Smooth Operators and the New Zealand Current Account

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Abstract

A present value model offers a tractable explanation for the evolution of the current account as a shock absorber, allowing domestic agents to smooth consumption by borrowing and lending broad. New Zealand's current account is more strongly mean reverting than those of most other OECD countries and so especially lends itself to tests of the PVM. However, New Zealand's current account fails the cross equation restrictions (CER) implied by the PVM, a result in common with most other countries' current accounts. In this paper, we assess the robustness of this result by (i) presenting both a linear and nonlinear CER; and by (ii) using Bayesian sampling to generate distributions of the test statistics.

To explore reasons for the failure of the CER, we use an estimated small open economy DSGE model that nests the PVM. We find that habit formation in consumption, imperfect capital mobility and permanent technology shocks can explain failure of the CER. This does not, however, imply that habit in consumption explains the bulk of the historical variation in the current account. Both historical and variance decompositions suggest that domestic technological innovations and external valuation shocks (a proxy for exchange rate and terms of trade effects) are important in driving current account dynamics. World cost of capital and fiscal shocks play a relatively small role. Our results support the idea that New Zealand's presently large current account deficit reflects rational savings and investment decisions.

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1 Introduction

In December 2005 New Zealand's current account deficit was 8.9 per cent of GDP. Should we be concerned? The present value model (PVM) of the current account provides a simple, but tractable approach to understanding the current account as a means by which domestic agents use foreign borrowing and lending to smooth consumption.[1]

In a closed economy, the sum of agents' borrowing must be financed by domestic savings such that domestic savings equals domestic investment. In an open economy, however, this budget constraint is relaxed: the economy as a whole can invest more than it saves, by borrowing from abroad and so running a deficit on its current account. In the PVM, the current account acts as a shock absorber, allowing households to smooth consumption in the face of temporary shocks to net income, much as an individual uses deposit and overdraft facilities with a bank to save and borrow.

The PVM focuses on savings and investment decisions rather than the effects of competitiveness and the real exchange rate on trade flows. The model implies a current account that is the result of rational savings and investment decisions, a perspective that has gained ground in the past two decades. The New Zealand current account is an appealing candidate for the PVM. A liberalised domestic financial system, a high degree of capital market integration, small size relative to international capital flows, a large stock of external liabilities, and a floating exchange rate suggest few restrictions on domestic or international borrowing.

This paper updates the PVM tests for New Zealand previously conducted by Kim, Buckle, and Hall (2006) to include the 1999 to 2005 period. We use Bayesian sampling to assess the robustness of the results and present both the standard nonlinear CER and a linear CER to illustrate and avoid the problems associated with the former.

In some respects, that the New Zealand current account is consistent with the PVM. It is stationary (mean reverting) consistent with a shock-absorber role. The degree of mean reversion is high relative to other OECD countries such as Australia and the US (figure 1). Alternatively, consumption and

[1] The PVM was originally proposed by Sachs (1981). The empirical tests set out in Campbell (1987) and Campbell and Schiller (1993) are extended to include a variable interest rate in Bergin and Scheffrin (2000) and habit in consumption by Gruber (2002). Kano (2003) shows the observational equivalence between habit in consumption and a transitory consumption shock. There is a large body of empirical work, which includes Scheffrin and Woo (1990), Otto (1992), Ghosh (1995) and Bergin and Scheffrin (2000). For New Zealand, see Kim, Buckle, and Hall (2006). Nason and Rogers (2006) explore reasons for the failure of the PVM for Canadian data using model simulations. Obstfeld and Rogoff (1995) provide a review of the literature.

disposable income are cointegrated and the difference between them – the current account – is stationary.

However, the cross equation restrictions implied by the PVM are rejected by the data. Consequently, any inference on the strength of the observed consistency is likely to be misleading in the general case.

Nason and Rogers (2006) use a calibrated DSGE model that nests the PVM to explore reasons for the failure of the CER for Canadian data. In this paper we extend their approach by using a DSGE model that is estimated on New Zealand data using Bayesian techniques. Simulations from this estimated model yield artificial data, and cross equation restrictions calculated from these are compared with those from the observed data. The simulated data fail the cross equation restriction in the same direction as the data. Simulation experiments show that habit in consumption, imperfect capital mobility and permanent technology shocks shift the cross equation restriction toward the empirical statistics and so help to explain the failure of the CER on the observed data.[2]

While these features help to explain failure of the CER, they do not necessarily explain the bulk of the historical variation in the current account. We find that historical variation may be attributed to domestic technological innovations and to positive valuation shocks (a proxy for exchange rate and terms of trade effects).

These results are also corroborated by a variance decomposition on the model which indicates that permanent technology shocks and external valuation shocks and are important in driving current account dynamics. Fiscal shocks play a small role, as, contrary to our priors, do world cost of capital shocks. The variance decomposition is consistent with the notion that high exchange rates may have played an important role in the recent deterioration in the current account by increasing the attractiveness of investment. Overall, the results support the idea that New Zealand's large current account deficit reflects rational savings and investment decisions.

The rest of the paper is structured as follows. Section 2 provides a brief overview of the present value model and tests. Section 2.3 presents PVM test results and their distributions for New Zealand for the period 1985 to 2005. Section 3 sets out the small open economy model and presents the results of the simulation experiments. Section 4 concludes.

[2]Early results using a *calibrated* model and adding additional features to a PVM-equivalent model, suggested that habit formation in consumption, non-separable utility and a world cost of capital shock in combination with an endogenous risk premium help to account for the failure of the PVM, consistent with Nason and Rogers (2006) results. However, these explanations for the failure of the PVM are rejected by the estimated structural model.

2 The PVM and the New Zealand current account

2.1 The present value model

The present value model of the current account is a simple, one-shock model, built around a representative, infinitely lived consumer who maximizes the present value of expected future utility:

$$\max \sum_{j=0}^{\infty} \beta^j E_t[u(C_{t+j})] \tag{1}$$

where β is the subjective discount rate, and C_t is consumption at time t.

The intertemporal resource constraint is derived from the combination of the national accounts identity

$$Y_t = C_t + I_t + G_t + NX_t \tag{2}$$

where Y_t is GDP, C_t is consumption, I_t is investment, G_t is government spending, and NX_t is level of net exports.

Assets and debt are accumulated through holdings of a single riskless bond, B, denominated in units of consumption. The economy is assumed to be open and small so that the bond is traded freely with non-residents given a world real interest rate which is assumed to be fixed, rather than stochastic or endogneous. The law of motion of bonds is:

$$B_{t+1} - B_t = rB_t + NX_t \tag{3}$$

The current account, the right hand side of equation 3, is a sum of the investment income (interest on bonds, rB_t) and net exports, and is financed by the change in bond holdings.

Substituting for NX_t in (2), and solving forward, the intertemporal budget constraint can be written:

$$\begin{aligned} -(1+r)B_t &= \sum_{j=0}^{\infty} \left(\frac{1}{1+r}\right)^j (Y - C - I - G)_{t+j} \\ &= \sum_{j=0}^{\infty} \left(\frac{1}{1+r}\right)^j NX_{t+j} \end{aligned} \tag{4}$$

which is subject to a transversality (solvency) condition that prevents agents from running up infinite debt or infinitely rolling over debt

$$\sum_{\lim_{j\to\infty}} \beta B_{t+j} = 0 \tag{5}$$

Equation (4) says that, for solvency, the current outstanding stock of debt cannot exceed the discounted value of current and future trade surpluses required to repay the debt.

The Euler equation from intertemporal utility maximisation sets the marginal utility of consumption in period t equal to $(1+r)$ times the discounted marginal utility of consumption in period t+1

$$(1+r)\beta u'(C_{t+1}) = u'(C_t) \tag{6}$$

By assuming quadratic preferences $u(C) = C + a_0 C^2/2$, the necessary curvature of the utility function is obtained in a tractable functional form and we may write consumption as a function of initial wealth (bond holdings) and a discounted sum of future net income, $NY = Y - I - G$

$$C_t = \frac{r}{\theta}\left\{B_t + \frac{1}{(1+r)}E_t\left[\sum_{j=0}^{\infty}\frac{NY_{t+j}}{(1+r)^j}\right]\right\} - \frac{\alpha}{r} \tag{7}$$

where

$$\theta = \frac{\beta(1+r)r}{\beta(1+r)^2 - 1} \qquad \text{and} \qquad \alpha = \frac{1}{\alpha_0}\left[1 - \frac{1}{\beta(1+r)}\right]$$

Under rational expectations, consumers never *plan* to change consumption, but do so in response to news about the value of wealth or expected future net income. The optimal consumption smoothing component of consumption is defined as the component of C above that is consistent with $\beta = 1/(1+r)$, i.e., the rate of time preference is held equal to the market interest rate[3] so that $\theta = 1$ and $\alpha = 0$

$$\begin{aligned} C_t^* &= rB_t + \frac{r}{(1+r)}E_t\left[\sum_{j=0}^{\infty}\frac{NY_{t+j}}{(1+r)^j}\right] \\ &= \theta C_t + \frac{\theta\alpha}{r} \end{aligned} \tag{8}$$

[3]Note that in efficient markets the marginal investment return offsets the rate at which that future return is discounted.

2.2 Predictions of the PVM

Unit root tests and cointegration

Using the relationship $CA_t = NY_t + rB_t - C_t$ and equation (8), the optimal component of the current account CA_t^* – that which relates to optimal consumption C_t^* – can be estimated empirically as the residual of a regression of $NY_t + rB_t$ on consumption,

$$E_t NY_t + rB_t = \theta C_t + \theta \frac{\alpha}{r} + CA_t^* \tag{9}$$

If $(NY_t + rB_t)$ and C_t are I(1) and cointegrated, then CA_t^* should be I(0). If the PVM assumption that $\beta = 1/(1+r)$ holds then the estimated value of θ should be one. This also provides a useful approach to detrending the current account data.[4]

Cross equation restrictions

The current account path consistent with the optimal consumption path can be expressed analytically by substituting equation (8) into the definition of the current account (3) yielding

$$CA_t^* = -\sum_{j=1}^{\infty} \frac{E_t \Delta NY_{t+j}}{(1+r)^j} \tag{10}$$

If the relationship between ΔNY_t and CA_t can be represented by a 2-variable vector auto-regression (VAR): $W_t = DW_{t-1} + \varepsilon_t$, where $W_t = [\Delta NY_t, CA_t^*]'$, the unrestricted forecast of W_{t+j} is,

$$E_t[W_{t+j}] = D^j W_t \, . \tag{11}$$

Using the restricted (in sample) model forecast, denoted CAf_t^{NL}, equation (10) can be rewritten,

$$\begin{aligned} CAf_t^{NL} &= -F_1 \frac{D}{1+r} \left[I - \frac{D}{1+r} \right]^{-1} W_t \\ &= HW_t \end{aligned} \tag{12}$$

where $F_1 = [1\ 0\ 0\ \ldots\ |\ 0\ 0\ 0\ \ldots\ ]$.

We want to test whether the observed current account $[0\ 0\ 0\ \ldots\ |\ 1\ 0\ 0\ \ldots\ ]W_t$ is equal to the restricted model forecast of the current account, HW_t (i.e.,

[4] We employ this detrending approach here, but the results are very similar if a demeaned current account series is used.

to test if $H = [0\ 0\ 0\ \ldots\ |\ 1\ 0\ 0\ \ldots\ ]$). The right hand side of equation 12 is nonlinear and may lead to inappropriate inferences if the eigenvalues of $D/(1+r)$ are close to unity such that $[I - D/(1+r)]$ is near rank-deficient. Mercereau and Miniane (2004) show that even eigenvalues quite far from unity may lead to incorrect inferences. To avoid inverting $[I - D/(1+r)]$, Campbell and Schiller (1993) rewrite the equality as:

$$[00...0|10..0]\left[I - \frac{D}{1+r}\right]W_t = -[10...0|00..0]\frac{D}{1+r}W_t \tag{13}$$

which implies a set of linear cross equation restrictions – $G = [g_1\ \ldots\ g_{2p}]$ for a p^{th} order VAR. For a 2-lag VAR we have the restrictions,

$$g_1 : (D_{3,1} - D_{1,1})/(1+r) = 0$$
$$g_2 : (D_{3,2} - D_{1,2})/(1+r) = 0$$
$$g_3 : (D_{3,3} - D_{1,3})/(1+r) = 1$$
$$g_4 : (D_{3,4} - D_{1,4})/(1+r) = 0$$

These linear cross equation restrictions correspond to the nonlinear elements of H, but do not require the inversion of $[I - D/(1+r)]$. They can be tested individually with a t-test and jointly with a Wald test. Equation (13) can be derived from equation (10) by taking the first element of the infinite sum on the right hand side of equation (10) and rewriting as:

$$CAf_t^L = \frac{E_t CA_{t+1} - E_t \Delta NY_{t+1}}{1+r} \tag{14}$$

Thus the linear tests for the CER are single period tests rather than infinite period tests of equation 10.

Using G (or H) a model-consistent forecast GW_t (or HW_t) of the current account can be constructed, and its correlation with the observed current account can be examined. Further, the variance of the forecast can be tested for equality with the variance of the observed current account.

Orthogonality condition

The first-term factor of the infinite sum 10 can be used to form the current account update at $t+1$,

$$CA_t = \Delta NY_t + (1+r)CA_{t-1} \tag{15}$$

The residual $R_t = CA_t - \Delta NY_t - (1+r)CA_{t-1}$ should be uncorrelated with lagged W_t, or in the presence of serially uncorrelated demand shocks, with

W_{t-2}, W_{t-3}, ... as shown in Campbell (1987). This tests the orthogonality condition *ex post*, while the linear cross equation restriction (14) tests it in expectational form.

The predictions of the canonical PVM can be summarised as:

- net income and consumption are cointegrated and the current account (the error correction term) is stationary;
- the current account Granger-causes changes in net income;
- the cross equation restriction implies that, for a p^{th} order VAR, the $p+1$ element of G (or H) is unity and other elements are zero;
- the variance of GW_t (or HW_t) is equal to the variance of the observed current account;
- R_t is orthogonal to $\Delta NY_{t-1}, \Delta NY_{t-1}$ ... and CA_{t-1}, CA_{t-2} ... or in the presence of serially uncorrelated, i.e. unforecastable, demand shocks, is orthogonal to NY_{t-j} and CA_{t-j} for $j \geq 2$.

2.3 Testing the New Zealand data

Unit root tests and cointegration

Empirical tests in this section are carried out using real per capita data which are discussed in more detail in Appendix A. Unit root tests are shown in Table 2. C and $(NY + rB)$ test as I(1) and their first differences as stationary. The current account series derived from the national accounts, (NY+rB-C), also tests as stationary.

We test for cointegration between $NY + rB$ and C using the Engle-Granger approach (see Table 3).[5] The OLS estimate of the coefficient on consumption, θ in (9), is significantly different from unity for recent samples.[6] This is the result of the increasing divergence between $NY + rB$ and C in recent periods as shown in figure 2. In part this trend may reflect growth in real per capita GDP, which will lead to a divergence, even for a stable and sustainable current account to GDP ratio.[7] It may also reflect longer term trends such as increasing capital market integration.

We have a choice between detrending the current account using equation 9 or simply demeaning the current account, which imposes a coefficient of unity on θ. In the long run, this coefficient will tend toward unity and in practice, the choice makes little difference for the tests on the observed sample. However, in some simulated samples (which are also short samples for comparability), the trend may be important so we adopt the detrending approach to ensure that the VAR is estimated using stationary data.

Unit root tests show that the consumption-smoothing component of the current account is stationary. Figure 2 shows the data and figure 3 shows the estimated residual: the optimal consumption smoothing component of the current account, CA_t^*, and the component not being modeled. The large negative mean mainly reflects the investment income payments on the large outstanding external stock of liabilities.

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[5] The Johansen method has weak power for short samples and rejects cointegration between C and $(NY + rB)$ for New Zealand data. The trace and maximum eigenvalue test statistics are both 3.8 compared to critical values of 15.5 and 14.3.

[6] Estimates can sometimes be improved through dynamic OLS (DOLS) by adding leads and lags of ΔC on the right hand side to achieve more normal residuals. DOLS was not found to improve the distributions of the residuals in this case.

[7] Here, we take a sustainable current account to mean *epsilon* less than the stock of debt multiplied by nominal GDP growth which implies that B/Y will approach zero as $t \to \infty$.

Cross equation restrictions

VAR lag order selection criteria select a VAR lag length of 2 (table 4). VAR-2 estimation results are shown in table 5. One of the implications of the present value model is that the current account Granger-causes changes in net income. As shown in table 5, lagged current account terms are significant in the net income equation, as confirmed by a Granger causality test. The parameter on CA_{t-2} in the ΔNY equation is -0.32 and significant: a current account deficit (surplus) precedes an increase (decrease) in net income.

The linear (G) estimates of the cross equation restriction are significantly different from [0 0 1 0] (as shown in table 6).

Bayesian sampling is used to generate 5000 draws from the companion matrix, D, and distributions of G and H are constructed[8] (see figure 5). The p+1 element of H, is significantly below the theoretical value of 1. The first and p+2 elements of H are significantly above the theoretical value of zero. The linear restriction is more normally distributed. Consistent with individual elements of G being different from their theoretical values, the joint Wald test also fails (table 6) and the distribution of this test statistic is to the right of the critical value (figure 7).

Variance ratio test

The model-implied forecasts GW_t look very similar to the observed current account (figure 6). However, this is not because the data fit the model (G, $H \neq$ [0 0 1 0]), but because the elements of G that differ from their theoretical values (eg., CA_t and CA_{t-1}) are roughly offsetting. The linear cross equation restriction is closer to the model, as measured by the correlation of GW_t and HW_t with the observed current account and the variance ratio test.

As shown in table 6, the variance of the observed current account is not significantly different from that implied by the linear cross equation restriction. Bayesian sampling allows us to examine the distribution of the variance ratio (figure 8). In the linear case ($\text{var}(GW_t)/\text{var}(CA_t)$) the distribution of the variances is clustered around unity. In the nonlinear case ($\text{var}(HW_t)/\text{var}(CA_t)$), the distribution is much more dispersed, but given a large standard deviation, the hypothesis of equal variances cannot be rejected. While the variance ratio test cannot be rejected, like the visual inspection of the model-consistent series, the acceptance is for the wrong reasons.

[8]Software for Bayesian Analysis Computation and Communication is used for this exercise. BACC is available at http://www2.cirano.qc.ca/ bacc/.

The draws of G and H are used to generate error bands around the model-consistent series CAf_t^L and CAf_t^{NL} (see figure 9). Forty-two percent of observations are within the linear 5 and 95 percentile error bounds and 78 per cent of observations are within non-linear error bounds. More observations are within the error bounds of HW_t than GW_t because the error bounds of HW_t are wider, not because HW_t is closer to the observed current account data.

Orthogonality condition

The residual $R_t = CA_t - \Delta NY_t - (1+r)CA_{t-1}$ is not orthogonal to ΔNY_{t-1}, ΔNY_{t-1} ... and CA_{t-1}, CA_{t-2} ... (see Table 7). However, it is orthogonal to NY_{t-2}, NY_{t-3} ... and CA_{t-2}, CA_{t-3}, ..., suggesting that a transitory demand shock may be an explanation for the failure of the cross equation restriction (see Campbell (1987)).

3 What factors account for rejection of the CER?

3.1 The suspects

The failure of the cross equation restriction implied by the PVM could be due to a variety of factors. Without accounting for the failure, we cannot make statements about the current account relative to rational savings-investment behavior. The usual suspects for this failure, as set out in Nason and Rogers (2006) are nonseparable preferences, imperfect capital mobility, a high rate of time preference and additional shocks – such as a fiscal shock, a world real interest rate shock, and exchange rate and terms of trade effects.

Two recent studies Liu (2005) and Santacreu (2006) estimate habit formation to be important for New Zealand, implying a high degree of additional smoothing in consumption. With habit formation in consumption, utility is derived both from the level of consumption and from the increase over last period's consumption level, or from the steady state consumption level. Such additional smoothing in consumption implies more volatility into the current account. For example, in the absence of habit formation, permanent shocks lead to an immediate adjustment in consumption to the new optimal path. When habits are a feature of consumption choices however, a substantial component of *permanent* shocks may be initially absorbed in the current account as agents are loath to immediately shift consumption to a new optimal level. Allesi and Lusardi (1997) and Gruber (2002) extend the basic PVM to include habit formation.

Within this extended PVM, Kano (2003) shows that habit in consumption cannot be distinguished from a transitory demand shock in the time series data and uses model simulations to differentiate between the effects, finding that a world real interest rate shock improved the fit of the model to Canadian data more than the inclusion of habits. The Bayesian estimation process employed in this paper allows us to assess the relative merit of these features.

Nonseparable preferences dampen the response of consumption and labour input to intertemporal incentives, and may add an additional degree of smoothing to these variables, thereby increasing volatility in the current account.

Given New Zealand's large stock of net external liabilities, a rate of time preference above that implied by the world real interest rate (the "impatient" small open economy according to Nason and Rogers (2006)) is also a candidate for the failure of the CER.

As a small open economy, a world cost of capital shock and external valuation shocks (incorporating terms of trade and exchange rate valuation effects) are also appealing candidate explanations for the recent rise in New Zealand's current account deficit, especially given recent large fluctuations in the terms of trade and the exchange rate, and the low world cost of capital since 2001. While New Zealand's debt is largely denominated in domestic currency, exchange rate fluctuations can have significant effects on the domestic currency value of foreign assets. The large stock of liabilities in turn affects the response of the economy to shocks, particularly a shock to the cost of capital through its effect on debt repayment.

We now construct a small open economy model that includes all of these features, but nests the PVM as a special case. Our overall aim is determine which of the above suspects are most responsible for the failure of the present value model in explaining New Zealand's current account.

3.2 A small open economy model

Our model is based on Nason and Rogers (2006) and Kano (2003) who extends the former to include habit formation in consumption. The model is built around a representative, infinitely lived household that maximises expected future utility, invests in production, and buys and issues internationally traded bonds subject to a resource constraint, a production function, and a law of motion for capital.

The utility maximisation problem is given by,

$$\max \quad E_t \sum_{j=0}^{\infty} \beta^j \frac{[(C_{t+j} - hC_{t+j-1}]^{\phi} L_{t+j}^{1-\phi})^{1-\gamma} - 1}{1-\gamma} \tag{16}$$

which is subject to the resource constraint,

$$Y_t = C_t + I_t + G_t + NX_t, \tag{17}$$

where G_t is net government spending, I_t is new investment, and NX_t is net exports, Y_t is output, and parameters are restricted such that $0 < h, \phi < 1$ and $\gamma > 1$.

The constant relative risk aversion (CRRA) utility is nonseparable between consumption and leisure, except in the case where $\gamma = 1$.

Output is produced with constant returns to scale technology,

$$Y_t = K_t^{\theta}[A_t N_t]^{1-\theta}, \qquad 0 < \theta < 1 \tag{18}$$

where A_t is country-specific technological progress that drives permanent movements in $Y_t,\ C_t,\ I_t,\ G_t,\ NX_t$ and the capital and bond stocks and plays the role of the domestic disturbance to permanent income. Specifically, we assume that the logarithm of A_t is a unit root with drift $\alpha > 0$

The law of motion of capital is,

$$K_{t+1} = (1-\delta)K_t + \left(\frac{I_t}{K_t}\right)^{\sigma} I_t, \qquad 0 < \sigma, < \delta < 1 \tag{19}$$

The household accumulates internationally traded bonds B_t which are paid for from net exports NX_t. The change in the stock of bond holdings between periods is equal to the current account balance – the trade balance NX_t plus the investment income balance rB_t):

$$[B_{t+1} - (1+r_t)B_t]s_t = NX_t \tag{20}$$

where r_t is the world real interest rate and s_t is an "external valuation" shock. This is different to the Nason and Rogers (2006) terms of trade shock,[9] and accounts for the income (but not substitution) effects exchange rate,

[9] Where the resource constraint is $Y_t = C_t + I_t + G_t + s_t NX_t$ and the law of motion of bonds is $B_{t+1} = (1+r_t)B_t + NX_t$. See working paper version on Atlanta Fed website. While the shock enters the model in almost the same form, the formulation and interpretation are different and the shock has no effect on NX.

import and export price fluctuations. If there is no fluctuation in export or import prices (in foreign currency terms) then s_t would serve as an exchange rate, where an increase in s_t is an appreciation. While this shock is not a well formulated terms of trade shock, it should give an idea of the value of building a richer trade side to the model, while allowing us to focus on savings-investment decisions.

The interest rate paid on bonds, r_t is the world real interest rate q_t plus an endogenous country-specific risk premium that is internalised in decisions made by households, and increases with the stock of debt outstanding as in Schmitt-Grohe and Uribe (2003):

$$r_t = q_t - \varphi \frac{B_t}{Y_t}, \qquad 0 < \varphi < 1 \tag{21}$$

There are four exogenous processes. The technology shock, A_t, follows a random walk with drift,

$$A_t = A_{t-1} e^{\alpha + \epsilon_{a,t}}, \quad 0 < \alpha, \quad \epsilon_{a,t} \sim N(0, \sigma_a^2). \tag{22}$$

Government spending is assumed to be proportional to output, with a constant ratio g^*, and follows an AR(1) process,

$$\frac{G_t}{Y_t} = g_t = g^{*1-\rho_g} g_{t-1}^{\rho_g} e^{\epsilon_{g,t}}, \quad |\rho_g| < 1, \quad \epsilon_{g,t} \sim N(0, \sigma_g^2) \tag{23}$$

Similarly, the exogenous components of q_t and s_t follows AR(1) processes:

$$\begin{aligned} (1 + q_t) = (1 + q^*)^{(1-\rho_q)} (1 + q_{t-1})^{\rho_q} e^{\epsilon_{q,t}}, \quad |\rho_q| < 1, \quad \epsilon_{q,t} \sim N(0, \sigma_q^2) \\ s_t = s^{*(1-\rho_s)} s_{t-1}^{\rho_s} e^{\epsilon_{s,t}}, \quad |\rho_s| < 1, \quad \epsilon_{s,t} \sim N(0, \sigma_s^2) \end{aligned} \tag{24}$$

Maximising (16) subject to equations (17), (18), (19), (20) and (21) yields the stochastic discount factor, Γ_t,

$$\Gamma_{t+1} = \beta \left(\frac{C_{t+1} - hC_t}{C_t - hC_{t-1}} \right)^{\phi(1-\gamma)-1} \left(\frac{1 - N_{t+1}}{1 - N_t} \right)^{(1-\phi)(1-\gamma)}, \tag{25}$$

, and the **optimality conditions** in labour, capital and bond holdings:

$$\left(\frac{1-\phi}{\phi} \right) \left(\frac{C_t - hC_{t-1}}{1 - N_t} \right) = (1 - \theta) \frac{Y_t}{N_t} \left[1 + \varphi s_t \left(\frac{B_t}{Y_t} \right)^2 \right] \tag{26}$$

$$\left(\frac{K_t}{I_t}\right)^{\sigma} = E_t\Gamma_{t+1}\left\{\theta(1+\sigma)\frac{Y_{t+1}}{K_{t+1}}\left[1+\varphi s_t\left(\frac{B_{t+1}}{Y_{t+1}}\right)^2\right]\right\} + E_t\Gamma_{t+1}\left\{\left[1-\delta-\sigma\left(\frac{I_{t+1}}{K_{t+1}}\right)^{1+\sigma}\right]\left(\frac{K_{t+1}}{I_{t+1}}\right)^{\sigma}\right\} \tag{27}$$

$$1 = E_t\Gamma_{t+1}\frac{s_{t+1}}{s_t}\left[1+r_{t+1}-\varphi\frac{B_{t+1}}{Y_{t+1}}\right] \tag{28}$$

Equation 25 defines the stochastic discount factor – the rate at which agents discount future returns – as the ratio of the shadow price (or marginal utility) of consumption at time $t+1$ divided by the shadow price of consumption at time t. In the basic present value model with no habit in consumption (i.e. $h = 0$), separable utility ($\gamma = 1$) and a constant world real interest rate, the stochastic discount factor is the familiar $\beta(C_t/C_{t+1})$ which implies optimal smoothing of consumption over time. With non-separability in the utility function ($\gamma \neq 1$), leisure at t and $t+1$ affect the marginal utility of consumption at time t, and therefore the stochastic discount factor. With habit formation in consumption ($h \neq 0$) higher consumption at t lowers the marginal utility of consumption at $t+1$ and increases the rate at which consumption at $t+1$ is discounted.

Equation 26 equates the marginal rate of substitution between consumption and labour to the marginal product of labour adjusted for the response of the risk premium to a change in employment. The risk premium has a negative income effect, leading households to increase employment above that under perfect capital mobility.

Equation 27 equates the marginal cost of investment at time t, I_t/K_t^{σ} to the expected discounted benefit of an extra unit of capital at time $t+1$. The benefit of this extra unit stems from increased production, but is smaller than the benefit with perfect capital mobility given the rise in the risk premium from higher debt. The additional unit of capital reduces adjustment costs but contributes to higher depreciation next period.

Equation 28, is the optimality condition for international borrowing. It equates the marginal benefit of additional borrowing (the marginal utility of consumption $= \Gamma_{t+1}$) to the marginal cost of that borrowing (the interest rate net plus the increase in the risk premium) the following period. An increase in external debt increases the domestic interest rate which implies a lower stochastic discount factor and lower marginal utility of consumption.

Finally, transversality conditions ensure that the household cannot increase the capital stock or its stock of debt indefinitely,

$$\lim_{i\to\infty} \beta E_t \lambda_{B,t+1} B_{t+i+1} = 0 \quad \text{and} \quad \lim_{i\to\infty} \beta E_t \lambda_{K,t+1} K_{t+i+1} = 0$$

To solve the model, a log-linear approximation is taken around the steady state. First, all variables except labour and interest rates/discount factors are stochastically detrended by the random walk path of technology. A first order Taylor expansion of each of the equilibrium conditions is taken around the steady state. The log linear equations are shown in Appendix B. The model is solved using the method of Sims (2002).

The model is estimated using Bayesian techniques. Our prior parameter distributions are chosen to match aspects of the New Zealand data such as a large debt liability, a observed risk premium over world real interest rates, and major national accounts ratios. Where the observed data are not informative, we draw on standard RBC practice for our priors. Details of the model estimation are given in Appendix C.

3.3 Simulation strategy

Using Bayesian calibration, Nason and Rogers (2006) simulate data from restricted versions of a similar model, beginning with a PVM-equivalent model. Data generated by this simple PVM-equivalent has properties (namely the CER) close to the theoretical values, as would be expected. Nason and Rogers (2006) add features to the model one at a time and are interested in whether the addition of each feature moves the tests away from the theoretical values toward the empirical test results.

However, the model parameters are almost certainly not independent in the posterior draws. This makes it difficult to draw inferences using the calibration strategy. Two features may move the simulated data toward the empirical results, but a large value of one might imply a small value of the other.

Our initial experiments began by simulating data from the full estimated model and carry out experiments that remove features from the model, one at a time, to explore reasons for failure of the CER. We performed a number of experiments using importance sampling on the joint posterior distribution (e.g. by seeking the lowest or highest 10 per cent posterior densities relative to particular parameters or shock variances) but this had little effect on the cross equation restriction implied by the model. Therefore, we re-estimated the model, this time excluding features of interest (habit, non-separable preferences, imperfect capital mobility), and again generated and tested simulated data. To assess the effect of the different shocks, we also simulated data by excluding one shock at a time.

For each simulation experiment, 5,000 draws from the parameter space are used to generate 5,000 sets of NY, rB and C, each with 83 observations (the same as the length of the empirical data).[10] Distributions of test statistics for the simulated data are calculated in the same way as for the empirical data. Smoothed current account series CA^* are constructed from simulated data by regressing $NY + rB$ on C. Two-lag VARs are estimated to construct 5000 draws of G_s, from which we then construct theoretical error bounds.

To assess the goodness of fit between the simulated data and the observed data we focus on the distributions of elements of G_s and G_e. [11] We follow Nason and Rogers (2006) in using the standardized difference of means (SDM) and calculate a confidence interval criterion statistic (CIC) as in DIW96.

The SDM statistic, similar to a t-ratio, is the distance between the mean of the simulated distribution and the mean of the empirical distribution (or the theoretical value) normalised by the standard deviation of the empirical distribution,

$$\text{SDM} = [\text{mean}(\hat{G}(i)_s) - (\hat{G}(i)_e)]/\text{stdev}(\hat{G}(i)_e) \tag{29}$$

The CIC statistic, a measure of overlap, is the portion of the simulated distribution that lies within the 5 and 95 percent bounds of the empirical distribution. DeJong, Ingram, and Whiteman (1996) find a CIC statistic of 0.3 or greater to indicate support for the model.

$$\text{CIC} = \frac{1}{1-\omega} \int_{0.5\omega}^{1-0.5\omega} G_s(x)\text{d}x \tag{30}$$

where $G_s(x)$ is the simulated distribution and $1 - \omega$ is the confidence level.

3.4 Simulation results

The simulated data from the full estimated model fail the cross equation restriction by pushing the distributions of simulated test statistics in the same

[10] 283 observations are generated, but the first 200 are dropped to remove dependency on initial conditions

[11] Nason and Rogers (2006) look at the Wald statistic, LR test from orthogonality regressions and error bands. All of these test equation (10) in different ways. We prefer to focus on the elements of the cross equation restriction. The Wald statistic can match the empirical result for the wrong reasons (e.g. if the elements of the CER move away from the theoretical values, but in the wrong direction.

direction as the data (Appendix E, Figure 9). The failure is not as severe as the failure of the empirical data, particularly for the third and fourth elements of the cross equation restriction (CER) shown in the bottom two panels. The mean of the simulated distribution is, however, closer to the mean of the empirical distribution than to the theoretical values for the 1st, 2nd and 4th elements of the cross equation restriction ($\text{SDM}_t > \text{SDM}_e$) and equidistant from the empirical mean and theoretical value for the third element. The overlaps of the simulated and empirical distributions, as measured by the CIC are 0.71, well in excess of 0.3 threshold suggested by DeJong, Ingram, and Whiteman (1996).

As shown in Appendix E, Figure 10, the error bands from the simulated model are similar to the empirical error bands. More observations are inside the simulated error bands because the simulated data are closer to the PVM than the observed data.[12]

Parameter restrictions

We impose the PVM restrictions of separable preferences ($\gamma = 1$), no habit in consumption ($h = 0$), and perfect capital mobility ($\varphi \simeq 0$) on our model and assess the effect on the results. The model was re-estimated as each of these restrictions individually and successively were imposed.[13]

Based on the estimates of the full model, the hypothesis that $h = 0$ or that $\varphi \leq 0.0001$ are each rejected while the data do not reject the restriction that $\gamma = 1$.[14]

Figures 11 and 12 in Appendix E show the cross equation restriction and error bands for the *model without habit*. Recall that the full unrestricted model pushed the simulated CER distributions away from the theoretical values and towards the empirical CER. The CER for the model without habit formation return sharply toward the theoretical values. The overlap of the empirical and simulated distributions falls to less than 0.1 for the 1^st, 3^rd and 4^th elements of the CER. Though the overlap of the second element is high, this was not very different from the theoretical values even for the unrestricted model. Similarly the means of the simulated distributions are not significantly different from the theoretical values, except, again, for the

[12]If the CER is centered on the theoretical values [0 0 1 0] then 100 per cent of observations would be inside the simulated error bounds.

[13]Before re-estimating the model, we also pursued the option of sampling from the joint posterior distribution of parameter estimates to analyse the effect of the PVM restrictions on the model. However, most parameters were very precisely estimated, and attached near zero posterior probability to the PVM restrictions.

[14]φ cannot be set identically equal to zero, or the model will not converge. SeeSchmitt-Grohe and Uribe (2003).

2nd element. All observations are within the simulated error bands because the cross equation restriction is close to the theoretical values, rather than because the model is close to the data. The average overlap of the empirical and simulated distributions, as measured by the CIC statistic, falls from 0.71 to 0.26.

In the posterior estimates for the model without habit, one parameter, the intertemporal substitution parameter γ moved significantly (as measured by the posterior mode of the restricted model minus the mode of the full model divided by the standard deviation of the full model – a t-like statistic). The additional smoothing from habit shifts into a much higher estimate for γ which creates additional smoothing by allowing fluctuations in both consumption and labor to dampen intertemporal incentives.

Appendix E, Figures 13 - 14 show the cross equation restriction and error bands for the model with *separable preferences*. The cross equation restriction moves slightly back toward the theoretical values, but is almost indistinguishable from the full model results. The average overlap of the empirical and simulated distributions, as measured by the CIC statistic, falls from 0.68 to 0.66.

Appendix E, Figures 15 - 16 show the cross equation restriction and error bands for the model *with near-perfect capital mobility*. The restriction $\varphi = 0.0001$ implies a risk premium of less than 13 basis points compared to the observed 150-200 basis points) and allows the small open economy (which discounts the future more aggressively than the rest of the world) to have a steady state debt/GDP ratio of 800 per cent of GDP! As mentioned above, the hypothesis that the risk premium is this small is easily rejected by the the posterior parameter distribution of the full model. The first two elements of the cross equation restriction of the simulated data moves back to (or even beyond) the theoretical values and become very dispersed, leading to much wider error bounds. The 3rd element moves slightly away from the empirical distribution and toward the theoretical value, and and 4th element moves squarely back to the theoretical value. The average overlap of the empirical and simulated distributions, as measured by the CIC statistic, falls from 0.68 to 0.20.

In the posterior estimates for the model with near perfect capital mobility, several parameters move significantly away from the estimates in the unrestricted model – γ increases from 1.6 to 3.2, i.e. the utility becomes 'less' separable between consumption and leisure. Imperfect capital mobility prevents the small open economy from running up a very large debt if, for example, the cost of capital is low. The rise in γ allows fluctuations in consumption and labour to dampen intertemporal incentives helping to prevent a large run up in debt. The mean capital share θ falls from 0.46 to an implausible 0.11, slowing the investment response and therefore decreasing borrowing significantly. The mean depreciation rate δ increased from 0.006 to 0.014, reducing the expected future benefit of investment in new capital. The largest change in response to the imposition of near-perfect capital mobility is in the size of the terms of trade shock which increases almost seven fold. This may reflect the restraining effect of an exchange rate appreciation.

Shock restrictions

When examining the effect of additional *shocks* on the basic PVM, we assume that the general-equilibrium model is a "true" representation of the economy. Then, given the estimated historical shocks, we ask the counterfactual question: what would the CER have looked like if a particular shock had been absent.

Simulation results that exclude the *technology shock* are shown in Appendix E, Figures 17 and 18. The CER for the simulated distribution moves sharply back toward the theoretical values. The average overlap of the empirical and simulated distributions, as measured by the CIC statistic, falls from 0.68 to 0.33. Notably, in the single shock present value model, the shock to net income is not a permanent shock as it is in our model. In the PVM framework, a permanent technology shock would have no effect on the current account: consumption would immediately shift to the permanent income path. However, in the presence of habit, agents' desire to smooth changes in consumption, and leads to the permanent shock being initially partially absorbed in the current account as consumption adjusts more gradually to the permanent income path.

Simulation results that exclude the *fiscal shock* are shown in Appendix E, Figures 19 and 20. This has very little effect. The simulated distributions hardly move and the average overlap of the empirical and simulated distributions, as measured by the CIC statistic, falls slightly from 0.68 to 0.66.

Simulation results that exclude the *world cost of capital shock*, are shown in Appendix E, Figures 21 and 22. This takes the simulated data slightly closer to the empirical results. The average overlap of the empirical and simulated distributions, as measured by the CIC statistic, increases very slightly from 0.68 to 0.69.

Simulation results that exclude the *external valuation shock* are shown in Appendix E, Figures 23 and 24. This shock appears to have both a positive and negative effect in terms of taking the model closer to the data. In all cases, exclusion of the external valuation shock moves the means of the simulated CER distributions away from the theoretical values in the direction of the empirical failure. In the case of the 2nd element of the CER, the simulated distribution moves too far to the right of the theoretical zero restriction. In contrast, the average overlap of the empirical and simulated distributions, as measured by the CIC statistic, falls from 0.68 to 0.59 despite the movement of the simulated means toward the empirical ones. This is because the simulated distributions are more dispersed, leading to wider error bands. So the external valuation shock appears to be important in sharpening up the distributions which takes the model closer to the data, although its inclusion shifts the means of the simulated data away data taking the model closer to the data. This shock drives a wedge between domestic currency prices and the price of net exports and is thus a complex combination of the exchange rate, import and export prices. A richer representation of trade and the incorporation of a more standard terms of trade shock into the model may help to resolve this conflict.

Overall, it appears that habit in consumption, imperfect capital mobility, *permanent* technology shocks and external valuation shocks help to explain the failure of the CER.

4 Conclusions

Tests of the present value model of the current account on New Zealand data for 1985 - 2005 are generally consistent with those of Kim, Buckle, and Hall (2006) who consider the period 1982 - 1999. The current account is stationary and consistent with the idea that it plays a shock-absorbing role in the economy. It Granger-causes changes in net income, but the cross equation restrictions implied by the PVM are rejected. Despite the rejection of the CER, the in-sample model forecast is very similar to the observed current account. With Bayesian sampling, we assess the robustness of the results and show that the variance ratio tests on the model-implied current account relative to the observed current account cannot be rejected. We also illustrate the degree of distortion in the nonlinear cross equation restriction.

Simulations from a small open economy model were used to explore reasons for the failure of the CER. The simulation results show that, in our model, habit in consumption, imperfect capital mobility, permanent technology shocks and external valuation shocks – a proxy for exchange rate and terms of trade effects – shift the cross equation restrictions from the theoretical values toward the empirical results.

While these features help to explain failure of the CER, they do not necessarily explain the bulk of historical variation in the current account. Historical and variance decompositions suggests that domestic technology shocks and external valuation shocks account for the bulk of deviations in net exports and the current account from steady state. The historical decomposition is consistent with the notion that productivity improvements and terms of trade effects help to explain the recent deterioration in the current account. The world cost of capital appears to have offsetting effects: when funding is cheap increased investment is observed (implying greater borrowing through the current account), but a low cost of capital puts downward pressure on domestic borrowing costs reducing debt service payments. A richer trade side to better understand the external valuation shock and the addition of prices monetary policy and its exchange rate effect (however difficult to formulate) would enrich the model.

Our small model based on an optimising representative agent matches the current account well in terms of the cross equation restriction failure. Simulation results from the model generally support the idea that New Zealand's large current account deficit reflects rational savings and investment decisions.

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Table 1: Persistence of Australian, New Zealand and US current account/GDP ratios

	New Zealand		Australia		United States	
Unit root tests						
ADF	-4.34	**	-2.63		-0.25	
Ng Perron	-22.51	**	-9.39	*	1.96	
Phillips Perron	1.21	**	3.15		39.00	
AR(1) estimates						
constant	-0.017		-0.007		-0.001	
t-value	-3.95	**	-2.59	*	-1.15	
beta	0.646		0.840		.994	
t-value	7.91	**	-13.73	**	38.9	**
Implied Half life (quarters)	2		4		>100	
Implied Steady State	-4.8		-4.7		-14.0	

Notes: data are seasonally adjusted current account as a share of seasonally adjusted GDP for period 1982q2 to 2005q2. Sources: Australian Bureau of Statistics, Statistics New Zealand, US Bureau of Economic Analysis.

Table 2: Unit Root Tests

		ADF 1/		Ng-Perron 1/		Philips-Perron 2/	
$NY + rB$	level	-1.13		0.59		-1.94	
	1st difference	-10.95	**	-2.60		-16.98	**
Consumption	level	0.64		2.28		0.55	
	1st difference	-15.26	**	-37.12	**	-15.26	**
CA (BOP)	level	-2.73		-8.16	*	-4.01	**
CA (NY+rB-C)	level	-3.93	**	-10.64	*	-3.90	**

** indicates significance at the 1% level; * at the 5% level; † at the 10% level. Data are real, seasonally adjusted per capita. The results are therefore not directly coparable to those in Table 1.
1/ lag length based on Schwartz information criterion.
2/ lag length based on Newey-West Bandwidth.
1982q2 - 2005q2.

Table 3: Cointegration Regression

Dependent variable NY+rB:

	coeff	t-value		$H_0 : \theta = 1$	
				t-test	
θ	0.79	19.7	**	-5.25	**
$\theta\alpha/r$	0.61	3.04	**		
R^2				0.83	
R^2_{adj}				0.83	
SEE				0.18	
DW				0.69	
implied α				0.0035	
implied β	(r = 4% p.a.)			0.992	
Residual unit root tests					
ADF				-4.04	**
NgPerron				-17.97	**
Philips-Perron				-4.00	**

See notes to Table 2. 1985q3 - 2005q3.
** indicates significance at the 1% level; * at the 5% level.

Table 4: VAR Lag Order Selection Criteria

Endogenous variables: ΔNY, CA^*

Lag	LogL	LR		FPE		AIC		SC		HQ	
1	109.1	NA		0.00025		-2.63		-2.51		-2.58	
2	123.9	28.05	*	0.00019	*	-2.90	*	-2.66	*	-2.80	*
3	125.0	2.06		0.00020		-2.82		-2.47		-2.68	
4	125.6	1.07		0.00022		-2.74		-2.26		-2.55	

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion
Sample: 1985Q1-2005Q4, 84 observations

Table 5: VAR Estimates

	Unrestricted				Restricted		
	DNY		CAS		DNY		CAS
$\Delta NY(-1)$	-0.76		-0.21		-0.48		-0.48
	-5.58	**	*-1.60*		*-5.07*	**	
$\Delta NY(-2)$	-0.40		-0.29		-0.35		-0.35
	-4.00	**	*-3.01*	**	*-4.90*	**	
$CA^*(-1)$	0.29		0.77		0.03		1.03
	1.89		*5.25*	**	*0.25*		
$CA^*(-2)$	-0.48		-0.04		-0.26		-0.26
	-3.16	**	*-0.30*		*-2.46*	*	
R-squared	0.38		0.48		0.35		0.44
Adj. R-squared	0.36		0.46		0.32		0.42
Sum sq. resids	1.46		1.31		1.54		1.39
S.E. equation	0.14		0.13		0.14		0.13
F-statistic	15.92		23.63				
Log likelihood	48.81		53.30		1.39		
Granger Causality Test[a]							
χ^2 test	10.97		9.36				
pvalue	0.004	**	0.009	**			
Largest eigenvalue		0.89					

Sample: 1985q3 - 2005q4, 82 observations

Notes: t-values in italics. [a] Granger Causality test: joint exclusion of the CA^* terms from the ΔNY equation and vice versa. This is rejected in both cases: CA^* Granger-causes ΔNY and ΔNY Granger causes CA^*.

Table 6: Cross-equation restriction

	Theory:		G (Linear)		H (Nonlinear)
ΔNY_t	0		0.56		0.45
			5.12	**	
ΔNY_{t-1}	0		0.14		0.12
			1.58		
CA_t^*	1		0.48		0.41
			3.98	**	
		$H_0 \stackrel{?}{=} 1$	*-4.38*	**	
CA_{t-1}^*	0		0.49		0.26
			4.00	**	
Wald Test, χ^2 :			28.2		
p-value			*0.00*		
Corr(CA^*, CA^R)			0.93		0.91
Var. Ratio Test:					
$\sigma^2_{CA^*}/\sigma^2_{CA^R}$			1.03		1.91
χ^2 p-value[a]			*0.45*		*0.00*****
% obs in 5-95% error bounds			49		82

Calculated from VAR estimates in Table 5

Table 7: Orthogonality Tests

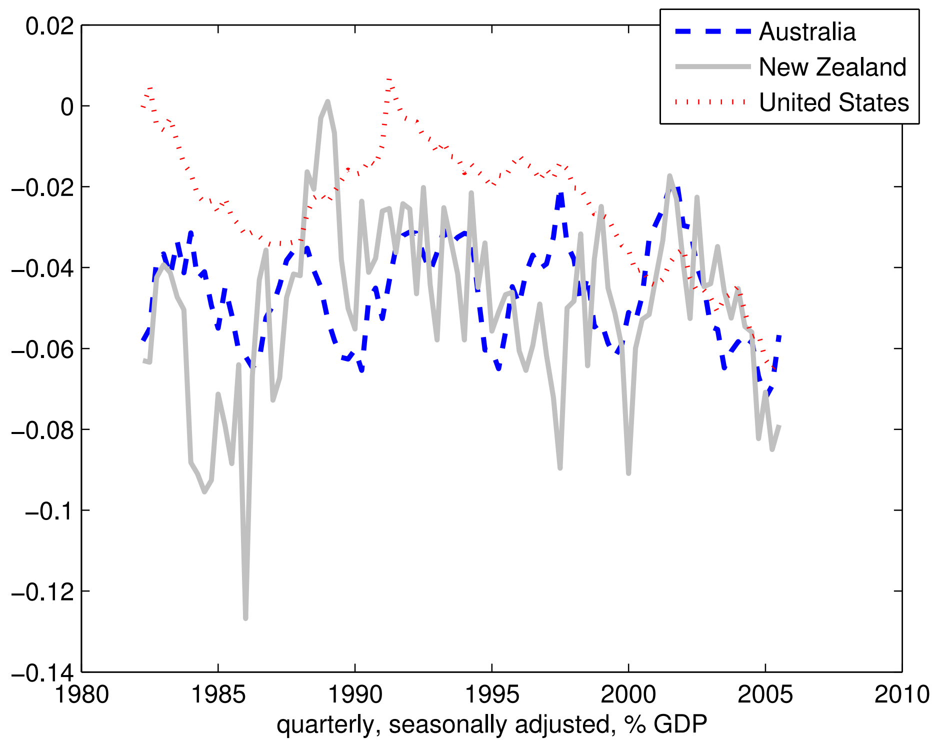
	PVM			PVM with transitory demand shock	
	coeff	t-value		coeff	t-value
ΔNY_{t-1}	0.56	5.20	**		
ΔNY_{t-2}	0.12	1.52	**	-0.14	1.15
ΔNY_{t-3}				-0.02	-0.20
CA_{t-1}	-0.54	-4.39	**		
CA_{t-2}	0.44	3.67		0.14	0.96
CA_{t-3}				0.20	-1.41
R^2		0.27			0.03
SEE		0.11			0.12
DW		2.07			2.86
LM test		29.6	**		1.43
5% critical value					

Sample 1985q1 - 2005q4
Dependent variable: $R_t = CA_t - \Delta NY_t - (1+r)CA_{t-1}$
** indicates significance at the 1 % level; * at the 5 % level.

Table 8: Variance Decomposition of Unrestricted Model

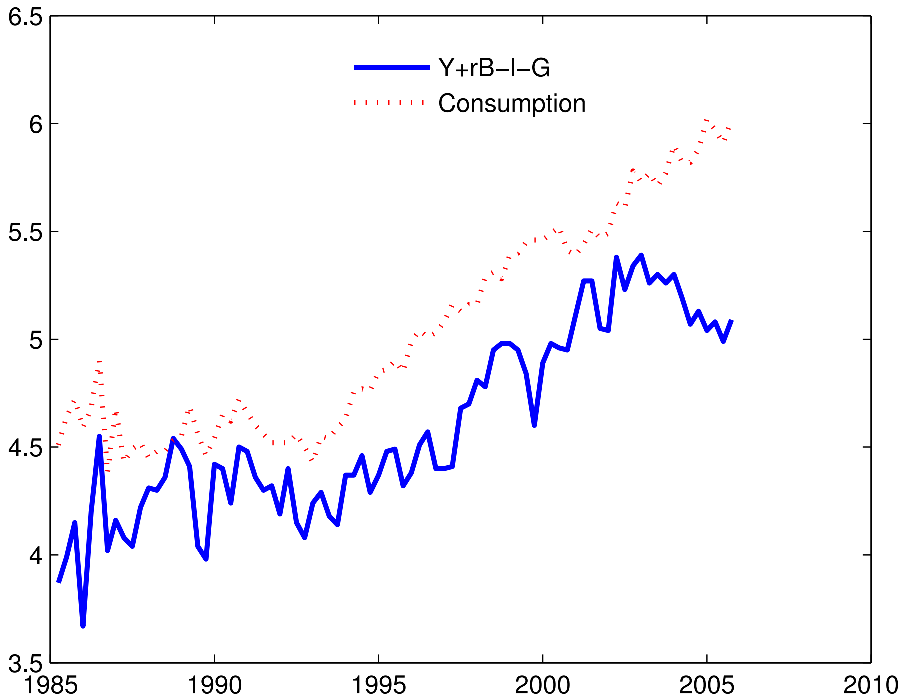
Shock	Output	Consumption	Investment	NX	CA
Technology	0.615	0.403	0.588	0.327	0.345
WCC	0.141	0.225	0.312	0.176	0.469
Fiscal	0.001	0.177	0.005	0.010	0.009
Ext Valuation	0.244	0.194	0.004	0.486	0.178

Figure 1: Australia, New Zealand and US Current Accounts



Note: Quarterly, seasonally adjusted data from Balance of Payments Accounts.
Sources: Australian Bureau of Statistics, Statistics New Zealand, US Bureau of Economic Analysis.

Figure 2: Consumption and Net National Income



Note: Real seasonally adjusted data are constructed by deflating nominal seasonally adjusted data
by the GDP deflator and dividing by working age population.
Source: Statistics New Zealand

Figure 3: Consumption smoothing component of current account

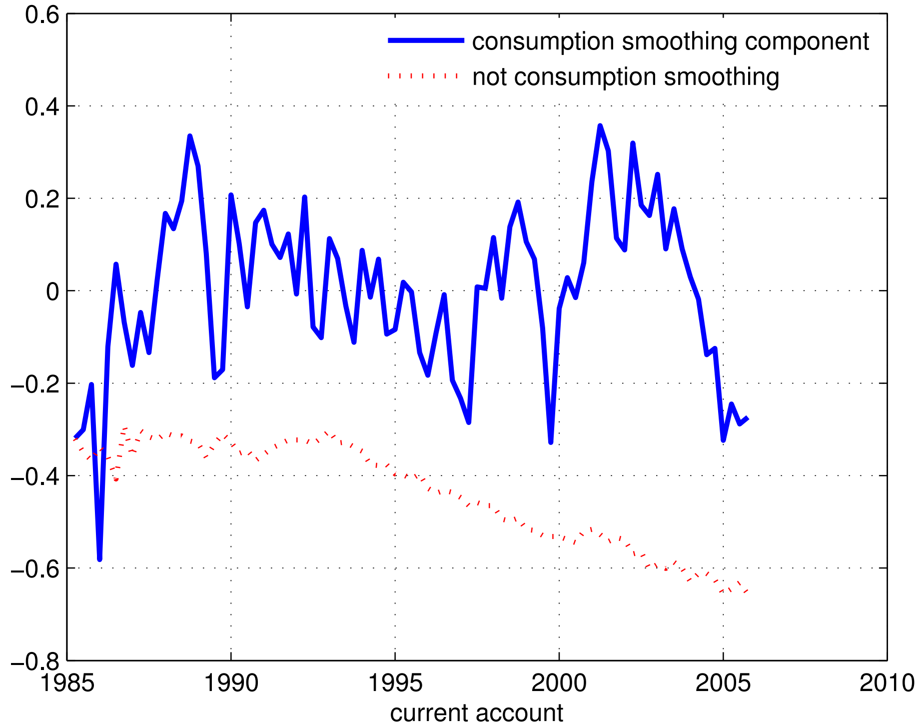


Figure 4: VAR3 Companion Matrix

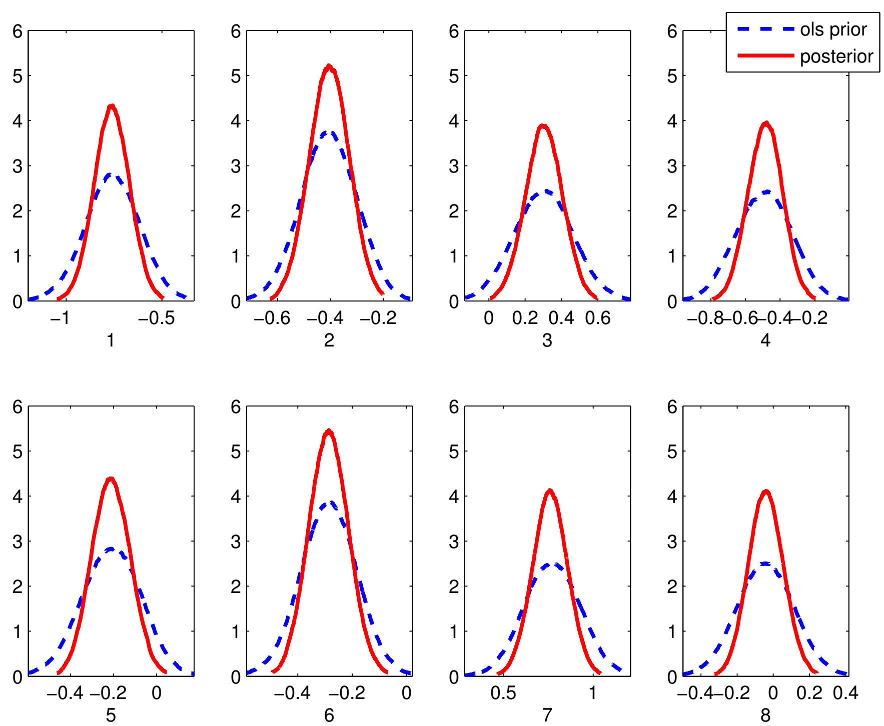
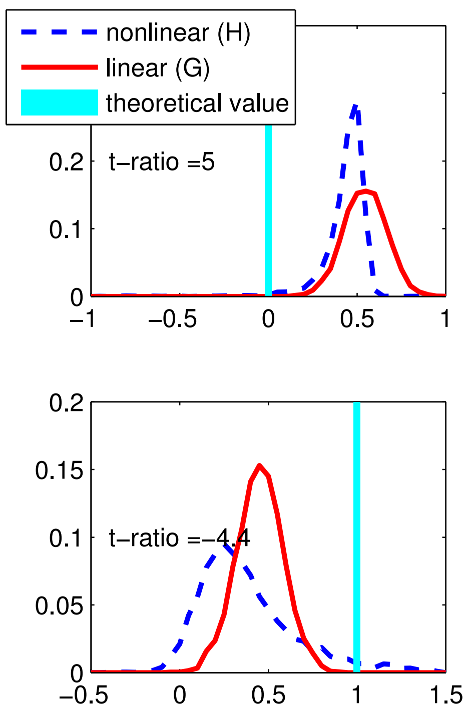


Figure 5: VAR2 Cross Equation Restriction: Distributions of G and H-vectors. Detrended by regression of $NY + rB$ on C



Note: t-ratios apply to linear (G) distribution.

Figure 6: VAR2 In-sample Model-Consistent Current Account Forecast

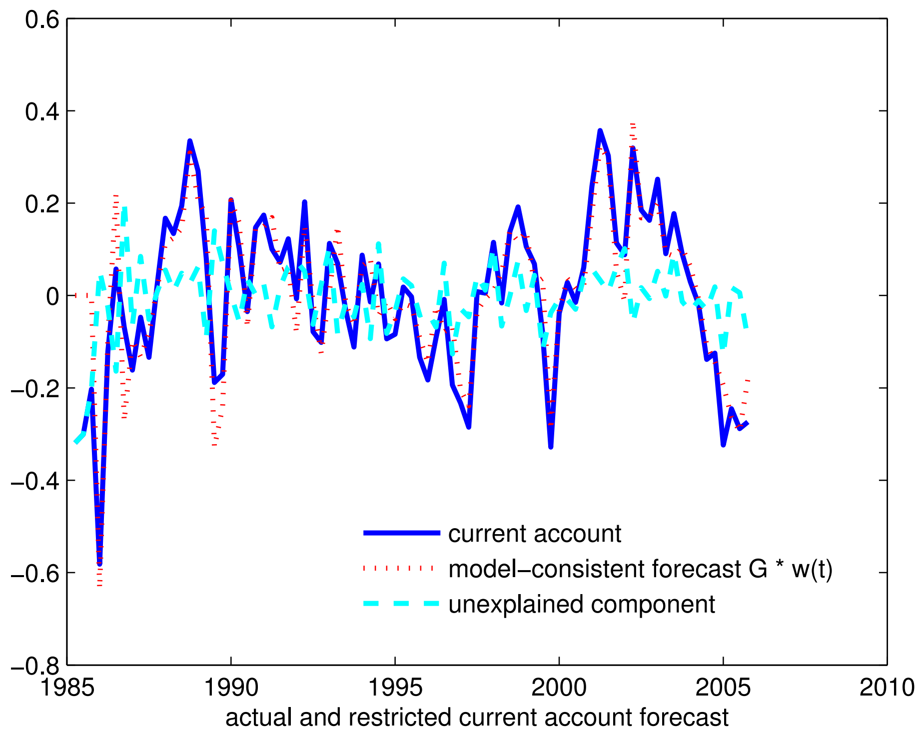


Figure 7: VAR2 Empirical Wald Test Distribution

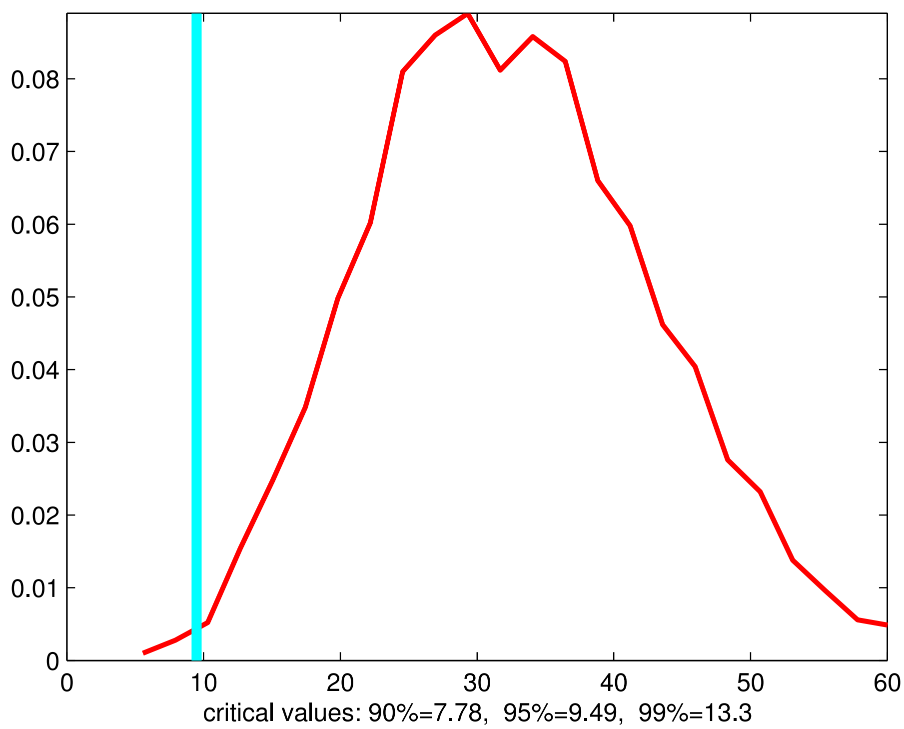


Figure 8: VAR2 Distribution of Variance Ratios

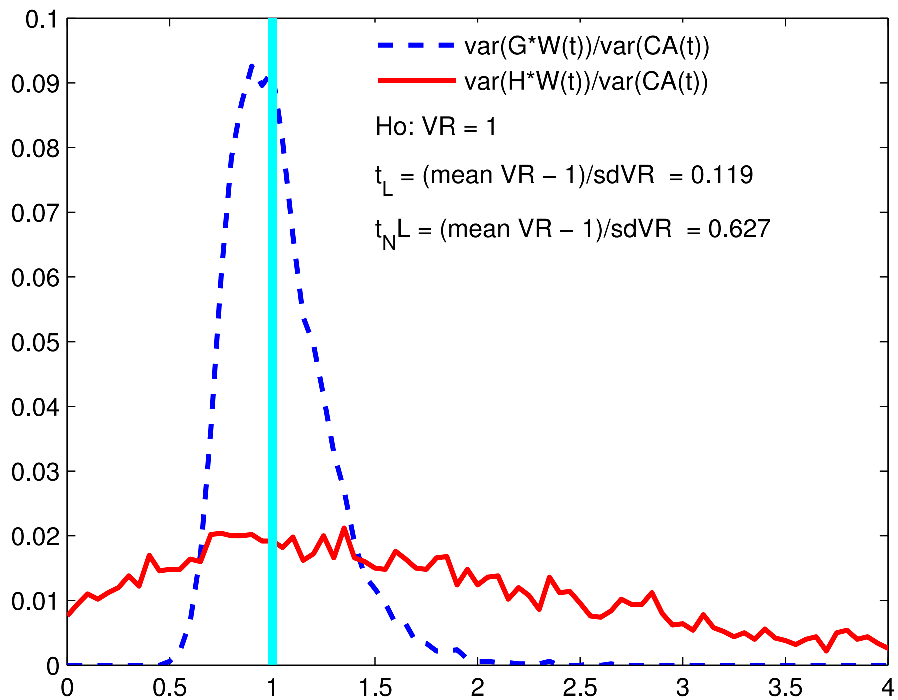
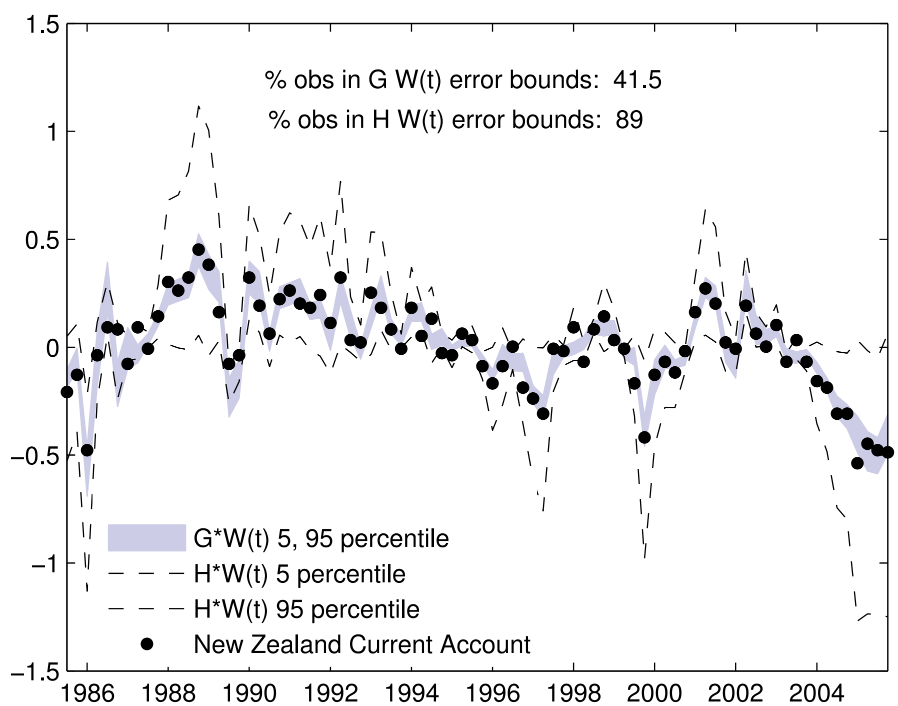


Figure 9: VAR2 In-sample Forecast Error bands



A Data

A.1 Empirical tests of the PVM

Data on GDP, consumption, investment and government spending are seasonally adjusted data in current prices from Statistics New Zealand. Investment includes a measure of the change in stocks. The investment income balance (rB) is from Statistics New Zealand's Balance of Payments accounts in current prices; the data do not exhibit seasonality. Nominal data are deflated by the GDP price deflator and divided by working age population which is seasonally adjusted. Our sample period is 1982Q2 to 2005Q2.

We use the GDP deflator for all series rather than Statistics New Zealand's individual price deflators to maintain ratios observed in the nominal data. This best matches the allocative decisions made by the representative agent in each period. Our series for investment is somewhat different from the individually deflated official Statistics New Zealand series for investment. The investment deflator includes quality adjustment and grows more slowly than the other deflators implying an upward trend in the investment/GDP ratio. This trend is subsequently removed in the regression of $NY + rB$ on consumption, yielding similar VAR, Wald, LM and variance ratio test results. On balance, the individually deflated data are closer to the PVM with a Wald statistic of 0.22 compared with 0.28 for the nominal data deflated by the GDP deflator for a 2-lag VAR. So, in terms of our test results, we report somewhat less support for the PVM than implied by a flatter deflator on investment.

A.2 Data for estimating a small open economy model

National accounts data used for model estimation are nominal and seasonally adjusted. We use the nominal ratios of investment, consumption and net government spending to GDP. The fourth data series used in the estimation process is a world interest rate. Given that the US has absorbed three-quarters of the world's savings in recent years, and that most US liabilities are denominated in US dollars, we use a US interest rate for the world cost of capital. While the model is at a quarterly frequency, we use the 2-year real interest rate to more accurately reflect the rate at which marginal borrowing decisions are being made. [15] The 90 day interest rate largely reflects monetary policy while the 2 year rate is much more strongly influenced by foreign interest rates.

[15] In practice agents do not repay their whole stock of debt each period.

B Log-linear Equations

B.1 Model Variables

Y_t	GDP	(quarterly, real, per capita)
C_t	consumption	(quarterly, real, per capita)
I_t	investment	(quarterly, real, per capita)
G_t	government spending	(quarterly, real, per capita)
B_t	bond holdings	(quarterly, real, per capita)
K_t	capital stock	(per capita)
N_t	hours (= 1-leisure)	(quarterly, per capita)
A_t	labour augmenting technology	index
r_t	domestic real interest rate	(quarterly per cent change)
q_t	world real interest rate	(quarterly per cent change)
s_t	external value index	index
Γ	stochastic discount factor	

B.2 Parameters

β	subjective discount rate
h	degree of habit formation in consumption
γ	coefficient of relative risk aversion/intertemporal substitution
ϕ	elasticity of substitution between consumption and labour
θ	elasticity of substitution between capital and labour in production
δ	rate of capital depreciation
σ	investment adjustment cost parameter
φ	risk premium parameter
α	steady state rate of technology growth
σ_a	std dev of technology shocks
g^*	steady state G/Y ratio
ρ_g	persistence of government spending shock
σ_g	std dev of govt spending shocks
q^*	steady state world real interest rate
ρ_q	persistence of world real interest rate shock
σ_q	std dev of world real interest rate shocks
s^*	steady state external value
ρ_s	persistence of valuation shock
σ_s	std dev of valuation shock

Notation

- $x_t \equiv X_t/A_t, \quad \text{for} \quad X_t \in \{Y_t,\, C_t,\, I_t,\, G_t,\, K_t,\, B_t\}$
- Steady state: $\bar{x}$
  Deviation from steady state: $\tilde{x}_t = x_t - \bar{x}$
- Log (percentage) deviation from steady state: $\hat{x}_t = \frac{x_t - \bar{x}_t}{\bar{x}_t}$

Log-linear equations

Production

$$\hat{y}_t = \theta \hat{k}_t + (1-\theta)\hat{N}_t \tag{31}$$

Law of Motion of Capital

$$(1+\alpha)(\hat{k}_{t+1} + \epsilon_{a,t+1}) = (1-\delta)\hat{k}_t + \left(\frac{\bar{i}}{\bar{k}}\right)^{1-\sigma} [(1-\sigma)\hat{i}_t + \sigma \hat{k}_t] \tag{32}$$

Intertemporal Budget Constraint

$$\begin{aligned} \bar{s}\bar{b}(1+\alpha)\hat{b}_{t+1} = \bar{s}\bar{b}[(1+\bar{r})\hat{b}_t + (\bar{r}-\alpha)\hat{s}_t + \tilde{r}_t - (1+\alpha)\epsilon_{a,t+1}] \\ + \bar{y}\hat{y}_t - \bar{c}\hat{c}_t - \bar{i}\hat{i}_t - \bar{g}\hat{g}_t \end{aligned} \tag{33}$$

Interest Rate

$$\tilde{r}_t = \tilde{q}_t - \varphi \frac{\bar{b}}{\bar{y}}(\hat{b}_t - \hat{y}_t) \tag{34}$$

Exogenous processes:

$$\begin{aligned} \Delta ln A_t &= \alpha + \epsilon_{a,t} \\ (\hat{g}_t - \hat{y}_t) &= \rho_g(\hat{g}_{t-1} - \hat{y}_{t-1}) + \epsilon_{g,t} && (35) \\ \tilde{q}_t &= \rho_q \tilde{q}_{t-1} + \epsilon_{q,t} && (36) \\ \hat{s}_t &= \rho_s \hat{s}_{t-1} + \epsilon_{s,t} && (37) \end{aligned}$$

Stochastic Discount Factor:

$$\begin{aligned} \hat{\Gamma}_{t+1} =& (\phi(1-\gamma)-1)\frac{1+\alpha}{1+\alpha-h}[\hat{c}_{t+1} + \epsilon_{a,t+1} - \hat{c}_t - h(1-\alpha)\epsilon_{a,t}] \\ &+ (1-\phi)(1-\gamma)\frac{\bar{N}}{1-\bar{N}}(\hat{N}_t - \hat{N}_{t+1}) \end{aligned} \tag{38}$$

Optimality Conditions:

$$\frac{\hat{c}_t + h(1-\alpha)\epsilon_{a,t}}{1-h(1-\alpha)} = \hat{y}_t - \frac{\hat{N}_t}{1-\bar{N}} + \frac{\varphi \bar{s}(\frac{\bar{b}}{\bar{y}})^2}{1+\varphi \bar{s}(\frac{\bar{b}}{\bar{y}})^2}(\hat{s}_t + 2\hat{b}_t - 2\hat{y}_t) \tag{39}$$

$$
\begin{aligned}
\sigma\left(\frac{\bar{i}}{\bar{k}}\right)^{\sigma}(\hat{i}_t-\hat{k}_t) = {} & E_t\left[\left(\frac{\bar{i}}{\bar{k}}\right)^{\sigma}\hat{\Gamma}_{t+1}\right] \\
& + E_t\left[\bar{\Gamma}-\theta(1+\sigma)\frac{\bar{y}}{\bar{k}}\left(1+\bar{s}\varphi\left(\frac{\bar{b}}{\bar{y}}\right)^2\right)\right] \\
& + E_t\left[\bar{\Gamma}\theta(1-\sigma)\frac{\bar{y}}{\bar{k}}\left(1-\bar{s}\varphi\left(\frac{\bar{b}}{\bar{y}}\right)^2\right)\hat{y}_{t+1}\right] \\
& + E_t\left[2\bar{\Gamma}\theta(1-\sigma)\frac{\bar{y}}{\bar{k}}\bar{s}\varphi\left(\frac{\bar{b}}{\bar{y}}\right)^2\hat{b}_{t+1}\right] \\
& + E_t\left[\bar{\Gamma}\sigma\left((1-\delta)\left(\frac{\bar{i}}{\bar{k}}\right)^{\sigma}+\left(\frac{\bar{i}}{\bar{k}}\right)\right)\hat{i}_{t+1}\right] \\
& + E_t\left[\bar{\Gamma}\theta(1-\sigma)\frac{\bar{y}}{\bar{k}}\bar{s}\varphi\left(\frac{\bar{b}}{\bar{y}}\right)^2\hat{s}_{t+1}\right]
\end{aligned} \tag{40}
$$

$$
0 = E_t\left[(\hat{\Gamma}_{t+1}+\hat{s_{t+1}}-\hat{s}_t)+\bar{\Gamma}\tilde{r}_{t+1}-\varphi\bar{\Gamma}\frac{\bar{b}}{\bar{y}}(\hat{b}_{t+1}-\hat{y}_{t+1})\right] \tag{41}
$$

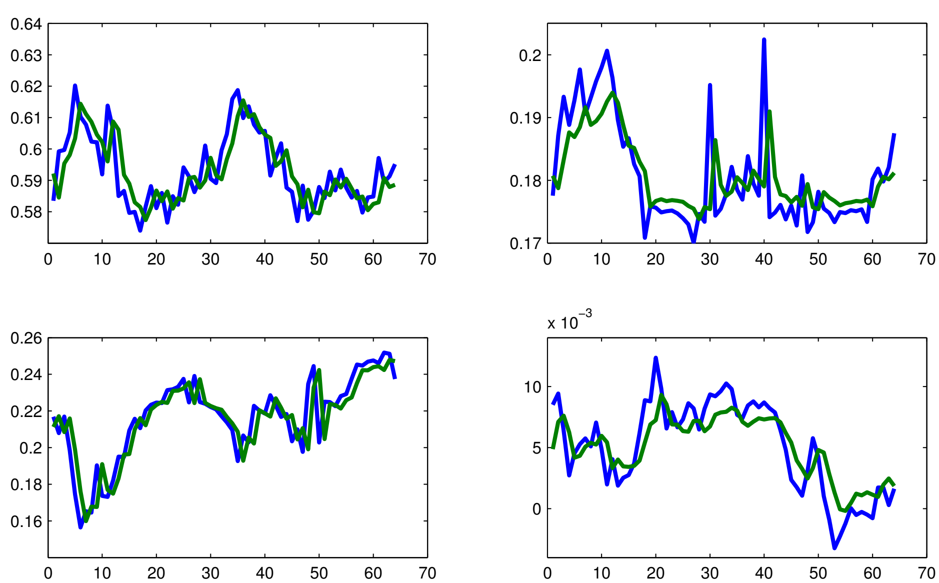
C Model estimation

The model is estimated on New Zealand data over the period 1990q1-2005q4 using Bayesian techniques. Four observable data series are required to identify the four shocks, and as mentioned above, we use the ratios of government spending ($Govt$) to GDP, consumption ($Cons$) to GDP, investment (Inv) to GDP, and a foreign real interest rate(FRR. Measurement errors, ξ_t^i, are included in these equations to aid estimation, which is achieved by maximum likelihood using the Kalman filter.

$$
\begin{aligned}
\frac{Cons_t}{GDP_t} &= \frac{\bar{c}}{\bar{y}}(1+\hat{c}_t-\hat{y}_t)+\xi_t^1 \\
\frac{Inv_t}{GDP_t} &= \frac{\bar{i}}{\bar{y}}(1+\hat{i}_t-\hat{y}_t)+\xi_t^2 \\
\frac{Govt_t}{GDP_t} &= \frac{\bar{g}}{\bar{y}}(1+\hat{g}_t-\hat{y}_t)+\xi_t^3 \\
FRR_t &= \bar{q}(1+\hat{q}_t)+\xi_t^4
\end{aligned}
$$

The data and fit of the measurement equations is shown in Figure C. Convergence of the parameters to the estimated posterior modes is shown in figure **??**. Most parameters are pinned down with some precision – the exception being the s^*, the mean of s_t, which sits on top of the prior, but conceptually the mean of this variable needs to be unity. Further investigation of this issue together with formal convergence diagnostics on the chain are necessary.

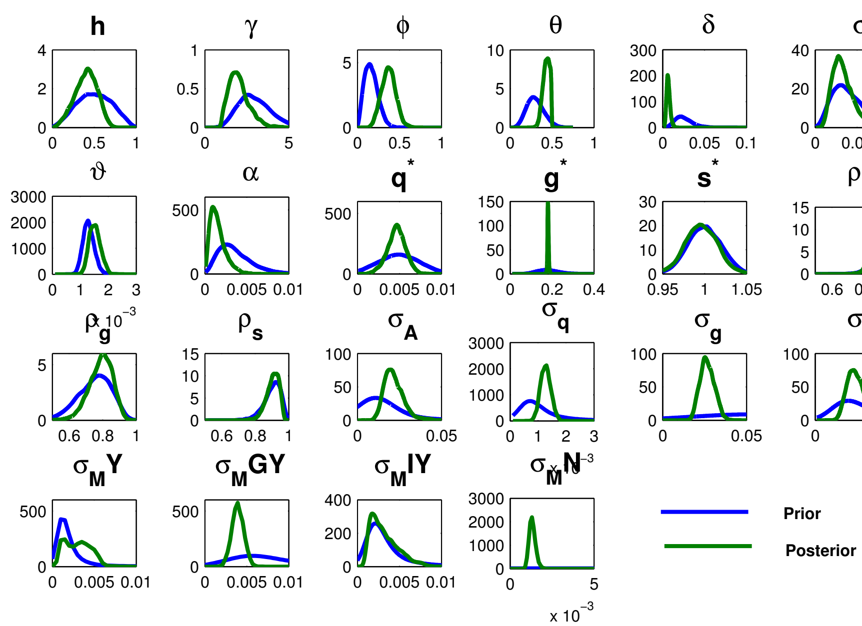
Figure 10: Estimation Data and Model Fit



Prior means for parameters are chosen either to be consistent with the RBC literature, or to match properties of the New Zealand data, and standard deviations are chosen to generate reasonably comprehensive coverage intervals. Parameters are drawn from the beta distribution (those that are theoretically bounded on the (0, 1) interval), the gamma and normal distributions (endogenous parameters), or inverse gamma distribution (exogenous shocks). 10,000 draws are taken from the prior distributions. 50,000 draws are used to generate the posterior distributions, but only the last 10,000 are used for performing the experiments detailed in the main body of the note.

The prior and posterior distributions of the parameters are shown in Figure C and Table 9.

Figure 11: Prior and Posterior Parameter Distributions



In the present value model the subjective rate of time preference is assumed to be equal to $1/(1+q*)$ (consistent with efficient markets), where q* is the steady state foreign real interest rate. At the mode of the posterior distribution, β is estimated at 0.99 so that $\beta < 1/(1+q*)$. Nason and Rogers call this the "impatient" small open economy case. A value of β near $1/(1+q*)$ gives a steady state debt/GDP ratio of about 30 per cent of GDP, much smaller than the observed 80 per cent of GDP. The wedge between the associated rates of time preference is about 200 basis points on an annual basis. This could be interpreted as "impatience" or as the wedge between the wholesale and retail interest rates.

The data were informative about all parameters except the mean of the valuation shock which is not of major concern as it is, by construction, near unity. The parameters that moved significantly from our priors are γ, θ, δ, α, σ_a, σ_q and σ_g.

For the full model, the mean posterior value of h is 0.46. This implies a modest degree of habit in consumption: about 98 per cent of consumption utility is derived from the level of consumption (the change in consumption is much smaller than the level). The estimated value is small compared to

Table 9: Prior and posterior parameter distributions

	Prior				Posterior			
	mean	std	90% confidence int.		mean	std	90% confidence int.	
β	0.99	0	[– ,	–]	0.99	0	[– ,	–]
h	0.5	0.2	[0.23 ,	0.78]	0.46	0.14	[0.24 ,	0.58]
γ	3	1	[1.8 ,	4.3]	**1.6**	**0.5**	[**1.3** ,	**2.6**]
ϕ	0.33	0.08	[0.07 ,	0.27]	0.35	0.09	[0.26 ,	0.46]
θ	0.3	0.1	[0.18 ,	0.44]	**0.46**	**0.07**	[**0.38** ,	**0.48**]
δ	0.025	0.01	[0.013 ,	0.038]	**0.006**	**0.002**	[**0.004** ,	**0.009**]
σ	0.04	0.02	[0.017 ,	0.067]	0.025	0.011	[0.019 ,	0.051]
φ	0.0013	0.0002	[0.0010 ,	0.0016]	0.0015	0.0002	[0.0013 ,	0.0018]
α	0.0036	0.002	[0.0014 ,	0.0062]	**0.0011**	**0.0007**	[**0.0006** ,	**0.0024**]
q^*	0.005	0.0025	[0.0018 ,	0.0082]	0.0048	0.0010	[0.0033 ,	0.0059]
g^*	0.18	0.05	[0.12 ,	0.25]	0.18	0.00	[0.18 ,	0.18]
s^*	1	0.02	[0.97 ,	1.03]	1.00	0.02	[0.97 ,	1.03]
ρ_q	0.9	0.05	[0.83 ,	0.96]	0.86	0.03	[0.81 ,	0.90]
ρ_g	0.75	0.1	[0.62 ,	0.87]	0.80	0.07	[0.71 ,	0.88]
ρ_s	0.9	0.05	[0.83 ,	0.96]	0.90	0.04	[0.85 ,	0.95]
σ_a	0.009	2	[0.006 ,	0.028]	**0.019**	**0.005**	[**0.016** ,	**0.028**]
σ_q	0.0018	2	[0.0012 ,	0.0053]	**0.0013**	**0.0002**	[**0.0011** ,	**0.0016**]
σ_g	0.05	2	[0.03 ,	0.15]	**0.02**	**0.00**	[**0.02** ,	**0.03**]
σ_s	0.02	2	[0.0132 ,	0.0614]	0.0220	0.0053	[0.0174 ,	0.0326]

Figures in bold indicate that the posterior is significantly different from the prior as measured by a t-type statistic: [mean(posterior) - mean(prior)]/std(posterior).

estimates by Liu (2005) and **?** of about 0.95 for Gali-Monacelli type models which have a richer trade side, but no capital stock.

The mean posterior value of the inter-temporal substitution coefficient γ is 1.6 which is significantly smaller than our prior of mean of 3. As $\gamma \rightarrow 1$, the utility function approaches log utility:

$$U(C, 1-N) = \phi ln(C_t - hC_{t-1}) + (1-\phi) ln(1-N_t)$$

The relatively small value of γ implies that fluctuations in consumption and labour have only a small effect on inter-temporal incentives.

The mean of θ, the capital share, is high at 0.46. The depreciation rate, δ, is estimated to be substantially lower (depreciation rate of 2.4 per cent per annum) than our prior (10 per cent per annum). The steady state growth rate of technology α is 0.4 per cent per annum compared to the prior of 1.4 per cent per annum.

The estimated variance of the technology shocks is much higher than out prior and the variances of world cost of capital shocks and fiscal shocks are lower.

Posterior Steady State At the mode of the joint distribution of posterior parameter estimates, private consumption is 62 per cent of GDP, business and government investment 18 per cent and government consumption 20 per cent (about the same as those observed). The bond/annual GDP ratio is

-60% of GDP compared to the 73 per cent net foreign debt/GDP and 88 per cent net IIP/GDP liability observed. As discussed above, to shift the steady state values toward the observed level of debt, a wedge of about 200 basis points (annual) was required (in addition to the risk premium) between the efficient markets discount rate $1/(1+q^*)$ and the discount rate in the model. Such a wedge has little effect on the cross equation restriction. Nason and Rogers (2006) refer to the $\beta < 1/(1+q)$ case as an "impatient" small open economy. However, the 200 basis points may in part reflect the difference between the wholesale world real interest rate used and the retail nature of some of the representative agent's decisions (e.g. consumption). At the posterior mode, the steady state world real interest rate is about 1.8 per cent per annum, the risk premium is about 149 basis points (annual) and the domestic real interest rate is about 3.3 per cent per annum and the rate of time preference is 4.1 per cent per annum. The investment income deficit, rB, is 2.0 per cent of GDP, net exports are 1.7 per cent of GDP and the steady state current account deficit is 0.3 per cent of GDP. The observed investment income and current account deficits are about 4 per cent larger mainly due to high observed rates of return on foreign equity investment in New Zealand, an effect not modeled here. At the mode of the posterior, the steady state labour input is 0.48, which is high compared to the share of time devoted to market activities generally thought to be about one third. This may reflect New Zealand's high labour input compared to the OECD average, a feature that has not eased with income growth, and continued rise in partiipation rates.

Table 10: Cross Correlation of Posterior Parameter Distribution

	β	h	γ	ϕ	θ	δ	σ	φ	α
β	1								
h	0	1							
γ	0	-0.36	1						
ϕ	0	0.07	-0.25	1					
θ	0	0.05	-0.07	-0.06	1				
δ	0	0.05	-0.35	-0.12	-0.34	1			
σ	0	-0.32	0.09	0.03	0.06	-0.07	1		
φ	0	0.00	0.19	0.01	-0.10	-0.08	-0.14	1	
α	0	-0.06	-0.21	0.08	0.07	-0.08	-0.06	-0.04	1
q^*	0	-0.18	-0.04	-0.10	0.21	0.27	0.07	-0.04	0.05
g^*	0	0.08	-0.02	0.07	0.01	0.01	-0.05	0.19	-0.06
q^*	0	-0.02	0.00	0.03	0.04	-0.04	0.03	-0.04	0.07
ρ_q	0	0.27	0.03	0.11	0.02	-0.17	-0.01	0.02	-0.02
ρ_g	0	0.02	0.05	-0.16	-0.01	0.00	-0.13	-0.21	0.08
ρ_s	0	0.01	0.18	0.03	0.04	-0.09	0.10	0.04	-0.01

	q^*	g^*	q^*	ρ_q	ρ_g	ρ_s
q^*	1					
g^*	-0.07	1				
q^*	-0.03	0.08	1			
ρ_q	-0.14	0.02	0.19	1		
ρ_g	-0.08	-0.14	-0.16	-0.04	1	
ρ_s	-0.04	0.17	0.26	0.25	0.04	1

Table 11: Cross Correlation of Posterior Parameters and Std Deviations of Shocks

	Shock Standard Deviations			
	Technology	WCC	Fiscal	Valuation
β	0.00	0.00	0.00	0.00
h	-0.01	-0.22	0.16	0.27
γ	0.26	-0.10	-0.07	0.31
ϕ	-0.17	-0.04	0.29	0.32
θ	-0.41	0.08	-0.08	0.02
δ	-0.07	0.18	-0.02	-0.32
σ	0.59	0.25	-0.06	0.06
φ	0.07	-0.04	0.11	0.10
α	-0.26	0.06	-0.10	-0.04
q^*	-0.13	0.15	-0.05	-0.05
g^*	0.00	0.07	-0.07	0.12
q^*	-0.06	-0.06	0.22	0.16
ρ_q	0.11	-0.48	0.15	0.35
ρ_g	-0.05	0.02	-0.41	0.00
ρ_s	0.08	-0.09	0.16	0.22

Table 12: Cross Correlation of Posterior Shock Std Deviations

	Correlation of Shock Std Deviations			
	Technology	WCC	Fiscal	Valuation
Technology	1			
WCC	- 0.01	1		
Fiscal	0.01	- 0.16	1	
Valuation	0.10	- 0.11	0.18	1

Figure 12: Estimated Historical Shocks

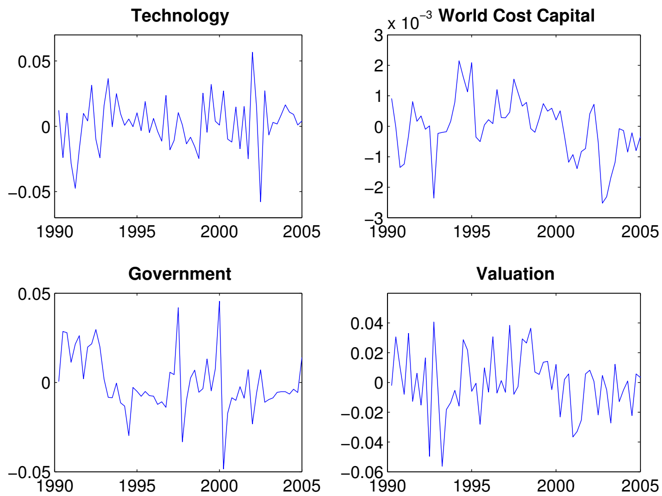


Figure 13: Historical Decomposition

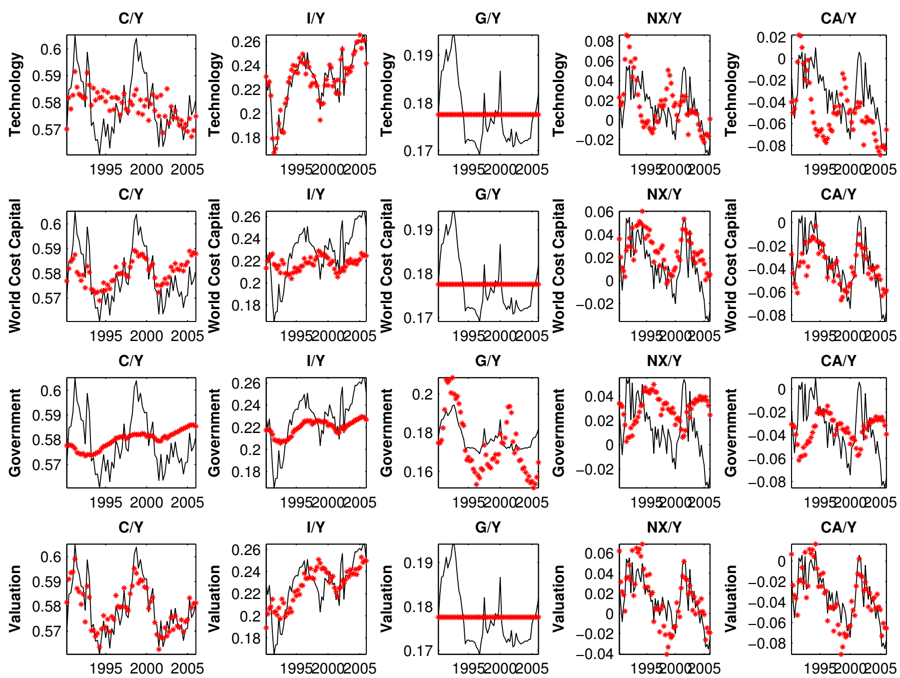


Figure 14: Response to a 1% permanent technology shock

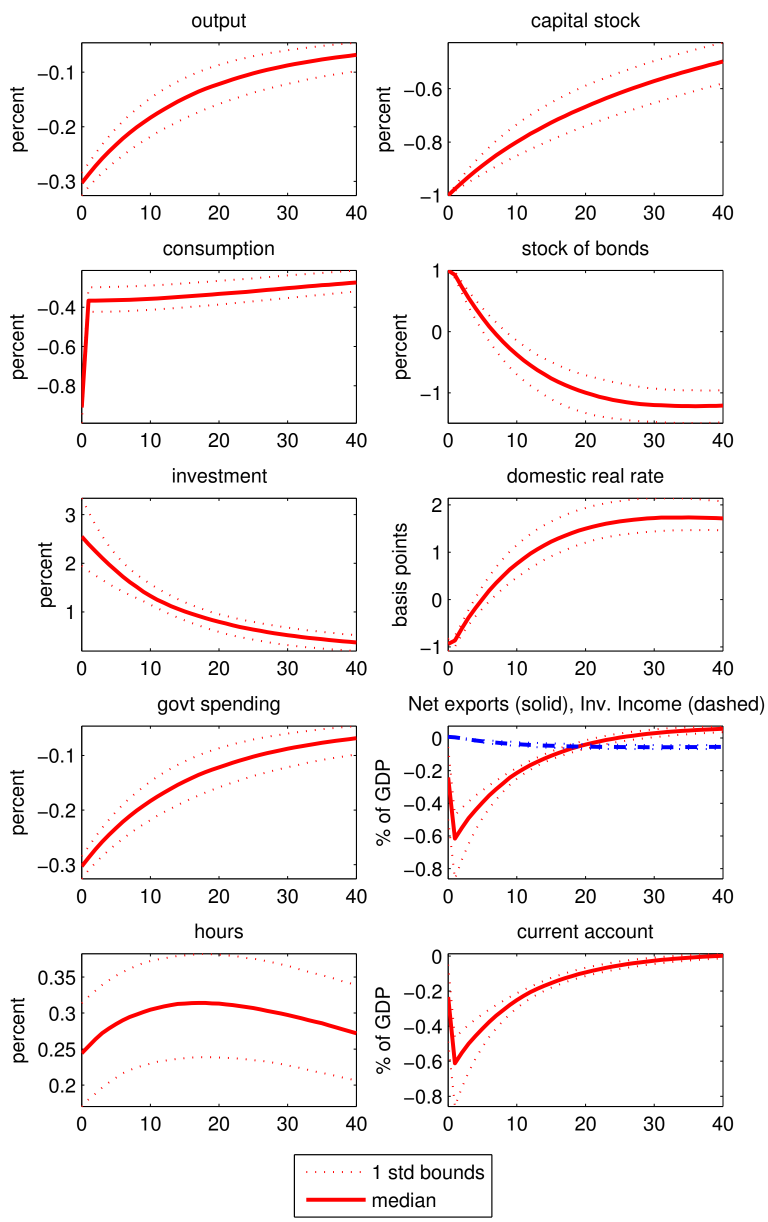


Figure 15: Response to a fiscal shock (1% of GDP)

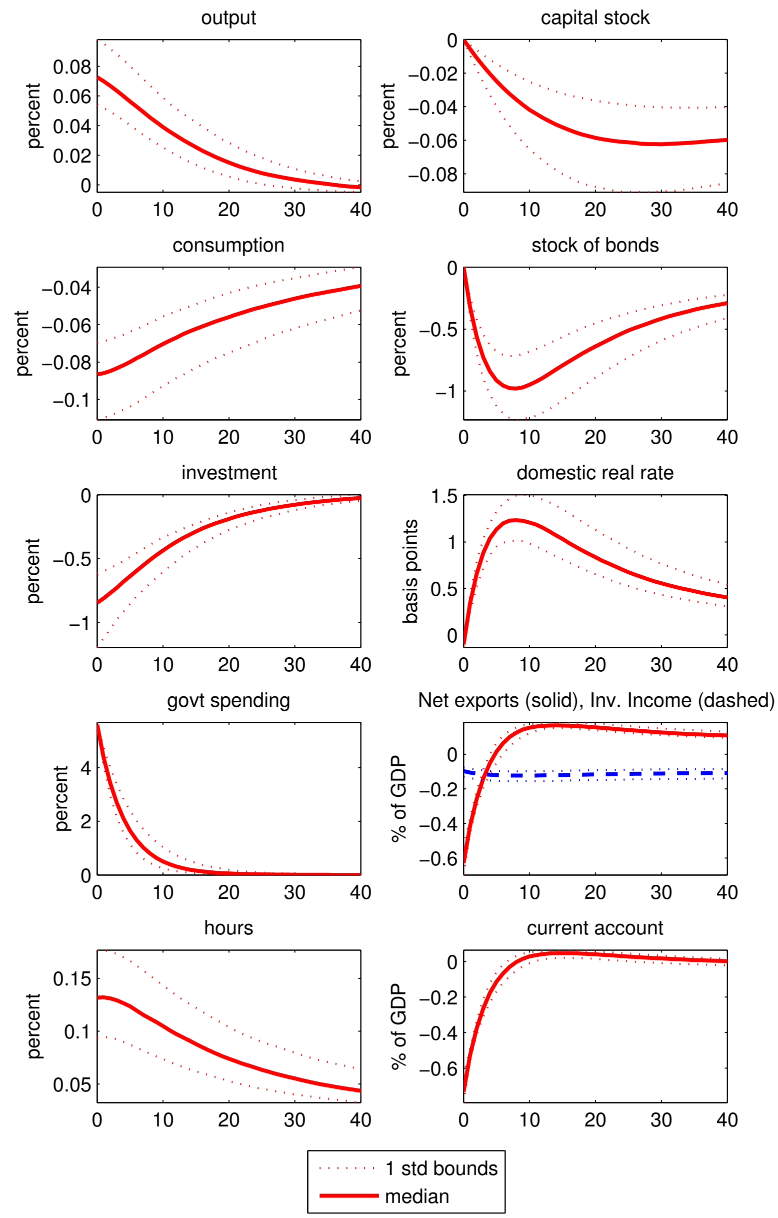


Figure 16: Response to a 100 basis point world cost of capital shock

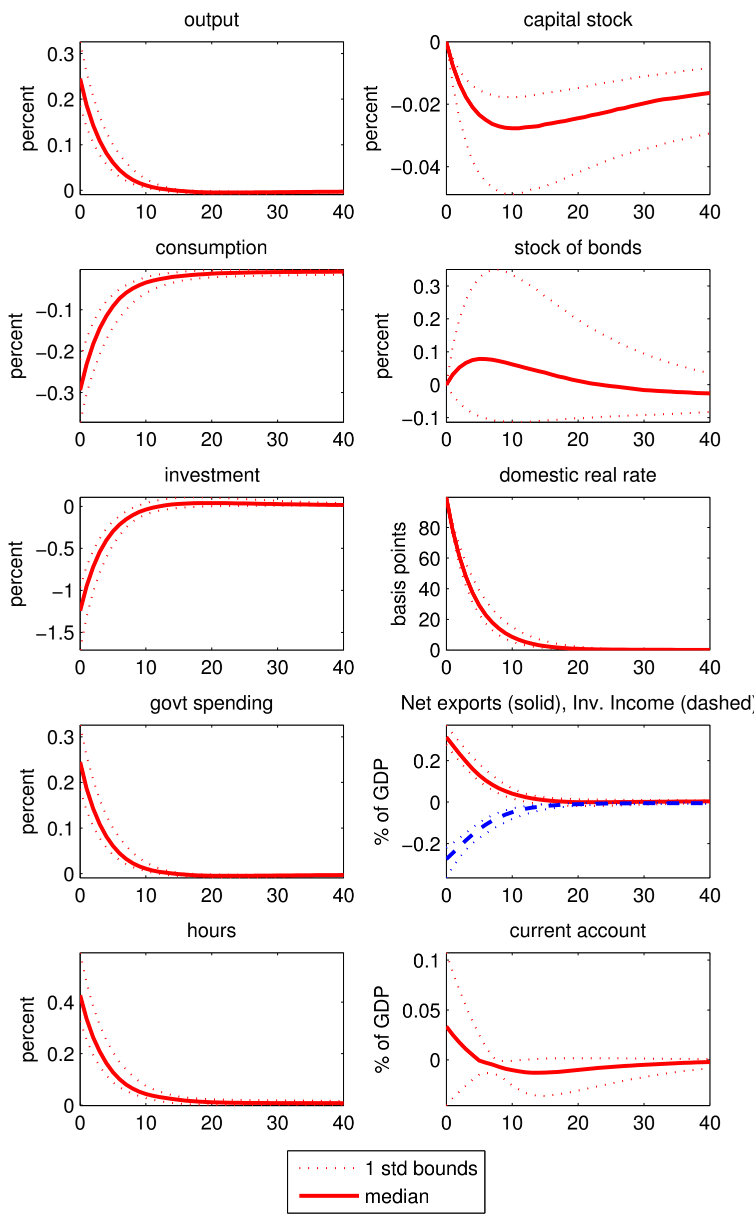
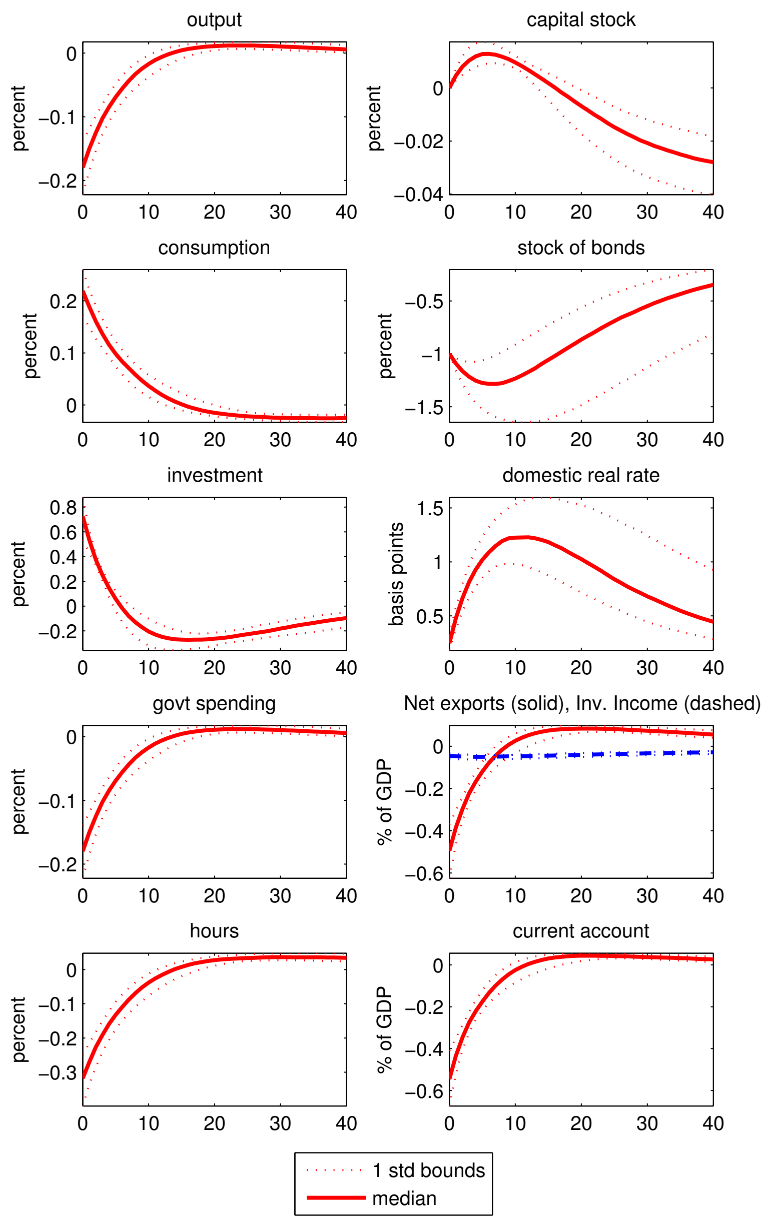


Figure 17: Response to an external valuation shock



D Monte Carlo Experiments

Figure 18: Full Model: Cross Equation Restriction

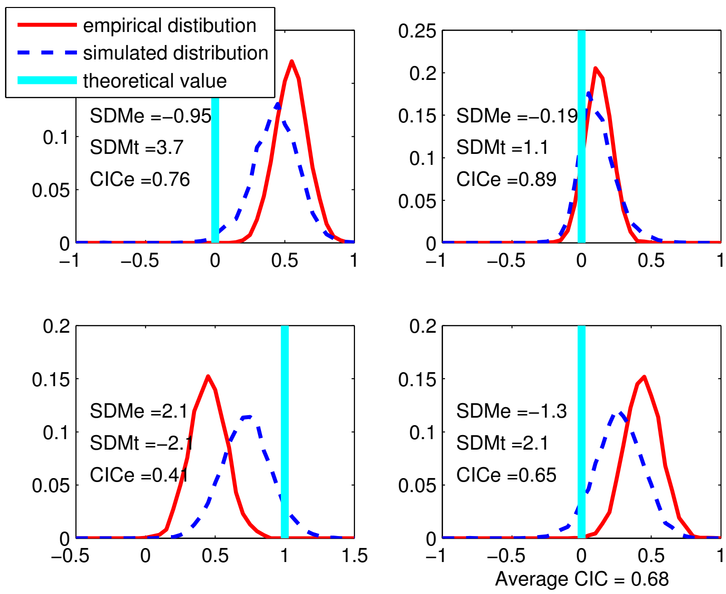


Figure 19: Full Model: Empirical and Simulated Error Bands

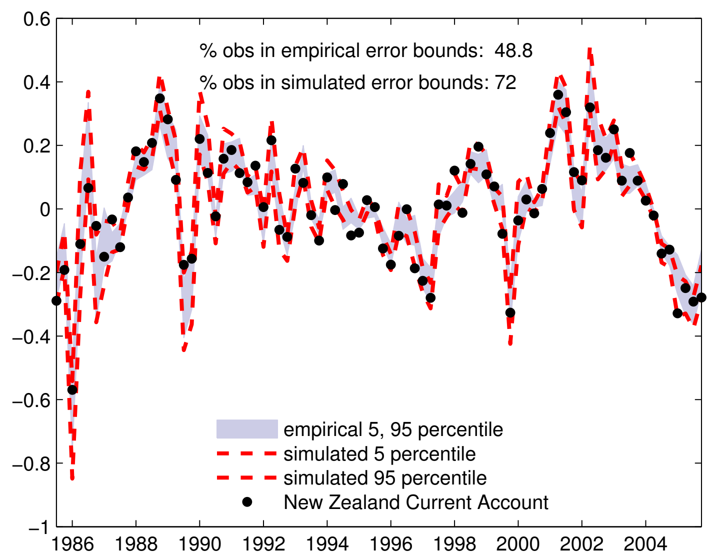


Figure 20: Cross Equation Restriction: No habit

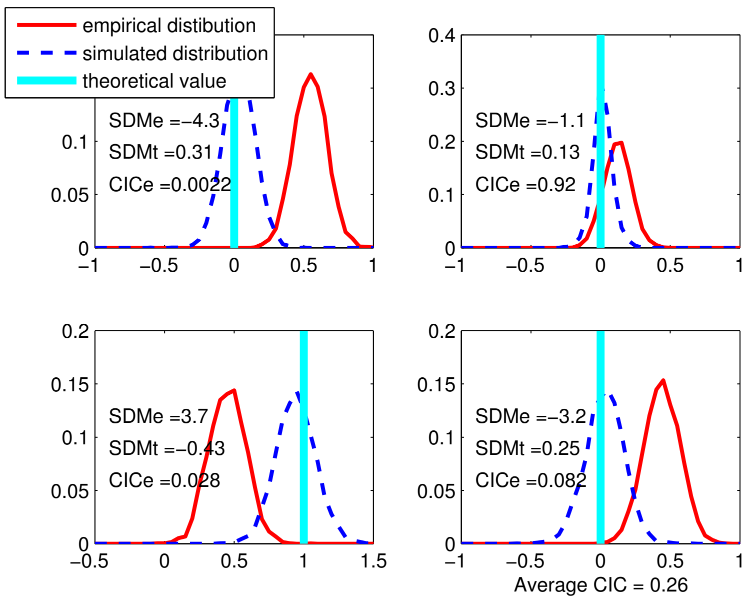


Figure 21: Empirical and Simulated Error Bands: No Habit

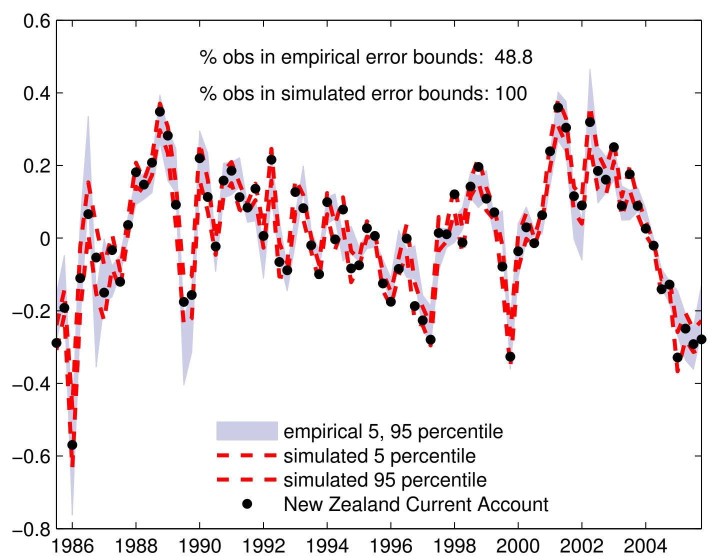


Figure 22: Cross Equation Restriction: Separable Preferences

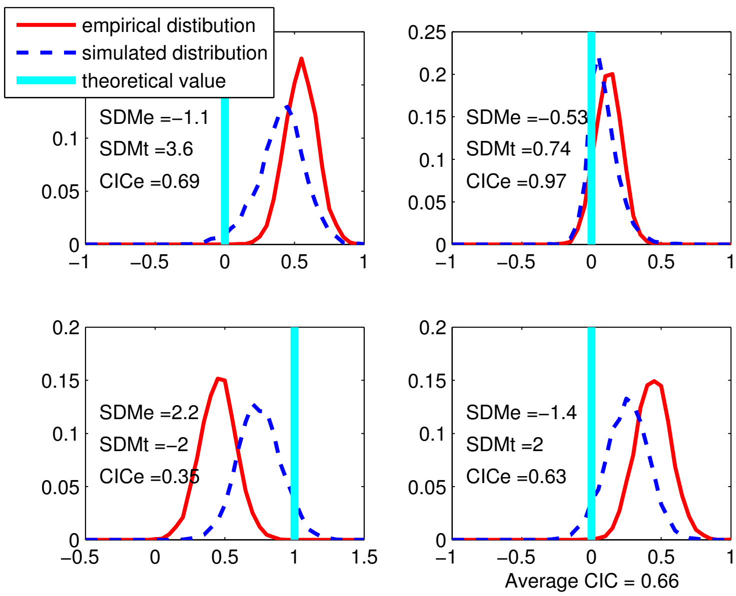


Figure 23: Empirical and Simulated Error Bands: Separable Preferences

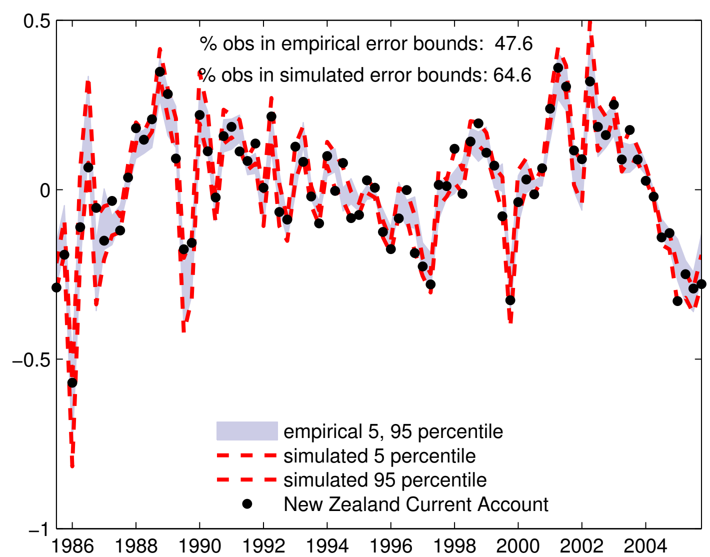


Figure 24: Cross Equation Restriction: (near) Perfect Capital Mobility (small φ)

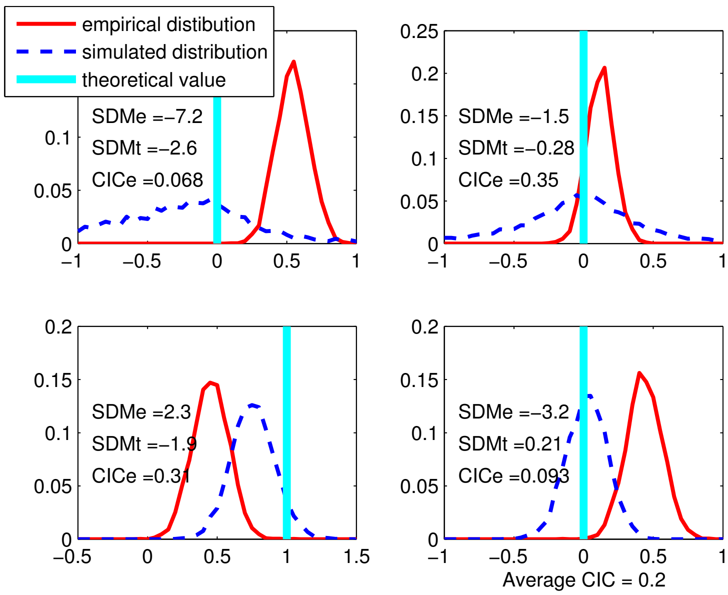


Figure 25: Empirical and Simulated Error Bands: (near) Perfect Capital Mobility (small φ)

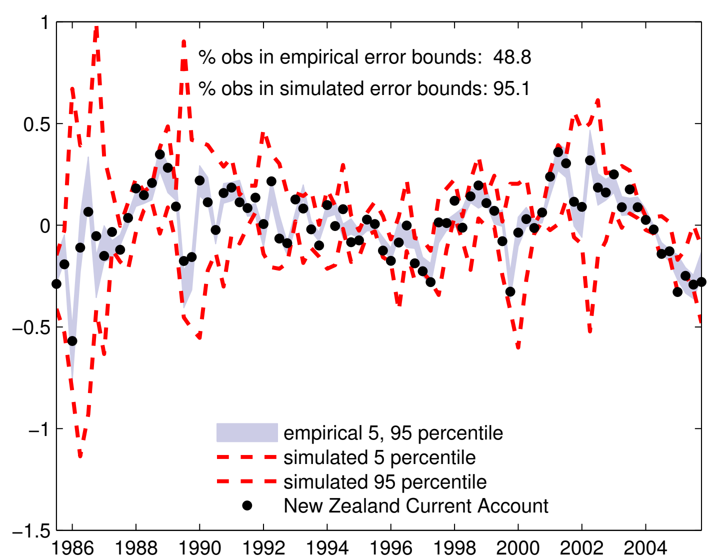


Figure 26: Cross Equation Restriction: No Technology Shock

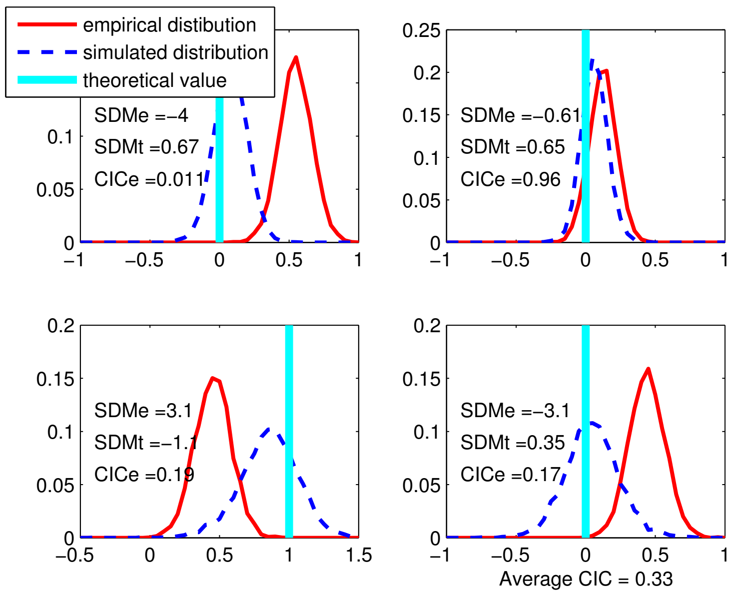


Figure 27: Empirical and Simulated Error Bands: No Technology Shock

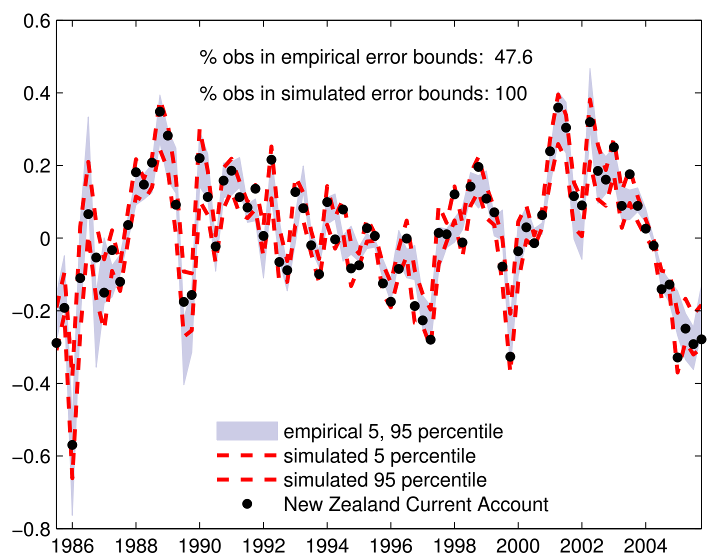


Figure 28: Cross Equation Restriction: No Fiscal Shock

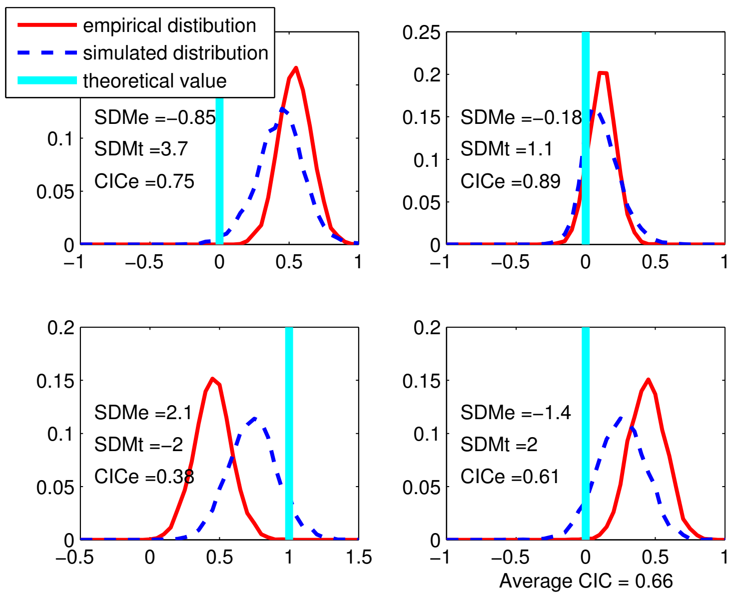


Figure 29: Empirical and Simulated Error Bands: No Fiscal Shock

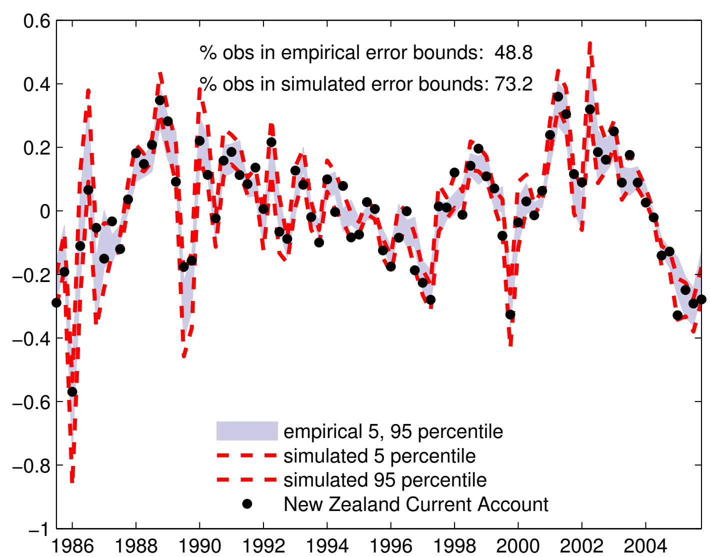


Figure 30: Cross Equation Restriction: No World Cost of Capital Shock

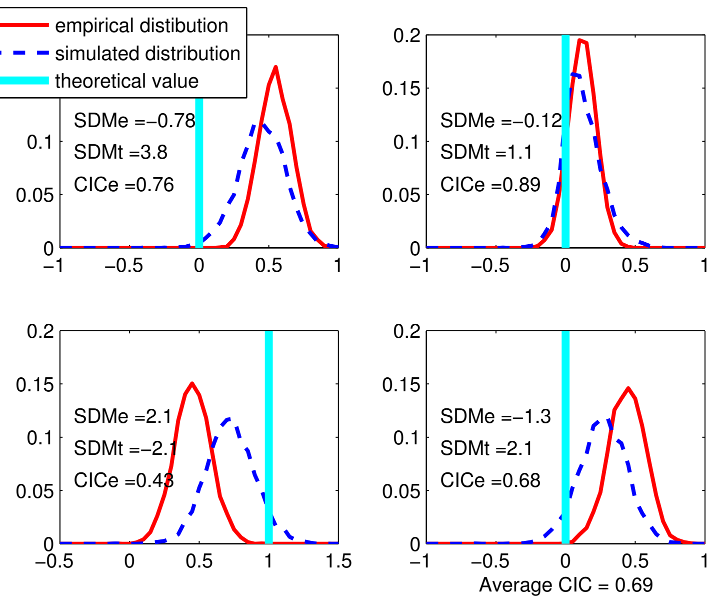


Figure 31: Empirical and Simulated Error Bands: No World Cost of Capital Shock

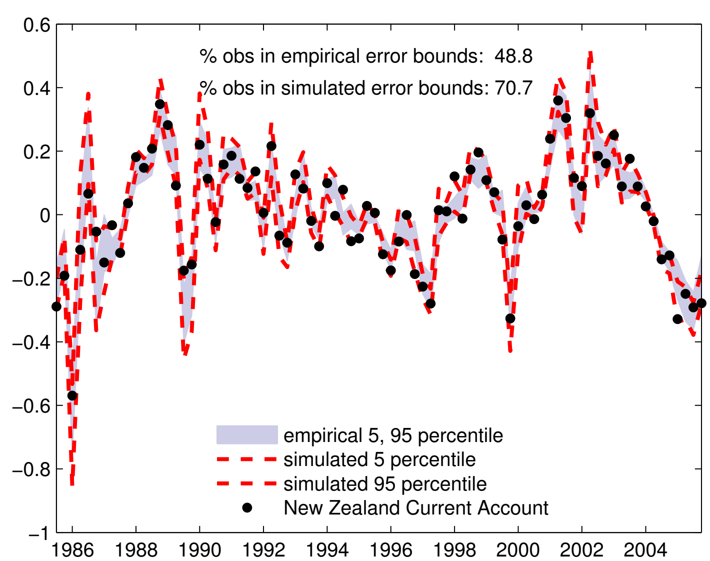


Figure 32: Cross Equation Restriction: No Ext. Valuation Shock

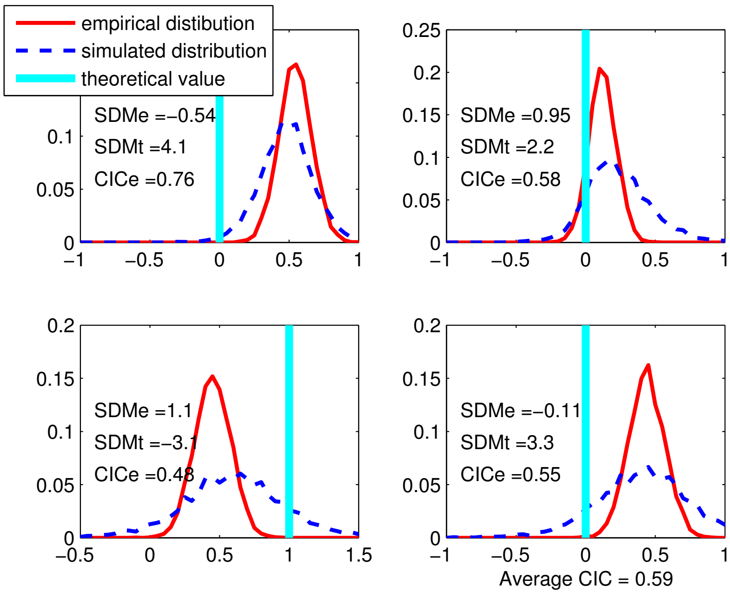


Figure 33: Empirical and Simulated Error Bands: No Ext. Valuation Shock