# Trans-Tasman Transmission of Monetary Shocks: Evidence From a VAR Approach

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**Abstract**

This study investigates the cross-country transmission of monetary shocks, using evidence from Australia and New Zealand. A vector autoregressive model is constructed, using data from 1985:1-2003:4. The empirical results indicate that a contractionary monetary shock in either Australia or New Zealand has real effects in the short-run in both countries, however an Australian shock generates more significant responses of most variables. Australian output is found to be significantly more sensitive than New Zealand output to monetary innovations in either country.

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## 1. Introduction

In the age of burgeoning international trade and globalization, a comprehensive understanding of the interrelatedness of economies is essential for economic policymakers. The effect of monetary policies and activity on both domestic and foreign variables is an issue of fundamental importance in open economy macroeconomics.

Contemporary theoretical predictions are that a contractionary monetary shock will result in an appreciation of the domestic currency, and a decrease in both output and the price level. The price level will be permanently lower if the shock is permanent, whilst all other variables are expected to return to their initial levels over time. Monetary shocks may have cross-country effects if the financial sectors of the two countries are interrelated to some extent. A contractionary innovation is expected to have negative spillover effects for affected foreign countries.

Many previous studies have investigated international linkages and influences, but most focus on one economy and use trade-weighted or US variables to represent exogenous world influences on domestic variables. Some authors such as Koray and McMillin (1999) and Kim (2001) investigate the impact of US shocks on foreign variables, and find some considerable evidence of international transmission. Unfortunately, fewer papers detail the bilateral transmission of monetary shocks between two small open economies such as Australia and New Zealand (NZ). A two-country model could theoretically be expected to yield symmetric responses to monetary shocks for each country.[1] There are, however, a range of reasons why this may not occur for Australia and NZ. Firstly there is the size discrepancy between the two economies, with Australian real GDP being more

[1] Holman and Neumann (2002) investigate the transmission of monetary shocks between the US and Canada, and find that shocks in both countries have significant domestic and foreign effects, and that Canadian innovations often result in responses that are of equivalent magnitude to US shocks.

than six and a half times greater than NZ real GDP in 2003.[2] Also in terms of trade Australia is of significantly greater importance to NZ than NZ is to Australia, in percentage terms.[3] Australia is NZ's largest trading partner, responsible for 21.8% of NZ's exports and 22.2% of NZ's imports in 2003. Whereas NZ was the destination of only 7.4% of Australia's exports, making it Australia's fifth largest market; and was the source of less than 3.9% of Australia's imports.[4]

Previous researchers have suggested a number of channels of international transmission of monetary innovations, including through the world interest rate and through exchange rates and trade balances. Much of the existing literature pertains to the US and other G-7 countries whose monetary policy actions may have the capacity to affect the world interest rate. Australia and NZ, on the other hand, must be regarded as small open economies that have no impact on the world interest rate, although this does not necessarily rule out interest rates as a channel of transmission, as the high level of integration and capital mobility between the two financial sectors allows movements in one country to affect rates of return in the other country at least temporarily. (how?)

Exchange rate movements resulting from monetary policy innovations may also have important effects on trans-Tasman trade, and subsequently on real and nominal variables in both countries. If monetary policy is transmitted internationally, then countries that are more closely tied to each other should display the strongest evidence of such links. Australia and NZ are major trading partners, and also have a long history of close economic, political, and social ties.

There has been minimal research done into the transmission of monetary shocks in either Australia or New Zealand; and to the author's knowledge, there has been no research published regarding the transmission of shocks between the two countries.

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[2] Statistics obtained from the Australian Department of Foreign Affairs and Trade.

[3] In nominal terms the exports from each country to the other are much more similar, but this constitutes a much greater proportion of NZ's total exports than it does Australia's.

[4] Statistics obtained from the Australian Department of Foreign Affairs and Trade.

Using evidence from this region will provide a contribution to existing literature on the topic, and should hopefully also provide an interesting insight into the interrelatedness of the two economies. This is particularly timely as discussion abounds concerning the possibility of future currency union between Australia and NZ. There has also been speculation by some commentators as to the prospect of an eventual political amalgamation. To facilitate informed discussion of such alternatives, there must be a considerable amount of research available considering issues such as the present political and economic interrelatedness of the two countries, and the nature, strength and direction of such processes.

In this study, an empirical investigation is conducted using vector autoregressive (VAR) models to study the effects of monetary shocks in Australia and NZ on macroeconomic variables in both countries. The effects of a contractionary monetary policy innovation on output, the price level, interest rates, and the exchange rate are observed and compared with the findings of existing literature and theoretical predictions.

The remainder of the study is structured as follows: Section 2 investigates the theoretical predictions and empirical evidence of the cross-country transmission of monetary shocks. Section 3 defines the data and methodology used in this investigation. The empirical results for Australia and NZ are presented in Section 4, and tests are conducted in Section 5 to confirm the robustness of these results. Section 6 provides some concluding remarks and suggests some possible extensions and avenues for future research.

## 2. Previous Literature

### 2.1 Theoretical Predictions

There has been considerable debate amongst economists and policy-makers as to the appropriate conduct of monetary policy. Keynesian theories advocate activist monetary policy, which aims to minimise the impact of shocks that hit the economy, and thus stabilise output over the business cycle. Output stabilisation is still a valued result of monetary policy, however its effectiveness as a policy target variable has been widely disputed by monetarists in recent decades. In Milton Friedman's 1968 presidential address to the American Economics Association, he argued that monetary authorities should pursue a constant rate of monetary growth, irrespective of developments in the business cycle. This approach was the evolution of views advocated by the classical school of economics, and was dubbed monetarism. Monetarists argued that significant lags exist in the transmission of monetary policy to real variables, meaning that monetary policy prescriptions based on present business cycle conditions may in fact be counterproductive by the time effects are realised. Monetarism (and especially the classical economics from which such views developed) is based to some extent upon a lack of confidence in the forecasting abilities of governments and monetary authorities; and whilst information availability and econometric forecasting have come a long way since Friedman's speech, pre-emptive Keynesian stabilising monetary policies have proved extremely difficult to successfully implement. The monetarist conclusion that money growth rates should be targeted has also been largely discredited, on the basis that the relationship between monetary base and broader money aggregates has proved to be unstable (Crosby and Milbourne ,1999).

The preferred monetary policy objective of most central banks nowadays is inflation targeting. Keeping inflation low is considered to be the most achievable and effective method of ensuring that monetary policy makes a positive contribution to the long-term growth and stabilisation of output and other important economic indicators. The Reserve Bank of NZ (RBNZ) has been a world leader in terms of inflation targeting, successfully pursuing inflation targeting objectives since 1989 (Buckle, Kim and McLellan, 2003). The Reserve Bank of Australia (RBA) also targets low inflation, and managed to successfully maintain a low rate of inflation throughout the 1990s, whilst the country experienced considerable growth in real output.[5] The RBA also explicitly considers output and unemployment as target variables when conducting monetary policy.

The Lucas (1972) imperfect-information model[6] suggests that economic agents may not have perfect information regarding the price level. Therefore some producers may incorrectly interpret an increase in the aggregate price level as a change in the relative price of their good. In a case of imperfect information such as this, the price level provides a channel through which monetary shocks may affect output. If aggregate price level changes are fully observed, then inflation does not alter the optimal level of production. Hence, under a scenario of perfect information money is neutral, the aggregate price level decreases in response to monetary contraction, but no real variables are affected. If producers, however, view a price increase or decrease as a change in the relative price of their product, then this will cause a change in the optimal level of production. Monetary shocks can therefore cause changes in aggregate output through the inflation or deflation of the price level, if imperfect information exists. Monetary innovations and inflationary developments and expectations are reasonably well publicised in both Australia and NZ, however it would be unrealistic to assume a case of perfect information for any economy, and we may therefore see the effects of imperfect information suggested by the Lucas model.

Monetarism is not the only school of economics that offers opposition to activist monetary policy. Lucas (1972) also presents a rational expectations hypothesis

[5] Between 1992 and 1997 inflation in Australia averaged 2.25% p.a., whilst average growth in real output averaged 3.5% (Crosby and Milbourne, 1999).

[6] This is sometimes referred to as the Lucas-Phelps model as the work of Phelps (1970) contributed significantly to its development.

(associated with a perfect information scenario in the model described above), which posits that economic agents will come to anticipate the inflationary effects of monetary policy innovations. Lucas' model does not actually require perfect information for these predictions to materialize; he was one of a group of young economists in the 1970s that were developing the rational expectations theory of monetary policy transmission. Rational expectations is a slightly more lenient set of assumptions than perfect information, requiring only that optimal forecasts are made based on all available information (as opposed to perfect information or all relevant information, some of which may not be available to the public), and that expectations are correct on average (as opposed to all the time). If these assumptions are met and the rational expectations hypothesis holds, then monetary policy will have no effect on real output or employment, and leads to a monetarist conclusion that any monetary policy attempts to counteract the business cycle will prove ineffective. Monetary innovations under a rational expectations hypothesis can still affect the price level, and thus achieve the Australasian policy goal of keeping inflation low.

Rational expectations theory forms part of the modern classical school of economic thought in regards to monetary policy. Modern classical economists assert that aggregate demand does decrease in response to contractionary monetary policy measures, however economic agents observe interest rate rises and predict the decrease in aggregate demand and the effect that this will have in increasing their real wage. Aggregate supply thus increases immediately; so that output returns to its natural level and monetary shocks have no impact on real variables. Reality does not tend to support the conclusions of rational expectations theory with regard to money neutrality, and in particular the assumption that output is always at its natural level (Spencer and Amos, 1993). Modern classical economists therefore have to extend their basic assumptions, and assert that people learn to anticipate systematic monetary policy. Consequently when authorities conduct monetary policy in a recurring and predictable manner only nominal variables such as the price level are affected. Real variables such as output are affected by unexpected movements, therefore an unanticipated shock still has the potential to affect output within a rational expectations framework.

A range of traditional open economy macroeconomic models including Mundell (1968), Calvo and Rodriguez (1977) and Frenkel and Rodriguez (1982), propose that a permanent contractionary monetary policy shock will result in a decrease in output and the price level, a rise in interest rates, an appreciation of the exchange rate, and a worsening of the trade balance. All variables other than the price level are expected to return to their initial values over time. The price level is expected to be permanently lower if the monetary shock is permanent. While testing these models, Koray and McMillin (1999) find that in response to a contractionary monetary shock, both domestic and foreign output temporarily declines, while there is a temporary appreciation of the real exchange rate. This long-term neutrality of monetary policy can also be seen in more recent models, including Obstfeld and Rogoff (1995, 1996).

A rise in domestic interest rates will lead to a subsequent rise in foreign interest rates. Intuitively, this must be the case if the country in which the shock occurs is a large economy such as the USA, which has the capacity to influence the world interest rate; or if the two countries in the model have open and somewhat integrated financial sectors and a reasonable level of capital mobility. In the case of Australia and NZ the two countries are regarded as small open economies, and are assumed to have a negligible effect on the world interest rate; however they are major trading partners and equivalent financial products in each country may be seen as substitutes. If interest rates rise in one country then capital will flow into that country from the country with lower interest rates. This will quickly cause an interest rate rise in the country experiencing a capital outflow, and an interest rate decline in the country where the monetary shock occurred. Interest rates will adjust until the interest rate differential is eliminated.

## 2.2 Empirical Evidence of the Transmission of Monetary Shocks

The effects of monetary policy have proved very difficult to isolate and model empirically. Early attempts to model relationships between monetary innovations and macroeconomic variables included simply regressing variables of interest on monetary variables.

One of the first attempts to model the effects of monetary policy on output was Andersen and Jordan (1968) who attempted to do so by performing a simple regression of output on money supply and its lagged values. This relationship is known as the St. Louis equation. Investigations using the St. Louis equation have often provided evidence of the expected results i.e. an increase in monetary aggregates leads to a smaller increase in output. However, the St. Louis equation does not control for the mutual causality (endogeneity) between money and output. This simultaneity bias comes from the possibility that monetary authorities may respond in relation to exogenous expansionary or contractionary factors that threaten the stability of variables such as output and inflation.

In light of some of the difficulties faced by initial empirical investigations, vector autoregressive (VAR) modelling techniques have become very popular in the study of monetary shock transmission, after the pioneering work of Sims (1980). A VAR is a system of equations where each variable in the system is regressed on a set of its own lagged values and lagged values of each of the other variables in the model.[7] This allows researchers to control for the endogeneity problem that plagued earlier research. VARs have been successful in allowing economists to gain greater insight into the responses of a range of variables to monetary shocks, and allow researchers to trace the transmission channels of shocks through the economy, and to obtain some quantitative insights into the magnitude and timing of responses.

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[7] See Romer (2001). It should be noted that this description is of a VAR in its simplest form. Many authors use long-run restrictions or structural VAR models, which impose greater restrictions on the equations in the system.

case for Australia and NZ also). Extensions to the research involve experimenting with altered orderings, although the results are found to be essentially identical. Koray and McMillin (1999) find that in response to a contractionary monetary policy shock, US output, foreign output, the US price level, and the foreign price level all decrease. The exchange rate appreciates immediately in response to a negative shock, but eventually returns to its initial level as predicted. This appreciation of the exchange rate is correlated with an initial improvement in the trade balance, followed by a strong deterioration, in line with the *J*-curve hypothesis.

Kim (2001) also uses a VAR model to investigate the transmission of US monetary shocks to non-US G-6 countries. This is done by utilising recursive schemes using a Choleski decomposition, as well as non-recursive schemes, and adding foreign variables one by one to the models of the US domestic system. Two VAR systems are used to investigate the domestic effects of monetary policy shocks; a four-variable VAR using the federal funds rate as a measure of monetary policy, and a five-variable VAR that also includes the ratio of non-borrowed reserves to total reserves. Real GDP, the implicit price deflator, and commodity prices are assumed to be contemporaneously exogenous to monetary policy instruments, and are thus ordered first. In the extended specification the reserves ratio is ordered before the federal funds rate, and is treated as the monetary shock variable. In response to an expansionary monetary shock, US output increases temporarily, prices increase over time, the monetary aggregate increases on impact, and the federal funds rate decreases on impact.

The system is then extended to examine the effects of US monetary policy shocks on foreign variables. Kim (2001) employs two different VARs to investigate the effects of shocks on firstly the trade balance, and secondly foreign output. There is some disagreement as to whether monetary policy affects these international variables contemporaneously or not,[8] and so Kim (2001) experiments with both a

[8] See Christiano, Eichenbaum and Evans (1998) for details.

contemporaneous effect of monetary policy and no contemporaneous effect of policy. In response to an expansionary shock, the trade balance worsens within a year, then starts to improve, becomes positive in about one to one and a half years, and further improves later. The peak improvement is found in two to four years. The trade balance returns to its initial level in about six years. Cushman and Zha (1997) and Betts and Devereux (2000a) found similar trade balance dynamics for Canada, and US versus non-US G-7 countries, respectively. Further investigation of the impulse responses of exports and imports reveals that the short-run decrease of the trade balance is driven by a significant short-run increase in imports, but that the long-run trade balance improvement is due to an increase in exports. Kim (2001) investigates the response of other trade-related variables to expansionary monetary shocks, and finds that the nominal exchange rate depreciates about 0.4-0.5% on impact, and returns to the initial level in three to four years. Terms of Trade do not increase on impact, but becomes positive about six months after the shock, with the peak increase found one year after the shock. In general these results are consistent with the Mundell-Flemming-Dornbusch model.

To test the predictions of the intertemporal model, Kim investigates the responses of aggregate consumption, saving, investment, and the real interest rate. In response to monetary expansion, consumption, saving and investment increase, but the real interest rate decreases. Kim (2001) concludes that the basic intertemporal model without investment/production opportunities cannot fully explain the short-run current account dynamics identified, and the model must be constructed with explicit production/investment opportunities. The author also examines the role of US monetary policy shocks in explaining the volatility of trade-related variables. Monetary policy shocks are found to explain between three and nine percent of fluctuations in trade balance, exports, and TOT at the peak, while they explain between fourteen and twenty-six percent of fluctuations in imports at the peak.

The effects of US monetary policy shocks on foreign output are investigated by looking at non-US G-6 countries. In most cases, expansionary shocks lead to increases in real GDP and industrial production in the foreign countries concerned. The increase in output in non-US G-6 countries is found to be 25-50% of the increase in US output. US monetary shocks explain 4.0-4.3% of foreign GDP and 6.4-6.7% of foreign IP at the peak. Kim (2001) investigates whether the trade balance is the primary channel of international monetary transmission, as suggested by the basic Mundell-Flemming-Dornbusch model. In general the trade balance of non-US G-6 countries does not change much, even though output increases significantly in response to US monetary policy shocks. The predictions of the Mundell-Flemming-Dornbusch model do not seem to be consistent with the empirical evidence, and the trade balance does not appear to be the major international monetary transmission mechanism. The intertemporal model suggests another channel of international spillover effects of monetary policy, through changes in the world interest rate (due to changes in the US real interest rate and the integrated nature of the world capital market). Kim (2001) details the mechanisms by which an expansionary monetary shock should affect the world interest rate in a way that leads to an increase in both consumption and investment in both the US and non-US countries, and finds that this does indeed occur, and that results are consistent with intertemporal model predictions of international monetary transmission through the world capital market.

A number of extensions are conducted to test the robustness of results. The experiments are replicated using monthly data (to cater for any possible restrictiveness of the three-month delays in non-contemporaneous effects implied by quarterly data investigation). The results are found to match those established with quarterly data. In initial experiments each international variable is added on its own. Nevertheless, it may be better to test the responses of international variables by considering interactions with other international variables. Variables are therefore added two at a time (in pairs that are expected to interact with each other e.g. foreign interest rate and nominal exchange rate), and similar results are found to the previous one-variable systems.

Holman and Neumann (2002) use a two-country VAR system with Choleski decomposition, similar to the method employed in this study, to analyze the transmission of monetary shocks between the US and Canada. Whilst many other studies have investigated the impact of US shocks on foreign variables, Holman and Neumann (2002) give equal attention to the effects of shocks in each country. However, unlike this paper, the authors acknowledge the likely influence of the larger US economy, and each US variable is ordered before its Canadian counterpart. Their analysis uses quarterly data, and covers the period from 1963 to 1996, and thus employs a dummy variable to cater for differences between the Bretton Woods and floating exchange rate periods.

The effect of monetary shocks on consumption, investment, employment, output, the nominal exchange rate and the trade balance, is investigated. Separating output into its capital and labour components makes this paper unique from most other studies, which employ an aggregate output variable. Real M2 is employed as the monetary variable of investigation.

Cointegration is found between the variables in the empirical model, so a VAR in levels is used. Holman and Neumann (2002) consider two separate specifications. One includes the following variables for each country: real M2, real investment, an employment index, real consumption, the nominal exchange rate, the real trade balance, and a flexible exchange rate dummy. The other uses real GDP in place of the investment and employment variables. It is assumed that monetary policy does not respond contemporaneously to changes in other variables, and money supply is thus ordered first.

Variance Decompositions show that US monetary innovations explain a large amount of the variation in domestic output (about one-third) and consumption (about twenty percent). US shocks also make a significant contribution to the variation of Canadian output (about ten percent) and consumption (about twenty percent).

Previous literature has suggested that non-US monetary shocks are unlikely to have significant effects on other countries, and thus focus only on the transmission of monetary shocks from the US (Kim, 2001). Holman and Neumann (2002), however, find that Canadian monetary disturbances affect real variables in both Canada and the US, often to the same magnitude as US shocks. Canadian monetary shocks explain about ten percent of both Canadian output and consumption. It is also found that Canadian innovations play a significant role in explaining the variation of both US employment and investment. Canadian shocks actually have a greater impact on US investment than US shocks do, and US employment and investment react more strongly to Canadian shocks than the equivalent Canadian variables. Although when real GDP replaces the capital and labour components of output, the effect of Canadian shocks on US output declines to less than that of US shocks.

It is worth noting that Holman and Neumann (2002) find that the trade balance is the primary mechanism of transmission between the US and Canada, as opposed to the exchange rate. This is in contrast to the findings of some other authors. Canadian monetary innovations have a much more significant impact on the nominal exchange rate than US shocks do.

Impulse Response Functions reveal results that are consistent with the results of other empirical findings. An expansionary US monetary shock causes an initial increase in US output and consumption, an increase in monetary aggregates, and a depreciation of the US dollar. Canadian output and consumption also increase following a US monetary shock. A Canadian monetary shock results in impacts that are equivalent in direction, if not always in extent, including a depreciation of the Canadian dollar after the first quarter. Holman and Neumann (2002) conclude that both US and Canadian monetary shocks tend to have expansionary impacts on both the domestic economy and the economy of the trading partner, in the short run. Over a longer time horizon there is some evidence of contractionary behaviour in both countries.

The Choleski decomposition provides a convenient method by which to construct a VAR model with minimum identifying restrictions. It allows for the investigation of a significant number of interactions in a system with a recursive structure. However some authors contend that economic processes can be more accurately modelled with VARs that impose greater restrictions upon the structural equations within the system (Sims, 1986; Romer, 2001). This has led to the development of advanced VAR modelling techniques that employ nonrecursive structures and allow the imposition of greater theoretical constructs upon models.

The Choleski decomposition imposes restrictions on the contemporaneous relations of variables, on the basis of the causal ordering employed. Another approach utilised in the VAR literature is to impose restrictions on the long-run relationships between the variables. McMillin (2001) investigates the effects of monetary policy shocks using a variety of both contemporaneous and long-run restrictions schemes. The model employed is that used by Christiano et al. (1994, 1996, 1998) and Bernanke and Milhov (1998), which includes output, the price level, commodity prices, total reserves, nonborrowed reserves, and the federal funds rate. The model is estimated using monthly data from 1962 to 1996.

Within contemporaneous restriction models McMillin (2001) employs four alternative identification schemes. Three use Choleski decomposition and differ on the basis of ordering, the fourth combines Choleski decomposition and a limited structural component that relates to the reserves market. In three of these specifications nonborrowed reserves are the shocked monetary variable, in one of the recursive schemes the policy variable employed is the federal funds rate. Regardless of the policy measure under investigation, all six variables are included in each VAR system.

The alternative to contemporaneous restrictions which McMillin (2001) employs, is to identify monetary policy shocks by imposing restrictions on long-run relations amongst the variables in the model. No contemporaneous restrictions are placed on the system. Price no longer enters the model independently, but is included in the log of real commodity prices. Nonborrowed reserves are selected as the policy variable. Unit roots are imposed on all variables, thus producing a model in first differences, which allows the system to measure the long-run effects of monetary shocks on the variables. Neutrality restrictions are imposed on the model by placing real variables prior to the monetary variable in the ordering. The restrictions are that shocks to monetary policy have no long-run effects on output, real commodity prices, or interest rates.

The empirical results suggest that the shape of the response functions for each variable is very similar under the five alternative models, however there is definite variation in the magnitude and persistence of effects. Following an expansionary shock to nonborrowed reserves, output increases in a hump-shaped pattern, and eventually returns to its initial value in four of the five models. The price level increases steadily over the four-year horizon and remains permanently inflated. The federal funds rate falls initially, before returning quickly to its initial level in most models. In one of the contemporaneously restricted models with nonborrowed reserves as the policy measure however, the federal funds rate rises significantly above zero after eight months and stays there for the rest of the forecast period.

To compare the variation in the results of restrictions based on contemporaneous and long-run relations, the author plots one standard deviation confidence bands of the long-run restrictions model on the point estimates of the other four models. This reveals that the results of the contemporaneous restrictions models generally lie within the long-run model's confidence bands with regards to output and the price level, but differ significantly with regards to the federal funds rate in some cases.

McMillin (2001) investigates adding a long-term interest rate to the model. In the long-run specification money is assumed to have no long-run effect on long-term interest rates. In all models the long-term interest rate is found to fall immediately following a monetary policy shock. For the models using contemporaneous restrictions the interest rate quickly returns to its initial level, and in all but one instance it stays there for the rest of the forecast horizon. In contrast the long-run modelling approach reveals a very long decline in the long-term interest rate following a monetary policy shock. It is concluded that in many ways the alternative identification schemes produce similar results, but that the long-run restrictions model (and some of the contemporaneous restrictions models) has some undesirable features. The main distinction of the results of the long-run restrictions scheme from the other models, is that the results for the federal funds rate appear to be very sensitive to the addition of a long-term interest rate, and that a monetary shock has a very sustained effect on the long-term interest rate.

Another VAR approach that has gained popularity in the investigation of monetary shocks is the use of structural VAR models that can be used to impose a range of restrictions on the relations between variables in the model. Structural VAR models allow nonrecursive contemporaneous interaction between variables, and give economists the power to specify which variables appear in the structural equations of other variables within the model.

Kim and Roubini (2000) use structural VAR modelling to investigate the effects of monetary policy shocks, and in particular try to develop an approach that provides a solution to a range of anomalies that previous researchers have found in monetary shocks investigations. The anomalies they investigate include 'liquidity', 'price', 'exchange rate', and 'forward discount bias' puzzles. These puzzles arise when results of a particular variable in response to a monetary shock defy conventional wisdom, whilst other variables within the system respond as expected. It is thought that these anomalies can often be traced back to some form of modelling shortcoming. A particularly common phenomenon in monetary policy models is that of the price puzzle, which occurs when an increase in interest rates is associated with the anticipated decrease in the money supply and output, whilst the price level is found to increase as opposed to decrease. Sims (1992) argued that the price puzzle might reflect the fact that interest rate innovations reflect inflationary pressures that lead to price increases. Sims and Zha (1995) propose that the price puzzle can be addressed by including variables proxying for inflation in structural VAR models with contemporaneous restrictions.[9] An index of sensitive commodity prices or inflationary expectations has been included in many unrestricted VAR models, and has succeeded in combating price puzzles; however Kim and Roubini (2001) believe that structural VAR modelling is a more effective method by which to prevent such anomalies.

The authors develop a structural VAR model that includes short-term interest rates, a monetary aggregate (M0 or M1), the consumer price index, industrial production, the world price of oil, the federal funds rate, and the exchange rate. This system is used to model the effects of non-US G-7 monetary policy shocks. The federal funds rate is included to control for the assumption that a component of domestic monetary policy in non-US countries is a response to US monetary policy developments.[10] The contemporaneous restrictions imposed by Kim and Roubini (2001) are influenced by Sims and Zha (1995), and differ quite substantially from some other papers. One point of interest is that monetary authorities are assumed to respond contemporaneously to developments in the money supply, the exchange rate, and the world price of oil, but only with a lag to movements in output, the price level, and the US federal funds rate. The model is estimated with monthly data for the period 1974:7-1992:12.

Contractionary shocks are applied to short-term interest rates in six countries.[11] No considerable evidence is found of any of the anomalies that have plagued earlier studies of the transmission of monetary shocks. Results for the six countries differ in terms of the magnitude and persistence of responses, however most results are qualitatively similar and consistent with theoretical predictions. A contractionary shock leads to an immediate rise in interest rates and contraction of the money

[9] Sims and Zha (1995) and Grilli and Roubini (1995) also suggest that this methodology may also succeed in combating the exchange rate and liquidity puzzles.

[10] Grilli and Roubini (1995) find evidence that the monetary policy of other G-7 countries follows that of the US.

[11] United Kingdom, France, Italy, Canada, Germany, and Japan.

supply, the price level eventually declines in all countries but with varying degrees of persistence, and output falls significantly for five of the six countries and eventually returns to its initial level.[12] The authors pay particular attention to the response of the exchange rate. In all six cases the result of a monetary contraction is a statistically significant appreciation of the domestic currency relative to the US dollar. Over time all exchange rates return to the initial levels.[13] It is interesting to observe that the federal funds rate is significantly affected by monetary shocks in some non-US G-7 countries, particularly Germany and Japan. The authors experiment with a recursive structure and find several puzzles in all countries. This leads them to conclude that a nonrecursive structure is very important to avoid incorrect responses to monetary innovations.

Structural VAR models have been used to model economic disturbances, including monetary shocks, for both Australia and NZ, and are discussed in more detail in the following section.

## 2.3 Empirical Evidence for Australia and New Zealand

To the author's knowledge there are no studies using VARs to investigate the cross-country transmission of monetary shocks between Australia and New Zealand. The VAR methodology has however been used by some authors to model elements of the economies in question.

Dungey and Pagan (2000) develop an eleven variable structural VAR for the Australian economy, using quarterly data from the period 1980 to 1998. This model includes a monetary policy component, and contains both foreign and domestic variables. However the emphasis is on modelling the Australian economy, and so the effects of Australian monetary shocks on foreign variables are not investigated. The variables included in their model are foreign output, terms of trade, foreign real

[12] Output also falls for Italy, but this is never statistically significant.
[13] The Yen is actually found to depreciate with statistical significance by the end of the four-year forecast horizon.

interest rates, exports, real foreign asset prices, real domestic asset prices, domestic aggregate demand, domestic output, inflation, a monetary policy instrument, and the real exchange rate. The monetary variable studied is the cash rate. US data was used to proxy the required foreign variables. The cash rate is ordered second to last of the eleven variables, and thus affects only itself and the exchange rate (as represented by the trade-weighted index) contemporaneously. It is also included in the equations of domestic asset prices, domestic demand, and domestic output, with a lag. However only lags subsequent to the first lag of the cash rate appear in the demand and output specifications. The authors claim that foreign variables do not influence the cash rate directly; however they indirectly affect monetary policy through their impact on domestic variables or the exchange rate. The cash rate is thus specified as a function of contemporaneous levels of gross national expenditure and inflation, as well as lagged effects of these two variables; the cash rate itself, and the exchange rate. The authors suggest that the RBA considers the degree of competitiveness of the Australian economy when setting the cash rate, and cater for this by including the exchange rate in the equation of the monetary variable. However they believe that it is unlikely that contemporaneous movements of the exchange rate would be significant, and it is therefore not included contemporaneously, but is with three lags.

One characteristic that makes this paper distinct from some of the other literature is the inclusion of both real Australian gross national expenditure and real Australian GDP, to represent domestic aggregate demand and domestic output respectively.

Some interesting observations are made about the Australian cash rate series for the period under investigation. Firstly, between the March and June quarters of 1985 the cash rate jumped by 300 basis points, which is a much larger movement than any other one-period change in the series. The authors identify the primary reason for this as being extreme volatility in the daily cash rate at this time, although the increase was largely maintained over subsequent quarters, suggesting that there may have been some tightening of policy. A second atypical result is observed in the third quarter of 1986, which the authors attribute to the flow-on effects of former Treasurer Paul Keating's infamous 'banana republic' statement. Dummy variables are added to the regressions to account for these fluctuations. These dummy variables are important as the two observations have a substantial effect on the magnitude and possibly even the sign of coefficients of responses to monetary shocks. Prior to the addition of dummy variables, the cash rate, as well as foreign asset prices and inflation, fail normality tests. The causes of this non-normality for the cash rate and real asset prices are identified as the large cash rate variability in 1985, and the 1987 stock market crash. Inserting dummy variables for 1985Q2 and 1987Q3 eliminates the non-normality for all variables except inflation. The cause of inflation non-normality proves difficult to identify and eliminate.

Once the systems have been developed to model the Australian economy, the effects of five shocks are investigated. Dungey and Pagan (2000) examine a U.S. GDP shock, a Terms of Trade shock, a shock to U.S. equity prices, an aggregate demand shock, and a monetary shock. The monetary shock in this case is an unanticipated increase in the domestic cash rate. One standard deviation shocks are applied to the variables of interest. A one standard deviation shock to the cash rate is quantified as a 1.4% p.a. increase. The effects of the monetary shock are much as expected, with a decrease in real domestic activity and inflation. It is interesting to note that the impact on expenditure is much greater than that on GDP, which reflects the fact that some of the reduced demand is absorbed by a decline in imports. The exchange rate appreciates following a monetary shock, and this appreciation is sustained for the first four quarters. This is followed by a two period depreciation, which interrupts the fall in the rate of inflation, after which the earlier pattern of declining real activity and inflation, and exchange rate appreciation resumes.

Dungey and Pagan (2000) investigate the impact of monetary policy on output by modelling GDP over the period without a monetary policy effect, and comparing this to the observed GDP. It is important to note that the authors assert that the effects of monetary policy cannot be captured completely by the effects of the cash rate shock. Movements in other variables may have indirect effects on other domestic variables through the reaction of the cash rate, and these indirect effects need to be added on to the direct effects of cash rate shocks to fully measure the impact of monetary policy. Their analysis suggests that monetary policy in Australia has performed in a counter-cyclical fashion, working to increase output during contractions and reduce it during expansions. The effects of monetary policy on GDP are not large, however it is concluded that monetary policy performs a stabilizing function, returning GDP to trend more quickly, and decreasing the variance around the trend line. However since monetary policy is found to take two quarters to impact on output, the Australian economy is usually well into a recession before policy moves to offset it, unless the recession is predicted sufficiently far in advance. As a final investigation Dungey and Pagan (2000) investigate the effects on the growth cycle identified by their VAR systems, if certain shocks are ignored. They find that the suppression of foreign influences makes a very significant difference to the amplitude of Australian recessions and expansions. This demonstrates that foreign variables are of considerable importance to the dynamics of the open Australian economy.

Buckle, Kim, Kirkham, McLellan and Sharma (2002) develop a structural VAR model of the New Zealand economy. Their objective was to identify the major shocks that had influenced the New Zealand economy over the last two decades, and investigate the contribution of these shocks to expansions and recessions in economic growth. Quarterly data from 1983:1 to 2002:1 is used. The variables included in the model are separated into four 'blocks'. The procedure of blocks of several structural equations has been used by other authors in structural VAR literature, including Dungey and Pagan (2000) and Cushman and Zha (1997) in their investigations of Australia and Canada respectively. In both of those studies variables are separated into blocks representing the international and domestic economies. Domestic variables are completely absent from structural equations in the international block, based on the assumption that the countries in question are small open economies. Buckle et al. (2002) extend this to also include an international trading prices block, and a domestic climate block. Dependant variables in the two domestic blocks are not included in the international blocks. The trade prices variables are also absent from the international economy block. The domestic climate block is of course not affected by any other variables, but it appears in the domestic economic block, as do all international variables. The international economy block includes measures of foreign real output (represented by trade-weighted industrial production), foreign nominal interest rates (a weighted average of Australian, United States, United Kingdom, Japanese and German 90-day interest rates), and foreign real asset returns (the Morgan Stanley World Capital Index of gross equity returns deflated by an index of US consumer prices). The international trading prices block consists of the foreign currency prices of NZ exports and imports. These are included separately from each other, due to the different commodity make-up of NZ exports and imports. The authors believe that it is important to use this separation, as opposed to an aggregated measure such as the trade balance. The domestic variables included are real aggregate demand (real gross national expenditure), real aggregate output (real GDP), real exports, the nominal exchange rate, interest rates, real asset returns (NZSE40 gross return index deflated by the NZ CPI), and consumer prices (CPI). Climatic conditions are represented by a measure of soil moisture.

In accordance with much of the existing literature surrounding the use of structural VAR to model economies, Buckle et al. (2002) focus on identifying the shocks that cause the NZ economy to temporarily deviate from its long-run growth path. Eight different types of shocks are investigated – foreign output, foreign interest rate, foreign equity, export price, import price, domestic interest rate, domestic equity, and climate shocks. The authors leave the explicit investigation of monetary shocks for a later study; however the effects of monetary policy are in many ways captured by the domestic interest rate shocks investigated. Buckle et al. (2002) follow recent research in assuming that Reserve Bank monetary behaviour is forward-looking, following a Taylor-type reaction function (Taylor, 1993). The monetary authority is thought to react to forecasts of inflation and demand three quarters in the future. In the interest rate equation the inflation and demand variables are therefore replaced by three-quarter-ahead forecasts. It was found that this methodology produced more meaningful responses to interest rate shocks than with the contemporaneous values. In response to a foreign interest rate shock, domestic interest rates increase immediately, returning to initial levels after five quarters. Increased domestic interest rates lead to lower demand for domestic equities. These two factors combined cause an eventual decrease in domestic demand, which is sustained over the response investigation period. A world interest rate shock also has deflationary effects on both import and export prices, which results in a fall in domestic output that it is significant for eleven quarters. A domestic interest rate shock results in an immediate decline in domestic equity returns, an appreciation of the exchange rate, a fall in both consumer price inflation and domestic output, and domestic demand increases for eleven quarters.

Buckle et al. (2002) investigate the relative contributions of different shocks to the NZ business cycle; by looking at ten of their original variables and the effects that each has had in causing GDP to deviate from its trend. They found that international variables have a significant influence on the New Zealand business cycle. Foreign variables have a greater explanatory power than domestic variables, as to the fluctuations of real GDP around its trend. Foreign output, equity, and interest rates, have all made large contributions to GDP fluctuations over the period under investigation. In general these fluctuations have been positively correlated with shocks. Shocks to domestic variables have contributed relatively little to deviations of GDP from trend. Interestingly it is climate, which has received little attention in economic literature as a source of NZ economic expansion and recession, which is found to be the dominant source of domestic shocks. Adverse climatic conditions were found to be the primary reason for the 1998 recession. This recessionary period is typically attributed to the "Asian crisis", however Buckle et al. (2002) find that international movements during this period did not cause GDP to deviate from its trend.

The structural VAR model of the NZ economy developed by Buckle et al. (2002) is used by Buckle, Kim and McLellan (2003) to evaluate the impact of monetary policy on NZ business cycles and inflation variability since the introduction of formal inflation targeting in 1989. Monetary policy is identified by a forward-looking Taylor rule. In the Buckle et al. (2002) model 90-day interest rates are used as a proxy for a monetary policy variable. This 90-day rate does not strictly measure monetary policy as it is not directly controlled by the Reserve Bank, however it does reflect the impacts of monetary policy, along with the influences of private expectations and shifts in portfolio decisions. The structural equation of the domestic interest rate contains contemporaneous and lagged values of the world interest rate, and three-quarter-ahead forecasts of the deviations from trend of logged real domestic demand and logged domestic prices.

A shock to monetary policy (through the domestic interest rate) is predetermined by the authors' structural equation specifications as having a contemporaneous effect on the exchange rate and domestic asset returns, and a lagged effect on these variables and also real domestic demand. A one standard deviation shock to the domestic interest rate is an increase of approximately 120 basis points above trend. It is interesting to note that this analysis does not encounter two of the puzzles described by Kim and Roubini (2000) in response to a positive interest rate shock. Kim and Roubini (2000) discuss a price puzzle, where the price level rises following an interest rate shock, whereas Buckle et al. (2002) observe a decline in consumer prices. The NZ study is also attractive in that it doesn't suffer from an exchange rate puzzle, where an interest rate shock is followed by a depreciation of the exchange rate, as opposed to the more logical appreciation seen in the Buckle et al. (2002) study.

The Buckle et al. (2002) paper reveals that domestic interest rate shocks, along with all domestic financial conditions, have not had an overly significant impact on NZ business cycles. The Buckle et al. (2003) companion paper delves further into attempting to capture fully the impacts of monetary policy. To achieve this the authors follow a methodology employed by Dungey and Pagan (2000), which includes computing detrended domestic GDP when the monetary authority's reaction function (which includes responses to deviations of domestic demand and prices from trend) is suppressed. This process is used to identify the induced effects of monetary policy, which are then added to the direct effects identified within the interest rate shocks, to gain a monetary policy index which measures how much monetary policy is adding to or subtracting from detrended GDP at each point in time. Monetary policy has generally been counter-cyclical, reducing business cycles and inflation variability. At times such as the recession of the early 1990s monetary policy played a significant role in moderating the depth of deviations from trend. Although there have been exceptions; for example monetary policy accentuated the business cycle upswing in 1994 and 1995, and had a small accentuation effect on the 1998 recession.

Buckle et al. (2003) also use the monetary policy index to investigate the effects of monetary policy on inflation variability in NZ. Prior to the introduction of formal inflation targeting the impact of monetary policy was inconsistent, with periods in which monetary policy was accentuating inflation variability, and other periods in which it was working to moderate it. However after the introduction of formal inflation targeting in 1989 the prevailing impact of monetary policy was to reduce the inflation variability resulting from other shocks. During the initial years of inflation targeting monetary policy in NZ, monetary policy was successful in reducing the variability of both inflation and output. However from 1996 to 2001 monetary policy was less effective in this regard. The authors identify a number of factors that possibly contributed to the reduction in effectiveness, including the brief adoption of the Monetary Conditions Index, the Asian crisis, and adverse domestic climatic conditions.

The relationship between output variability and inflation variability in NZ is also examined. This investigation is based upon the assumption that the monetary authority's objective is to minimize a weighted sum of the deviations of inflation and output from their target values. It is found that during the period prior to the advent of formal inflation targeting, NZ monetary policy was predominantly increasing inflation variability, whilst reducing the variability of output. After the introduction of inflation targeting this pattern changed. From 1990 to 1995 monetary policy usually depressed inflation variability by a small amount. During this period there was a much greater range of observations in regards to the impacts on output variability, with the most common occurrence being for monetary policy to reduce the variability of GDP. The findings of Buckle et al. (2003) during this period are consistent with those of other studies (Fischer and Orr, 1994; Hutchison and Walsh, 1998) that provide empirical evidence of enhanced monetary policy credibility during the early years of formal inflation targeting in NZ. Monetary policy was found to successfully reduce inflation variability, without any significant adverse impacts on output variability. The inflation and output variability findings are not as impressive after 1995. From 1996 to 2001 monetary policy predominantly increased output variability, whilst having little significant impact on inflation variability. The authors suggest a number of possible explanations for the reduced effectiveness of monetary policy in the late 90s; including the Reserve Bank's use of the Monetary Conditions Index, two large climate shocks the impact of which may have been difficult for policymakers to interpret, and the fact that inflation and output variability resulting from other sources was lower in this period, thus limiting the scope for monetary policy to limit variability.

## 3. Data and Methodology

### 3.1 Data

The data used in this analysis are obtained from a number of sources. GDP and CPI for each country are obtained from the IMF International Financial Statistics database. The data for the NZ overnight interbank cash rate and the exchange rate are obtained from the Reserve Bank of New Zealand. The Australian cash rate is obtained from Data Stream. Table 1 provides a complete list of the variables, definitions and sources of data used in this analysis.

The model contains the following variables for both Australia and New Zealand: Output (Y, measured by real gross domestic product), the price level (P, measured the consumer price index), and interest rates (R). Also included in the model is the nominal exchange rate (E), which is given as Australian dollars per NZ dollar. For Australia the interest rate variable employed is the official cash rate. In NZ the cash rate is also an official instrument of monetary policy, however this variable is not available for the full sample period as New Zealand only began employing an official cash rate in 1999. The overnight interbank cash rate is therefore used as a proxy of this variable.

The data consist of quarterly observations for the period 1985:1-2003:4. The selection of this period for analysis was motivated partly by data availability; and also by the fact that this is the period for which both Australia and NZ have been operating under a flexible exchange rate regime.[14] It would be entirely possible to conduct this analysis with data from the fixed exchange rate years, and it would be interesting to observe the discrepancies (and similarities) between the fixed and floating exchange rate periods. However to justify the necessary altered theoretical interpretation for the fixed exchange rate period, one would need data for a significant number of years for which Australia and NZ operated under fixed

[14] The Australian dollar was floated in 1983. NZ followed suit in 1984.

exchange rate regimes. This data was not available, and so to include a small number of years prior to the introduction of floating exchange rates, could stand to compromise the validity of results for what is an investigation of the transmission of monetary shocks for two countries with open economies and floating exchange rates. Conway (1998) also observes that NZ macroeconomic variables show significantly more evidence of being affected by international linkages when data sets include only data from after the extensive deregulation of 1984.

**Table 1. Definition and Data Source for the Variables Used**

| Variable | Definition | Data Source |
|---|---|---|
| Aus GDP | Australian Real Gross Domestic Product | IMF IFS |
| Aus CPI | Australian Consumer Price Index | IMF IFS |
| NZ GDP | NZ Real Gross Domestic Product | IMF IFS |
| NZ CPI | NZ Consumer Price Index | IMF IFS |
| Aus OCR | Australian Official Cash Rate | Data Stream |
| NZ Interbank Rate | NZ Overnight Interbank Cash Rate | RBNZ |
| Exchange Rate | Australian Dollars per NZ Dollar | RBNZ |

### 3.2 Methodology

To investigate the response of macroeconomic variables to monetary policy innovations, and the cross-country transmission of these shocks, VARs are employed. Following existing literature on the use of VARs to model monetary shocks (Eichenbaum & Evans, 1995; Koray & McMillin, 1999), logarithms were taken for all data other than the interest rate variables.

The lag length was selected by conducting a range of lag length selection tests, including Akaike Information Criterion, Schwarz Information Criterion and Likelihood Ratio tests. The optimal lag length was found to be three. A lag length of three is fairly typical for Australasian VAR studies. For example, Dungey and

Pagan (2000) and Buckle et al. (2002) estimate structural VAR models with three lags for all variables, for Australia and NZ respectively. Conway (1998) chooses a lag length of four, for his structural VAR investigation into NZ macroeconomic variability. As a robustness check the models are re-estimated in section 5.2 with a lag length of four.

Monetary shocks are identified using a Choleski decomposition of the variance-covariance matrix. Choleski decomposition is a popular method in the investigation of monetary shocks. The monetary policy variable employed in this study is the official cash rate for Australia, and the overnight interbank rate for NZ. It can be difficult to isolate the effects of monetary policy as the policy variables under investigation are subject to numerous exogenous influences. Previous authors have investigated either a monetary aggregate, and/or a centrally determined interest rate measure such as the federal funds rate or official cash rate. Holman and Neumann (2002) use M2 as a monetary policy variable for the US and Canada. The difficulty with using a broad monetary aggregate to measure monetary policy innovations is that movements in such variables can be caused by both money supply and money demand shocks. Other authors have therefore used variables over which the central bank has greater control. US-based studies such as Strongin (1995), Koray and McMillin (1999), and Kim (2001) all consider non-borrowed reserves as a policy variable.[15] Interest rate variables are also commonly investigated tools of monetary policy. Koray and McMillin (1999), Christiano et al. (1998), and Kim (2001) also consider shocks to the federal funds rate. Bernanke and Blinder (1992) propose that the federal funds rate is the most appropriate measure of monetary policy given that the Federal Reserve has generally let the money stock fluctuate in response to shifts in money demand; however Eichenbaum (1992) claims that nonborrowed reserves are preferable. Christiano et al. (1998) test the federal funds rate and nonborrowed reserves, as well as M2, and find that all work adequately and equally well as representations of monetary innovations. Other papers that consider several policy measures report only very minor discrepancies in the results.

[15] Strongin (1995) and Kim (2001) use the ratio of non-borrowed reserves to total reserves.

For Australia Dungey and Pagan (2000) consider a monetary shock by investigating official cash rate innovations, as is done in this paper. As mentioned earlier an official cash rate series for NZ is only available from 1999, so proxy variables must be employed. Buckle et al. (2003) investigate monetary shocks in NZ by giving a shock to the 90-day interest rate. Whilst this is seen as a good surrogate for the official cash rate, it is influenced significantly by exogenous factors such as private expectations. For that reason in this paper I employ the overnight interbank interest rate as the monetary variable. Like any available instruments it alone does not provide a complete measure of monetary policy, however it is seen as an appropriate estimation as it is strongly determined by the actions of the Reserve Bank.

The Choleski decomposition imposes a recursive structure on the contemporaneous interaction of the variables. This methodology involves identifying restrictions resulting from the ordering of the variables. Variables higher in the ordering are assumed to have a contemporaneous effect on variables lower in the ordering, whilst all variables may affect those higher in the ordering with a lag. Results may be sensitive to the ordering employed. In this paper Australian and NZ monetary shocks are analysed separately, however variables from both countries are included in each model.

Two Wold causal orderings are investigated for each country. In the first specification the ordering is Y, P, Y*, P*, R, R*, E, where Y*, P*, and R* represent the foreign variables. Specification I follows assumptions made by a range of past studies of monetary transmission, including Eichenbaum and Evans (1995), Christiano et al. (1996), Koray and McMillin (1999), and Kim (2001). Domestic output and price level, and foreign output and price level, are ordered before the monetary variables, implying that monetary innovations affect these variables only with a lag, and also that the Reserve Bank may react to current period movements in output and prices both at home and across the Tasman. R* and E are ordered after the monetary variable being shocked, implying that monetary policy actions may have contemporaneous effects on these variables, and that the Reserve Bank responds to changes in foreign interest rates and the exchange rate only with a lag. It may appear contradictory to suggest that R can affect R* contemporaneously, whilst R* can only affect R with a lag, but that is one of the restrictions faced by VAR modelling, and can be addressed by alternate specifications for each country's monetary shock within a two-country open economy model. This is one of the reasons why it is preferable to investigate Australian and NZ monetary shocks separately, and to give causal priority to the monetary variable under investigation. The other alternative would be to take the approach used by Holman and Neumann (2002) when modelling the US and Canadian economies, and always place the variables of the larger economy (in this case Australia) first. This approach was tried with respect to the interest rate variables, and the results are discussed shortly. Eichenbaum and Evans (1995) place R* before the monetary policy variable, implying that US monetary actions have no contemporaneous effect on foreign interest rates. Koray and McMillin (1999) suggest that this is a questionable assumption, and I choose to place the domestic cash rate before foreign interest rates due to the integratedness of the Australian and NZ financial markets. The placement of monetary variables in the ordering is a contentious issue in studies of the transmission of monetary shocks. The exchange rate on the other hand is typically placed at the end of the ordering, as it contemporaneously reacts to changes in all other variables. It is also assumed that the Reserve Bank will only respond to sustained developments in foreign exchange markets, and the exchange rate thus has only a lagged impact on the monetary variables. Dungey and Pagan (2000) suggest that the exchange rate does impact on the cash rate as the Reserve Bank considers the degree of international competitiveness of the Australian dollar when determining monetary policy. However they believe that there is no contemporaneous causality from the exchange rate to the cash rate, so it is included in the structural VAR equation only with a lag of three periods.

For a NZ monetary shock I also experimented with ordering R after R* (leaving the rest of the ordering unchanged). This alteration acknowledges that the Australian financial market is likely to have a more pervasive and immediate impact on NZ interest rates, than NZ does on Australian interest rates. The cash rate in the larger Australian market is now contemporaneously exogenous to NZ monetary innovations, whereas NZ interest rates have the potential to respond to movements in Australian financial markets without a lag. The results with this ordering were effectively no different to the previous ordering where R was placed before R*, with only the Australian Cash Rate being affected by the change. R* reacts more strongly to a NZ monetary shock when it is ordered before R. Only the first ordering of specification I is discussed in the empirical results section, however the results of the alternative ordering are reported as a robustness check in section 5.1.

The second specification used is R, R*, Y, P, Y*, P*, E. This approach places the monetary variables at the beginning of the ordering, which allows monetary shocks to have a contemporaneous effect on all variables in the model. This ordering may have some validity as it reflects the fact that the Reserve Banks of both Australia and NZ conduct reviews of the official cash rate periodically,[16] and monetary policy variables may thus only react to changes in other variables with a lag. This approach is similar to that of Lastrapes and Koray (1990), Joyce and Kamas (1994), and Holman and Neumann (2002), all of whom place the monetary variables first. However in those papers a money supply variable is employed, as opposed to interest rates.

In the following section the response of both domestic and foreign output, the price level, interest rates, and the exchange rate, to monetary policy shocks are analysed by computing and plotting impulse response functions (IRFs). IRFs are widely used in VAR literature, and are valuable as they allow us to trace the time path of shocks on the other variables in the model. We compute the effects of a one standard deviation shock to the cash rate / overnight interbank rate. This shock is an increase in R, and can be seen as a contractionary monetary policy initiative. As is commonplace in VAR modelling, sixty eight percent confidence intervals have been

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[16] The Board of the Reserve Bank of Australia meets monthly to discuss alterations to the target cash rate (Crosby and Milbourne, 1999). In NZ the Reserve Bank makes Official Cash Rate announcements eight times per annum (RBNZ).

estimated for the IRFs and included on IRF diagrams in the following section as an indication of significance. These confidence bands are obtained from a 10,000 draw Monte Carlo simulation.

## 4. Empirical Results

The Impulse Response Functions (IRFs) in the following section display the response of the specified variable to a one standard deviation monetary shock for either Australia or New Zealand. The forecast horizon displayed is sixteen quarters. The solid line represents the estimated response of the variable, whilst the dashed lines represent one standard error confidence bounds around the point estimates.

### 4.1 Australian Monetary Shock

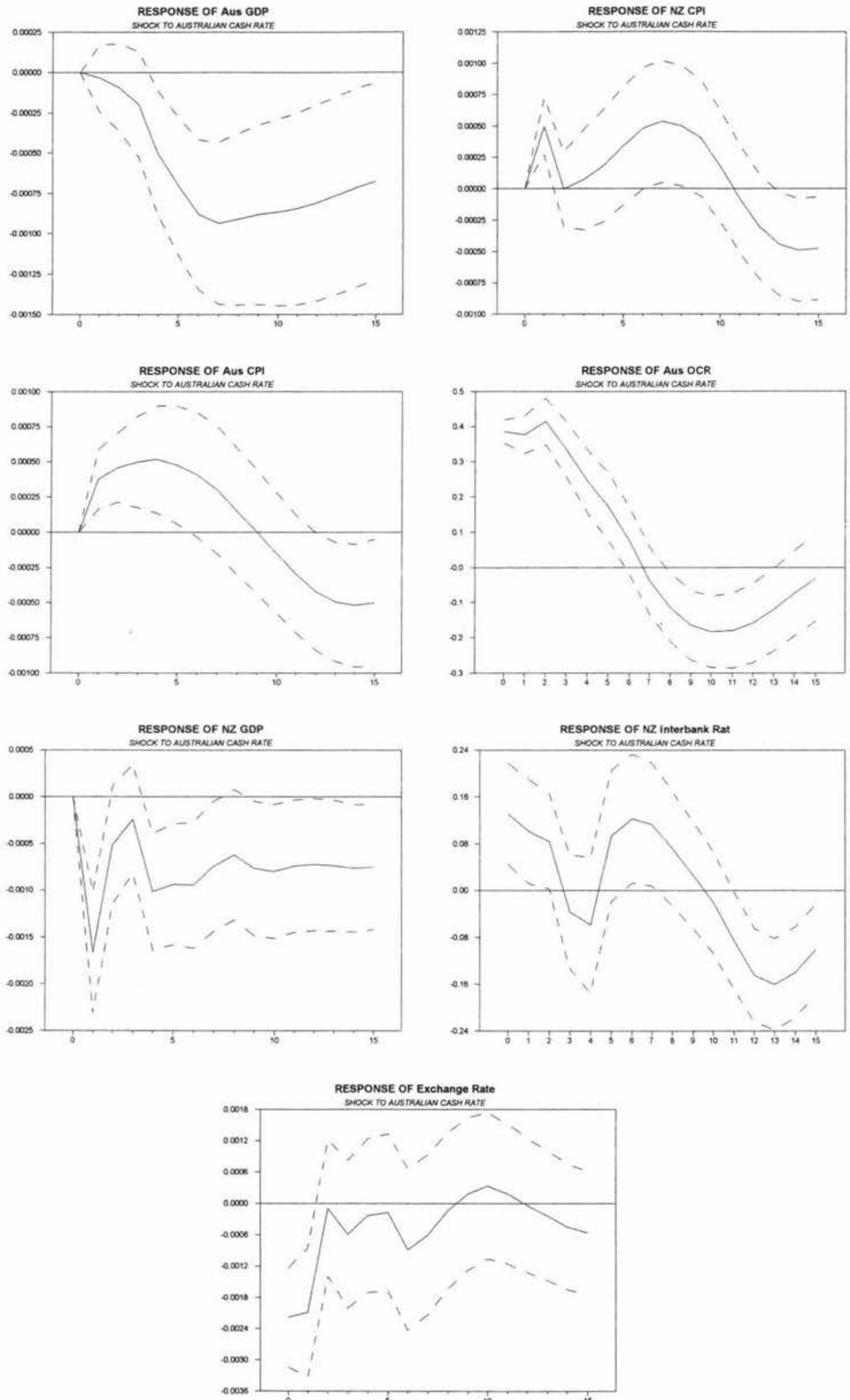
#### 4.1.1 Specification I

A one standard deviation shock is given to the Australian cash rate under the ordering Y, Y*, P, P*, R, R*, E. This specification, in which the output and price variables are contemporaneously exogenous to monetary innovations, is similar to most existing models of the transmission of monetary shocks. Figure 1 shows the IRFs for all variables in the model, in response to an Australian monetary shock.

**Response of Australian Cash Rate**

A positive shock is applied to the Australian cash rate (R). This can be interpreted as a contractionary measure by the Reserve Bank. The IRF shown in figure 1 reveals that this is a temporary shock, as the cash rate returns to its initial level after seven quarters. As expected the shock results in a considerable initial increase, with R actually peaking after two quarters. After this there is a steady decline and the confidence band spans zero by the sixth quarter. R continues to decline below its initial level, and this decline is significant between the eighth and thirteenth quarters. R reaches its lowest point ten quarters after the shock, and then begins to increase so that the confidence band spans zero again by the end of the forecast horizon.

# Figure 1. Impulse Responses to Australian Monetary Shock – Specification I



Worthy of note, Koray and McMillin (1999) observe similar qualitative results for the US federal funds rate when it is used as the monetary variable, in terms of a sharp initial increase and an eventual return to the initial level.

**Response of NZ Overnight Interbank Rate**

Figure 1 shows the response of the NZ Overnight Interbank Rate (R*) to an Australian cash rate shock. As expected R* increases immediately in response to an Australian monetary shock. This emphasises that the financial markets of the two countries are integrated to some extent. Australian financial opportunities are seen as substitutes to NZ financial products, and NZ interest rates must therefore rise in response to the increased rate of return on foreign investments. Given that the financial sectors of the two countries are open and competitive, an increase in R may also increase the demand for loanable funds in NZ, as NZ interest rates will be lower than Australian interest rates following an Australian monetary shock. However in these highly responsive open financial markets, increased demand will cause R* to rise very quickly. Unlike Australian interest rates, the NZ interest rate begins to decline immediately after the initial reaction to the shock. The confidence band spans zero after three quarters, and the estimated response function drops below the initial level of R* for the third and fourth quarters. Beyond this R* begins to rise and is above its initial level with more than 68% probability in the sixth and seventh quarters. In the long run R* experiences a decrease to significantly below its initial level, and the confidence band does not span zero again over the forecast horizon.

Koray and McMillin (1999) observe that a contractionary shock to the US federal funds rate causes foreign interest rates to increase immediately, and then to gradually decrease over the forecast horizon, eventually declining to significantly below the initial level. They find that the response of R* is similar to that of R, although not as strong.

**Response of Exchange Rate**

In response to a contractionary Australian monetary shock the exchange rate (E) experiences a sharp appreciation, before returning to its initial level relatively quickly. Remembering that the exchange rate variable under investigation is reported as Australian dollars per NZ dollar, the impulse response in figure 1 which shows E contemporaneously falling significantly below its initial level, represents an appreciation of the Australian dollar versus the NZ dollar. This is not a surprising result, as higher interest rates resulting from the monetary shock will lead to an inflow of capital to Australia from countries with lower interest rates. This results in increased demand for Australian dollars and thus an appreciation of the Australian dollar. The appreciation is clearly temporary, as E has almost returned to its initial level two quarters after the shock, and the confidence band spans zero for the rest of the forecast period. This is consistent with the previous literature, which repeatedly found temporary appreciations. For instance, Koray and McMillin (1999) find that the US exchange rate appreciates for seven quarters after a monetary shock, after which point the confidence band spans zero. Kim (2001) investigates an expansionary shock and finds that the US exchange rate depreciates on impact, and returns to its initial level within three or four years[17]

**Response of Australian Output**

Real GDP (Y) decreases in response to a contractionary Australian monetary shock. The upper limit of the 68% confidence band drops below zero after four quarters, and remains below zero for the entire forecast horizon. Output reaches its trough seven quarters after the monetary shock. Beyond this point Y begins to increase, but after four years the impulse response is still well below its initial level. This is surprising given the temporary nature of the monetary shock, and the short-lived appreciation of the exchange rate. Whilst the prolonged duration of the output

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[17] Eichenbaum and Evans (1995) on the other hand observe a persistent exchange rate appreciation over the forecast horizon.

decrease may be a slight surprise, the decrease itself is not. A contractionary monetary shock affects output through numerous channels. The most significant channel of monetary shock transmission to output is through investment (Crosby and Milbourne, 1999). Higher interest rates increase the opportunity cost of investment, which leads to a decrease in investment, therefore depressing aggregate demand. Lower aggregate demand leads to a reduction in output. Aggregate demand also suffers from a decrease in consumption. Higher interest rates make current goods more expensive in terms of future goods, thus discouraging consumption.

The shock to R also influences Y through the exchange rate appreciation that can be observed in figure 1. An appreciation of the Australian dollar makes imports cheaper in terms of domestic currency, and also makes Australian exports less competitive. Exports will suffer, and this will be reflected in reduced national income and output.

Dungey and Pagan (2000) also find that Australian GDP decreases in response to a contractionary cash rate innovation. However they find that the decrease ceases to be significant after ten quarters, and eventually GDP actually rises above its initial value, although this increase is never statistically significant. Koray and McMillin (1999) find that US industrial production declines in a similar fashion to Australian GDP following a monetary shock, however they find that the decrease is only significant for just over two years.

**Response of Australian Price Level**

Following an Australian cash rate shock the domestic price level (P) in figure 1 is seen to rise immediately. The 68% confidence band remains above zero for six quarters, and P reaches its peak in the fourth quarter after the shock. After ten quarters the point estimate of P drops below its initial level and continues to decrease over the remainder of the forecast horizon. This deflation is significant beyond the twelfth quarter.

This is an unexpected result as theoretical predictions are that the price level will experience a decline following a contractionary monetary innovation. Whilst theory suggests that P should decrease following a positive shock to R, price puzzles such as the one seen here are not unheard of in the VAR literature. A price puzzle exists where other variables (such as output) respond as expected following a contractionary shock to interest rates, whilst the price level defies expectations and increases. Koray & McMillin (1999) observe some evidence of a price puzzle when commodity prices fail to fall below zero for more than two quarters after a federal funds rate shock. But after this they find that P decreases as expected for approximately three years, before eventually increasing above its initial level. Kim & Roubini (2000) investigate a number of 'puzzles' that have plagued empirical investigations into the transmission of monetary policy, including price puzzles. Sims (1992) proposes that a prize puzzle may result from the fact that contractionary monetary policy innovations and price level increases can both result in part from inflationary pressures. Sims and Zha (1995) contend that structural VAR models can be used to address and overcome the price puzzle under the inflationary pressures explanation, by including contemporaneous restrictions that include variables that proxy expected inflation. Koray and McMillin (1999) and Christiano et al. (1996) use a similar technique by including additional price variables in unrestricted VAR models.[18]

It is interesting to note that Dungey & Pagan (2000) do not encounter any price puzzle in response to a shock to the Australian cash rate in their structural VAR model. They discover that the rate of inflation falls in response to a monetary shock, however this fall is not significant until the ninth quarter after the shock, and

[18] Koray and McMillin (1999) include an index of sensitive commodity prices), whilst Eichenbaum et al. (1996) include a proxy of inflationary expectations.

eventually the rate of inflation returns to its initial level. They also find that the response of inflation lags that of output.

**Response of NZ Output**

NZ real GDP (Y*) falls sharply in response to an Australian monetary shock. For the first quarter following the shock to R, Y* reacts much more strongly than Y. Whilst the decline in Y is persistent throughout the four year observation period, the confidence band of Y* spans zero after only two quarters. After almost returning to its initial level in the third quarter, the response function of Y* decreases again, and stays below its initial level throughout the forecast horizon, however this is usually only with borderline significance. It is evident that a contractionary Australian monetary shock causes a reduction in NZ output, however this is not as significant as the impact on Australian output.

The reasons for the decline in Y* are much the same as the reasons for the decline in Y. NZ interest rates rise following a monetary shock across the Tasman, leading to reduced investment and consumption, and therefore reduced output.

Buckle et al. (2002) briefly investigate the effects on NZ macroeconomic variables of a positive (contractionary) shock to the world interest rate. This is immediately translated into higher NZ interest rates, and for the reasons previously discussed aggregate demand is reduced and NZ output falls, and this decline is statistically significant between five and ten quarters after the initial shock.

Koray and McMillin (1999) find that Y* reacts to a contractionary monetary innovation in a qualitatively similar manner to Y, although the response of Y* is not as strong. Kim (2001) finds that an expansionary US monetary shock results in significant increases in both GDP and industrial production in non-US G-6 countries. Kim (2001) finds that the increases in Y* are about 25-50% as large as the increases in Y.

**Response of NZ Price Level**

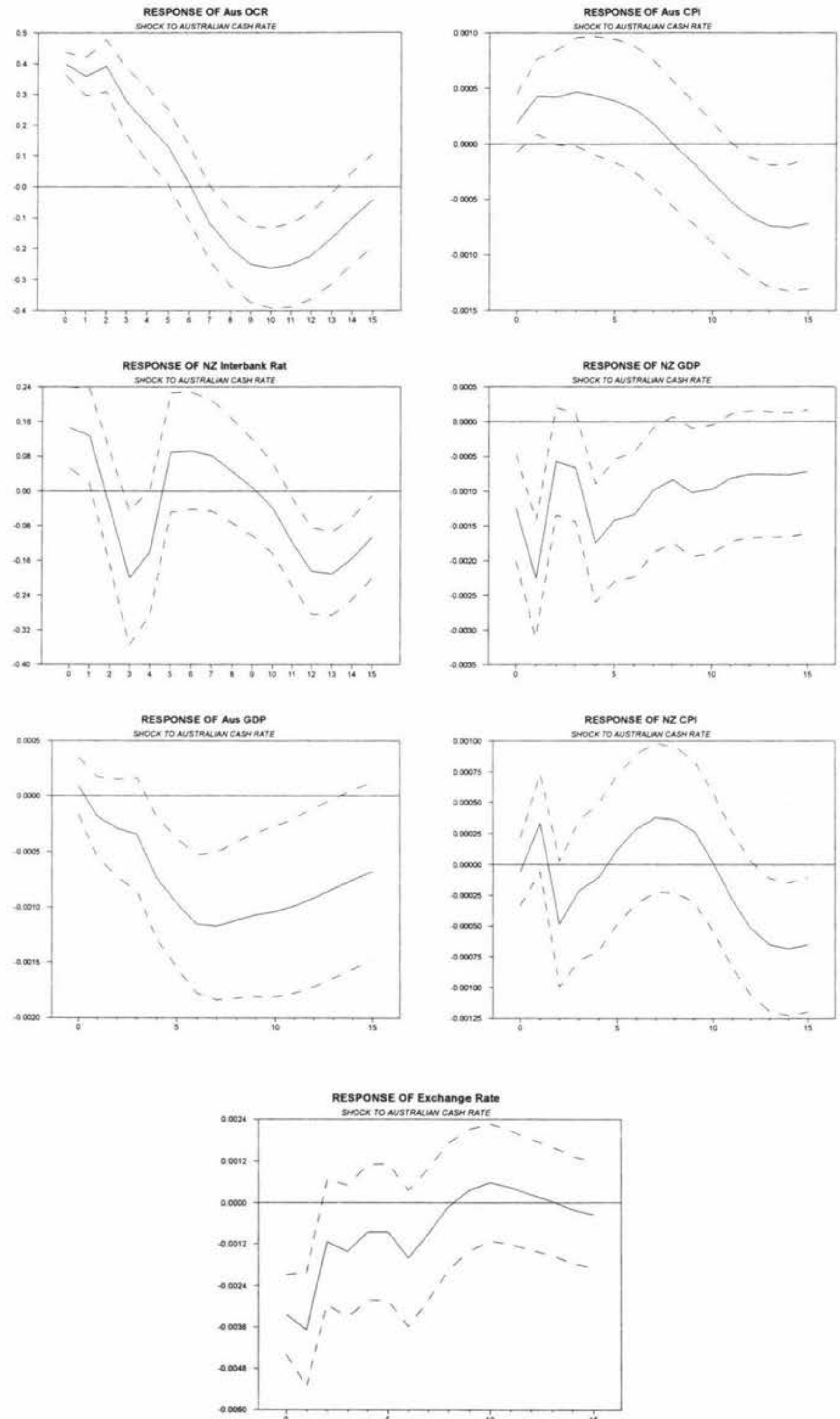
The NZ price level (P*) also displays a price puzzle following an Australian monetary shock. P* increases sharply in the first quarter following the shock, however after two quarters P* has returned to its initial level. Beyond the second quarter P* remains above its initial value for nine quarters, and this increase is significant for the seventh and eighth quarters. After the initial variation in the first two quarters following the shock, the response of P* seems to model that of P, except with a lag.

### 4.1.2. Specification II

A one standard deviation shock is given to the Australian cash rate under the ordering R, R*, Y, Y*, P, P*, E. The significant difference between specification II and specification I is that specification II allows monetary shocks to have an immediate effect on all variables in the system. This methodology is not common in unrestricted VAR models, however it is worth investigating given that the Reserve Banks of both Australia and NZ only consider official cash rate alterations periodically, and thus may not react contemporaneously to movements in any other variable. In creating structural VAR models of monetary shocks, Sims and Zha (1995) and Kim and Roubini (2000) argue that informational delays mean that monetary authorities cannot respond contemporaneously to output and price level developments, which was facilitated by the ordering in specification I. Holman and Neumann (2002) use the Choleski decomposition for a two-country model, and place their monetary variables at the beginning of the ordering. Figure 2 shows the IRFs for all variables in the model, in response to a contemporaneously exogenous Australian monetary shock.

Figure 2 shows that the responses of all variables under specification II are qualitatively very similar to specification I. Minor developments observed after the change of ordering include NZ interest rates becoming significantly negative three

# Figure 2. Impulse Responses to Australian Monetary Shock – Specification II



quarters after the shock, with the lower confidence band never rising above zero after this point. Price puzzles are still observed for both countries, however these are less pronounced, with the Australian price level only rising above its initial level with more than 68% probability for one quarter, and the confidence band for the response of the NZ price level spanning zero for the entire forecast horizon apart from the final three quarters which see the anticipated decrease in P*. The response of the exchange rate is the same in terms of shape, but increases in magnitude.

Now that the output variables are allowed to react contemporaneously to the monetary shock it is interesting to note the difference in the shapes of the response functions of Y and Y*. Following an Australian monetary shock, NZ GDP reacts significantly and experiences its greatest deviation from zero after only one quarter. The decrease in Australian GDP on the other hand does not become significant until the fourth quarter, and reaches its trough after seven quarters, by which point the confidence band of NZ GDP is close to spanning zero for the second time.

## 4.2 NZ Monetary Shock

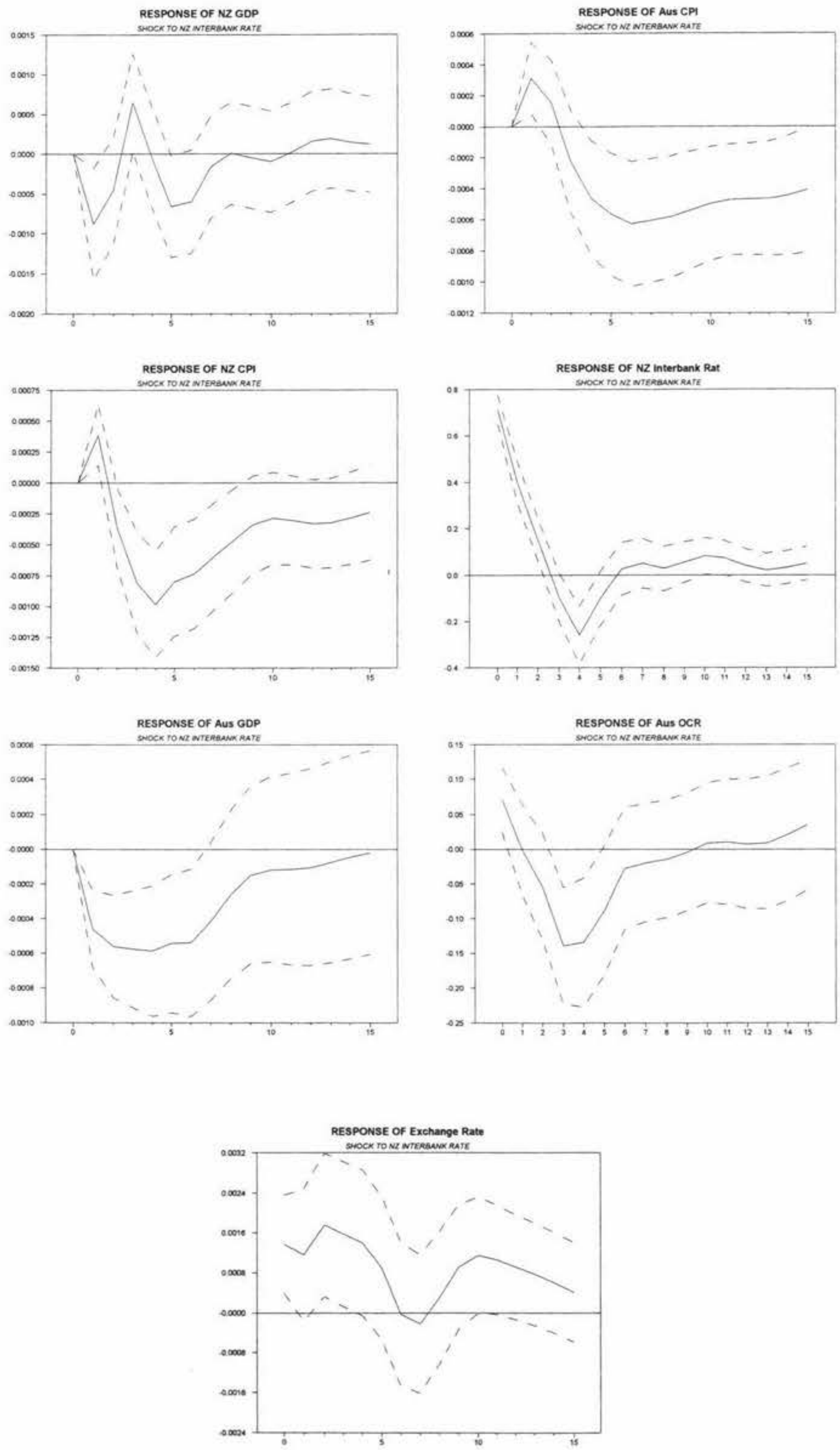
### 4.2.1. Specification I

A one standard deviation shock is given to the NZ overnight interbank rate under the ordering Y, Y*, P, P*, R, R*, E. Figure 3 shows the IRFs for all variables in the model, in response to a NZ monetary shock.

#### Response of NZ Overnight Interbank Rate

A positive shock is applied to the NZ overnight interbank interest rate (R). This represents a contractionary monetary policy action by the Reserve Bank. After the significant rise in R resulting from the initial shock, the response function decreases quite rapidly and drops below the initial level of R by the third quarter after the shock. This sharp decline in R confirms the temporary nature of the shock, and is a

## Figure 3. Impulse Responses to NZ Monetary Shock – Specification I



quicker response than was observed for the Australian cash rate when it was the shock variable under investigation. R drops significantly below its initial level four quarters after the shock, and then quickly returns to hover around its initial level for the rest of the forecast horizon.

**Response of Australian Cash Rate**

In response to a NZ monetary shock the Australian cash rate (R*) rises above its initial level, however this contemporaneous increase is no longer significant one quarter after the shock. The most significant response of R* to a contractionary NZ monetary shock is to decrease from its initial level between one and nine quarters after the initial shock. This decrease is significant in the third and fourth quarters. Beyond this point the confidence band spans zero and R* returns to its initial level. Figure 3 confirms that the interest rates of NZ and Australia seem to move together very closely. This suggests substitutability of financial instruments in both countries, and may also reflect monetary authorities responding in a similar manner to the exogenous effects of the monetary shock. It is interesting to observe that R* does not respond very strongly to the initial increase in R, however a decrease in R seems to incite a much more significant decrease in R* (relative to the original increase).

**Response of Exchange Rate**

The exchange rate (E) appreciates in response to a contractionary monetary shock. This is to be expected as higher interest rates in NZ attract foreign investment and drive up the price of the NZ dollar on foreign exchange markets. However this appreciation of E is only significant with more than 68% probability immediately following the shock, and again in the second and third quarters. The confidence band spans zero for most of the forecast horizon, however the point estimate only decreases to its initial level temporarily in the sixth and seventh quarters. It does however appear that the value of the NZ dollar is returning to its initial level by the end of the estimation period as predicted. There is a small contrast between the behaviour of the exchange rate in response to an Australian monetary shock and a NZ monetary shock, with an Australian shock causing a somewhat sharper immediate appreciation (of the domestic currency) followed by a quick depreciation back to its initial level.

Buckle et al. (2002) find that the NZ exchange rate appreciates immediately following a monetary shock, however the strongest reaction is after four quarters. E does not return to its initial level over the seven year forecast horizon, but the confidence band spans zero after nine quarters.

**Response of NZ Output**

The response of NZ output (Y) to a contractionary monetary shock is not particularly strong. Y decreases as expected following the shock, however the confidence band spans zero two quarters after the shock and only drops below once more with borderline significance in the fifth quarter. The response function of NZ GDP is the same shape following a NZ monetary shock as it is following an Australian shock, however the IRFs suggest that the response is more significant after an Australian monetary contraction.

Buckle et al. (2002) find that NZ GDP decreases significantly in response to a contractionary interest rates shock, however the greatest impact is not observed immediately, but after almost three years. Buckle et al. (2003) find that there is only a weak channel of transmission from domestic interest rates to aggregate demand, however the exchange rate and tradeables sector are found to play a more significant role in transmitting interest rate changes to domestic output and prices.

**Response of NZ Price Level**

The IRF of the NZ price level (P) following a NZ monetary shock shows a price puzzle for the first quarter, as pervaded the results of both countries following an Australian shock. However unlike the results following an Australian shock, which showed price puzzles lasting two to three years, P here drops below its initial level by the second quarter after the shock. The decrease in P is significant between the second and eighth quarters, and reaches its trough one year after the shock. After two years the confidence band spans zero and P appears to be returning towards its initial level.

Buckle et al. (2002) find that the CPI starts to decrease almost immediately following a contractionary interest rate shock, and that the trough occurs over eighteen months after the shock. The price level slowly returns to its initial level and it appears that the impact of the shock is not permanent.

**Response of Australian Output**

Australian output (Y*) decreases sharply following a NZ monetary shock. The greatest response is observed after four quarters, and the decrease is significant with more than 68% probability for six quarters following the shock. Y* reaches its initial level by the end of the four year forecast horizon. Theoretical predictions were that Y* would decrease in response to a NZ monetary shock, however the strength of the shock is somewhat surprising given that R* only increases for one quarter and then exhibits a significant decrease. Australian output does not respond by as much in response to a NZ monetary shock as it does in response to an Australian shock, but the significance of the decrease in figure 3 adds further evidence of the sensitivity of Australian output to interest rate movements in the short-run.

For the US and Canada, Holman and Neumann (2002) find that US monetary shocks have a significant impact on domestic output and borderline significance for Canadian output. Canadian monetary innovations have a lesser impact on both variables.

There is little precedent for the effects of the NZ cash rate (or overnight interbank rate) on foreign variables in broad macroeconomic models. Buckle et al. (2002) place block exogeneity restrictions on their structural VAR model, which prevents domestic variables from affecting foreign variables. As a small economy NZ has a negligible effect on the world interest rate, and it is entirely possible that Australia is the only sizable economy that would produce significant observable responses to NZ monetary innovations. It is therefore satisfying to see that a NZ monetary shock produces significant deviations in Australian real and nominal macroeconomic variables.

**Response of Australian Price Level**

In response to a contractionary NZ monetary shock the Australian price level (P*) displays a price puzzle lasting more than two quarters, then decreases to below its initial level for the rest of the forecast horizon, reaching its lowest point six quarters after the shock.

Dungey and Pagan (2000) do not investigate a foreign interest rate shock in their model of the Australian economy. Holman and Neumann (2002) do not include a price variable in their two-country VAR. However Kim and Roubini (2000) find that the price level decreases in all non-US G-6 countries following a contractionary shock to the US federal funds rate. This fall is persistent in most countries.[19]

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[19] However when the world oil price was removed from the model a price puzzle was found for Italy.

**4.2.2. Specification II**

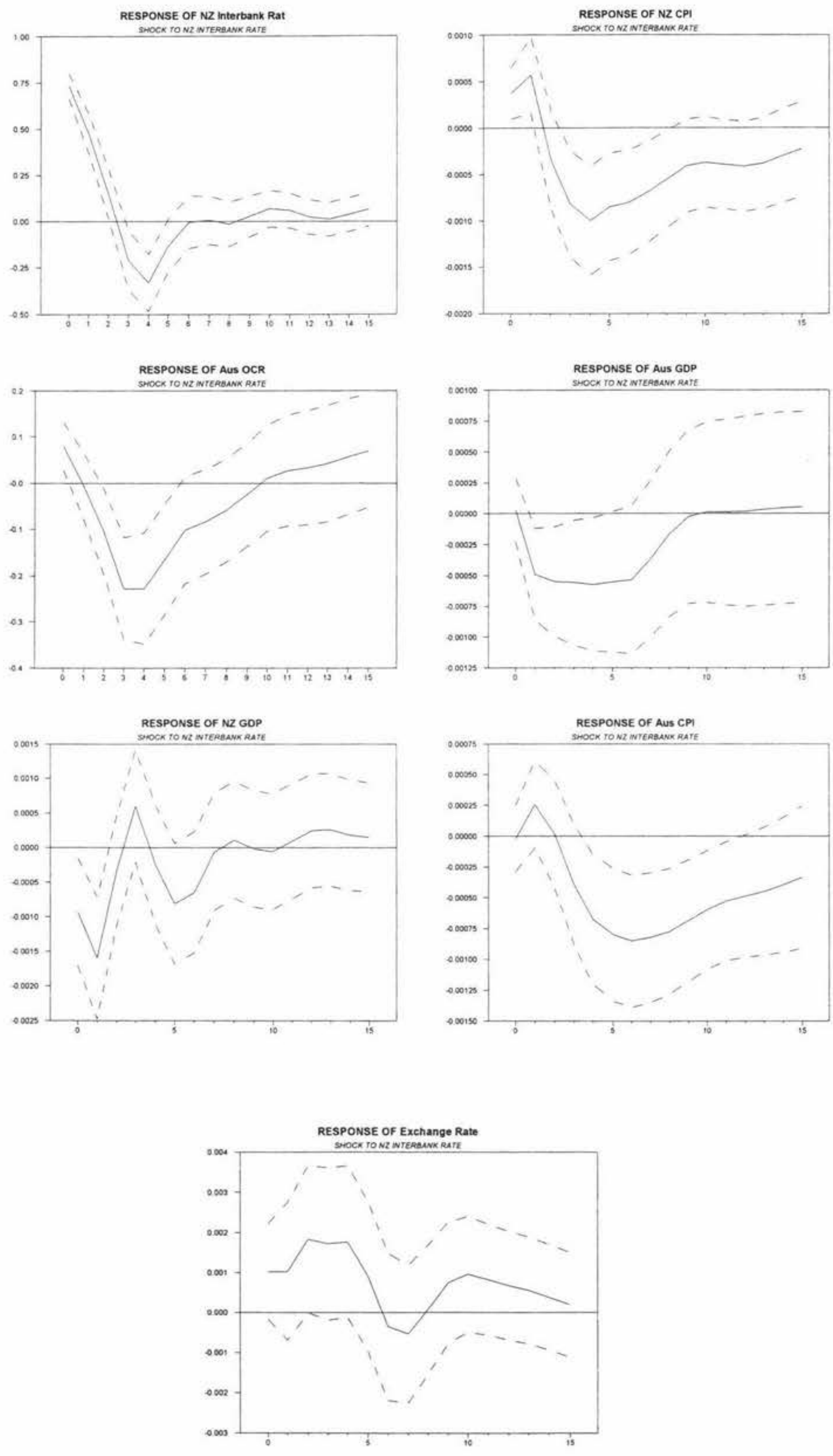
A one standard deviation shock is given to the NZ overnight interbank rate under the ordering R, R*, Y, Y*, P, P*, E. The monetary shock is now able to affect all other variables in the system contemporaneously, and interest rates will only respond to movements in other variables with a lag. Figure 4 shows the IRFs for all variables in the model, in response to a NZ monetary shock with specification II.

As was the case for an Australian monetary shock, the results differ very little between the two specifications. We can therefore conclude that the results are not very sensitive to the ordering selected.

One change that is evident with specification II is that the appreciation of the exchange rate is no longer significantly different from zero at any stage. This suggests that a short-term interest rate rise such as this, may not induce a considerable enough capital inflow to have a significant impact on the foreign exchange market. This suggestion is supported by the response of the Australian cash rate, which only experiences a small one quarter increase in response to a NZ monetary shock.

Figure 4 reveals more about the output responses of the two economies following a monetary contraction. Now that the shock may have a contemporaneous impact on Y, we see NZ output decrease immediately, and with greater magnitude than in specification I. Australian output on the other hand does not experience an immediate decline, however the eventual decrease of Y* is much more enduring than that of Y.

# Figure 4. Impulse Responses to NZ Monetary Shock – Specification II



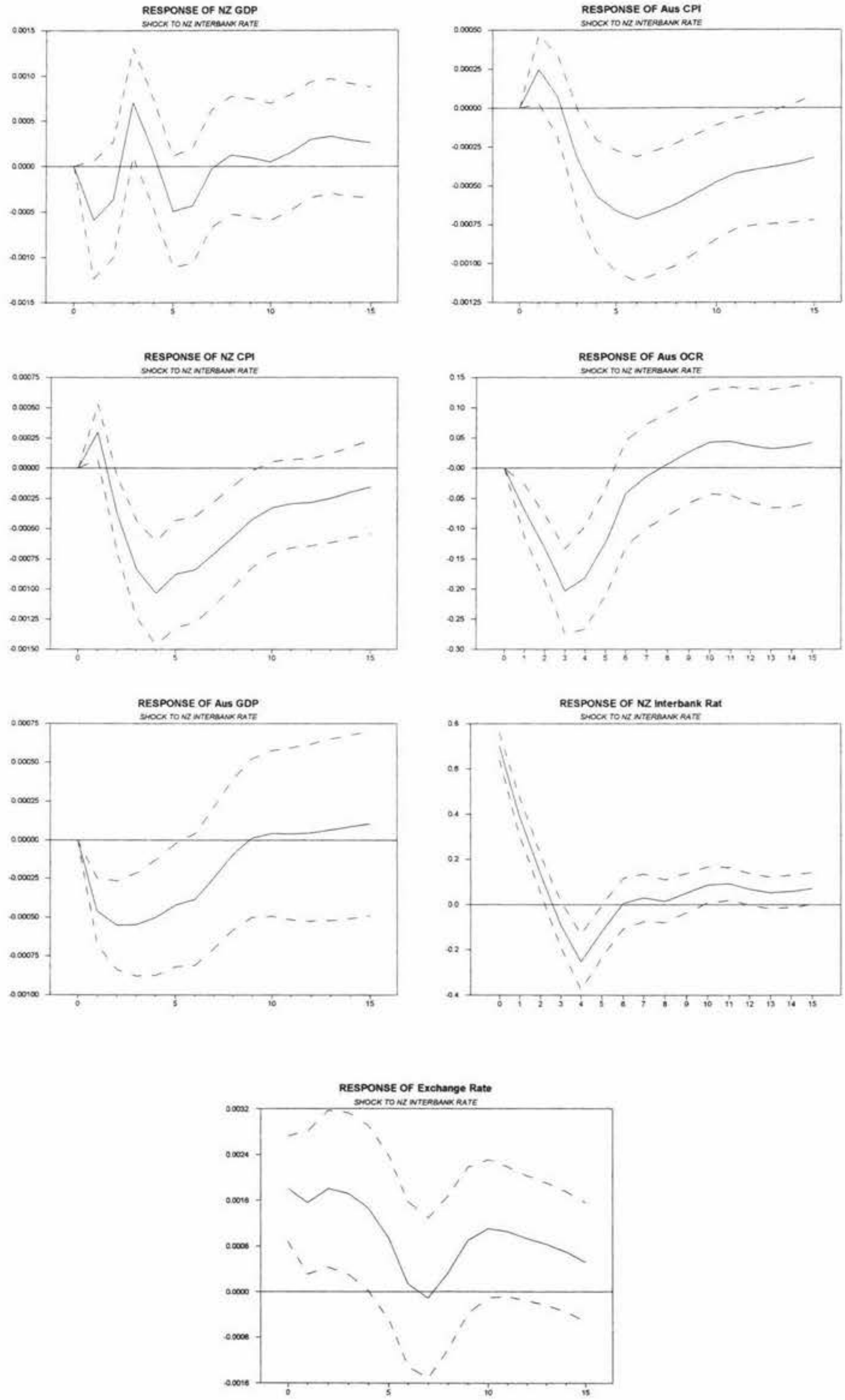
## 5. Robustness Tests

### 5.1 New Zealand Monetary Shock with Contemporaneous Effect of Australian Interest Rate

Figure 5 shows the IRFs of all variables in the system in response to a NZ monetary shock under the ordering Y, Y*, P, P*, R*, R, E. The only difference between this ordering and the ordering employed in specification I is that the Australian cash rate is now contemporaneously exogenous to the NZ monetary variable. The reasoning for this alteration is to acknowledge that any contemporaneous causality in interest rate movements is more likely to run from Australia to NZ, than vice versa. NZ interest rates may now respond contemporaneously to developments in Australian financial markets, whereas the Australian cash rate is only affected by a NZ monetary shock with a lag.

There is little change in the response functions of all variables other than the Australian cash rate. The most notable developments are that the response of Y to a domestic monetary contraction is no longer significant after one quarter, and that the responses of Y* and P* are not as persistent when the shock has no contemporaneous effect on Australian interest rates. However the behaviour of the Australian cash rate is interesting. Now that it does not react contemporaneously to a NZ monetary shock, R* no longer experiences any increase in response to a rise in NZ interest rates. The immediate response of R* is to decrease, and this decrease is sustained for five quarters. It is also interesting to note that the expansionary behaviour of Australian interest rates is not reflected in the response of Australian output, which still decreases with significance for five quarters following the initial shock.

**Figure 5. Impulse Responses to NZ Monetary Shock with Contemporaneous Effect of Australian Interest Rate**



**5.2 Extended Lag Length**

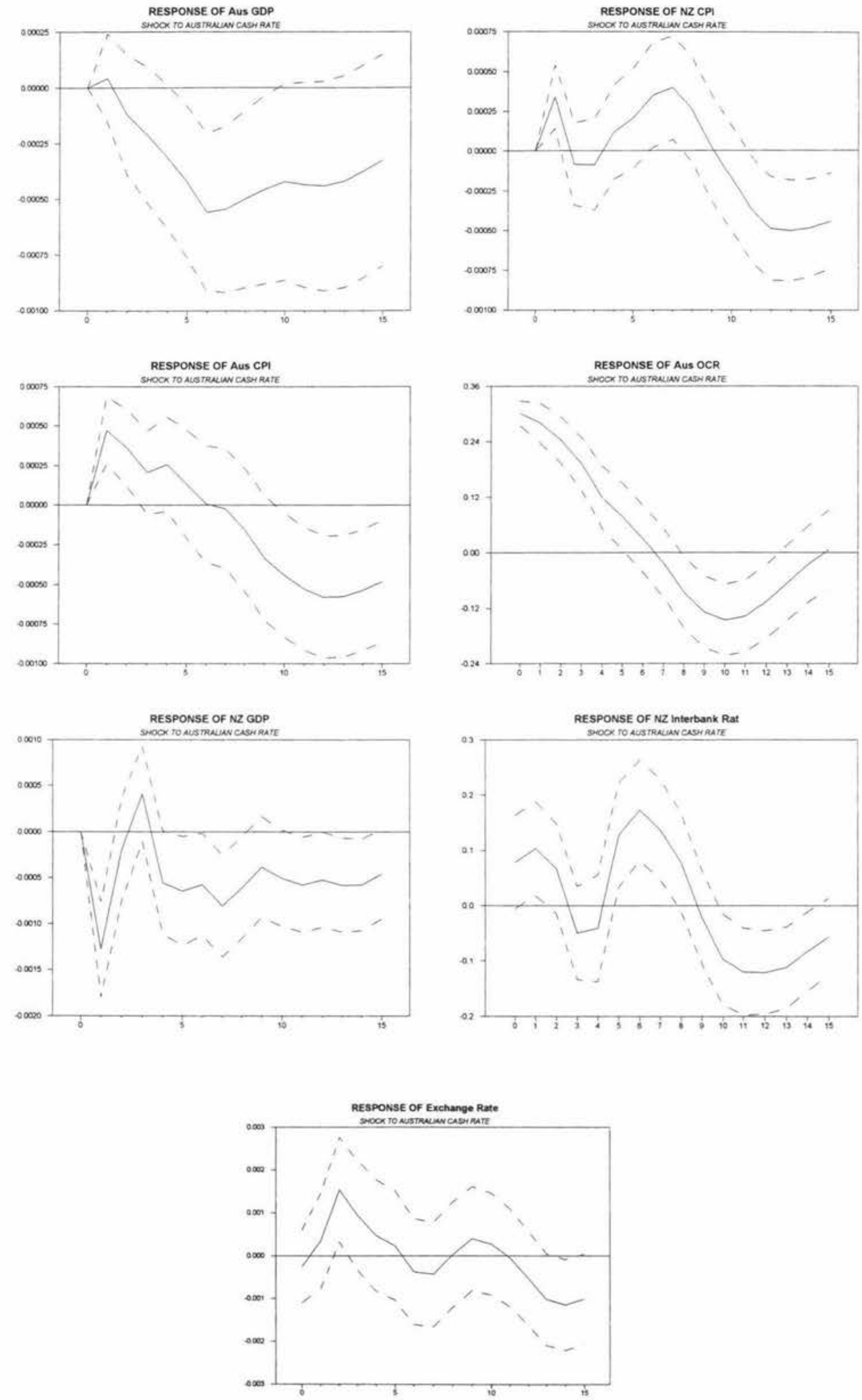
Figure 6 shows the impulse responses to an Australian monetary shock with a lag length of four. The most notable difference with the increased lag length is the response of the exchange rate. E no longer appreciates following an Australian monetary shock and subsequent rise in interest rates. The Australian dollar actually depreciates with significance two quarters after the shock, before returning to fluctuate around its initial level.

The IRFs of other variables do not change considerably when the lag length is extended from three to four. The only significant development is that the responses of both Y and Y* are less significant and persistent in the four-lag model. This suggests that the exchange rate appreciation may have been an important transmission channel.

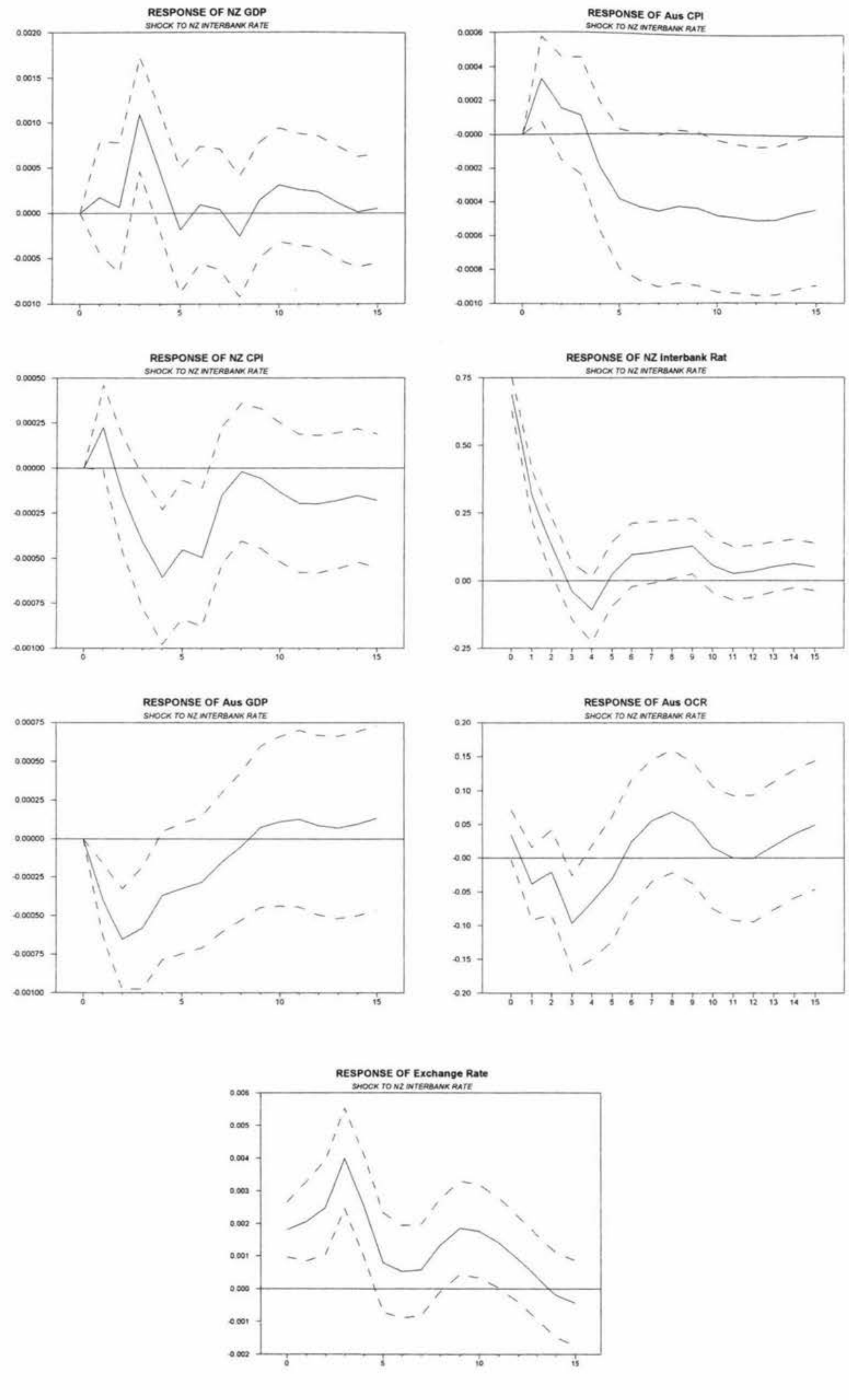
Figure 7 shows the impulse responses to a NZ monetary shock under the four-lag model. Results are less satisfying with four lags than with three. The response of Y no longer shows any decrease following a contractionary shock, and in fact shows an increase in NZ GDP three quarters after the shock. The decrease in Y*, whilst still significant, is of less duration in the four-lag model, lasting for only three quarters as opposed to the six quarter decline observed with three lags. The duration of the price puzzles for both countries are increased when the lag length is extended to four; and eventual deflations in the price level are lessened significantly in terms of both magnitude and duration.

One element of the four-lag model results that is pleasing is that the exchange rate appreciates with significance for four quarters after the shock, and again between the ninth and eleventh quarters. This is a more significant appreciation than was observed when three lags were included in the model, however this change does not seem to have much effect on other variables in the system.

# Figure 6. Impulse Responses to Australian Monetary Shock with Four Lags



# Figure 7. Impulse Responses to NZ Monetary Shock with Four Lags



## 6. Conclusion

This study examines the domestic and cross-country transmission of Australian and New Zealand monetary shocks. The effects of shocks on domestic and foreign output, price level, interest rate, and exchange rate variables are investigated, and the findings are generally consistent with theoretical predictions and existing empirical evidence.

A contractionary Australian monetary shock results in a significant immediate increase in interest rates in both countries, although the Australian cash rate rises significantly more than New Zealand interest rates. The Australian dollar experiences an immediate short-lived appreciation versus the New Zealand dollar. Domestic output appears to react sluggishly to changes in interest rates, however after one year Australian GDP experiences a significant decrease, which is sustained over the forecast horizon. New Zealand output also decreases following an Australian monetary shock, and reacts much more quickly than Australian output does, however this response is only temporary. The price levels for each country display price puzzles lasting two to three years after the shock, and beyond this point the price level drops below its initial level as expected. Responses of interest rates and the exchange rate are very much temporary, whilst there is some evidence that prices and in particular Australian output, may not return to their initial levels. However there is not strong enough evidence to conclude that monetary shocks have a permanent impact on these variables.

A New Zealand monetary shock produces results that are qualitatively fairly similar to an Australian shock. The interbank overnight rate rises sharply as a result of the shock, however the shock is temporary and interest rates return to their initial level within six months. The Australian cash rate also displays a short-lived increase, before decreasing significantly below its initial level. The New Zealand dollar appreciates with significance for up to a year following a monetary shock. Output responses are similar to those observed after an Australian monetary shock, with New Zealand GDP only decreasing for one quarter, whilst Australian GDP displays a more significant and sustained decrease. It is interesting to note that Australian output seems to be more sensitive to monetary policy innovations than New Zealand output is, and that a contractionary Australian shock has a greater impact on output of both countries than a New Zealand shock does. The price levels of both countries still display price puzzles, however these do not last nearly as long as they do following an Australian shock. After six months the price level of both countries falls below the initial level. All responses to a New Zealand monetary shock appear to be temporary, and a contractionary monetary innovation appears to have significant short-run consequences, but no permanent effects.

Results appear to be largely robust to variations in the lag length and ordering employed, however the original lag length of three produces results that are more consistent with theoretical predictions, than an extended lag length does.

This investigation aims to provide some initial data-oriented evidence of the domestic and cross-country transmission of monetary shocks in Australia and New Zealand. There is plenty of scope for future studies to test and extend these results. Within a recursive VAR system such as that employed here, the most obvious way to gain a greater understanding of the transmission mechanism of monetary shocks is to add more variables of theoretical significance. Possibilities could include adding an aggregate demand measure, or separating output into its investment and consumption components. This will allow a more detailed investigation of the domestic transmission channels. Imports and exports could be included to see how monetary shocks and any resulting exchange rate movements affect trans-Tasman trade. An index of sensitive commodity prices could also be included, in an effort to account for inflationary expectations, and thus potentially eliminate the price puzzles that pervade these results.

This was a data-oriented approach to test the effects of monetary shocks on a few major macroeconomic variables; the predictions of particular theoretical models could be tested using VARs, possibly with the imposition of some structural restrictions. Within a structural VAR system a variety of identifying assumptions could be imposed upon the model. This could include imposing long-run monetary neutrality, however this would restrict some of the interesting channels of cross-country transmission of shocks. Another option is to follow the approach of some authors creating two-country models involving the US, and regard the smaller country as a small open economy that has no impact on variables in the larger economy. This would mean imposing an asymmetrical structure that eliminates the impact of New Zealand variables on the Australian economy, and includes the Australian variables as exogenous influences in the structural equations of New Zealand variables. However such an approach would appear unjustified in light of the findings of this study that show considerable effects of New Zealand monetary shocks on some Australian variables.

Another possibility is to use VAR modelling to build on the findings of Dungey and Pagan (2000) and Buckle et al. (2003), who investigate the contributions of monetary disturbances to business cycles and inflation variability. The relative effectiveness of Australian and New Zealand monetary policy in stabilizing target variables could be compared, and a two-country system used to investigate the cross-country effects of any pro-cyclical or counter-cyclical monetary policy.

Australia and New Zealand are closely related in geographic, social, political, and economic terms. As well as being major trading partners, their financial markets are open, competitive and integrated to some degree. For these reasons they provide some satisfying insights in a two-country model of the transmission of monetary shocks. However as small open economies they do not operate in isolation from the rest of the world, and to achieve a more complete picture of the economies in question world variables could be added to the system. This could be achieved through a structural VAR system that includes some broad world variables as exogenous influences on a more open two-country Australasian system; or could involve the addition of some trade-weighted variables of particular interest, in either recursive or non-recursive VAR systems.

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