A structural VAR model of the New Zealand business cycle

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Abstract

This paper develops a new open economy structural VAR model of the New Zealand economy. The model adopts techniques introduced by Cushman and Zha (1997) and Dungey and Pagan (2000) to identify international and domestic shocks and dynamic responses to these shocks in a small open economy. The international variables are block exogenous and the model includes restrictions on contemporaneous and lagged variables. Novel features include the introduction of an expanded set of domestic financial variables not captured in previous New Zealand VAR models, the use of a forward looking Taylor Rule to identify monetary policy, and the introduction of a climate variable to capture the impact of climatic conditions on the business cycle. Key results to emerge are the significant influence of international variables on the New Zealand business cycle, the importance of separately identifying import price and export price shocks, and the significant influence of climate.

JEL CLASSIFICATION C22 Time series models; E32 Business fluctuations, cycles; E44 Financial markets and the macroeconomy; F41 Open economy macroeconomics

KEYWORDS Open economy; structural VAR models; business cycles; climate; commodity prices; international linkages; financial conditions.

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1 Introduction

Expansions and recessions in economic growth characterise all economies and have significant effects on employment, investment and economic welfare. During the past two decades New Zealand has experienced short-lived expansions and frequent recessions during the 1980s, a major recession from 1991 to 1993, and a long expansion during the 1990s that ended with the recession of 1998. There has been ongoing debate about the reasons for these expansions and recessions and attributed causes have ranged from the influence of international business cycles, overly aggressive monetary policy, volatile exchange rates, while the "Asian crisis" is a popular explanation for the 1998 recession.

The propagation impulse framework first introduced to economics by Frisch (1933) and Slutsky (1937) has come to dominate the analysis of expansions and recessions that characterise the evolution of economic growth. This approach, well illustrated by Blanchard and Watson's (1986) analysis of US business cycles, conceives of fluctuations in economic activity as arising from impulses (shocks) that affect the economy through a complex dynamic propagation process. Therefore identification of shocks that precipitate expansions and recessions in economic growth, or business cycles, represents a major conceptual and statistical challenge. This complexity means that debates concerning the causes of booms and recessions and the contribution of macroeconomic policy are often not satisfactorily resolved.

The purpose of this paper is to develop a statistical model capable of identifying the major shocks to the New Zealand economy during the last two decades, to understand the dynamic response of the economy to these shocks and to measure their contribution to New Zealand expansions and recessions in economic growth. The model is a structural vector autoregressive (VAR) model of the New Zealand economy. Since its introduction by Sims (1980), VAR modelling has become a standard empirical method for evaluating the properties of macroeconomic systems and for tackling the challenges that have been set for this paper. This is illustrated for example in Blanchard's (2000) recent review of the historical developments in theoretical and empirical macroeconomic modelling.

There are important geographical and industrial characteristics that must be captured in a VAR model of the New Zealand economy if that model is to be capable of identifying the major shocks and their propagation dynamics. These characteristics justify a more ambitious attempt to capture international trade and financial linkages than have been attempted in previous New Zealand models. New Zealand's industrial structure is important in the way it influences the commodity structure of imported and exported goods. The industrial structure, with a relatively heavy weighting toward agricultural based production, combined with its geographical location and characteristics, justify attempting to capture the consequences of climatic conditions on the evolution of New Zealand's real output growth and other macroeconomic variables.

Satisfactorily capturing these open economy and industrial features, while simultaneously understanding the way international and domestic sourced shocks impact on key New Zealand macroeconomic variables, poses several major modelling challenges. The choice of variables to include in the model has been informed by New Zealand's characteristics and prior research. The model presented here has 13 variables, a large number for a VAR model. This is the largest structural VAR model of the New Zealand economy estimated to date.

There have been several important developments in model specification and estimation procedures that we have been able to draw on to estimate such a large VAR model. Included in these techniques are the block exogeneity procedures introduced by Cushman and Zha (1997) and Dungey and Pagan (2000) to identify international and domestic shocks and dynamic responses to these shocks in a small open economy. We have expanded on the number of international variables that have previously been included in New Zealand VAR models. These international variables are block exogenous and the model includes restrictions on contemporaneous and lagged variables. Given the interest in the relative importance of domestic interest rates and the exchange rate in generating expansions and recessions, the model includes a wider range of domestic financial variables than in previous models. Another novel contribution of this model is the inclusion and identification of the relative importance of domestic climatic conditions in generating business cycle fluctuations.

The model is used to identify the impact of foreign and domestic shocks on New Zealand macroeconomic variables including real GDP and prices, and to uncover the propagation process. Key conclusions to emerge from these model simulations include the following. International variables have been the dominant influences on fluctuations in New Zealand real GDP around its trend. Fluctuations in domestic climatic conditions have also been important, particularly in specific periods such as the 1998 recession.

In contrast to the attention they receive in public debate, shocks from the domestic exchange rate have been relatively unimportant. While the impact of monetary policy also features in public debate, this is treated in a companion paper (Buckle, Kim and McLellan, 2003). The interest rate shocks examined in this paper combine the effects of monetary policy and other influences on interest rates. Separation of these effects is essential before an evaluation of monetary policy is appropriate.

The remainder of the paper is structured as follows. Section 2 discusses in more depth the modelling procedure and the econometric issues involved in specifying the model and the restrictions required to identify the range of shocks that are of interest. The overall structure of the model and motivation for specific equation restrictions are discussed in Section 3. The next two sections discuss applications. The first set of applications discussed in Section 4 includes the simulation of international financial and trade shocks, domestic financial shocks and climate shocks. These are presented in the form of response multipliers or impulse response functions. The second set of applications includes historical decompositions (or accounting) of the contributions of these shocks toward booms and recessions in New Zealand's real GDP. These results are reported in Section 5. Section 6 summarises key conclusions and discusses potential applications of the model.

2 Modelling approach

2.1 Scope of the structural VAR model

The minimum set of variables to include in the structural VAR model is governed by the aim of determining the main shocks to impact on New Zealand real GDP, domestic demand, exports and prices. The choice of variables is also influenced by insights from prior research. No model can include all principal interactions in the New Zealand economy. Even the relatively large models developed by Szeto (2002) and by Black, Cassino, Drew, Hanson, Hunt, Rose and Scott (1997) omit some variables. Nevertheless, to achieve the objectives set for this paper, for a small open economy like New Zealand the relevant set of variables should include measures of the following foreign and domestic variables.

The foreign variables should include measures of foreign real output, foreign nominal interest rates and foreign real asset returns. The differing commodity make-up of New Zealand exports and imports suggests the separate inclusion of the foreign currency prices of New Zealand exports and imports, rather than the portmanteau terms of trade variable. The reason is that fluctuations in the terms of trade arise from changes in either the prices of exports or the prices of imports and their impact on the domestic economy can differ.

The domestic variables should include measures of real exports, real aggregate domestic demand, real domestic aggregate output, domestic consumer prices, a monetary policy instrument, the nominal exchange rate and domestic real asset returns. The relative importance of agricultural production in New Zealand, its sensitivity to climatic conditions and the sensitivity of production in several other industries to climatic conditions, such as primary food manufacturing and electricity generation, suggest that a measure of climatic conditions should also be included.

The basic model therefore includes 13 variables. Each variable is explained by a structural equation that has an error term associated with it. The error term for each equation is interpreted as representing a particular innovation or shock. These shocks are labelled according to the structural equation from which they derive. For example, the error term derived from the equation for export prices is given a name such as ‘export price shock’. Appropriate specification and estimation of the system of 13 equations captures the systematic effect of export prices and other relevant variables in the model on the behaviour of the domestic variables such as real exports, real domestic demand and output. The full system of equations can be used to simulate the reaction of endogenous variables such as real exports, real domestic demand and output in response to ‘export price shocks’. The system can also be used to decompose and account for past influences on macroeconomic fluctuations and the business cycle, including the influence of fiscal and monetary policy.

For simulations and for historical decompositions to have meaningful interpretations, the ability to identify the relative size and dynamic impact of shocks, such as an export price shock, depends on the variables included in the model and on the restrictions placed on each structural equation. For example, the inclusion of a variable to capture climatic conditions will facilitate the identification of the size and dynamic impact of climate shocks. If climatic conditions prove to be a significant explanation for deviations of real GDP from trend, we could infer from this result that models for New Zealand real GDP that do not account for the influence of climate would at best incorporate its effect in the error term for real GDP and perhaps the error terms for other variables and could therefore easily result in misinterpretation of the explanation for these errors or shocks.

Although 13 variables is a relatively large number to include in a structural VAR model, with the specific variables included in this model sufficient to identify particular trade, financial and climatic shocks, it is not sufficient to analyse influences that are not identifiable from the shocks that have been distinguished. It would not be appropriate, for example, to use shocks identified from the structure of this model to attempt to identify the impact of fiscal policy initiatives such as the "Think Big" capital expenditure programme of the early 1980s, the benefit reforms of the early 1990s, or the income tax changes introduced in 2000. In this model, the consequences of these fiscal policy initiatives are likely to be subsumed into the aggregate domestic demand variable and perhaps also into the aggregate domestic supply variable if they involve changes in the economy's productive infrastructure.

One of the reasons for developing a structural VAR model to evaluate the impact of trade, financial and climate shocks is to provide a basis for eventually developing a richer model that will enable the identification and the simulation of the impact of monetary policy and fiscal policy initiatives on the domestic macroeconomy. An evaluation of the impact of monetary policy on the business cycle requires appropriate separation of monetary policy influences from all the endogenous variables in the model. This procedure and results are presented in Buckle, Kim, and McLellan (2003).

The application of the model for fiscal policy analysis has been deferred until more appropriate time series data for government transactions that separately identify revenue and expenditure flows are available. Theory and international empirical research (see for instance Blanchard and Perotti, 1999) would suggest this separation is important both for identifying discretionary fiscal policy and for understanding its dynamic impact. We considered using the net cash flow from operations variable (NCFO) derived in Buckle, Kim and Tam (2001) in their evaluation of the sources of shocks to the government budget balance. However, the NCFO variable is a net cash flow variable and, while suitable for evaluating the impact of non-fiscal shocks on the governments net cash transactions from operations, the expenditure component of that series does not include government capital expenditure.

The focus of this paper is the identification of shocks that push the New Zealand economy temporarily away from its long-run growth path. In other words, in line with the structural VAR models of Sims (1980), Bernanke and Blinder (1992) and Dungey and Pagan (2000), departures from trend are viewed as transient. This approach means the dynamics generated by each shock are directly comparable with the dynamics arising from temporary shocks simulated by the two operational calibrated New Zealand economy-wide models (Szeto, 2002; Black, Cassino, Drew, Hanson, Hunt, Rose and Scott, 1997). These models conceive of variables growing along a steady state growth path. These calibrated models are capable of changing the steady-state growth path. Although we view this as an important direction for future development, this is not a feature of the structural VAR model developed in this paper. The comparison with the calibrated models is therefore restricted to deviations around given long-run growth paths.

To make this approach operational we first detrend the variables in our structural VAR model. The appropriate choice of detrending procedure is not straightforward. A linear deterministic trend has been the preferred method for several recent Australian structural VAR models (Dungey and Pagan, 2000; Dungey and Fry, 2000; Fry, 2001; Joiner, 2002). This procedure is appropriate if the aim is to avoid removing the stochastic trend component from the growth cycle. A potential drawback of a linear trend is it can result in periods where the deviation from trend is large or is sustained for long periods of time if the underlying trend involves a significant change during the sample period. This is a feature of many of the time series included in our model. A linear trend applied to New Zealand real GDP, for example, over the sample period used to estimate this model results in historically very large output gaps during the 1980s.

The approach used in this paper is to detrend all variables using the Hodrick-Prescott filter (Hodrick and Prescott, 1997) with the exception of the climate variable, which has been detrended by removing the long run average for each quarter. These detrending procedures are consistent with the focus of the paper, which is to understand the dynamic impact of temporary shocks around a long-run growth path. Shocks may be persistent, but they are transient. The model could nevertheless be extended in the future to capture the stochastic trend component by modelling the quarterly growth rates and applying an error correction procedure.

2.2 Structure and identification issues

VAR models are equivalent to a system of reduced form equations relating each endogenous variable to lagged endogenous (predetermined) and exogenous variables. Since the model contains 13 variables, there are several challenges in recovering robust estimates of the parameters in the structural form equations from the estimated parameters in the reduced form equations.

The approach used is to assume the economy is described by a structural form equation, ignoring constant terms, given by

$$B(L)y_t = u_t \qquad (1)$$

where $B(L)$ is an p^{th} order matrix polynomial in the lag operator L, such that $B(L) = B_0 - B_1L - B_2L^2 - .....B_pL^p$. B_0 is a non-singular matrix normalised to have ones on the diagonal and summarises the contemporaneous relationships between the variables in the model contained in the vector y_t. y_t is a n vector of variables and u_t is a n vector of mean zero serially uncorrelated structural disturbances. The variance of u_t is denoted by Λ. Λ is a diagonal matrix where diagonal elements are the variances of structural disturbances; therefore the structural disturbances are assumed to be mutually uncorrelated.

Associated with this structural model is the reduced form VAR which is estimated

$$A(L)y_t = \varepsilon_t \qquad (2)$$

where $A(L)$ is a matrix polynomial in the lag operator L; ε_t is a n vector of serially uncorrelated reduced form disturbances; and $\mathrm{var}(\varepsilon_t) = \Sigma$. The relationships between the components of equations (1) and (2) are as follows

$$A(L) = B_0^{-1}B(L) = I - A_1L - A_2L^2 - .....A_pL^p \qquad (3)$$

and

$$\varepsilon_t = B_0^{-1}u_t \qquad (4)$$

Recovering the structural parameters of the VAR model specified by equation (1) from the estimated reduced form coefficients requires that the model is either exactly identified or over-identified. Exact identification requires the same number of free parameters in B_0 and Λ as there are independent parameters in the covariance matrix (Σ) from the reduced form model.

Using equations (3) and (4), the parameters in the structural form equation and those in the reduced form equation are related by

$$A(L) = I - B_0^{-1}[B_1 L - B_2 L^2 - .....B_p L^p] \quad (5)$$

and

$$\Sigma = B_0^{-1} \Lambda B_0^{-1 \prime} \quad (6)$$

Maximum likelihood estimates of B_0 and Λ can be obtained only through sample estimates of Σ. The right-hand side of equation (6) has $n(n+1)$ free parameters to be estimated. Since Σ contains $n[(n+1)/2]$, we need at least $n[(n+1)/2]$ restrictions. By normalising n diagonal elements of B_0 to ones, we need at least $n[(n-1)/2]$ restrictions on B_0 to achieve identification. This is a minimum requirement. In the structural VAR approach, B_0 can be any structure as long as it has sufficient restrictions.

There are several ways of specifying the restrictions to achieve identification of the structural parameters. One procedure for determining appropriate restrictions to identify a structural VAR is to use the restrictions that are implied from a fully specified macroeconomic model. The structural VAR models estimated by Blanchard and Watson (1986), who used theory to incorporate short run restrictions, Shapiro and Watson (1988) and Blanchard and Quah (1989), who used theory to justify the inclusion of long-run restrictions, and Gali (1992), who used theory to justify both short-run and long-run restrictions, are examples of this approach. Garratt, Lee, Pesaran and Shin (1998), Huh (1999) and Buckle, Kim and Tam (2001) also followed this approach.

The alternative and more common approach is to choose the set of variables and identification restrictions that are broadly consistent with the preferred theory and prior empirical research. The metric used to evaluate the appropriateness of the variables and restrictions is whether the behaviour of the dynamic responses of the model is consistent with the preferred theoretical view of the expected response. Recent attempts to identify monetary policy effects in small open economies by Kim and Roubini (2000) and Brischetto and Voss (1999) are some of the many examples of this second approach.

This alternative approach has been described by Leeper, Sims and Zha (1996) as an informal approach to applying more formal prior beliefs to econometric modelling. They argue that the approach is in principle no different from other specification methods used in modelling, so long as the modeller does not fail to disclose the methods used to select the model. As Brischetto and Voss point out however, there are still several concerns about the identification restrictions that have been applied to structural VAR models in this manner. These include the robustness of the conclusions to alternative reasonable identification restrictions (see Faust, 1998 and Joiner, 2002), and the difficulty of clearly interpreting what aspects of the model arise from restrictions imposed on the model and what arise from the data. However, these concerns can arise in most multi-equation models and are not restricted to structural VAR models.

A popular and straightforward method is to orthogonalize reduced form errors by Choleski decomposition as originally applied by Sims (1980). However, this approach to identification requires the assumption that the system of equations follows a recursive structure, that is, a Wold-causal chain.

In some circumstances, Choleski decomposition may coincide with the prior theoretical view of the appropriate model structure. This procedure can therefore be viewed as a special case of a more general approach. However, there are many circumstances where restrictions resulting from Choleski decomposition will be unreasonable. It would not be appropriate for example if there were contemporaneous interaction between variables. In those circumstances, if monetary policy for example was implemented according to an explicit policy rule, such as a Taylor Rule, the Choleski decomposition would not enable private sector responses, such as the responses of GNE and GDP, to shocks to foreign variables and to monetary policy in a small open economy to be differentiated.

A more general method for imposing restrictions was suggested by Blanchard and Watson (1986), Bernanke (1986) and Sims (1986), while still giving restrictions on only contemporaneous structural parameters. This method permits non-recursive structures and the specification of restrictions based on prior theoretical and empirical information about private sector behaviour and policy reaction functions.

This more general approach has subsequently been extended to the small open economy by Cushman and Zha (1997) and Dungey and Pagan (2000) in their structural VAR models of Canada and Australia respectively. Their approach is to impose two blocks of structural equations. One block represents the international economy. The other block of structural equations represents the domestic economy. Dependent variables in the domestic economy block are completely absent from equations in the international block. This follows naturally from the small open economy assumption.

There are several potential advantages to be gained from this block exogeneity approach for the small open economy. One advantage claimed by Cushman and Zha (1997), Kim and Roubini (2000) and Brischetto and Voss (1999) is it helps identify the monetary policy reaction function for a small open economy. This approach enables monetary policy to react contemporaneously to a variety of domestic and international variables whose data are likely to be immediately available to the monetary authority. Kim and Roubini (2000), for example, included contemporaneous exchange rate and world price of oil (as a proxy for expected future inflation) variables in the domestic monetary policy reaction function. Cushman and Zha (1997) and Brischetto and Voss (1999) also included the contemporaneous US Federal Funds rate in their specification of the domestic monetary policy reaction function.

The block exogeneity approach also has the advantage of enabling a larger set of international variables to be included in the model, while reducing the number of parameters needed to estimate the domestic block. Cushman and Zha (1997) included four international variables in their model of the Canadian economy: United States (US) industrial production, US consumer prices, US Federal Funds rate and world total commodity export prices. Dungey and Pagan (2000) included real US GDP, real US interest rates, the Australian terms of trade, and the Dow Jones Index deflated by the US consumer prices index. They also treated Australia’s real exports as exogenous to the domestic economy, making a total of 5 variables in their international block.

The lessons from the recent developments in open economy VAR modelling is the inclusion of more foreign variables is likely to be important for correct specification, for better identification of contemporaneous interactions, and for a richer set of lagged responses.

3 An open economy structural VAR model of the New Zealand economy

The structural VAR model of the New Zealand economy contains 13 variables and structural equations. There are two stages in the process that has been followed to decide on the functional form of each structural equation. The first stage is to arrange the variables into four blocks. The second stage involves specification of the functional form of each equation in each block. The functional form for each equation must be consistent with the block exogeneity restrictions and will reflect information from prior theoretical research or empirical single equation and VAR research that has been accepted as a useful characterisation of the variable being modelled.

3.1 Block structure

The equations in this model are arranged into four blocks. There is an international economy block, an international trading prices block, a domestic block, and the fourth block emerges by breaking the domestic block into two parts: a domestic economy block and a domestic climate block. The four blocks are a consequence of the reasonable assumptions that New Zealand is a small open economy and that climate is exogenous. Dependent variables in the two domestic blocks are completely absent from the international economy block and the trading prices block. Furthermore, variables appearing in the trading prices block are also completely absent from the international economy block. Variables appearing in the international economy and trading prices blocks may appear in the domestic economic block, but they cannot appear in the system exogenous domestic climate block. Variables in the domestic climate block can appear in the domestic economic block (but not in the international economy block or the trading prices block).

These block exogeneity restrictions are summarised in Table 1. The rows indicate whether the dependent variables that appear in the specified block are influenced by dependent variables located in another block. The columns show whether dependent variables located in a particular block appear as explanatory variables in any equation for a dependent variable that is located in another block. These relationships are indicated by the symbol "*".

Table 1: Block exogeneity restrictions

		Independent Block			
		IE	TP	DC	DE
Dependent Block	International Economy (IE)	*			
	Trade Prices (TP)	*	*		
	Domestic Climate (DC)			*	
	Domestic Economic (DE)	*	*	*	*

3.2 Data and variables

Our choices of quarterly data series to represent the 13 variables contained within the four blocks are as follow. Foreign real output is represented by the log of trade weighted world industrial production (y^w).[1] Foreign nominal interest rates (i^w) are represented by a weighted average of Australian, United States, United Kingdom, Japan and German 90 day interest rates, where the weights are determined by the ratio of country GDP to the sum of GDP for all these economies. Foreign real asset returns are represented by the log of the Morgan Stanley World Capital Index of gross equity returns (q^w) deflated by an index of United States consumer prices.

The foreign currency price of New Zealand exports is calculated by multiplying Statistics New Zealand's domestic currency export price index by the trade weighted exchange rate and expressed in logs (px^w). The foreign currency price of New Zealand imports is calculated by multiplying Statistics New Zealand's domestic currency import price index by the trade weighted exchange rate, and expressed in logs (pz^w). The domestic exchange rate is represented by the nominal trade weighted exchange rate for New Zealand, expressed in logs (e).

Domestic real aggregate output is represented by Statistics New Zealand's chain-linked measure of production based quarterly real GDP that has been calibrated back to 1978 by Haugh (2001) and expressed in logs (y). Domestic real aggregate demand is represented by Statistics New Zealand's chain-linked measure of quarterly real gross national expenditure back-dated[2] to 1982:2, expressed in logs (d). Domestic real exports are represented by Statistics New Zealand's System of National Accounts measure of real exports of goods and services, expressed in logs (x) and also backdated to 1982:2.

Domestic prices are represented by Statistics New Zealand's Consumers' Price Index for New Zealand, expressed in logs (pc). Domestic interest rates are represented by New Zealand 90-day interest rates (i). Real returns on domestic equities is represented by the NZSE40 gross return index available from Datastream, deflated by the New Zealand Consumers' Price Index and expressed in logs (q). Domestic climate is represented by the number of days of soil moisture deficit in each quarter estimated by the National Institute of Water and Atmospheric Research Limited (NIWA) (2001), and is denoted as (c).

Each data series enters the structural VAR as a deviation from long run trend, where the trend is estimated using the Hodrick-Prescott filter, with the smoothing parameter, λ, set equal to 1600. The value for λ is based on Kim, Buckle and Hall (1994) who used λ=1600 to analyse key features of New Zealand business cycles. The climate variable is detrended by removing from each quarterly value the long run average value for that quarter. This is done to measure climatic conditions that differ from the normal seasonal pattern to model the impact of climatic conditions above and below the norm on the New Zealand economy. The climate variable therefore represents the soil moisture deficit level above or below the normal seasonal level. The quarterly values and trend lines for all variables are displayed in Figure 1. The model is estimated using the deviations from trend quarterly data from 1983:1 to 2002:1.

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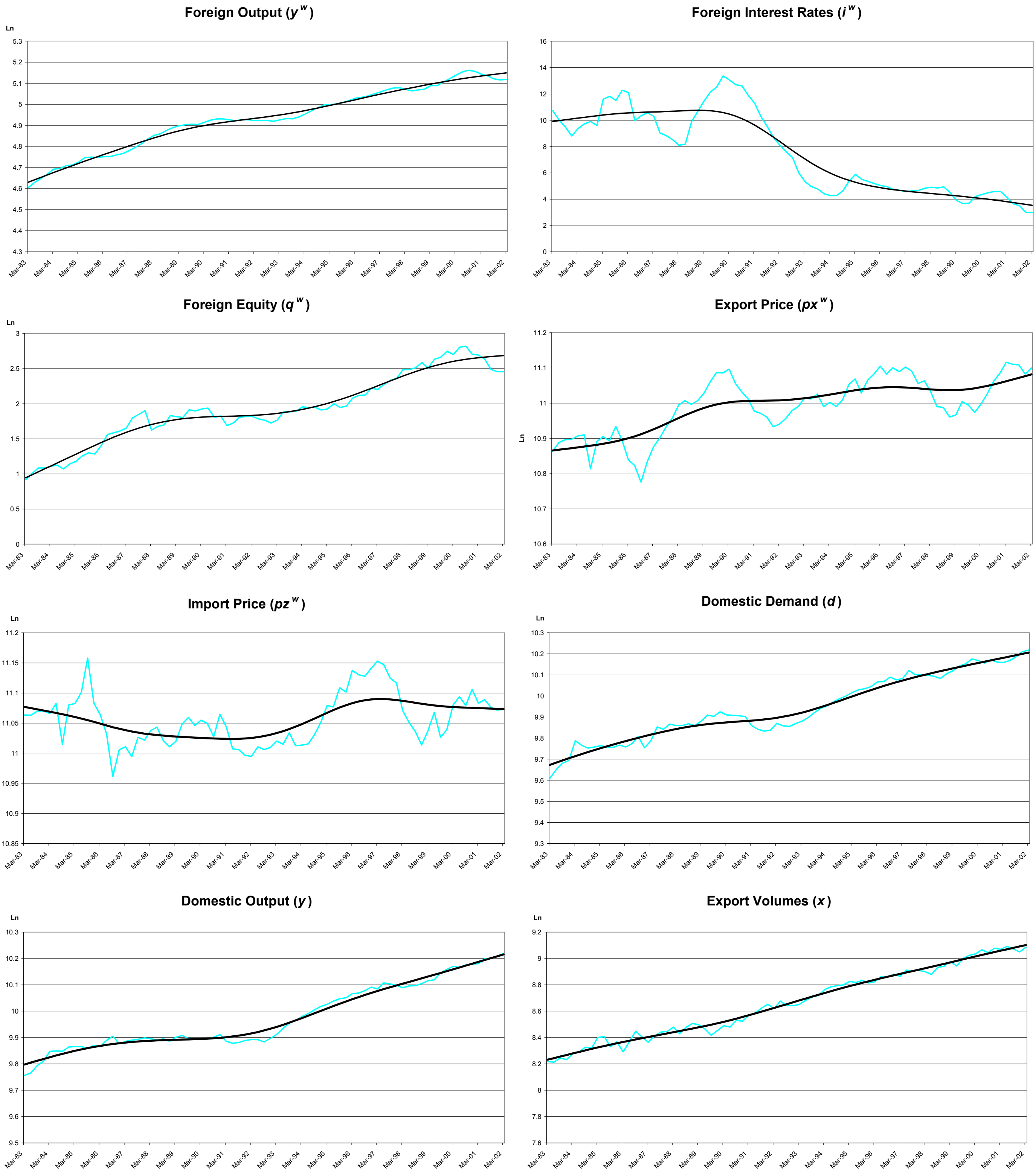
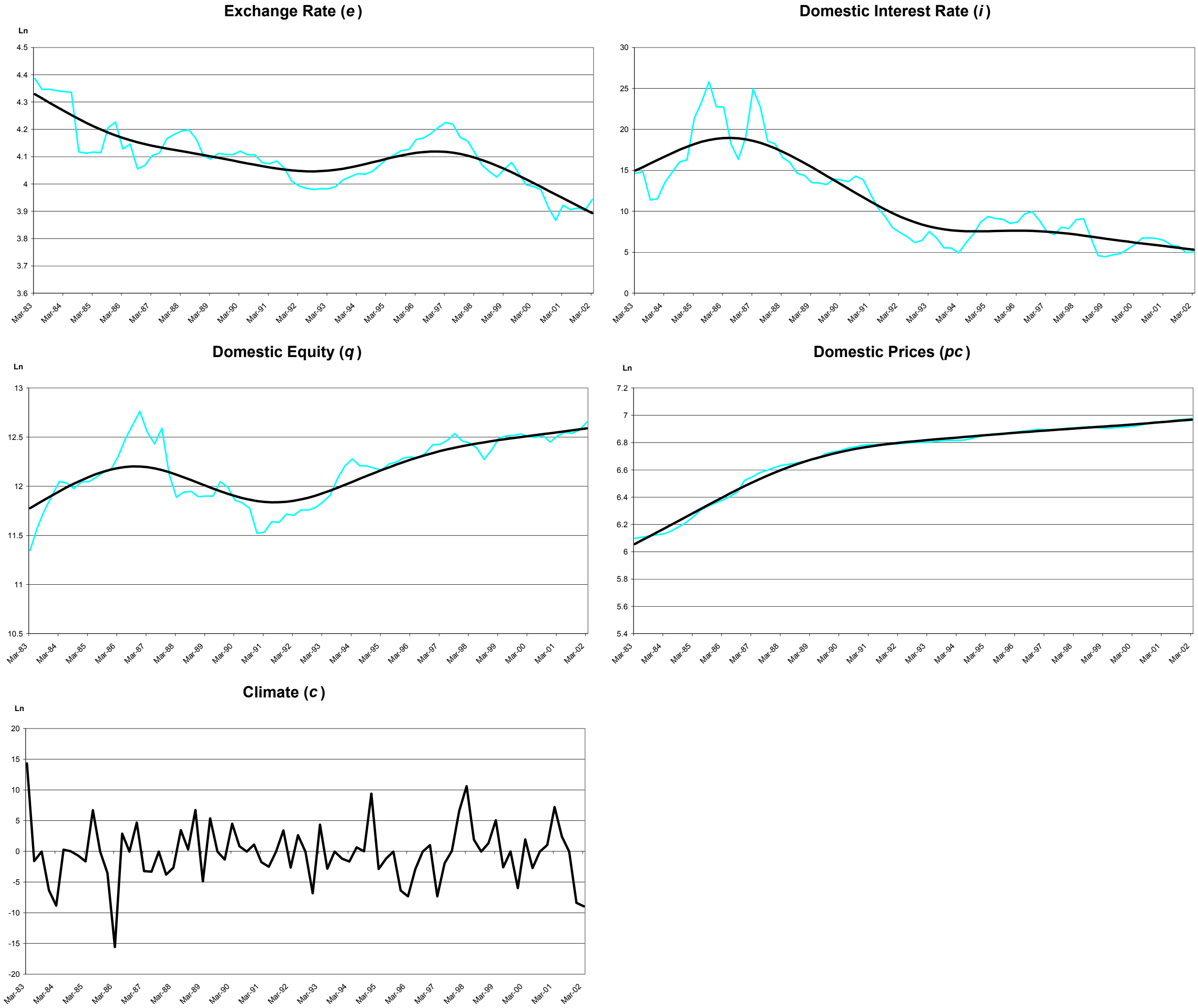
[1] Weighted by the two-year moving average of New Zealand's main export destinations (Australia, US, UK, Japan, Germany, Hong Kong, Taiwan and South Korea). The industrial production indices are from "Datastream".

[2] Backdated using the quarterly percentage changes from the System of National Accounts 1968 gross national expenditure series.

Figure 1: Variables included in the New Zealand open economy structural VAR model





3.3 Summary of the structural equations

The second stage of the model development is to specify the functional form of the structural equations for each variable. The functional form for each equation must be consistent with the block exogeneity restrictions and reflect information from prior theoretical research or from empirical single equation and VAR research.

Tables 2 and 3 summarise the structural equations and lag structure. The rows show the dependent variable in each equation. The columns show which of the variables appear as explanatory variables in each equation. The shaded cells indicate these. Table 2 shows the contemporaneous relationships. Table 3 shows the lagged variables that appear in the equations for each dependent variable.

The unshaded cells in Table 2 represent the contemporaneous restrictions in the matrix B_0. There are 119 unshaded cells or contemporaneous restrictions. The number required to just identify the model is 78.

Table 2: Contemporaneous structure of the model

Independent Variables

Dependent Variables

	y^w	i^w	q^w	px^w	pz^w	d	y	x	e	i	q	pc	c
y^w													
i^w													
q^w													
px^w													
pz^w													
d													
y													
x													
e													
i													
q													
pc													
c													

Table 3: Lag structure of the model

Independent Variables (columns); Dependent Variables (rows)

	y^w	i^w	q^w	px^w	pz^w	d	y	x	e	i	q	pc	c
y^w	■	■	■										
i^w	■	■											
q^w	■	■	■										
px^w	■			■									
pz^w	■				■								
d				■	■	■	■		■	■	■	■	
y	■			■	■	■	■	■	■				■
x				■				■	■			■	■
e	■	■	■	■	■	■	■	■	■	■	■	■	
i		■				■				■		■	
q	■		■	■	■	■	■		■	■	■		
pc				■	■	■			■			■	■
c													■

3.4 The International Economy Block

The set of international variables included in the first New Zealand VAR model developed by Wells and Evans (1985) was limited to the exchange rate and international trade prices. This choice was based on the reasonable argument that under the pervasive regulatory environment that applied during their sample period to private international capital transactions, domestic financial markets and exchange rates, the main channels through which international activity was likely to impact on the domestic economy were the export and import price channels. Furthermore, they observed at that point in time econometric results from structural models had not revealed any significant effect of interest rate differentials on private international capital movements (Wells and Evans, page 424).

International linkages are likely to have become more complex and more pervasive as a result of deregulation of New Zealand trade and financial markets since 1984. Financial deregulation is likely to have created direct financial linkages, increasing the sensitivity of domestic financial markets to international financial conditions. Export product and market diversification suggest that New Zealand tradeable goods production is likely to be more responsive to international demand conditions. Evidence consistent with this argument can be found in Conway (1998). Using a structural VAR model that included US GDP and US interest rates, Conway found the proportion of the variance of New Zealand real GDP attributable to US GDP and US interest rates increased when the sample period was truncated to exclude the period prior to 1985:1.

Theory and subsequent empirical results provide strong justification for expanding the set of international variables to allow for more direct linkages with New Zealand domestic variables in addition to the international trade price links captured by Wells and Evans. Our model therefore includes foreign real output, foreign interest rates and foreign real asset returns. The international block is a Wold recursive system in the contemporaneous variables. The contemporaneous causal ordering runs from foreign real output to foreign interest rates and real asset returns. Foreign real output (y^w) depends upon lags of foreign nominal interest rates (i^w) and foreign real asset returns (q^w).

Foreign nominal interest rates respond to contemporaneous movements in foreign real output and to lags in foreign real output and foreign interest rates. This aspect of the model is therefore similar in structure to the corresponding component of Dungey and Pagan's (2000) model for Australia. As they point out, if the typical interest rate decision rule for central banks is approximated by a Taylor rule, then the equation for the foreign interest rate is likely to be mis-specified since it implies that central banks only vary interest rates in response to an output gap. Although the full model does include international prices, they are only representative of the prices of goods exported and imported by New Zealand and are unlikely to be sufficiently representative of the prices of concern to the world's major Central banks.

Foreign real asset returns (q^w) respond contemporaneously to foreign real output and foreign interest rates, and to lags in these variables and its own lags. The inclusion of q^w reflects growing integration of New Zealand financial markets with international markets since financial deregulation during the mid 1980s implied by Conway's (1998) results. Several single equation investigations (including Dyer, 1994; Grimes, 1994; Rae, 1995; and Eckhold, 1998) justify attempting to capture more directly the significance of international financial market conditions on New Zealand interest rates and financial asset returns.

3.5 The International Trading Prices Block

Several classes of models have been used to evaluate external price effects in New Zealand (see Wells and Easton, 1986). These have included for example the classical homogeneous product model (applied by Bailey, Hall and Phillips, 1980), and the Scandinavian model cast in terms of traded and non-traded goods (applied by Ursprung, 1984). Some models have attempted to capture these international price effects by using the portmanteau terms of trade variable (Kim, 1994; Hansen and Hutchison, 1997; and Conway, 1998) or international oil prices to represent common global shocks (Selover and Round, 1995) or to act as a proxy for foreign demand conditions (Claus, 2002).

Others have argued that the Australian three-goods model of the dependent economy (developed by Salter, 1959 and Swan, 1963), which emphasises the distinction between imports, exports and non-traded goods, and has exogenous terms of trade, is a more appropriate basis for modelling the impact of international traded goods prices on the New Zealand economy. New Zealand models structured in this way include Wells and Evans (1985), Buckle and Pope (1985) and Szeto (2002). The basis for adopting this three-good approach is that New Zealand's industrial structure falls between the typical characteristics of developed and developing economies. Consequently, a substantial proportion of New Zealand's imported goods are inputs to the production process and a significant proportion of its exported goods are primary based products with a low proportion of exportable production absorbed by home consumption.

Within the context of this type of commodity structure, Findlay and Rodriguez (1977), Bruno and Sachs (1985) and Buckle and Pope (1985) demonstrated that rising import prices, including oil prices, have a stagflation effect on the domestic economy. In the contemporary environment of a floating exchange rate and inflation targeting by the New Zealand Central bank, the impact on domestic inflation would be smaller but the short-run effect on output could be accentuated. Because export commodities make up only a small proportion of final consumption, rising export prices will increase real incomes and have a small impact on domestic inflation.

The effects of import and export price shocks on domestic real output and inflation therefore need not necessarily be mirror images of each other. This argument is supported by the results from Wells and Evans (1985). They found an increase in export prices raised private sector output and employment and had virtually no effect on output prices. An increase in import prices reduced private sector output and employment but also raised output prices, the classical stagflation effect. Their results were estimated using data from 1961:1 to 1981:1.

Changes to the New Zealand policy and trading environment and changes in industrial structure since the mid 1980s are unlikely to have diminished the merits of the 'Australian model' and the relevance of Wells and Evans' results. New Zealand's industrial structure during the 1980s and 1990s still warrants the separate identification of import and export price shocks. Furthermore, recent international research has demonstrated the utility of differentiating between commodities in the context of understanding business cycles in small open economies (see for example Kose, 2002).

Consistent with the small open economy assumption, we model the foreign currency price of New Zealand exports (px^w) and the foreign currency price of New Zealand imports (pz^w) as responding to contemporaneous and lagged foreign real output and to their own lags.

3.6 The Domestic Climate Block

The significance of the agricultural sector as a source of final output and intermediate inputs to several manufacturing industries and the significance of hydro electricity as a source energy renders New Zealand aggregate real output potentially sensitive to changes in climatic conditions. One of the reasons for constructing this structural VAR model is to try to identify the impact of climatic conditions on New Zealand business cycle fluctuations.

New Zealand research examining the impact of climate on New Zealand agriculture dates back to Maunder's impressive programme of research initiated during the 1960s. This research involved the creation and development of indicators of climatic conditions generated from data collected by the New Zealand Meteorological Service. Maunder's research included the development of agroclimatological models using rainfall, temperature and sunshine to predict the effect on butterfat production (see for example Maunder 1966; 1968 and Maunder and Ausubel, 1985). Building on these developments, subsequent research estimating single equation behavioural models have evaluated the impact of climatic conditions on livestock investment and slaughter rates (Tweedie and Spencer, 1981) and on farm profits (Wallace and Evans, 1985).

The National Institute of Water and Atmospheric Research Limited (2001) identifies several potentially suitable indicators of climatic conditions including the southern oscillation index which has been shown to have a significant impact on Australian agricultural production, various indices of wind strength, temperature variations across regions, sea surface temperatures and a measure of soil moisture conditions. We have chosen to use the soil moisture conditions variable derived by Porteous, Basher and Salinger (1994) to capture the impact of climatic conditions on New Zealand real GDP and exports. This soil moisture variable is calculated from the daily water balance. It measures the net impact of rainfall entering the pasture root zone in the soil and that which is lost from this zone as a result of evapotranspiration or use of water by the plants.

The soil moisture variable is block exogenous. To capture the impact of climatic conditions we postulate that changes in soil moisture conditions have significant contemporaneous and lagged effects on total New Zealand real GDP (y) and on New Zealand export supply (x).

3.7 The Domestic Economy Block

The previous three blocks identify international trade, international financial, and domestic climate shocks to the New Zealand economy. The domestic economy block contains the domestic reactions to these shocks. It is also the source of domestic policy and non-policy shocks such as exogenous changes to interest rates, the exchange rate and equity returns, and exogenous changes to private demand.

There are two main components to the domestic economy block. Three variables represent aggregate real domestic output and aggregate real demand for domestic output (y, d, x). Four variables represent prices and real returns to wealth (e, i, q, pc). Since real GNE includes spending on imports, the inclusion of real GDP and real GNE in the same model imply the model captures shocks to the balance of trade. This feature is also present in Dungey and Pagan's (2000) model for Australia. They point out that because log GNE minus log GDP is approximately equal to the trade balance to GDP ratio, whenever log GNE and log GDP are included in the same equation the two variables are equivalent to log GDP and the trade balance ratio.

Shocks to GNE are interpreted as aggregate demand shocks. Contemporaneous influences on domestic demand include shocks to foreign prices for exports and imports (px^w and pz^w), reflecting the terms of trade effect on the purchasing power of New Zealand output, and domestic equities. Income and relative price effects arising from changes to domestic real GDP (y), interest rates (i), the exchange rate and domestic prices (pc), impact after a one-quarter lag. Apart from the terms of trade effect, other international variables are considered to impact on domestic demand indirectly via their impact on real output and relative prices. This may appear unduly restrictive, particularly if international conditions affect expectations and spending decisions other than through their impact on export and import prices. However, sensitivity analysis suggests that allowing all the foreign variables to affect domestic demand directly does not materially change the impulse response function of domestic demand to foreign shocks.

During the late 1980s, the evolution of GNE was affected by demand shocks associated with unusually high demand in anticipation of the foreshadowed introduction of a goods and services tax (GST). The GST changes were introduced in 1986:4 and 1989:3. Domestic spending was unusually high during the quarter immediately prior to each tax increase. We have absorbed these shocks into two GST dummy variables. The first takes the value 1 in 1986:3 and zero in all other quarters; the second takes the value 1 in 1989:2 and zero in all other quarters.

Contemporaneous shocks to aggregate real GDP arise from two sources of demand shocks, domestic GNE (d), and export demand (x), and two supply shocks, climate (c) and other unexplained supply shocks that are captured by the error term in the equation for real GDP. To allow for the possibility of spillover effects from world productivity shocks, lagged foreign output is included in the equation for domestic real GDP. Other influences include lagged expenditure switching effects arising from shocks to the exchange rate, export prices and import prices.

New Zealand producers are assumed to face infinitely elastic demand on world markets. Contemporaneous influences on export supply include climatic and other export supply shocks. Real exchange rate effects arising from changes to world prices for exports, the exchange rate and domestic prices (px^w, e, pc) impact after a one-quarter lag.

The domestic price variable (pc) is the difference between the log of the domestic Consumers' Prices Index and its trend value. It is therefore a measure of the extent to which prices are growing faster or slower than trend growth and can therefore be interpreted as trend adjusted domestic inflation. The equation for domestic prices can be interpreted as a reduced form equation capturing mark-up on cost pricing by domestic firms and the direct price effects of final tradeable goods that are consumed domestically, similar to that estimated by Hampton (2001).

The production costs of domestic firms include prices of imported intermediate production inputs, labour costs and productivity. Labour costs are assumed to be determined by a Phillips curve that relates wage inflation to demand pressure and expected inflation. Demand pressure is proxied by the deviation of real GNE from trend (d). Expected inflation is assumed to be determined by a combination of current and lagged price inflation (pc). Domestic currency prices of imported intermediate goods are captured by the world price of imports (pz^w) and the exchange rate (e), while the domestic currency prices of final tradeable goods consumed locally are captured by foreign prices for exports, imports and the exchange rate (px^w, pz^w, e).

Shocks to the domestic price equation are therefore a combination of shocks to mark-up pricing, wages and foreign prices of final tradeable goods. Shocks to domestic prices cannot therefore be simply interpreted as "supply" or "productivity" shocks as they are typically labelled in the international literature. The world price indices for imports and exports are only an approximation of the prices of intermediate and final tradeable goods. More detailed modelling of international linkages might warrant separation of price indices for tradeable goods by function (see for example Kose, 2002).

Domestic prices were affected by the two goods and services taxation (GST) shocks during our sample period. A 10 percent tax was introduced in 1986:4 and a further 2.5 percent was added in 1989:3. These GST shocks have been absorbed by two dummy variables. The first takes the value 1 in 1986:4 and zero in all other quarters; the second takes the value 1 in 1989:3 and zero in all other quarters.

The equation for domestic interest rates (i) is intended to capture the monetary authority's reaction function. Recent research suggests that for most of our sample period, the conduct of monetary policy in New Zealand approximates a Taylor-type (Taylor, 1993) reaction function (see Plantier and Scrimgeour, 2002; Huang, Margaritis and Mayes, 2001). The basic specification of the interest rate equation reflects this idea, but with several modifications.

The New Zealand monetary authority's behaviour is probably appropriately described by forward-looking behaviour. This model therefore embodies a variant of the Taylor Rule in which the monetary authority reacts to forecasts of inflation and demand three quarters in the future. The Taylor Rule takes the form expressed in Tables 2 and 3, but with the independent variables replaced with three-quarter-ahead forecasts generated from the reduced form VAR. Stock and Watson (2001) compare the implications of backward and forward-looking Taylor Rules in a three variable model of U.S. inflation. They found the choice of specification affected interest rate impulse response functions. We found that the choice of a forward-looking specification produced different and more sensible reactions to interest rate shocks.[3]

Although the cash rate is the current monetary policy instrument in New Zealand, this variable is unavailable for the full sample period. We have therefore used the 90-day rate as a proxy variable. The 90-day rate is not strictly controlled by the monetary authority and can be influenced by private expectations and shifts in portfolio decisions. We therefore include the world interest rate as a direct contemporaneous and lagged influence on the domestic interest rate.

Real returns on domestic equities (q), represented by the NZSE40 gross return index and deflated by the New Zealand Consumers' Price Index, are specified as a function of contemporaneous foreign real output (y^w), foreign real asset returns (q^w) and the exchange rate (e) to reflect the globalisation of international asset markets. Real domestic equity returns are also specified as being influenced by variables considered likely to affect expectations of domestic real output growth (px^w, pz^w, y) and returns from alternative financial assets (i).

3.8 Estimation

Although it was theoretically possible to estimate the reduced form VAR model with five lags, the selection of lag length was restricted to between one and four, owing to difficulty in estimating a non-singular variance-covariance matrix. On the basis of both the Akaike Information criterion (AIC) and the Bayesian Information criterion (BIC), the sample evidence for the entire reduced form VAR system suggested a lag length of one. A series of sequential likelihood ratio tests for a shorter lag length versus a longer lag length, suggested a lag length of two. A lag length of one or two is quite short compared with other New Zealand VAR studies. For example, Evans and Wells (1985) chose a lag length of three and Conway (1998) a lag length of four. Moreover, there was evidence of serial correlation in some of the reduced form residuals, when the VAR was estimated using lags of both one and two.

Given these considerations, we estimated the reduced form VAR with three lags. This was done using Seemingly Unrelated Regression (SUR), rather than Ordinary Least Squares (OLS), owing to the inclusion of zero restrictions on some lagged variables (which results in inefficient OLS estimators when the residuals are correlated across equations). The Durbin H statistic suggested that the reduced form VAR with three lags was absent of serial correlation.

The contemporaneous matrix, B_0, was estimated using maximum likelihood. Initial starting values for B_0 were found using the genetic algorithm. The estimates from the genetic algorithm were then used as starting values to find the final parameter estimates for B_0 using the Broyden, Fletcher, Goldfarb and Shanno (BFGS) algorithm. As part of the sensitivity analysis, the model was estimated over sample sub periods to test the robustness of coefficient estimates. The estimation results from different sub periods suggested the model was robust to changes in the sample period. Sensitivity analysis of the model to alternative identifying restrictions was also done.

[3] To capture changes in the operation of monetary policy over the sample period, alternative specifications for the interest rate equation that included intercept and interactive dummy variables were tried. For example, a dummy variable that interacted with the exchange rate, and which took on a value of one between 1997:2 and 1999:4 and zero elsewhere, was used to capture the operation of monetary policy when monetary policy decisions were based on the monetary conditions index (MCI). This alternative specification for the interest rate equation had little discernable effect on the ability to identify monetary policy.

4 Macroeconomic responses to trade, financial and climate shocks

Structural VAR models have typically been used to identify dynamic responses of an economy to particular shocks. This serves two purposes. It provides a means of analysing an estimated structural VAR and it reveals information about the dynamic properties of the economy investigated. The results can be used to inform policy makers and economic forecasters how economic variables such as real output and prices respond over time to changes in policy or other events. This type of analysis can also be used to inform the development of calibrated macroeconomic models (such as those developed for New Zealand by Black, Cassino, Drew, Hanson, Hunt, Rose and Scott, 1997 and Szeto, 2002) about the dynamic structure those models should be capable of replicating.

As with all empirical work, the information value of dynamic simulations depends on the validity of the structure of the simulated empirical model. For this reason, the analysis is restricted to dynamic properties in response to shocks that appear to have been identified. These include shocks to international variables, domestic financial variables and domestic climate. We do not attempt in this paper to separate out the impact of domestic fiscal, trade and industrial policy changes that have taken place in New Zealand during the past two decades. These are left for future development work.

The traditional means of analysing an estimated structural VAR model is through impulse response functions (Hamilton, 1994). Impulse response functions (IPS) represent the dynamic response of a variable in the model to an error term (referred to as a shock or innovation) in one of the structural equations. The transmission of the shock will depend on the form of the structural equations. Using Tables 2 and 3, a shock to px^w, for example, will have a contemporaneous impact on domestic GNE, the nominal exchange rate, domestic asset returns and domestic prices, and an impact on these and other variables one period into the future, two periods into the future, ….etc. These reactions represent the impulse responses.

Each variable in our model can be expressed as a combination of current and all past errors in the structural equations. That is, from equations (2) and (4), the SVAR can be written in moving average representation as follows:

$$y_t = A(L)^{-1} B_0{}^{-1} u_t \qquad = \Theta(L) u_t \tag{7}$$

where $\Theta(L)$ contains the dynamic multipliers used to map out the impulse response functions following innovations to the structural error terms. The impulse response function represents the dynamic path for y_t from the ith equation following an innovation to the structural error term u_t from the jth equation, holding all other structural error terms constant.

The evolution of domestic output for example is therefore determined by all shocks that enter the system of equations (13 in this system). However, as explained in Section 2.1, while some of these shocks are in principle capable of being identified and interpreted (such as climate shocks), others are more difficult to interpret. For example, although it is common practice to classify the shocks from GDP and GNE as supply and demand shocks respectively, this is not always justified and would not be appropriate for this model. One obvious reason is that some components of expenditure, such as investment and government infrastructure spending, simultaneously affect aggregate demand and supply and these components of demand cannot be identified in this model. The approach adopted here is therefore to label shocks on the basis of the structural equation from which they emanate.

Table 4: Impulse response shocks: One standard deviation of the structural error

y^w	0.006	d	0.011	pc	0.004
i^w	0.470	y	0.007	x	0.024
q^w	0.063	e	0.019	c	4.241
px^w	0.024	i	1.21		
pz^w	0.020	q	0.063		

Note: The size of each shock is equal to one standard deviation of the structural error term. For example, the size of the foreign output shock corresponding to the impulse response functions presented below is equal to 0.6%.

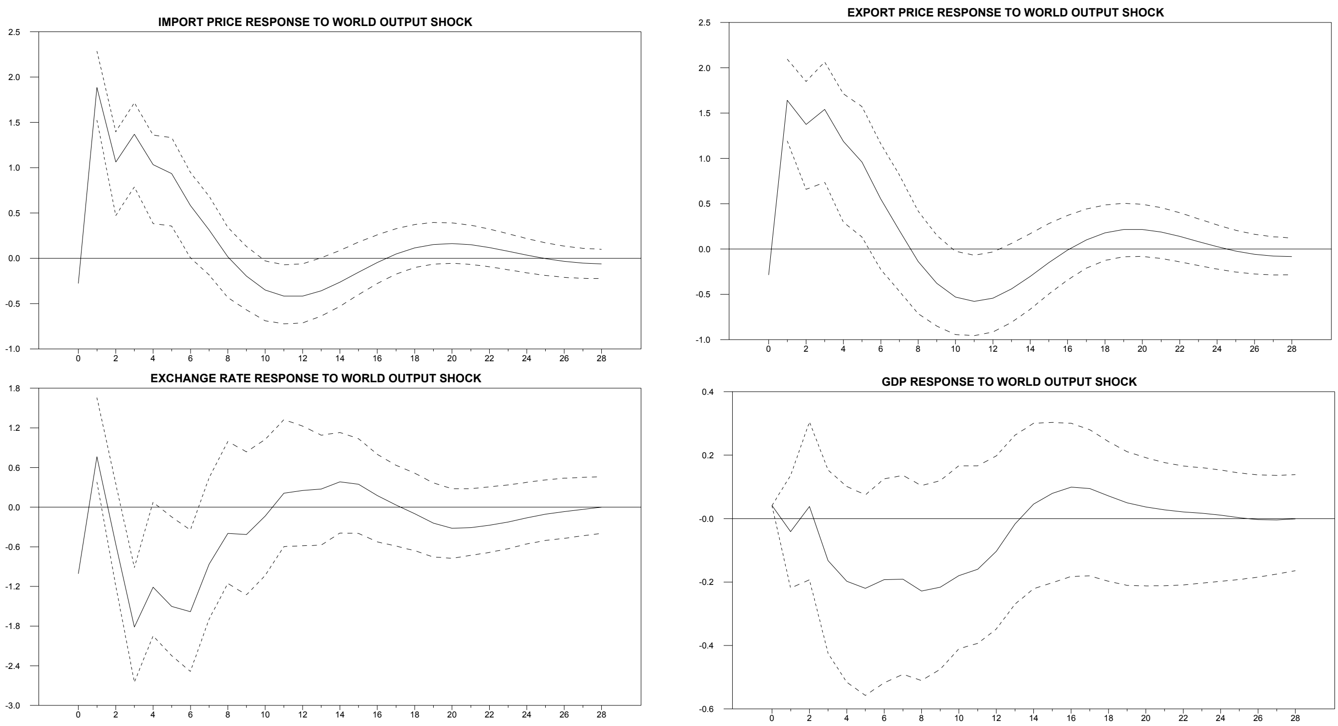
The sizes of shocks applied to structural VAR systems are traditionally measured as either one unit or one standard deviation shocks of the structural error. The metric applied in this paper is a one-standard deviation shock of the structural error. The impulse response functions have been normalised by dividing by one standard deviation of the structural form shocks. This normalisation enables all the impulse responses to be plotted on a single scale. The sizes of each shock are shown Table 4.

As is commonplace in the VAR literature, sixty-eight percent confidence bands have been estimated for the impulse response functions using the Monte Carlo bootstrapping approach of Runkle (1987). This approach simulates the SVAR model to generate error distributions. The actual residuals are randomly sampled (with replacement), and the sampled residuals are then used to create artificial data to re-estimate and simulate impulse responses. That procedure is repeated 1000 times to calculate standard errors for the parameter estimates and the impulse response functions. The programming required for model estimation, simulating impulse responses and historical error variance decompositions discussed in Section 5 was undertaken using the RATS software (Estima, 2000).

4.1 Foreign output shock

The first shock examined is the impact of a positive innovation to world output (y^w). Figure 2 illustrates an immediate response by export prices (px^w) and import prices (pz^w). Their peak responses both occur in the first quarter after the shock. However, the impact of the rise in pz^w on domestic GDP is greater than the impact of the rise in px^w, as reflected in the eventual decline in domestic output (y). The exchange rate (e) appreciates over the first two quarters, which will also dampen domestic output. The exchange rate eventually depreciates in response to relatively higher world output and higher world interest rates.

Figure 2: Responses to foreign output shock



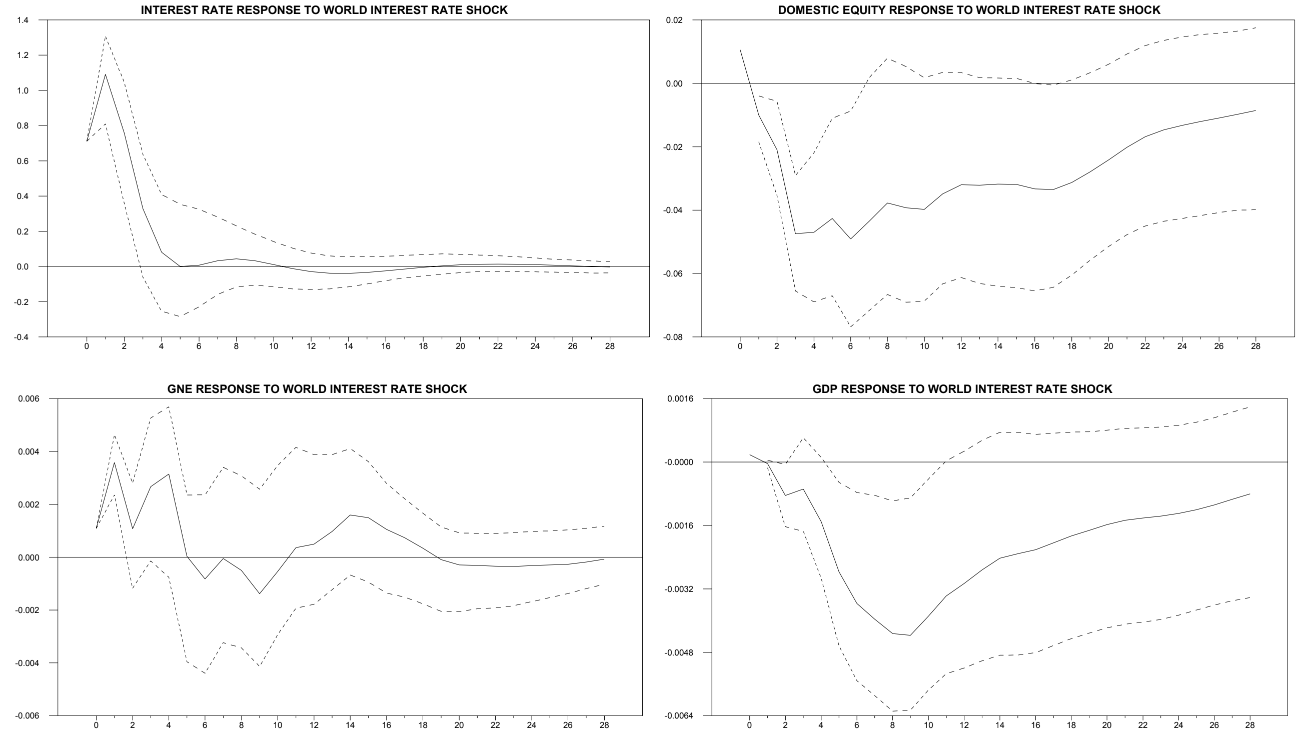
4.2 Foreign financial shocks

4.2.1 Foreign interest rate shock

The responses to a rise in the world interest rate (i^w) are illustrated in Figure 3. This shock is transmitted immediately into higher domestic interest rates (i). Higher domestic interest rates imply higher demand for domestic bonds and therefore lower demand for domestic equities (q), reducing real returns on domestic equities. Domestic demand eventually falls in response to higher domestic interest rates and the fall in domestic equities.

Although not shown in Figure 3, higher world interest rates reduce the growth of import (pz^w) and export (px^w) prices for up to eleven quarters. The impact on exports (x) (not shown) is initially small but exports increase after three quarters. The net effect of higher foreign interest rates is a fall in domestic output.

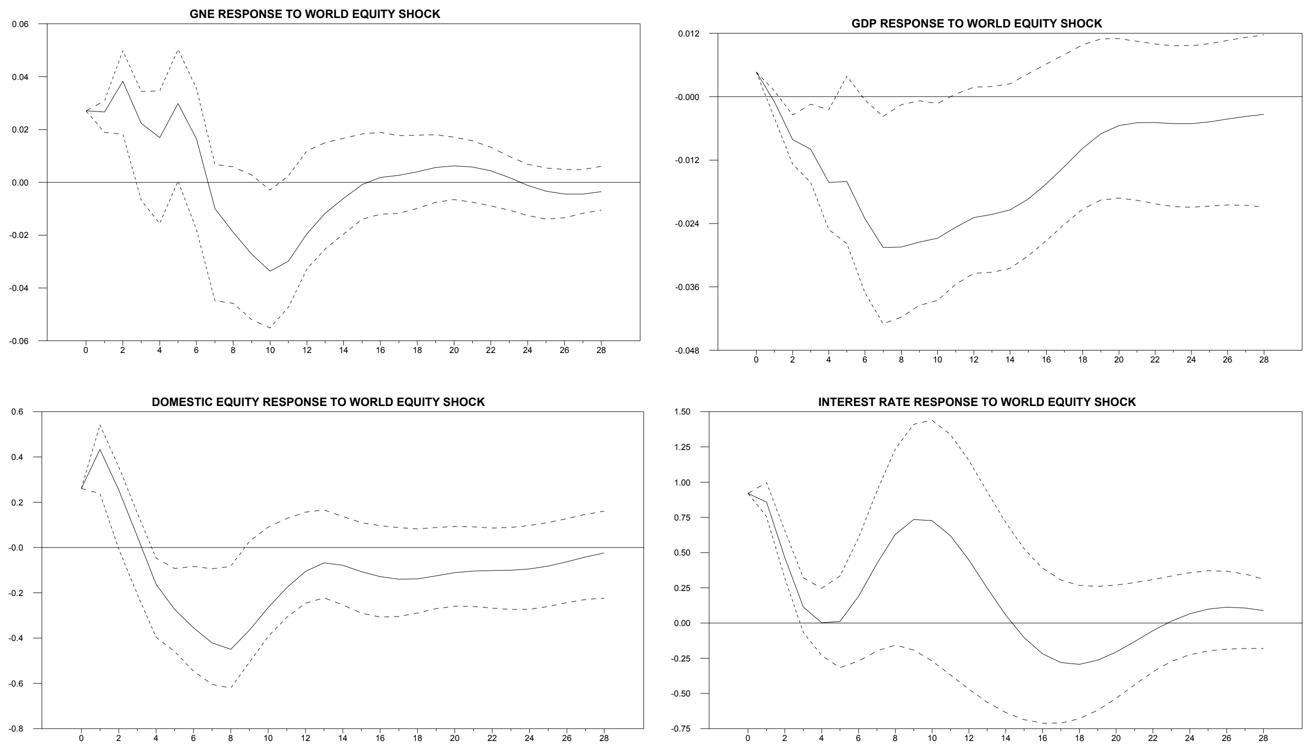
Figure 3: Responses to foreign interest rate shock



4.2.2 Foreign equity shock

Figure 4 shows that an increase in returns on world equities provokes an immediate increase in returns on New Zealand equities and a rise in domestic demand and domestic output. Domestic interest rates rise, which results in an eventual, fall in domestic demand and domestic output.

Figure 4: Responses to foreign equity shock

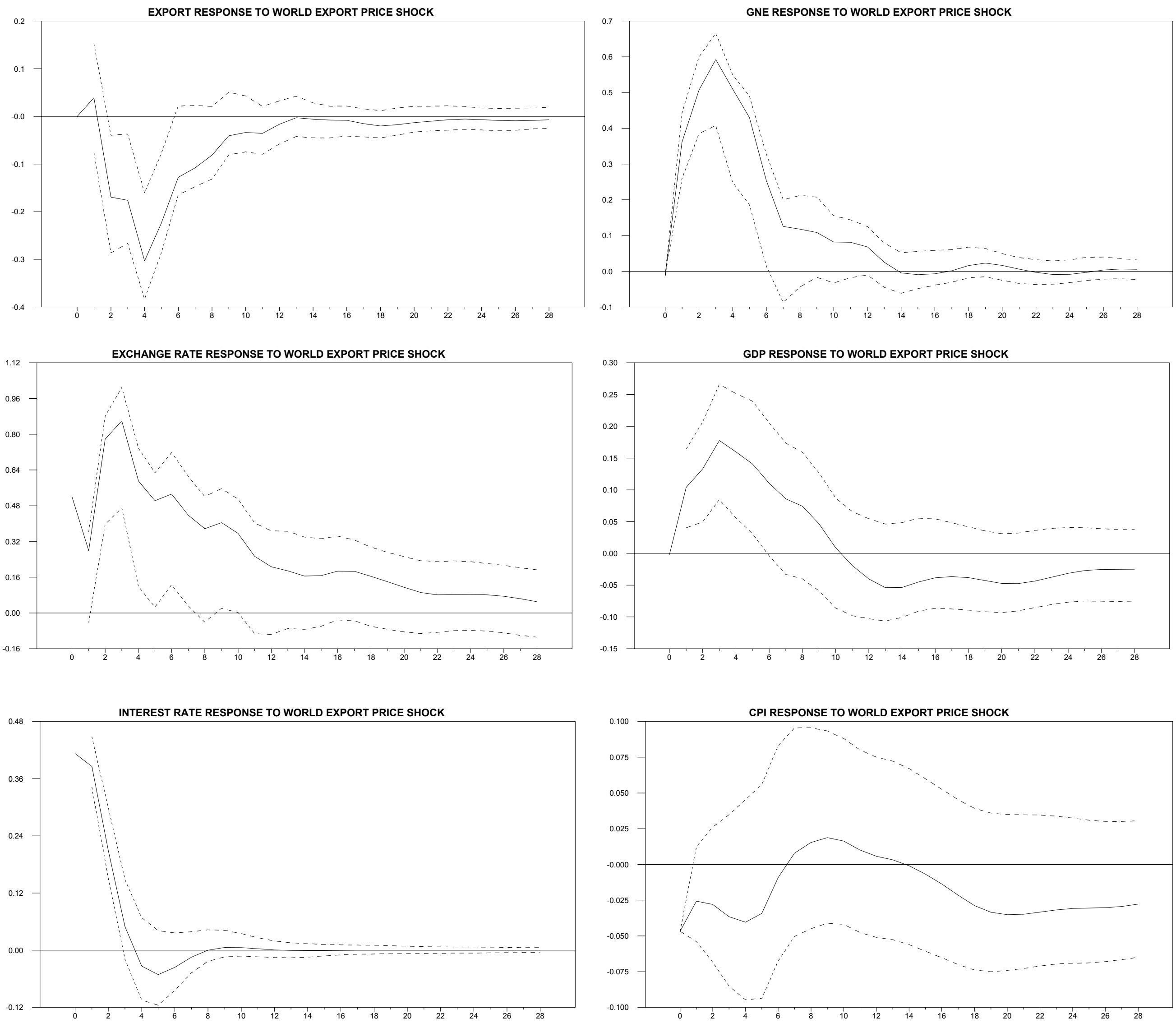


4.3 Terms of trade shocks

4.3.1 Export price shock

Responses to a rise in export prices (px^w) are shown in Figure 5. The exchange rate (e) appreciates resulting in a decline in export volumes. There is a sharp rise in domestic interest rates. The rising terms-of-trade-adjusted income, probably explains the strong increase in domestic demand (d) for several quarters after the shock. Although domestic output (y) also increases to satisfy higher domestic demand, its response is not as strong, implying deterioration in the trade balance.

Figure 5: Responses to export price shock

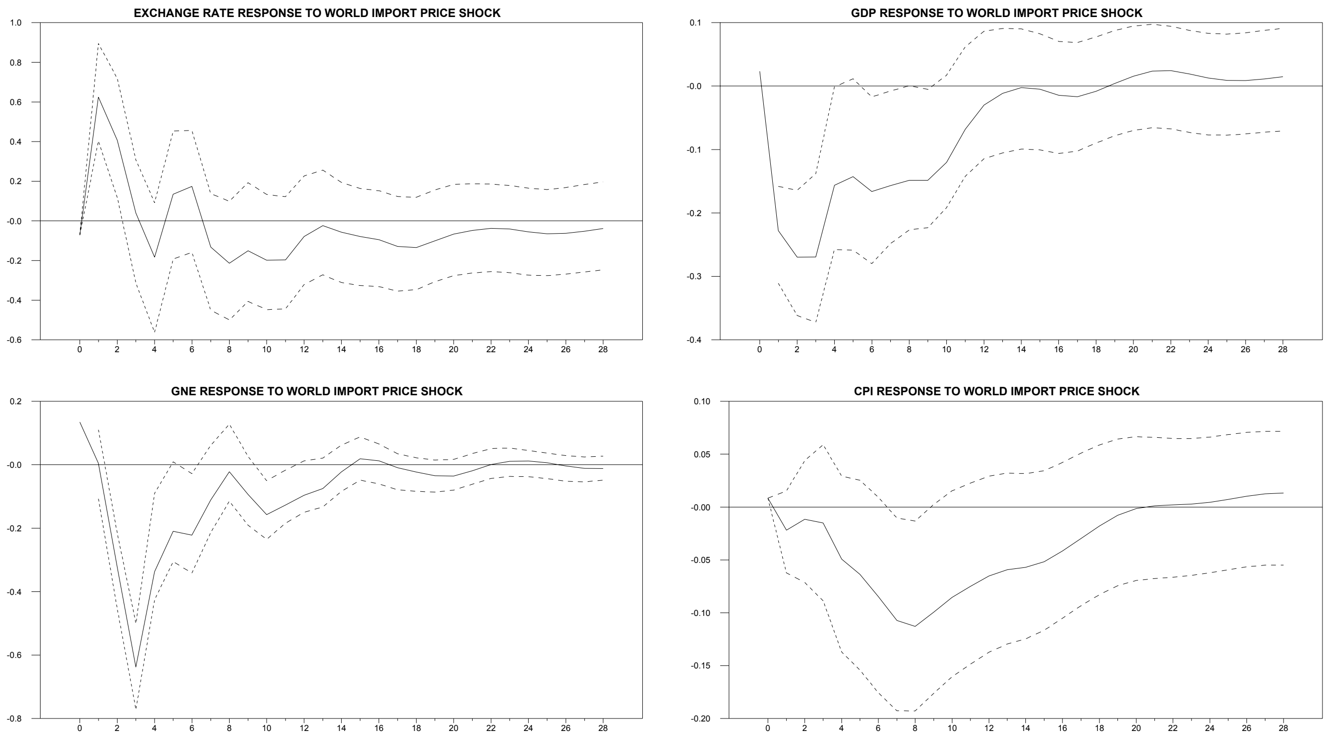


4.3.2 Import price shock

The responses to an increase in foreign import prices are shown in Figure 6. Although domestic output (*y*) falls one quarter after the shock, the maximum response does not occur until the third quarter. This decline in domestic output (*y*) may reflect the higher cost of imported intermediate inputs to production. It will also reflect the sharp fall in domestic demand (*d*) in response to higher import prices.

Reflecting the combined impact of an appreciation in the exchange rate (*e*) and a decline in both domestic demand (*d*) and domestic output (*y*), domestic prices (*pc*) fall. Although domestic prices (*pc*) decline almost immediately, the trough does not occur until eight quarters after the shock. This trough in domestic prices (*pc*) is sometime after the maximum response of the exchange rate (*e*), domestic demand (*d*) and domestic output (*y*) to the import price shock. Owing to the falls in domestic demand (*d*) and domestic prices (*pc*), the domestic interest rates (*i*) (not shown) also falls.

Figure 6: Responses to import price shock



4.4 Domestic financial shocks

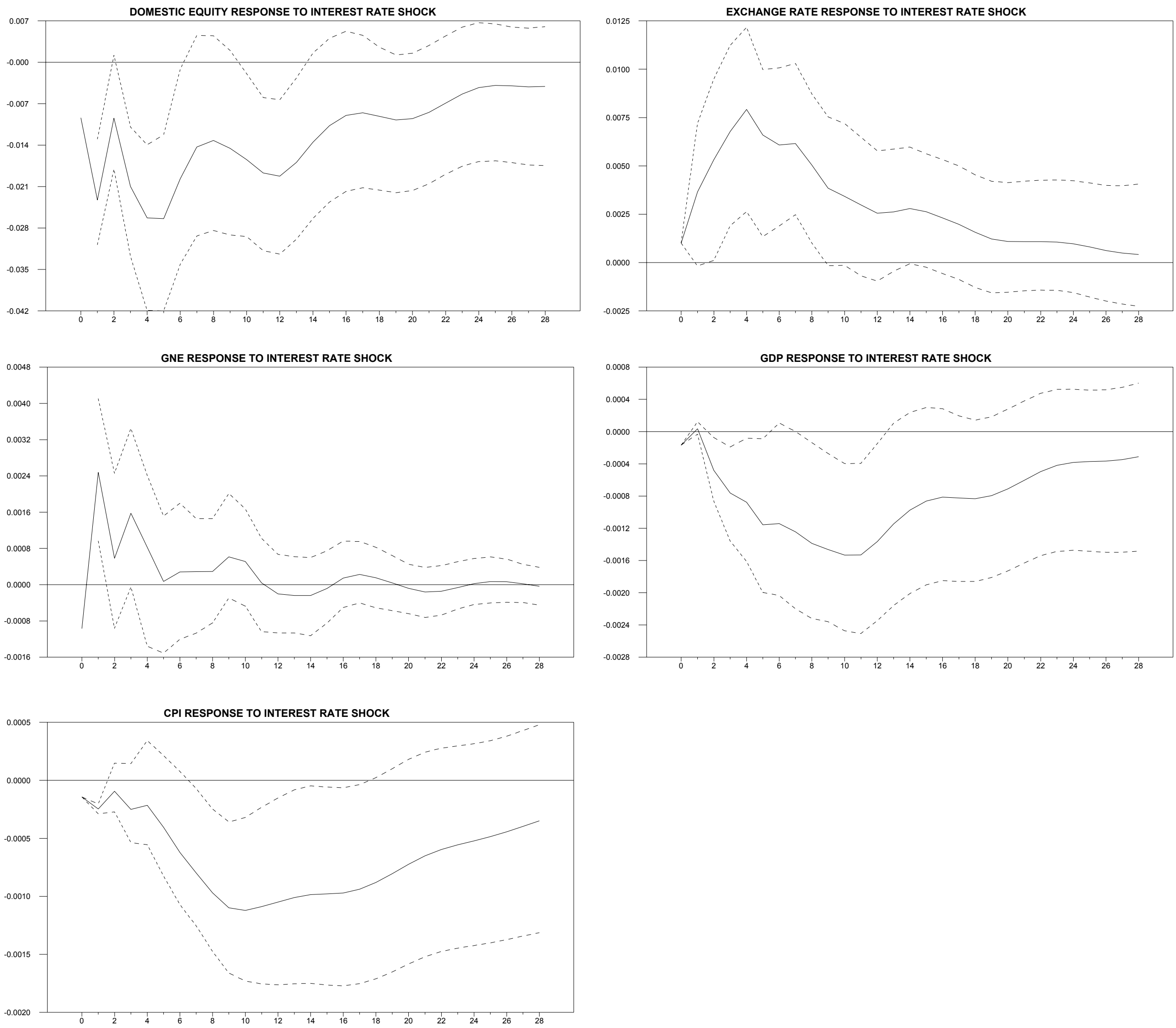
4.4.1 Domestic interest rate shock

The responses to an increase in domestic interest rates (i) are shown in Figure 7. As expected, there is an immediate decline in domestic equity returns as equities are substituted for bonds. The exchange rate (e) appreciates, although the strongest reaction is after four quarters. This response is likely to reflect the impact of an increase in the interest rate differential between the domestic and foreign interest (i^w) rates.

As a consequence of the exchange rate appreciation, domestic consumer price inflation (pc) falls. While domestic inflation starts to fall almost immediately after the increase in the domestic interest rate, the trough occurs over eighteen months after the shock. This is consistent with the presence of nominal price rigidities and slow exchange rate pass through (IMF, 2001). Domestic output's response to the interest rate innovation follows a similar profile to that generated for the CPI.

A number of VAR studies have encountered difficulties in detecting the impact of monetary policy actions on other macroeconomic variables. Kim and Roubini (2000) outlined several empirical "puzzles" that have been associated with attempts to identify monetary policy in both open and closed economies. One attractive feature of this structural VAR model developed is that it does not encounter two of the puzzles discussed by Kim and Roubini (2000), namely the price puzzle (where the price level rises in response to a positive interest rate shock) and the exchange rate puzzle (where the exchange rate falls following a positive interest rate shock). Monetary policy appears to have been successfully identified using a forward looking Taylor rule (explained in Section 3.7), without the need to include non-monetary policy variables that several other VAR studies have had to resort to in order to identify monetary policy (see for example Brischetto and Voss, 1999 and Kim and Roubini, 2000).

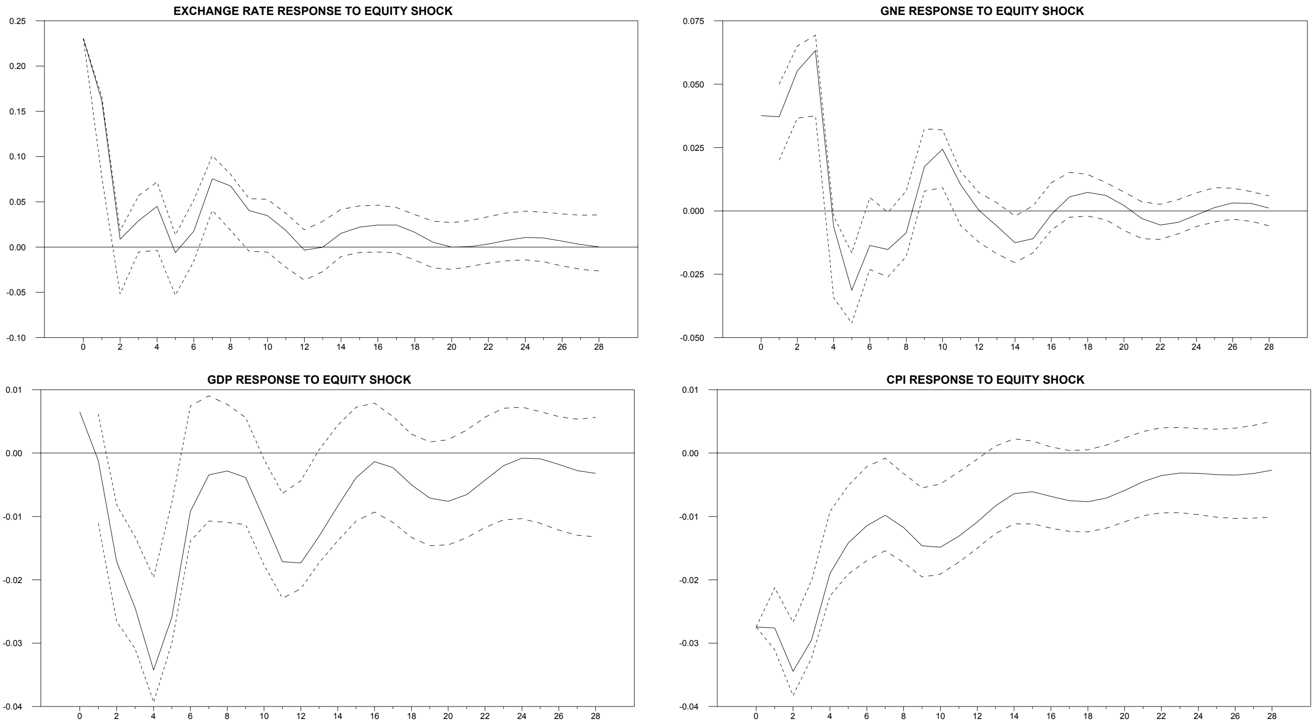
Figure 7: Responses to domestic interest rate shock



4.4.2 Domestic equity shock

Figure 8 shows the responses to a positive innovation to domestic equity returns (q). There is an immediate increase in domestic demand (d). This demand reaction is likely to represent increased investment by firms (a Tobin q effect) and higher consumption by households (a wealth effect). Given that monetary policy is forward looking in this model, the current and expected future rise in domestic demand results in a rise in domestic interest rates (i) (not shown) to dampen the demand pressure on inflation. The rise in domestic interest rates is also consistent with results for the domestic interest rate shock and perhaps also reflects the substitution out of bonds. Domestic output (y) initially rises but falls soon thereafter, despite domestic demand rising over the first year. This may be in part a response to a decline in exports, which fluctuate with the exchange rate.

Figure 8: Responses to domestic equity shock



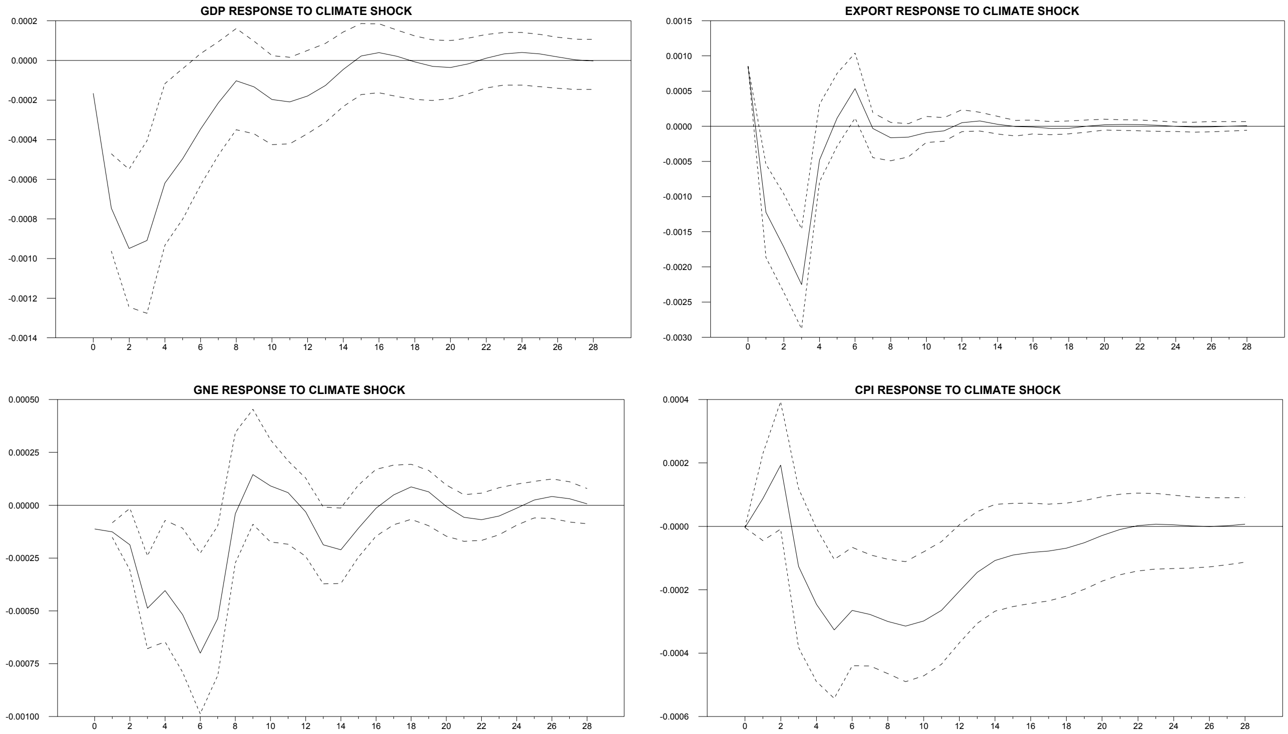
4.5 Climate shock

We expect New Zealand's geographical characteristics and industrial structure will combine to render domestic output sensitive to climate changes. If so, we would expect to find a significant business cycle response to changes in climatic conditions. The responses to an increase in the soil moisture deficit shown in Figure 9 are consistent with this hypothesis.

A positive innovation to the soil moisture deficit (c) results in an immediate and significant fall in domestic output (y). The trough in real GDP occurs after two quarters. Interestingly, export volumes (x) increase contemporaneously with the climate shock. This may reflect an increase in the slaughter rate by farmers in response to unexpected drier climatic conditions. Eventually exports also decline and the peak decline occurs after three quarters. This may be the consequence of reduced livestock as a result of the initial increase in the slaughter rate. Domestic demand (d) falls, however the trough comes four quarters after the peak decline in GDP.

Domestic prices (pc) increase relative to trend during the first three quarters following the climate shock. This may reflect price responses to shortages in agricultural produce that are sensitive to climate change, such as fruit and vegetables. Although domestic demand initially falls in response to the climate shock, the interest rate (i) rises (not shown). This reflects the reaction to the outlook for inflation. This increase in domestic interest rates, in conjunction with an appreciation in the exchange rate (e) (not shown), leads to a fall in inflation (pc) after the first three quarters.

Figure 9: Responses to climate shock



In general, the impulse response functions generated from the SVAR model produce sensible reactions by variables in the domestic economy block. These impulse response functions are helpful in informing how the economy responds if a particular shock occurs. In Section 5 the model is applied differently by using it to identify what shocks actually occurred over the past two decades and examine what the effects of those shocks were on New Zealand's business cycle.

5 Historical analysis of the contributions to New Zealand business cycles: 1984 to 2002

Impulse response functions are useful for understanding macroeconomic dynamics that eventuate from a particular shock. However, many macroeconomic debates are centred on the causes of the business cycle. A typical example is the debate concerning the contributions of changes in interest rates and exchange rates to the New Zealand business cycle either through their impact on exports or domestic investment and housing demand.

The difficulty in resolving these debates typically concerns the accurate identification of interest rate and exchange rate changes that have occurred over and above the endogenous or automatic process of adjustment that takes place in response to shocks originating from other sources. In the context of this structural VAR model for example, a rise in import prices is associated with a fall in domestic GDP, falling interest rates and an appreciation of the exchange rate. To the extent that the simulation captures the actual New Zealand response to an import price shock, these responses represent the configuration of events that commentators would observe at various points in time during New Zealand's history. However, these observations would not be sufficient to identify whether the observed exchange rate and interest rate changes were having a significant influence on the decline in GDP or whether they were simply endogenous outcomes in response to the common import price shock (or any other shock that generated a similar configuration).

Structural VAR models can be used to help resolve these debates by identifying the relative contributions of different shocks to the business cycle. The purpose of this section of the paper is to use the structural VAR model to identify the relative importance of international and domestic shocks, where domestic shocks include domestic interest rate and domestic climate shocks, to fluctuations in New Zealand GDP around trend during the past 15 years.

The business cycle represented here is the percentage deviation of real GDP from its trend level, which is also known as the growth cycle. Therefore, this part of the paper concentrates on contributions to detrended domestic GDP (y). Following equation (7), the structural VAR can be written in moving average representation to explain the impact of shocks to detrended GDP as follows:

$$y_t = \textit{initial conditions} + \sum_{i=0}^{t-1}\sum_{j=1}^{13}\theta_{ij}u_{j,t-i} \qquad (8)$$

where θ_{ij} is the ith impulse response associated with the jth shock, with 13 shocks in our system.

Figure 10 shows the contributions to detrended GDP (y) arising from foreign output (y^w), foreign interest rates (i^w), foreign equity returns (q^w), import prices (pz^w), export prices (px^w), exchange rates (e), domestic interest rates (i), domestic equity returns (q), domestic demand (d) and climate (c) during the period 1983:1 to 2001:2. Each diagram in Figure 10 shows the contribution to detrended GDP (*y*) from one of the 10 variables listed above. The zero line in each diagram represents the point at which GDP is at trend and it also represents the point where the respective shocks are making a zero contribution to deviations in GDP from trend. For example, if the variable plotted lies above the zero line, it would imply that it had contributed towards moving GDP above trend.

At the beginning of the sample period, initial conditions will contribute a substantial proportion to deviations of real GDP from trend growth. But over time the contributions from initial conditions converge toward zero. Therefore, this analysis applies predominantly to the period since the mid 1980s.

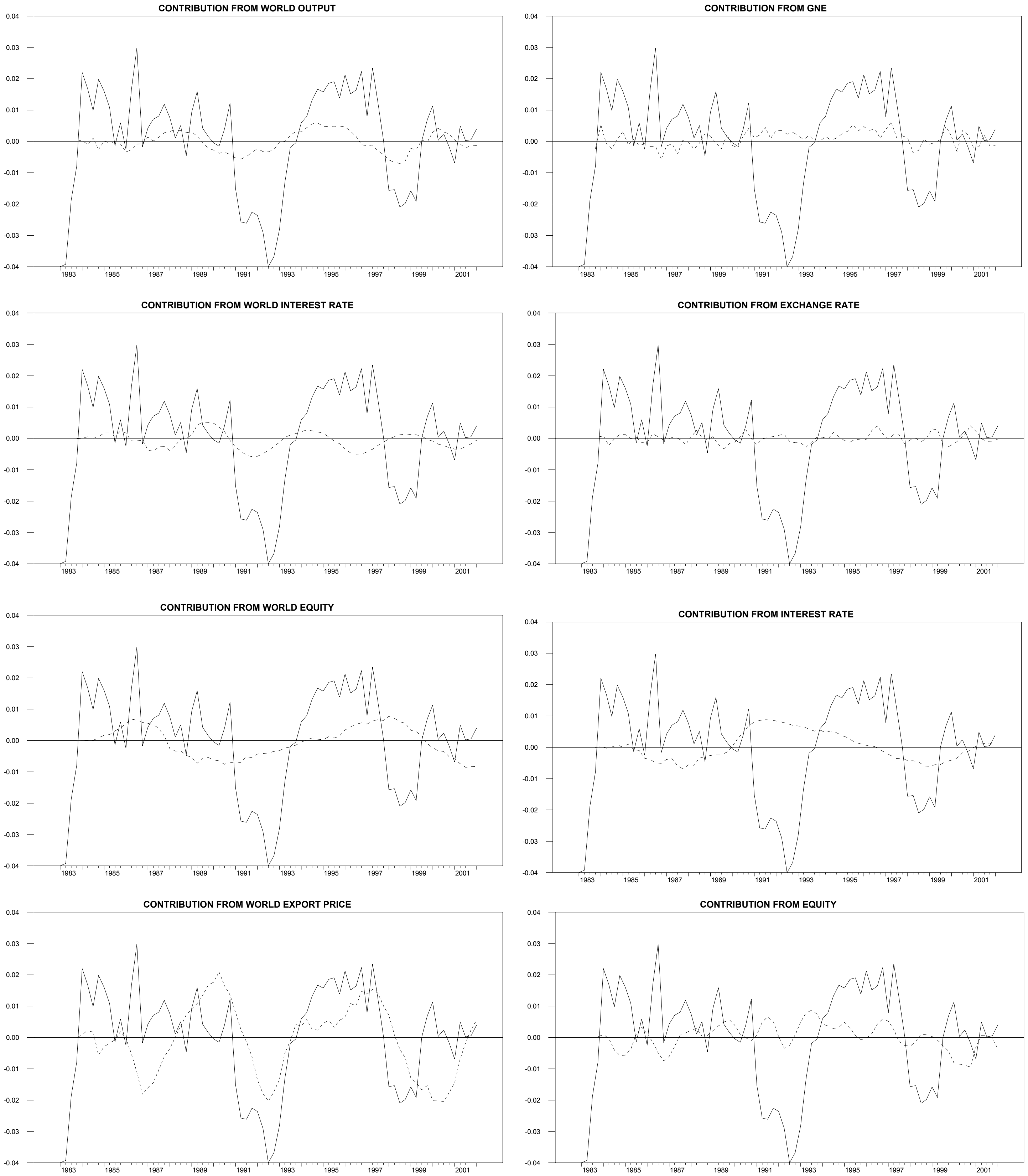
It is apparent from Figure 10 that internationally sourced shocks (that is y^w, i^w, q^w, pz^w, and px^w) in general tend to contribute more to detrended New Zealand GDP fluctuations than shocks that originate from the domestic economy (e, i, q, $d \quad c$).

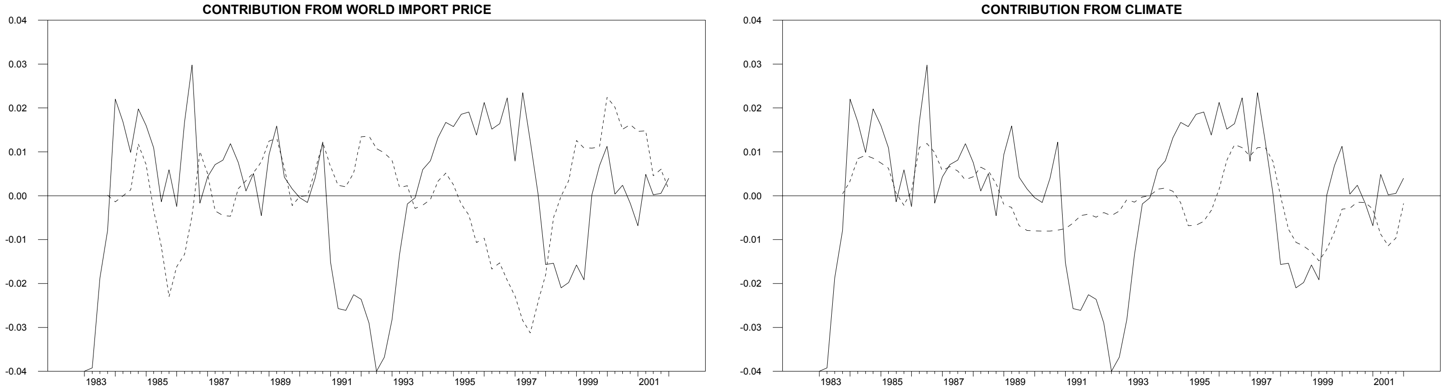
World output, world equity and the world interest rate disturbances have made large contributions to fluctuations in domestic GDP from trend. In general, fluctuations in domestic GDP around trend have been positively correlated with these shocks

Contributions from export and import prices shocks to real GDP fluctuations vary over the sample period, highlighting the importance of separating out the two variables rather than using a portmanteau terms of trade variable. Contributions from export price shocks have tended to have a relatively long cycle, whereas import prices, at least until the mid 1990s, tended to be more volatile.

Figure 10: Contributions to the New Zealand business cycle

International | *Domestic*





Exchange rates contribute very little to the deviations in New Zealand GDP from trend over the sample period. The relatively low importance of shocks from exchange rates is in marked contrast to the attention they receive from economic commentators and highlights the importance of statistical procedures that can identify these contributions.

Shocks from domestic demand and domestic equities have also tended to contribute less to fluctuations in GDP from trend compared to the contribution from foreign shocks. Throughout the 1980s and 1990s contributions from domestic demand shocks have been very small. Domestic equity shocks have tended to have relatively short cycles.

Domestic interest rates have generally been countercyclical. An exception was the 1998 recession when they partially contributed to GDP being below trend. The contribution of domestic interest rates to the 1998 recession was however smaller than the contributions from export prices and climate.

In contrast to interest rates and exchange rates, climate shocks have attracted less interest as sources of expansions and recessions. Climate has also been largely ignored in previous macroeconomic modelling. It is apparent from Figure 10 that in New Zealand climate is an important contributor to the New Zealand business cycle. In particular, climate appears to have been the dominant source of domestic shocks. Climate shocks made significant contributions to the 1991 to 1993 recession and the 1998 recession. Climate also contributed positively to above trend domestic GDP in the mid-1980s and the mid-1990s.

Throughout most of the 1990s, internationally sourced shocks generated a substantial amount of the deviations from trend in New Zealand's GDP. This highlights the importance of international linkages in understanding the evolution of detrended domestic GDP (*y*). The most noticeable period where domestic shocks dominated was in the mid-1980s, between 1995 and 1997, and the 1998 recession. The contribution of climate to the 1998 recession was especially important, as illustrated by Figure 10.

6 Conclusions

The structural VAR model of the New Zealand economy developed in this paper significantly expands on previous VAR models for New Zealand. This new model extends the range of international macroeconomic linkages, captures the impact of climatic conditions, and extends the range of domestic financial variables. The model seems to behave broadly as expected in response to various shocks.

Historical decompositions are used to evaluate the structure of the New Zealand business cycle during the last two decades, and to identify the predominant shocks and their contribution to deviations in New Zealand GDP about its trend. Individually, international variables, notably world output, world equities, world interest rates, import prices and export prices have been dominant influences on the New Zealand business cycle. These results underscore the importance of earlier attempts to evaluate the impact of international price effects on New Zealand real GDP by Wells and Evans (1985) and Conway's (1998) attempt to explore whether international influences had changed since market deregulation in the mid 1980s. The results also provide strong justification for our attempt to expand the international linkages to include, in addition to world prices, world output and several more direct financial linkages.

A novel feature of this structural VAR model is the attempt to capture the effect of changes in domestic climatic conditions. These have been found to be important, particularly in explaining the 1998 recession. The decomposition of contributions to the 1998 recession illustrates the utility of the structural VAR modelling procedure. Contrary to popular belief, the results presented here show that summation of international influences during the 1998 recession would have resulted in New Zealand real GDP being maintained around trend during the so called "Asian crisis". Foreign output movements appear to have contributed to the 1998 recession but that contribution was largely offset by positive foreign equity shocks. A detrimental climate shock was a principal reason for the 1998 recession.

The effects of climate change on the New Zealand economy warrant more attention in public debate and New Zealand macroeconomic modelling. In contrast to the attention received in public debate, shocks to the exchange rate have been a relatively unimportant contributor to New Zealand recessions and expansions during the last two decades. Changes in domestic interest rates also receive considerable attention; yet their contributions to business cycles in New Zealand have been less important than shocks to export prices, import prices and climatic conditions.

There are several directions in which to build on the model developed in this paper. One direction is to use the model to evaluate the impact of monetary policy on the New Zealand business cycle. This is undertaken in a forthcoming paper (Buckle, Kim, and McLellan, 2003). Another direction is to modify the model to evaluate fiscal policy. The analysis of the impact of fiscal policy will require the inclusion of suitable fiscal variables. The identification of the direct and indirect effects of fiscal policy on domestic economic activity represents a difficult challenge but one that would be worthwhile in order to interpret the impact of fiscal policy. A third direction for future development is to evaluate the sectoral implications of international and domestic shocks. There is also the potential to specify the model to include the stochastic trend component of growth and to evaluate the impact of international and domestic shocks on New Zealand's long run growth rate.

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