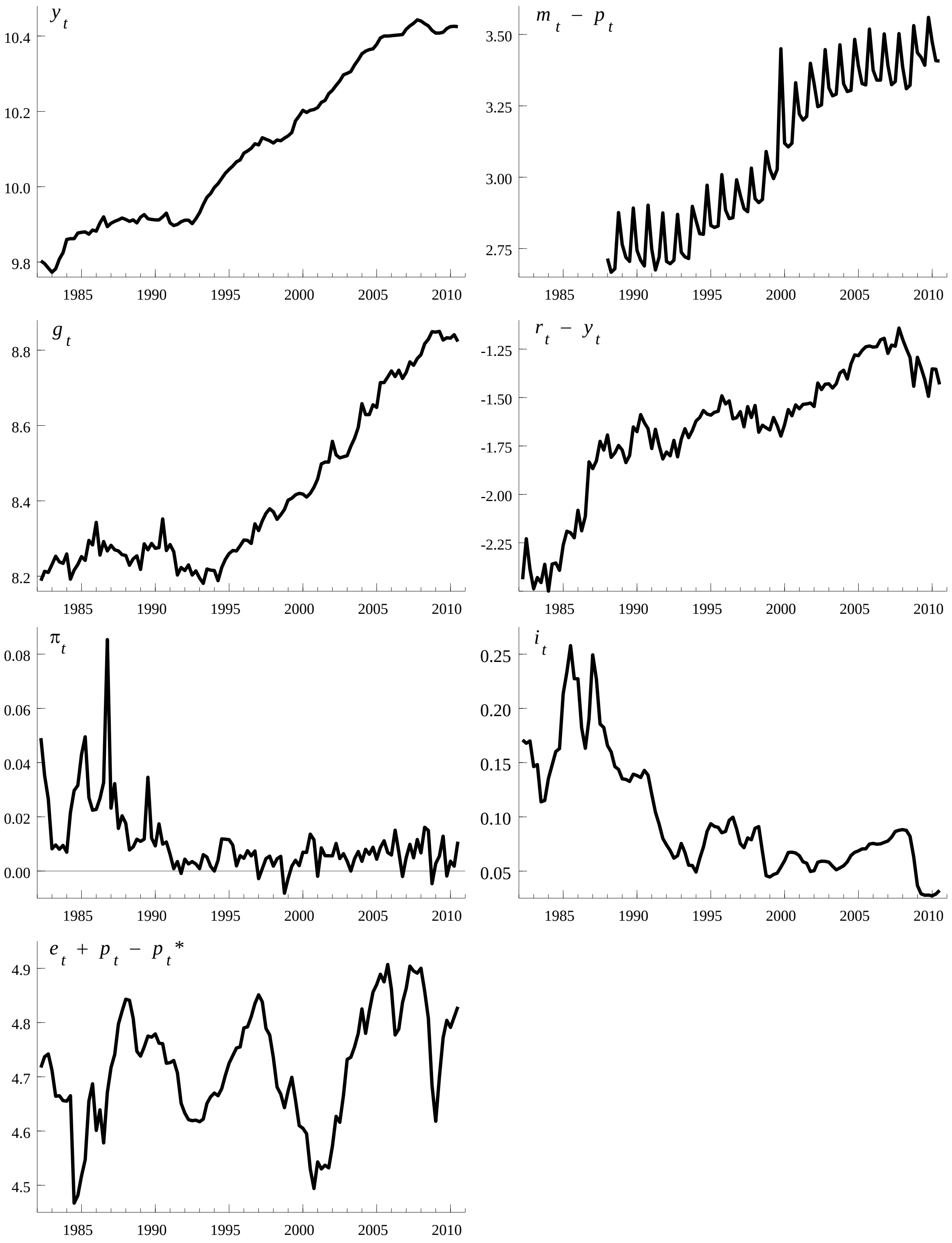


Figure 7: New Zealand macroeconomic time series

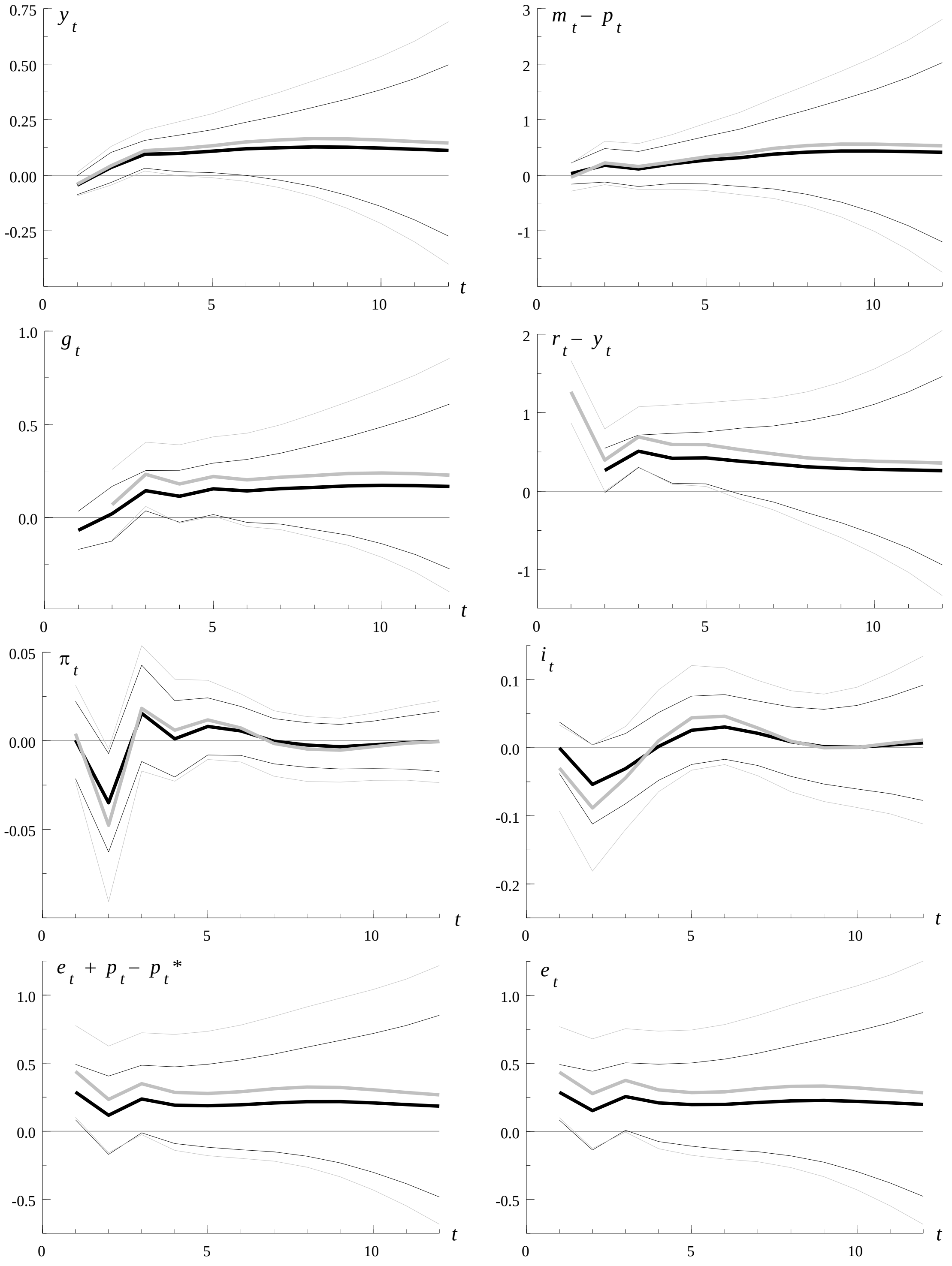


Figure 8: Impulse responses for a unit shock to $[r_t - y_t]$ based on the equation (7) VAR

Black lines show responses assuming $[r_t - y_t]$ is weakly exogenous to g_t, and grey lines responses assuming g_t is weakly exogenous to $[r_t - y_t]$. Dashed lines show the 95% confidence intervals.

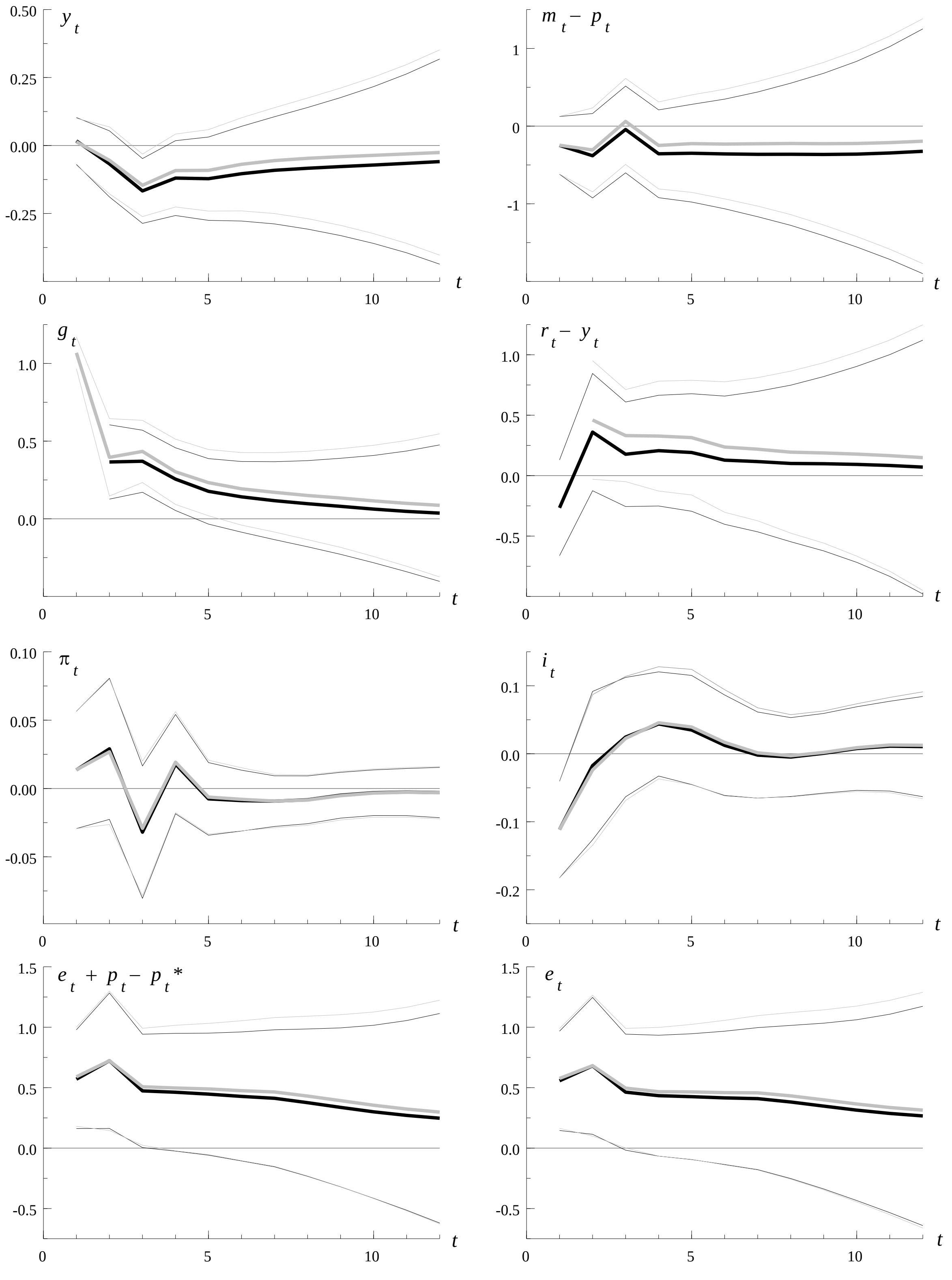


Figure 9: Impulse responses for a unit shock to g_t based on the equation (7) VAR Black lines show responses assuming g_t is weakly exogenous to $[r_t - y_t]$, and grey lines responses assuming $[r_t - y_t]$ is weakly exogenous to g_t. Dashed lines show the 95% confidence intervals.

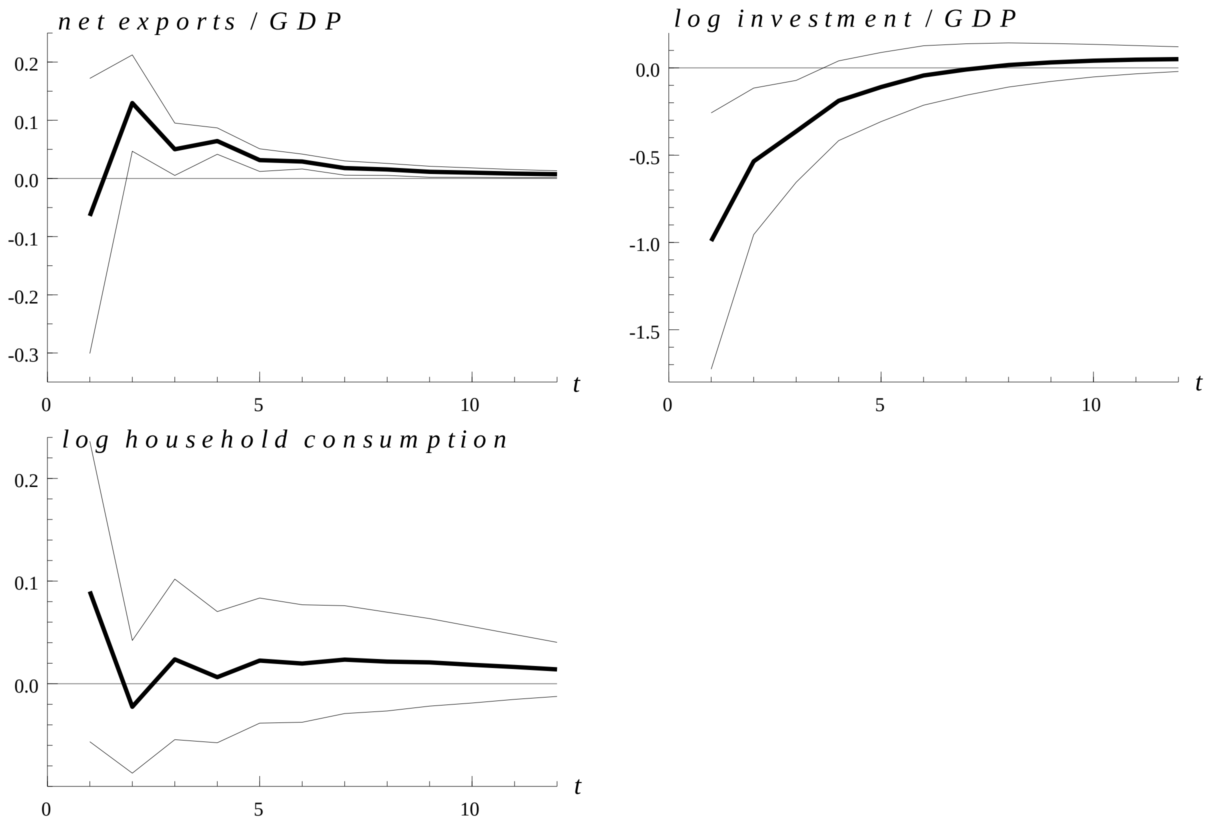


Figure 9a: Impulse responses for a unit shock to g_t (additional variables)

The responses are constructed assuming g_t is weakly exogenous to $[r_t - y_t]$. Dashed lines show the 95% confidence intervals.

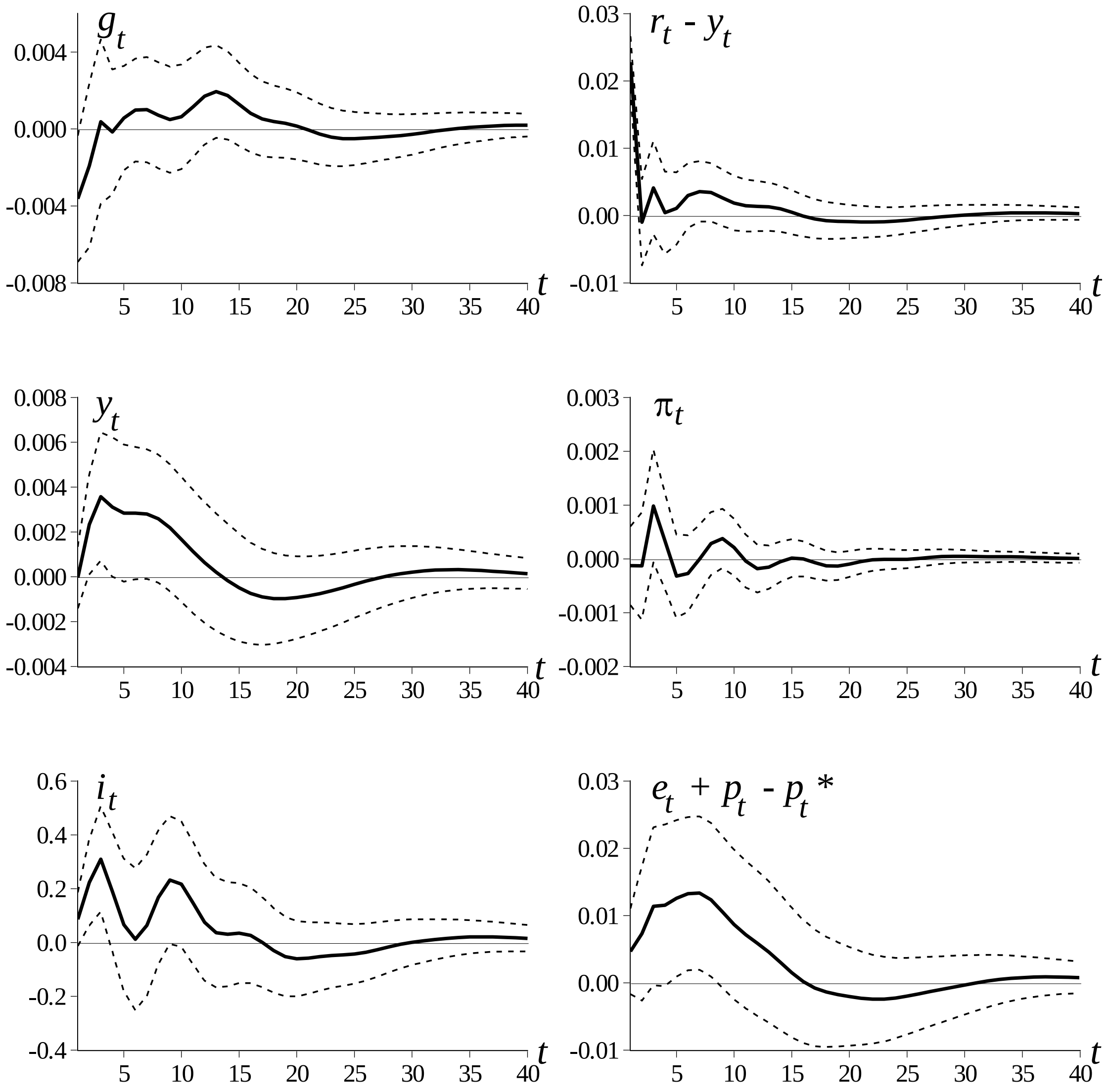


Figure 10: Impulse responses for a 1 s.d. shock to $[r_t - y_t]$ based on a Cholesky Decomposition

Dashed lines show the 95% confidence intervals.

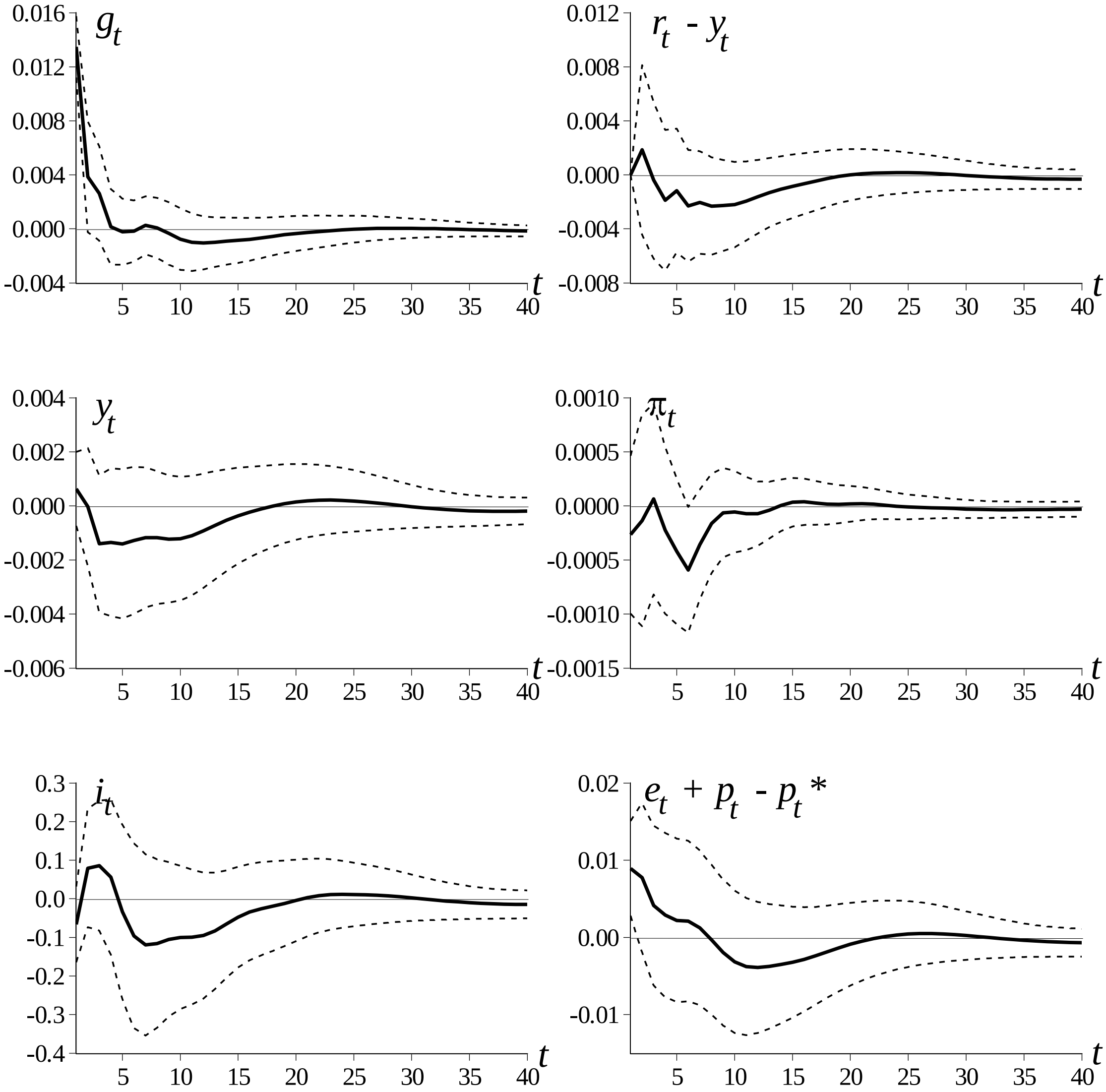


Figure 11: Impulse responses for a 1 s.d. shock to g_t using a Cholesky Decomposition

Dashed lines show the 95% confidence intervals.

Appendix 1: Stationarity and CointegrationTest Statistics

A1. Stationarity Tests

Table A1 includes Augmented Dickey-Fuller Test statistics for the variables in the equation (1) VAR and the equation (5) VAR. For each variable s_t, the regression equation is of the form

$$\Delta s_t = \gamma_0 + \sum_{i=1}^{i=p} \gamma_i \cdot \Delta s_{t-i} + \delta_1 \cdot s_{t-1} + v_t \tag{A1}$$

where v_t is a white-noise error term, and the test statistic is the t-ratio on the parameter δ_1. The lag order p is selected on the basis of the Schwartz Bayesian Criterion. In the case of $[m_t - p_t]$ and π_t, the regression equation also includes quarterly dummies. (There is no significant seasonality in any other variable.) For the financial variables (the interest rates i_t and i_t*, and inflation π_t), the sample period begins in 1990q4, excluding the era of monetary instability and high inflation. For the other variables, the sample period extends back as far as possible, and the starting date depends on data availability and the lag order chosen. For all variables, the sample period ends in 2010q3; excluding the Global Financial Crisis data for 2008q2-2010q3 does not make any substantial difference to the results.

The table indicates the sample period used for each test, the number of lags and the test statistic. Using a 5% confidence interval, the null that the series is difference-stationary can be rejected against the alternative that it is stationary in the case of π_t, i_t, i_t^*, $[e_t + p_t - p_t^*]$, π_t^{OIL} and c_t. These variables are treated as stationary in the models discussed in the main text; the other variables are treated as difference-stationary.

A2. Cointegration Tests

In the equation (7) model, there are four endogenous difference-stationary variables: y_t, $[m_t - p_t]$, g_t, and $[r_t - y_t]$, plus one exogenous difference-stationary variable, y_t^*. We test for cointegration by fitting a VAR that incorporates just these five variables. The VAR includes an unrestricted intercept and restricted seasonal dummies; y_t^* enters as a restricted regressor. Three lags of the variables are required to ensure that the residuals are not autocorrelated. After fitting the VAR, Johansen Max Test and Trace Test statistics are calculated. These are reported in Table A2. The null of a rank less than four can be rejected at the 1% level in both tests.

Table A1

Stationarity Test Results

variable	*sample period*	*lags*	*ADF t-ratio*
y_t	1982q4-2010q3	1	-0.40
$m_t - p_t$	1988q4-2010q3	1,2	-0.24
g_t	1982q4-2010q3	1	0.29
$r_t - y_t$	1982q4-2010q3	1	-2.45
y_t*	1983q1-2010q3	1,2	-2.19
π_t	1990q4-2010q3	none	-6.69
i_t	1990q4-2010q3	1	-4.37
i_t*	1990q4-2010q3	1	-2.86
$e_t + p_t - p_t$*	1989q3-2010q3	1,8	-3.02
π_t^{OIL}	1982q4-2010q3	1	-8.34
c_t	1982q3-2010q3	none	-7.97

Table A2

Johansen Cointegration Test Statistics for $\{y_t, [m_t - p_t], g, [r_t - y_t], y_t^*\}$

rank	max test		trace test	
0	273.90	$p < 0.01$	198.79	$p < 0.01$
1	75.11	$p < 0.01$	34.62	$p < 0.01$
2	40.50	$p < 0.01$	21.47	$p < 0.01$