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Thesis

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

*A Thesis submitted in partial fulfillment of the requirements of  
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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.<sup>1</sup> 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

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<sup>1</sup> 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.<sup>2</sup> Also in terms of trade Australia is of significantly greater importance to NZ than NZ is to Australia, in percentage terms.<sup>3</sup> 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.<sup>4</sup>

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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<sup>2</sup> Statistics obtained from the Australian Department of Foreign Affairs and Trade.

<sup>3</sup> 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.

<sup>4</sup> 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.<sup>5</sup> The RBA also explicitly considers output and unemployment as target variables when conducting monetary policy.

The Lucas (1972) imperfect-information model<sup>6</sup> 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

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<sup>5</sup> 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).

<sup>6</sup> 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.<sup>7</sup> 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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<sup>7</sup> 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,<sup>8</sup> and so Kim (2001) experiments with both a

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<sup>8</sup> 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.<sup>9</sup> 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.<sup>10</sup> 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.<sup>11</sup> 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

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<sup>9</sup> 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.

<sup>10</sup> Grilli and Roubini (1995) find evidence that the monetary policy of other G-7 countries follows that of the US.

<sup>11</sup> 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.<sup>12</sup> 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.<sup>13</sup> 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

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<sup>12</sup> Output also falls for Italy, but this is never statistically significant.

<sup>13</sup> 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.