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MONETARY POLICY EFFECTS IN AN AUSTRALIAN BAYESIAN VAR MODEL*

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ABSTRACT

The objective of the structural VAR model developed in this paper is to identify the effects of Australian monetary policy on the economy, within a small open economy framework. The methodology applied is the Bayesian techniques of Sims and Zha (1998) and Waggoner and Zha (2000) to incorporate prior information into the VAR model. Results consistent with economic theory are achieved by employing a block exogeneity assumption combined with additional contemporaneous and lagged linear restrictions. The paper examines the effects of introducing a mark-up pricing model restriction in to the monetary policy environment. In summary, the effects of restricting the model with this assumption, in comparison to the base model, is to lengthen the negative output gap produced by a wage inflation shock. Conversely, a price inflation shock induces a relatively larger fall in real wages that subsequently leads to a more pronounced above trend phase in output. The effect of a cash rate increase in the mark-up restricted model is to have a very similar effect on reducing the level of GDP to the unrestricted case.

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I. INTRODUCTION

The vector autoregressive (VAR) methodology provides a flexible technique for assessing relationships between economic variables both within and between countries. Australia, like many other countries, has a small open economy that is influenced substantially by international economic activity (see Gruen and Shuetrim (1994)). This paper builds a Bayesian VAR (BVAR) model of the Australian economy incorporating the small open economy assumption.

Bayesian VAR modelling overcomes the degrees of freedom issues common to standard VAR approaches. However, until relatively recently there was little in the way of economic restrictions imposed in the BVAR literature. The advances associated with Cushman and Zha (1997), Sims and Zha (1998), Zha (1999) and Waggoner and Zha (2000) have gradually introduced a means of imposing sensible restrictions, based on economic theory, to BVAR models whilst containing the computational difficulty of estimating such a model.

The existing Bayesian VAR models for Australia are currently very few. Trevor and Thorpe (1988) compared forecasts obtained from a VAR with different data treatments; detrended, differenced and in levels with Bayesian priors. A contemporary BVAR is maintained at the Melbourne Institute, documented in Summers (1999) and Summers (2001). The model incorporates both foreign (U.S.) and domestic sectors. In Summers (2001) there is no block exogeneity assumption, although more recent versions of the model have adopted this. Willard, Voss and Zha (2001) have developed a BVAR model where the exogenous U.S. sector is based on the Atlanta Federal Reserve Bank model of Leeper and Zha (1999). It is characterised by having a larger number of international variables than domestic variables, an unusual feature in this literature when studying the Australian economy.

In this paper a BVAR model of the Australian economy is developed with a block exogenous foreign sector. There are a number of restrictions on the contemporaneous relationships in the model. Additionally the lag structure is restricted. In particular, the model seeks to capture the delays between changes in monetary policy and their effects on the economy. The instrument of monetary policy is the short-term cash rate and the delay is modelled by restricting the first lag of cash rate effects on output, inflation and the labour markets to be zero. A further contribution is the inclusion of the labour market, comprising of unit labour costs and the unemployment rate with results that correspond to economic theory. This is a new aspect to the work.

A motivation for the move to VAR modelling from the Cowles Commission approach was Sims' (1980) criticism of the theoretical restrictions applied in empirical work. This paper examines the result of imposing such restrictions, in comparison with the a base case BVAR model. The restriction imposed is of mark-up pricing. That is, an increase in unit labour cost and import price inflation are completely and directly transmitted to price inflation. This is, of course, an extreme version of the theoretical result, but it gives an indication of the potential importance of mark-up restrictions in structural modelling. The results show that under this form of mark-up pricing wage inflation shocks result in longer, but not deeper, periods of below trend GDP, while cash rate shocks result have a very similar effect when reducing the level of GDP. These types of differences in point estimates are important when using models, either VAR or structural, for forecasting purposes.

The remainder of this paper is structured as follows: Section II briefly lays out the methodology, including the Bayesian approach and estimation method. The structure of the Australian BVAR is outlined in Section III and the identification of the model in Section IV. The resultant impulse response functions are presented in Section V, and the impact of the mark-up pricing restriction on those impulse responses is explored in Section VI. Section VII concludes the paper.

II. METHODOLOGY

The development of the VAR methodology, especially for use in macroeconomics, was made prominent by Sims (1980) and Litterman (1979) who maintained that VARs would provide more accurate forecasts than the previously used structural equation models. Earlier conceptions of theoretical economic relationships were to be placed aside and the empirical results were to be based solely on the data. Furthermore, it is argued that the VAR methodology should be used primarily to determine interrelationships between variables rather than the parameter estimates themselves. A distinct advantage of VARs is that the user can determine the contemporaneous relationships captured by the model. Since Sims' (1980) caution not to impose "...incredible identification restrictions..." VAR models have become increasingly parsimonious, especially models used for forecasting in which overparameterization can affect forecasting accuracy. With the advent of the structural VAR (SVAR), such models have gone from being overparameterized to many being over-identified with restrictions being placed on variables both contemporaneously and in the lag structure. The benefit of including such restrictions in the model allows for the introduction of additional economic theory as well as the stylised facts established by previous empirical work.

Advances in the VAR methodology have come at a cost. A large body of research has raised the issue of whether or not VAR systems can adequately model the effects of monetary policy and whether they are appropriate for policy analysis (see Brunner (2000), Rudebusch (1998a,b) and Evans and Kuttner (1998)). Two prominent arguments questioning the use of VAR's to examine monetary policy are: (i) the need to make specific identifying assumptions regarding the policy reaction functions and (ii) whether or not the policy instrument, in Australia's case the cash rate, can proxy actual central bank policy decisions. The first of these points is perhaps the most contentious as very few empirical studies on monetary policy agree on a specific policy reaction function. Two popular methods of identifying monetary policy in the literature are to either follow a policy rule, such as the 'Taylor Rule' (see Taylor (1993)) or to attempt to model central bank behaviour by including as much relevant information in the function as possible at

the time the authority takes its policy decision, as suggested by Zha (1997). The method of identifying the monetary policy reaction function in this paper is based largely on the policy rule approach, which includes measures of output and inflation. But it is recognised that decisions about Australian monetary policy are influenced by the policy stance of the U.S., (see Dungey and Hayward (2000)) especially in the 1990's. Therefore, there are also some behavioural aspects included in the function. It is clear that there is some overlap in these methods. For example, a measure of inflation is contained in the rule approach and would certainly represent critical information in making policy decisions, especially considering that Australia has employed an explicit inflation targeting regime since the early 1990's.¹ The second of these issues is whether or not the cash rate is an adequate proxy for monetary policy. Rudebusch (1998a) argues that VAR models do not make any distinction between exogenous and endogenous monetary policy actions. This paper adheres to the view of Sim's (1998) that most of the variation in monetary policy instrument is explained by responses of policy, rather than effects from other economic variables. This is especially true in Australia over the period since the introduction of inflation targeting, after which the cash rate has become a virtual step function. This is supported by Battellino, Broadbent and Lowe (1997) who assert that much of the 'noise' in cash rate fluctuations has been removed due to monetary policy actions becoming more transparent. Therefore this paper takes the cash rate as the most appropriate indicator of changes in the stance of monetary policy.

This paper applies the VAR estimation technique developed in Waggoner and Zha (2000) to an Australian model. This methodology has the advantage of both alleviating the computational burden of estimating relatively large models, as well as allowing for increased flexibility in imposing linear restrictions.

The structural form of the VAR model is expressed by the following

¹ This is in contrast to Willard, Voss and Zha (2001) who contend that such information on prices is unavailable contemporaneously. The specification in this paper reflects what was thought to be the most appropriate identification using quarterly data, after considering the vexed issue of the timing of data lags, data releases and Reserve Bank policy meetings.

$$y_t' A_0 = C' + \sum_{l=1}^p y_{t-l}' A_l + \varepsilon_t' \quad \text{for } t = 1, \dots, T. \quad (1)$$

Where A_0 and A_l are the contemporaneous and the lagged parameter matrices respectively. Both A_0 and A_l have dimensions $n \times n$. C is an $n \times 1$ vector containing the constant and ε_t is an $n \times 1$ vector of independently, identically distributed structural disturbances (i.i.d) with zero mean and a covariance matrix equivalent to an identity matrix. T is the sample size.² The reduced form parameters and residuals are obtained by multiplying the structural form by the inverse of the contemporaneous matrix, A_0^{-1} . This does not alter the initial assumptions concerning the error terms.

Bayesian Approach

The SVAR model in this paper is estimated using the Bayesian techniques developed by Waggoner and Zha (2000) which themselves are based on earlier work by Zha (1999), Sims and Zha (1998) and Cushman and Zha (1997).

The application of Bayesian methods to the estimation of VAR models is not new (see Doan, Litterman and Sims (1984), Todd (1984) and Litterman (1986)) and contemporary studies have been founded in these earlier works. The objective of this approach is to improve the accuracy of estimates and subsequent forecasts by introducing appropriate prior information into the model. In this way a posterior density function is obtained, from which estimates and inference are derived, analogous to the classical likelihood estimation. Litterman's initial work specified the prior distribution on the reduced form of the problem as a random walk, that could include drift. As this describes the behaviour of many economic time series this was a suitable choice. Sims and Zha (1998) extend Litterman's methodology to introduce prior information to the structural model rather than the reduced form. They also substitute a Normal-Wishart distribution rather than a random walk assumption, allowing a more flexible implementation of the prior (see

² The sample size T is augmented by the $n + 1$ dummy observations that precede the data which are necessary in the application of the hyperparameters (see below), μ_5 and μ_6 . See Sims and Zha (1998) for additional information.

Robertson and Tallman (1999) for more information on these differences). In both Sims and Zha and the Litterman methodology the amount of prior information used in the model can be regulated. The weight given to the prior information applied to the model is governed by six hyperparameters³, λ_0 , λ_1 , λ_3 , λ_4 , μ_5 , and μ_6 . The properties of the hyperparameters are described below.

λ_0 - influences the “tightness of beliefs” regarding the coefficients in the contemporaneous matrix, A_0 . As λ_0 increases the ‘looser’ the prior, which allows the coefficients to have increased variance in the structural form, in effect permitting the model to stray further from a random walk in the reduced form. In addition, λ_0 influences the prior on the entire model as the prior on the lagged parameter matrices and constant are conditional on that put on the contemporaneous matrix.

λ_1 - controls how tightly the model complies to the random walk prior. λ_1 is unconditional and is implemented only on the lagged matrices. Increasing λ_1 implies that the random walk prior will not be enforced as strictly.

λ_3 - governs how greatly the coefficients in the lagged matrices, subsequent to the first, may vary. An increase in λ_3 allows the parameters contained in these lags to vary less around their conditional mean of zero.

λ_4 - affects the standard deviation of the constant in each equation and is conditional on λ_0 . Increasing λ_4 allows greater variance for the constant around the conditional mean of zero.

Sims and Zha (1998) advocate the use of the following parameters to allow for unit roots and cointegration between variables that exist in many macroeconomic time series.

³ Sims and Zha(1998) introduce two additional hyperparameters, μ_5 and μ_6 , and remove one initially used

μ_5 - is the ‘sum of coefficients’ parameter that gives weight to the possibility that the model may be stated as a first difference model. Therefore as μ_5 increases, the greater the likelihood that the model can be expressed in first differences.

μ_6 - allows for the possibility of variables in the data being cointegrated, despite being within the framework of the random walk prior. Increasing the value of μ_6 increases the weight of there being a common stochastic trend between the variables.⁴

The choice of values for the hyperparameters is usually determined by obtaining values from previous studies or by evaluating the forecast performance of the model over a range of hyperparameters (as suggested by Robertson and Tallman (1999)). The latter method is applied by Summers (2001) and Willard Voss and Zha (2001) in which the hyperparameters that are chosen minimise the forecast errors over a range of within sample forecasts. In this paper the hyperparameters are chosen primarily with a view to obtaining sensible responses, a view akin to the latter approach, and mirroring the normal VAR approach as in Hall (1995).⁵ A further consideration was the intuitive application of the prior information.⁶

Once the prior information is incorporated into the model, the resulting posterior density function is evaluated to obtain parameter estimates and then inference can proceed. The method used to apply the priors to the model is contained in Sims and Zha (1998) and Waggoner and Zha (2000).

by Litterman (1986), λ_2 , which is made redundant using the Normal Wishart prior.

⁴ Robertson and Tallman (1999) note that the values of μ_5 and μ_6 do not necessarily need to be the same, allowing for the weighting of differing relationships across equations.

⁵ The hyperparameter values used in this model are 0.7, 0.7, 5, 10, 1, 1 respectively.

⁶ Intuitively, the set of hyperparameters tends to favour quite a tight adherence to the random walk assumption, as reflected in λ_0 and λ_1 . The values of μ_5 and μ_6 assign a low weight to the probability of a first difference model or a common cointegrating vector.

Restrictions and Bayesian VAR estimation

The desire to incorporate increasing numbers of variables in Bayesian VAR systems has led to a number of computational challenges. The resampling process used in obtaining estimates is prohibitively expensive in computation time. In addition, the development of structural VAR modelling has been associated with a desire to impose some economic theory based restrictions on the models. The first, and most innocuous of these has been block exogeneity representing the small open economy assumption, first presented in the work of Cushman and Zha (1997). Zha (1999) lays out the means by which estimation of a VAR system can be computationally simplified in this case by dividing the system into two blocks. Estimation can then proceed for each draw with the exogenous block estimated as a single system and integrated into the full model at the second stage.

Waggoner and Zha (2000) further generalise the estimation approach of Zha (1999) to incorporate the potential for linear restrictions in both contemporaneous and lag structures in VARs. While contemporaneous restrictions are common in both Bayesian and non-Bayesian VARs, it seems that a non-recursive structure is less common in the Bayesian literature. Restricted lag structures are relatively uncommon in both streams of literature, one exception being Dungey and Pagan (2000). A contribution of this paper is to provide a practical application of the Waggoner and Zha methodology including linear restrictions in the lag structure of a Bayesian VAR model.

The Waggoner and Zha methodology recognises that the model can be divided into a number of components, reflecting the restrictions applied to each equation in the system. The parameter space containing the solutions to these restrictions is used in obtaining the prior distributions. To be more specific consider equation (1). Following Waggoner and Zha, let each column of the matrix A_0 be denoted a_i , and columns of A_l be denoted f_i .⁷ Letting Q_i and R_i be the appropriate size matrices with non-zero rank, the restrictions on the matrices A_0 and A_l can be expressed as:

⁷ This is an adaption of Waggoner and Zha's notation, they specify a system similar to (1) which may also contain exogenous variables, the matrix F is then the collection of all variables on the RHS of a system such as (1). The f_i are then columns of that greater matrix. For transparency we retain their notation.

$$Q_i a_i = 0 \quad (2)$$

$$R_i f_i = 0 \quad (3)$$

Under the assumption that non-degenerate solutions exist to this problem, define a matrix U_i which is orthonormal to Q_i and a matrix V_i which is orthonormal to R_i . Then the restrictions in (2) and (3) will be satisfied if and only if vectors b_i and g_i exist such that:

$$a_i = U_i b_i \quad (4)$$

and

$$f_i = V_i g_i. \quad (5)$$

The model is then much easier to handle by forming priors on b_i and g_i when there are restrictions on the lagged parameters. Waggoner and Zha demonstrate that using this approach the distributional simulations can be carried out on an equation by equation basis, which vastly reduces the computational burden of the problem. Two steps occur in estimation. The second is to simulate draws from the conditional posterior density for A_t given a particular draw for A_0 . This is based on a multivariate normal distribution. However, the first step of simulating a draw for A_0 is less straightforward. Waggoner and Zha develop a Gibbs sampler to overcome this problem. In this paper the Waggoner and Zha method is applied using MATLAB code adapted from the Canadian example written by Zha (1999).

III. MODEL STRUCTURE AND SPECIFICATION

In general, contemporary SVAR models of the Australian economy consist of two blocks, one representing an exogenous external sector, the other, the domestic economy. A small open economy assumption implies the Australian economy has no impact on international events. Recent examples include Brischetto and Voss (1999), Dungey and Pagan (2000) and Voss, Willard and Zha (2001). In each of these, and in much existing

single equation work, the international environment is represented by the U.S. economy. The model developed here is in this tradition.

The model contains eleven variables, four of which represent international conditions and the remaining seven the domestic economy. The four international variables are: U.S. real GDP (USY), the U.S. inflation rate (USP) and the Federal Funds rate (USR) and import Prices (IMP). The latter is included as an international variable as Australia has little or no influence on setting the international prices in which it trades⁸. The domestic variables include, export prices (EXP), an asset market indicator, the All Ordinaries share index deflated by the implicit price deflator for plant and equipment (AUSQ), real GDP (GDP), unit labour cost inflation (ULC), the unemployment rate (UN), price inflation calculated from the headline CPI (P), the cash rate (R) and the nominal exchange rate (EXC), which is expressed as the amount of U.S. currency that can be purchased by one Australian dollar. USY, AUSQ, GDP and EXC are in logarithms whereas USP, USR, IMP, EXP, ULC, UN and P are in percentage terms. USY, GDP, UN and AUSQ have been detrended by removing a linear trend with drift from each series as per Dungey and Pagan (2000).

In summary, the model contains the variables

$$y_t = (USY, USP, USR, IMP, EXP, AUSQ, GDP, ULC, UN, P, R, EXC)'$$

The data used in estimation are quarterly over the period 1980:Q1-2000:Q4; Complete data descriptions and sources are given in Appendix One. The choice of this start date is governed by the financial deregulations that occurred in the early 1980s. Extensions to the 1970s do not seem to produce results consistent with the later period, although the inclusion of 1980-1983, prior to the float of the Australian dollar, does not generally cause a problem. A further concern was the effect that the introduction of the Goods and Services Tax, introduced in mid-2000, had on the inflation variable. Although this only

⁸ Import and Export prices have been included separately replacing the terms of trade used in a previous version of this paper

affects the last two observations it has been overcome by replacing the CPI in the last two quarters of 2000 with GST adjusted figures obtained from Econtech.⁹

In addition to the block exogeneity assumption in the model, there are structural restrictions on the contemporaneous and lagged matrices, A_0 and A_l . The use of restrictions in the contemporaneous matrix is reasonably common, in this case overidentifying restrictions are specified. Restrictions in the lag matrices are less common, and their use in the Bayesian framework is a novelty of this paper. The restrictions imposed in the model are detailed in the following section.

IV. MODEL IDENTIFICATION¹⁰

Identification of the U.S. Economy

The foreign sector, containing the U.S. variables: GDP, price inflation and the Federal Funds rate, is characterised by the block exogeneity assumption. These initial variables are identified recursively (in the above order) reflecting the assumptions that changes in both prices and interest rates affect U.S. output only in lags (i.e after one quarter). The U.S. output gap is exogenous, contemporaneously, to all other variables in the model. The U.S. inflation rate over the period emanates from demand driven fluctuations in the output gap. Finally, the monetary policy of the Federal Reserve is assumed to be primarily concerned with the maintenance of output growth and the stability of inflation. Contemporaneously, this specification assumes the form of a ‘Taylor Rule’ (see Taylor (1993)), which has received much support in recent empirical work (see McCallum (1999)). Introducing lags of output and inflation, two key determinants of Federal Bank behaviour, extends this policy rule. The impact of changes in the Federal Funds rate on U.S. output and inflation are restricted to the second lag to reflect the delay in the

⁹ This CPI measure is freely available from the Econtech website: www.econtech.com.au

¹⁰ A table showing the full equation by equation identification of the model is given in Appendix Two.

transmission of monetary policy. This is consistent with similar restrictions imposed on the domestic sector. A comparable structure is imposed in Dungey and Fry (2001).

Applying this form of identification also has the benefit of simplifying the monetary policy behaviour of the Federal Reserve by focussing on the policy instrument, without the use of a monetary aggregate, and therefore is suitable for this limited analysis of U.S. policy.

The IMP variable is exogenous to domestic variables, only responding to fluctuations in foreign activity, in this case U.S. business cycle (i.e. U.S output and inflation). This is a similar the manner in which Gruen and Shuetrim (1994) treat domestic the terms of trade (which in this case the IMP and EXP variables serve to proxy). Beechey et al (2000) incorporate a G7 weighted nominal exchange rate in their equation for import prices, yet in this model the bilateral U.S.-Australian dollar rate alone was found not to have a strong relationship with either import or export prices.

Identification of Australian Economy

The EXP equation reflects the demand for Australian goods in the overseas sector, represented by USY.

The AUSQ equation includes USGDP and GDP contemporaneously thus reflecting the strong relationship between asset prices and domestic and foreign economic activity. The cash rate is also included to reflect the cost of borrowing in the domestic capital market. These restrictions persist throughout the lag structure with no other variables entering the equation.¹¹

The output equation, GDP, is deemed to be relatively exogenous to the domestic variables varying only with USY contemporaneously in order to reflect foreign economic conditions. In lags the equation becomes similar to that of Beechey et al (2000) which itself is based on a common specification used in the literature for the Australian

economy. It includes all foreign and domestic variables in the lags apart from US interest rates, which is in line with independent national monetary policy setting, and the unemployment rate. The effect of the cash rate is omitted in the first lag. This coincides with much empirical evidence suggesting that output does not react to changes in monetary policy for approximately two quarters (see Lowe (1992) and Gruen and Shuetrim (1994)).¹² A similar structure was used in Dungey and Pagan (2000).

The labour market equations, ULC and UNEMPLOYMENT, are specified identically, both containing GDP, ULC, UNEMPLOYMENT and P contemporaneously. No foreign variables are included as it is assumed that any fluctuations in the U.S. business cycle will be transmitted to unit labour costs and unemployment through levels of Australian output. (The exchange rate is omitted on similar grounds.) This assumption holds throughout the lag structure whereas all domestic variables, except for the cash rate, are left unrestricted. The assumption that the cash rate does not effect output in the first lag is extended to the labour market. Unemployment and output would represent deviations from the long-term trend rate of unemployment and the output gap. Consequently, both ULC and UNEMPLOYMENT equations are analogous to that of a short-run Phillips curve.

The model of inflation includes IMP, GDP and ULC contemporaneously. The effect of a foreign price shock is transmitted through import prices¹³. All domestic variables are included in lags, as before the cash rate has been omitted in the first lag representing the delayed effect of monetary policy. This specification attempts to account for the primary sources of demand and supply side inflation as well as imported inflation. These are similar to the determinants outlined in Dwyer and Leong (2001), the difference lying in whether or not fluctuations in EXC can adequately account for any inflation that has been imported.

¹¹ This is in contrast with Beechey et al (2000:34) where share prices are unaffected by shocks to either output, inflation or shifts in monetary policy.

¹² For causes of this lagged effect see Gruen, Romalis and Chandra (1997).

¹³ Experimentation with including USP in the specification resulted in extremely large pass through to Australian prices. The inclusion of USP could also result in double-counting of the effect of U.S. prices which would be included in the import price measure.

In this model the cash rate represents the Reserve Bank's monetary policy instrument. The reaction function is structured in the 'Taylor Rule' fashion with the GDP and P variables representing the output gap and the level of inflation. Despite the close relationship between changes in the Federal Funds rate and the cash rate, (see Dungey & Hayward (2000)) USR is omitted as it was in Dungey and Pagan (2000). Although, the inclusion of the Federal Funds rate was used to identify monetary policy in the model of Brischetto and Voss (1999), for Australia, as well as Cushman and Zha (1997) for Canada. Unlike these two studies, the model in this paper does not use a monetary aggregate to identify monetary policy. This decision is supported by evidence in Tallman and Chandra (1997) suggesting that monetary aggregates do not provide significant information to assist in forecasting real output growth or inflation.¹⁴ The model also differs from Brischetto and Voss (1999) insofar as it includes inflation in the monetary policy equation, which would seem entirely appropriate for an inflation targeting country. The cash rate takes into account the lagged impact from all variables, with the exception of AUSQ and USR.

The exchange rate equation, EXC, contains all foreign and domestic variables apart from ULC and UNEMPLOYMENT. This indicates the susceptibility of the exchange rate to both foreign and domestic activity and monetary policies.

V. RESULTS

The results from the model are analysed using impulse response functions created from one standard deviation shocks to the innovations. The size of these shocks is shown in Table 1. For the detrended variables, the results are interpreted as deviations from the long-term linear trend. Consequently, these results are not directly comparable, in terms of magnitude of shocks and responses, to other contemporary studies that have been estimated in levels.

¹⁴ The unsuitable nature of Australian monetary aggregates is well documented, see Edey and Romalis (1996) and de Brouwer and O'Reagan (1997). In addition to providing limited information, the aggregates are also very sensitive to changes in both the data period and model specification.

Table 1

Magnitude of One Standard Deviation Shocks			
USGDP	0.0064 (0.64%)	GDP	0.0069 (0.69%)
USP	0.0040 (0.4%)	ULC	0.0095 (0.95%)
USR	0.0085 (0.85%)	UN	0.0019 (0.19%)
IMP	0.0294 (2.94%)	P	0.0059 (0.59%)
EXP	0.0228 (2.28%)	R	0.0156 (1.56%)
AUSQ	0.0762 (7.62%)	EXC	0.0184 (1.84%)

Foreign Innovations

The effects of the foreign shocks in this model are relatively persistent compared with the domestic shocks, that is the period until the return to trend values is longer for the US based shocks. The following briefly describes the results.¹⁵

A shock to the USGDP variable has a positive effect on the Australian economy, increasing domestic GDP, AUSQ and lowering unemployment. This expansionary phase accelerates inflation and subsequently the cash rate increase in response.

A U.S. inflation shock attracts an increase in U.S. interest rates through the action of tightening monetary policy. The result is lower U.S. output which is then transmitted to lower Australian GDP.

The innovation in the Federal Funds rate is interpreted as a tightening of U.S. monetary policy. This has the effect of lowering inflation and dampening output. The relatively higher U.S. interest rate depreciates the Australian dollar. The economic downturn in the U.S. is transmitted to the Australian economy reducing GDP and AUSQ.

¹⁵ Impulse responses for the foreign sectors and exports price have been excluded for reasons of space opting to concentrate on key domestic variables.

The effects of an import price shock is to increase domestic prices which in turn serve to increase the cost of labour. Subsequently, this results in an increase in the rate of unemployment which holds the level of GDP at the long term trend.

Domestic Innovations

A positive shock to export prices has a positive effect on GDP pushing it above the trend level and therefore lowers the rate of unemployment and increases the rate of inflation.

The AUSQ innovation has a significant positive effect on GDP (Figure 1(a)) that may reflect increased activity stimulated by additional investment. The unemployment rate decreases immediately in line with simultaneous increases in output and inflation (Figure 1(b)). The exchange rate appreciates due to the growth in output, and the subsequent increase in interest rates. The appreciation may also reflect an increase in demand for the Australian dollar caused by additional foreign investment in the domestic market due to the initial increase of asset values above trend.

FIGURE 1 Responses of GDP and INFLATION to a AUSQ Shock¹⁶

Figure 1(a)

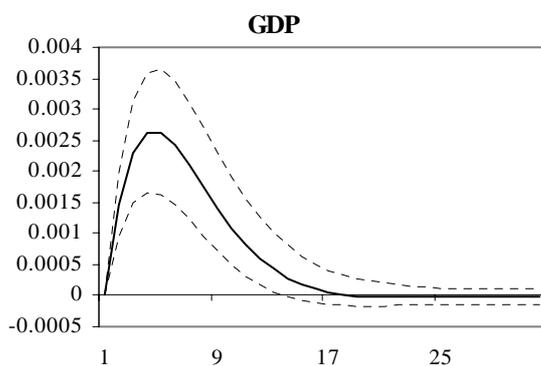
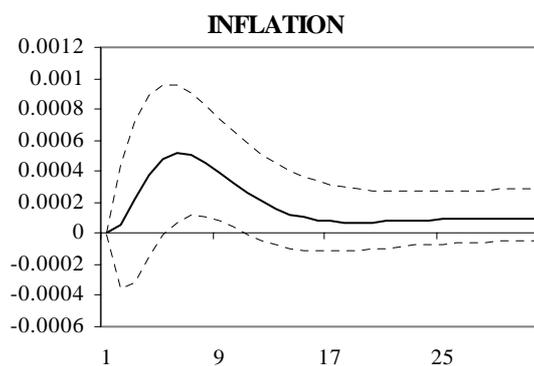


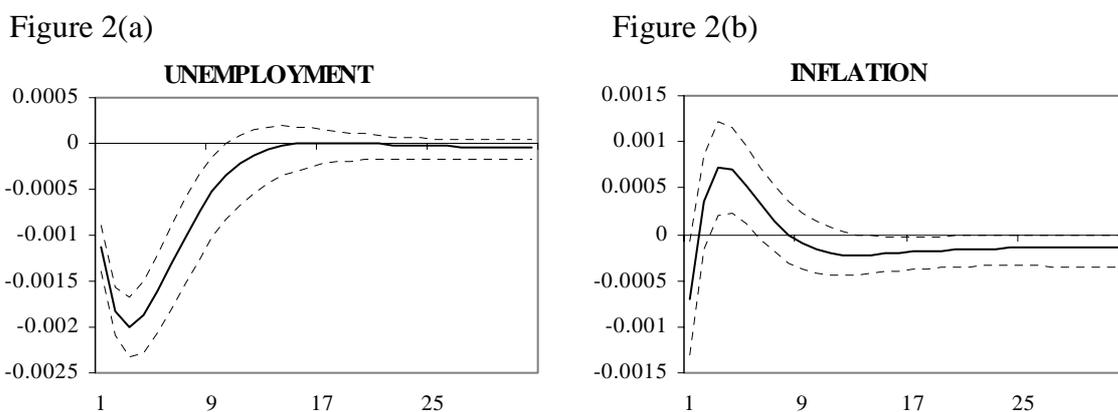
Figure 1(b)



¹⁶ The error bands (denoted '-----') are 68% intervals computed for the impulse response functions and are calculated using 50,000 draws applying the procedure described in Waggoner and Zha (2000).

The shock to domestic GDP creates a positive output gap that serves to stimulate the labour market and significantly reduces unemployment below the trend level (Figure 2(a)). The increased demand for labour creates a temporary increase in the cost of labour. These factors serve to accelerate price inflation, following an initial decline (Figure 2(b)). This prompts a monetary policy response in the form of an increase in the cash rate.

FIGURE 2 Responses of INFLATION, UNEMPLOYMENT to a Shock in GDP



The effects of the unit labour cost innovation last for about one year. This combined with a decrease in the inflation rate (Figure 3(a)), which may be caused by the fall in output, results in a large increase in real cost of labour. Subsequently, the unemployment rate is pushed above the trend level, where it stays for approximately three years (Figure 3(b)). The weakening of the Australian economy causes a depreciation in the Australian dollar. This coupled with sustained higher costs of labour act to return inflation to previous levels. The recessionary environment, reflected by the negative output gap (Figure 3(c)), induces a decrease in the cash rate in order to stimulate the economy (Figure 3(d)). However, the charts show that none of these effects are statistically significant at the 68% level.

FIGURE 3 Responses of GDP, UNEMPLOYMENT, INFLATION, CASH and EXCHANGE RATE to a UNIT LABOUR COST Shock

Figure 3(a)

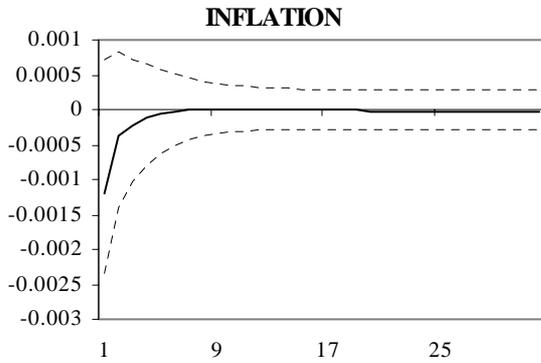


Figure 3(b)



Figure 3(c)

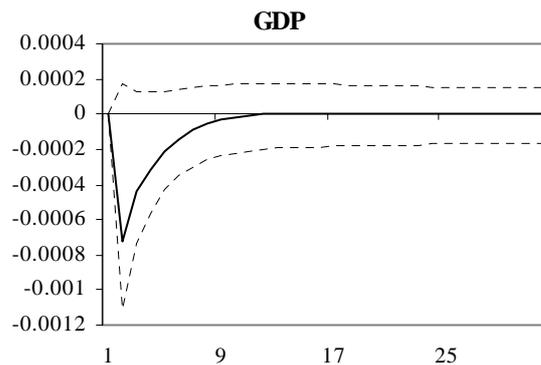
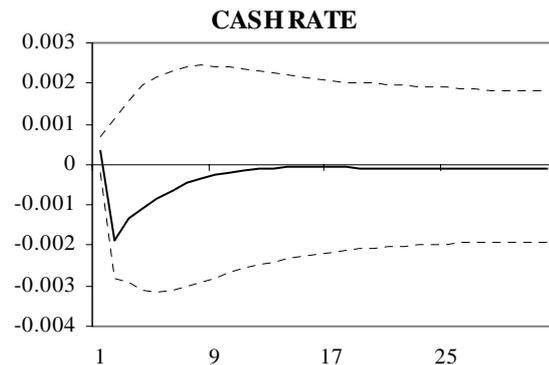


Figure 3(d)



The innovation to the unemployment rate briefly increases GDP before a negative output gap is created Figure 4(a). Unit labour costs decrease due to the decreased demand for labour. The inflation rate increases due to the initial increase in the output gap. In both cases these shocks have wide error bands and the direction of the response is not statistically significant. Smith and Murphy (1994) find similar anomalous results in which output and money supply (akin to inflation) both rise, highlighting the difficulty in identifying a shock to the unemployment rate. Both this model and that of Smith and Murphy experience a decrease in unit labour costs and wages respectively.

FIGURE 4 Responses of GDP and UNIT LABOUR COSTS to an UNEMPLOYMENT Shock

Figure 4(a)

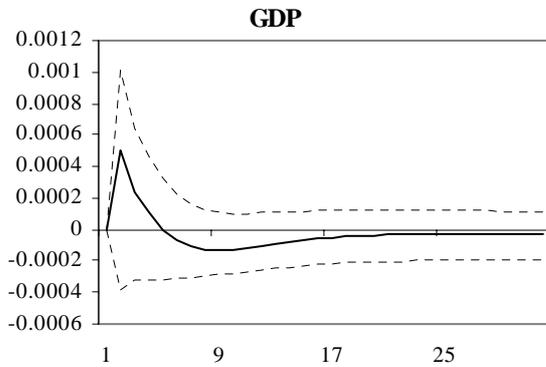


Figure 4(b)



The result of an inflationary shock is to induce an immediate positive response in interest rates. This tightening of monetary policy in response to inflation decreases output (Figure 5(a)). The combination of decreased output and the increase in unit labour costs (Figure 5(b)) caused by the inflationary pressure serve to significantly increase the level of unemployment (Figure 5(c)).

FIGURE 5 Responses of GDP, UNIT LABOUR COSTS and UNEMPLOYMENT to an INFLATION Shock

Figure 5(a)

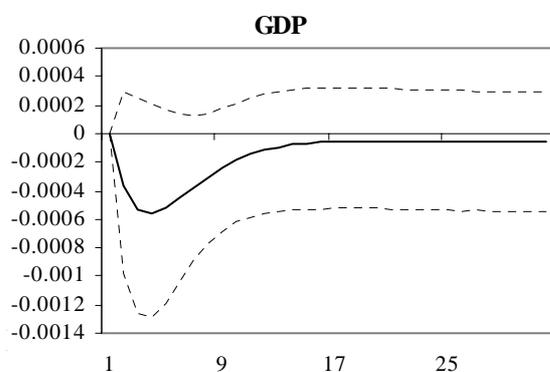
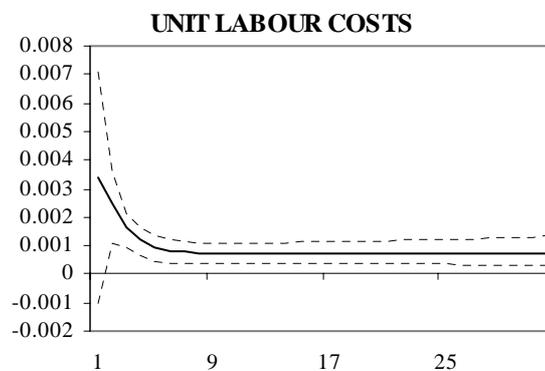


Figure 5(b)



The cash rate innovation is deemed to be an unanticipated tightening of monetary policy. This innovation seems particularly useful in analysing policy shocks as it converges quite quickly without fluctuations that may indicate effects other than a policy shift. The increasing cash rate has a marked effect on GDP opening up a negative output gap that persists for approximately three years (Figure 6(a)). Again the negative output gap increases the unemployment rate above the trend rate, both of which last for a similar amount of time (Figure 6(b)). The cash rate shock has the desired policy effect of inducing a decrease in the inflation rate (Figure 6(c)) and also reduces labour cost inflation (Figure 6(d))¹⁷. The increased cost of borrowing and recessionary gap make investment less attractive and subsequently AUSQ decreases in the short-run (Figure

¹⁷ This may not be a desirable feature of the model, given the evidence for nominal wage rigidity in Australia (see, for example, Dwyer and Leong (2000)).

6(e)). The exchange rate initially appreciates, in response to the higher interest rate, but depreciates with the weakening economy (Figure 6(f)).

FIGURE 6 Responses of GDP, UNEMPLOYMENT, INFLATION (dashed line), UNIT LABOUR COSTS, AUSQ and EXCHANGE RATE to a CASH Shock

Figure 6(a)

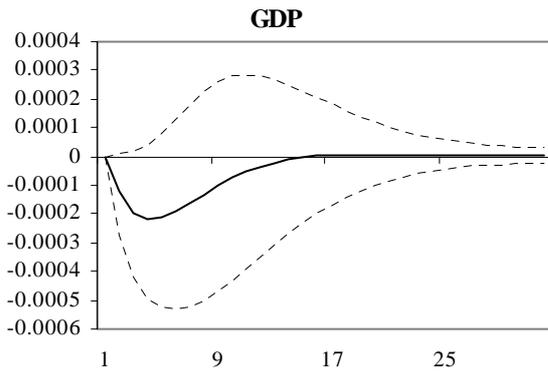


Figure 6(b)

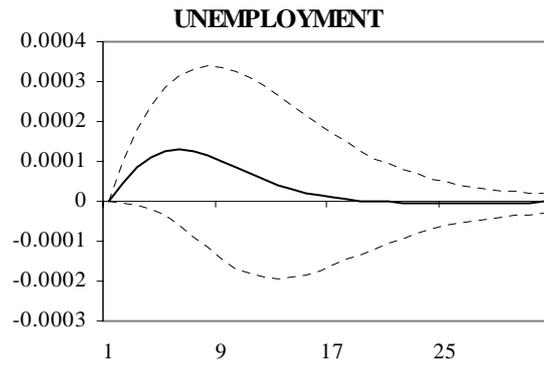


Figure 6(c)

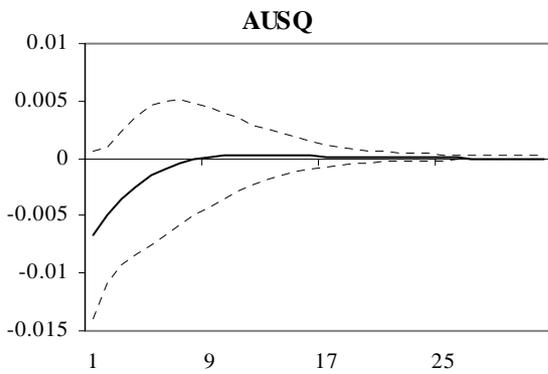


Figure 6(d)

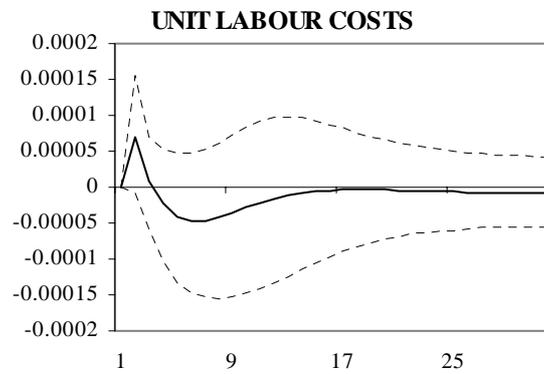


Figure 6(e)

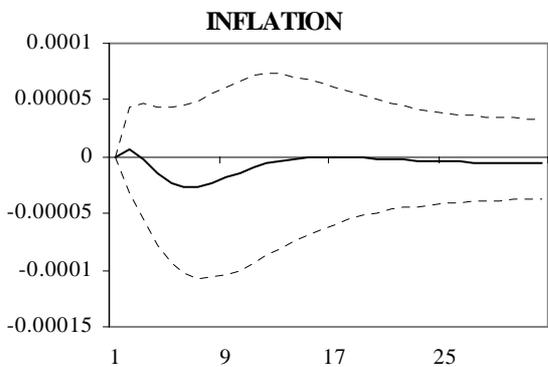
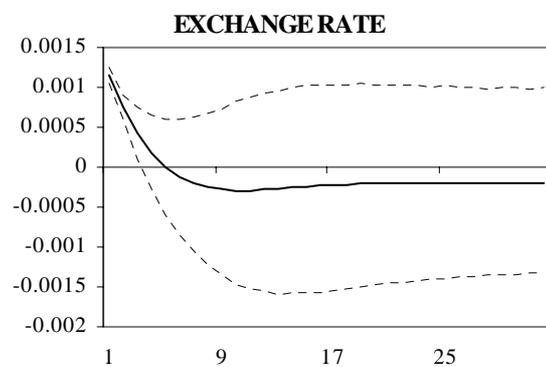


Figure 6(f)



It is extremely difficult to conceive of an independent and exogenous shock to the exchange rate. Here, an unanticipated appreciation of the Australian dollar increases the level of GDP in the short term and decreasing it over a longer horizon, similar to a J-curve effect.

This section has described the main features of the BVAR model. In the following section an experiment is carried out in which a mark-up restriction is placed on the system in order to examine the effects of such an identification restriction within the model.

VI. AN EXPERIMENT

Monetary policy analysis in Australia has put substantial weight on the Phillips curve at various times (see the historical overview in Gruen, Pagan and Thompson (1999)). This seems to have also been true in recent years. Mark-up pricing is an important component of recent models of inflation emerging from researchers located at the Reserve Bank of Australia; see for example, Dwyer and Leong (2001), Beechey et al (2000), de Brouwer and O'Reagan (1997). Submissions by the Reserve Bank to the Australian Industrial Relations Commission (AIRC) with regards to the 'Living Wage Cases' have led to the AIRC reducing wage claims on the basis that increases in minimum wages would necessarily be inflationary and hence induce a monetary policy response.

Given that mark-up pricing is often invoked in economy wide models it is useful to examine the effects of such a restriction using a relatively unrestricted VAR model as specified here. That is, to conduct an experiment along the lines of Sims' (1980) 'incredible restrictions' and examine the outcome for the model. The aim of this experiment is to gain some insight into the effects on point estimate outcomes, and hence inform us about the relative merits of popular forms of approaching economic analysis.

To impose full mark-up pricing, the inflation equation is specified to restrict the contemporaneous coefficients on price inflation and the sum of unit labour costs and

import prices to be equal. No other restrictions are imposed - all the other influences on inflation follow as per the discussion in Section IV. In the ensuing discussion the focus is on the outcomes for unit labour costs, price inflation and cash rate shocks to the economy with and without the mark-up restriction.

The mark-up restriction is modelled as follows

$$P_t = \beta ULC_t + \lambda IMP_t \quad (6)$$

where the total change in the price level is the sum of the change in unit labour costs and the change in import prices¹⁸. This restriction put in place is that of static homogeneity in which $\beta + \lambda = 1$, to this end the coefficients in the VAR estimation are weighted in order to ensure this result. The weights are calculated using the empirical work from Beechey et al (2000) and Dwyer and Leong (2001), in both studies the ratio of the contribution changes in unit labour costs and changes in import prices make to price inflation is approximately 60:40. These weights are applied to the contemporaneous coefficients in the inflation equation of the full model the model, with the addition an output gap term in order to represent demand side pressures on inflation.¹⁹ No restrictions have been introduced into the lags structure which remains as it was in the initial base model.

The first shock considered is a positive innovation to unit labour cost inflation. The results are similar in shape in both the restricted and base models (Figure 7(a)). In the original model this was associated with an initial decline in inflation and a consequent increase in real unit labour costs. This resulted in a lower than trend GDP outcome (Figure 7(b)). In the restricted case unit labour inflation and price inflation move together in the initial shock, however, there remains a real unit labour cost increase in the economy, albeit smaller than in the unrestricted case. In the restricted model the larger response of inflation to the original shock (Figure 7(c)) provokes a much higher

¹⁸ This specification is broadly similar across recent literature e.g. deBrouwer and Ericsson (1995) and Cockerell and Russell(2001).

contractionary response in the cash rate (Figure 7(c)) which serves to prolong the below trend phase of GDP. The unemployment rate response mirrors this.

FIGURE 7 Responses of GDP, UNIT LABOUR COST and INFLATION to a UNIT LABOUR COST Shock

(Dashed line = base model, Solid line = mark-up restricted model)

Figure 7(a)



Figure 7(b)

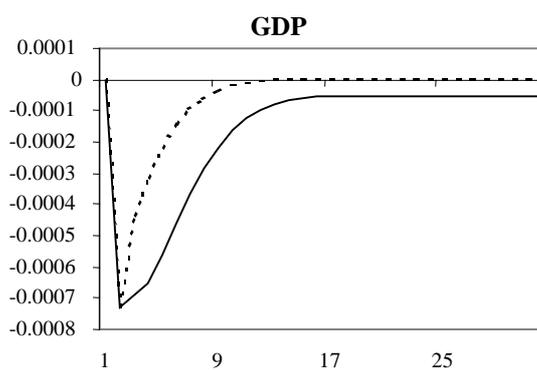


Figure 7(c)

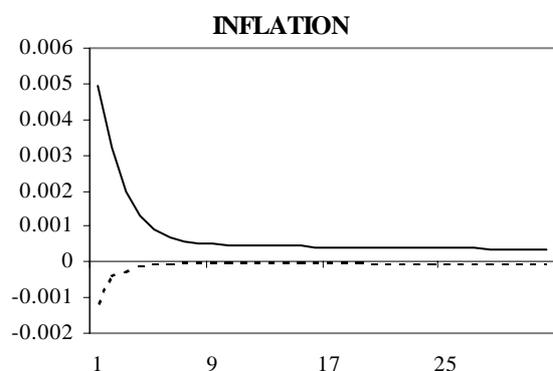
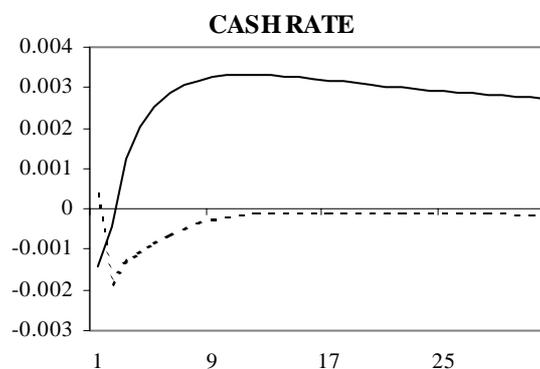


Figure 7(d)



A price inflation shock in the restricted case does not impose an equivalent unit labour cost inflation shock. The restriction is imposed on the evolution of price inflation from unit labour costs, not in reverse. Further, the price inflation shock in the restricted case is slightly smaller than in the unrestricted case (Figure 8(a)). Real labour costs initially fall under the mark-up restriction as opposed to remaining relatively stagnant in the base

¹⁹ As occurs with many inflation equations See Beechey et al (2000) for example.

model. (Figure 8(b)). The fall in real unit labour costs in the restricted model allows the output gap to remain positive by dampening any increase in unemployment (Figure 8(c)). Although the slightly larger shock to inflation in the restricted case initiates a highly cash rate response (Figure 8(d)) that reduces GDP after approximately four quarters for a sustained period.

FIGURE 8 Responses of GDP, UNIT LABOUR COST and INFLATION to an INFLATION Shock

(Dashed line = base model, Solid line = mark-up restricted model)

Figure 8(a)

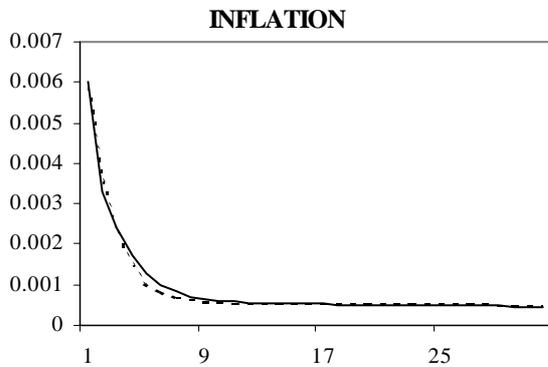


Figure 8(b)



Figure 8(c)

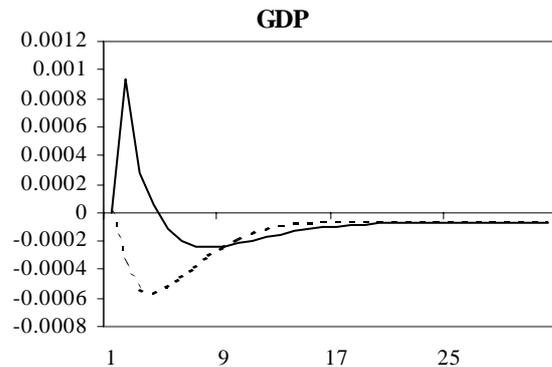
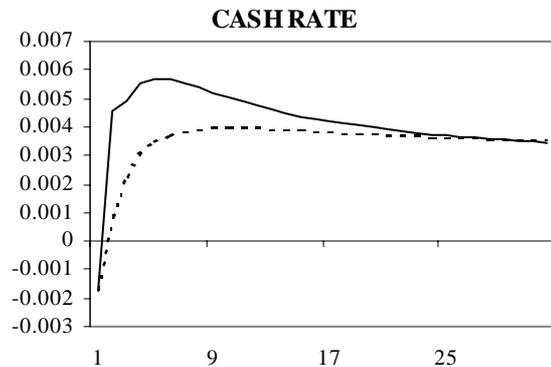


Figure 8(d)



The cash rate shocks are directly comparable, being the same size in each scenario (Figure 9(a)). In both cases the impact of higher cash rates on the economy is to reduce price inflation and output (Figures 9(b) & 9(c)). In the restricted case the impact on inflation is larger in magnitude. Unit labour cost inflation initially rises in response to the cash rate shock in both cases (Figure 9(d)), falling after about three quarters. Unit labour

costs decrease slightly more in the restricted case in response to the corresponding lower inflation level than was found in the base model. The effect on output is extremely similar in the two scenarios which would indicate, as it does with the previous shocks, that the relationship between the cash rate and output is much stronger than that between output and levels of inflation and/or unit labour costs.

FIGURE 9 Responses of GDP, UNIT LABOUR COST and INFLATION to a Shock in CASH

(Dashed line = base model, Solid line = mark-up restricted model)

Figure 9(a)

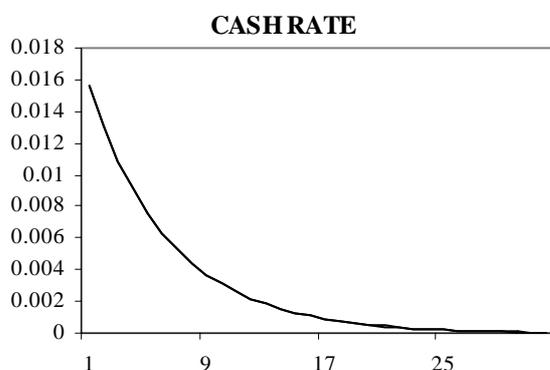


Figure 9(b)

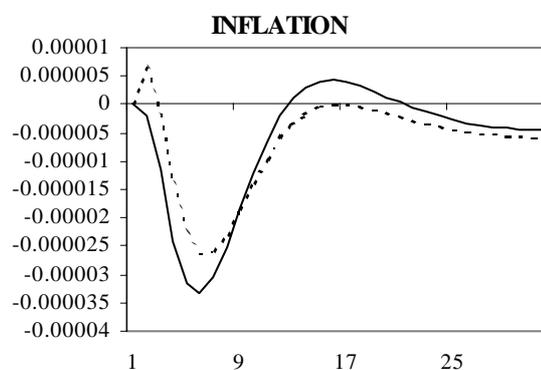


Figure 9(c)

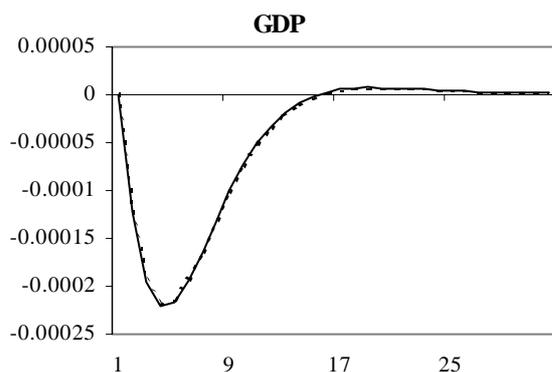
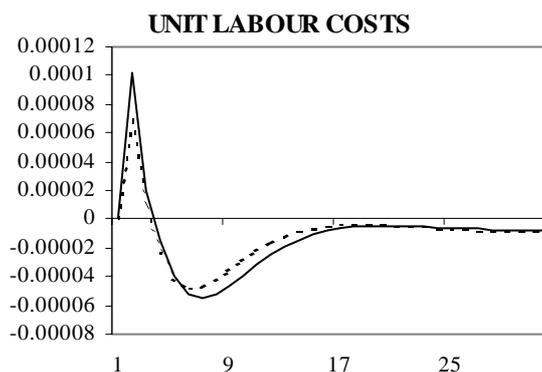


Figure 9(d)



In conclusion the effects of restricting the model to reflect mark-up pricing, at least contemporaneously, have been to lengthen, the below trend output response to a unit labour cost shock. In contrast, a price inflation shock is associated with a larger fall in real unit labour costs in the restricted case, and hence a larger initial above trend phase in

output and a reduced recessionary phase than the unrestricted case. The results from a cash rate innovation show that for the same level of increase in the cash rate the mark-up restrictions lead to very similar period of below trend GDP. Experimentation imposing mark-up restrictions across the lag structure led to very similar results.

This experiment has shown that the imposition of a simple modelling restriction has important implications for the point estimate outcomes produced. While there is no claim that the model presented is more fundamentally ‘correct’ than a given alternative it serves to demonstrate the need to take care when imposing particular restrictions which are unsupported by the data. The evidence from our experiment, and other work, is that price inflation does not have a one to one relationship with unit labour cost inflation and import prices. Furthermore, it seems more than likely that the mark-up itself is not constant over the cycle. For example, Banerjee and Russell (2001) find that mark-up varies inversely with the level of inflation for the G7 countries and Australia (with the exception of Japan) and Beechey et al (2000) include the output gap in their inflation equation to capture cyclical variation in the mark-up.

VII CONCLUSIONS

The recent developments in Bayesian VAR estimation techniques have allowed a greater flexibility in the economic content included in these relatively large multivariate models. This is well suited for modelling economies such as Australia, where, in particular, a small open economy assumption is well supported in the existing literature. The recent work of Cushman and Zha (1997), Sims and Zha (1998), Zha (1999) and Waggoner and Zha (2000) is applied here to estimating a BVAR model of Australia. The model represents the small open economy assumption with block exogeneity of the foreign (U.S.) sector, similar to Cushman and Zha (1997) for Canada. In addition there are a number of other restrictions on the contemporaneous and lagged relationships in the model. Notably, the effect of monetary policy on the economy is restricted to reflect the known delays in the transmission of monetary policy. To this end the effects of the policy

instrument, represented by the cash rate, on output, inflation and labour market variables is restricted in the first lag in the model. Using this specification the results for the domestic economy were analysed, and found to produce results supporting by economic theory and contemporary empirical work.

An advantage of VAR approaches is that the results are primarily data determined, as opposed to the greater degree of structure imposed in, for example, dynamic CGE models. To assess the potential impact simple theoretical restrictions mark-up pricing is imposed on the BVAR model and the outcomes from the restricted and unrestricted case compared. The restrictions maintain that shocks to unit labour cost inflation are transmitted directly to price inflation. The experiment shows that this has a substantial effect on many of the impulse responses obtained from the model. In particular, a positive shock to wage inflation results in a longer fall in real GDP below trend in the restricted case. Conversely, a price shock results in GDP in the base model staying below trend for a longer period. However, the positive cash rate shock leads to remarkably similar result by inducing below trend GDP that is virtually the same in the restricted and unrestricted cases. While there is no claim that the model presented is more fundamentally ‘correct’ than a given alternative it serves to demonstrate the need to take care when imposing particular restrictions which are unsupported by the data.

The contribution of this paper is an application of the Waggoner and Zha (2000) methodology to a problem which incorporates restrictions in both contemporaneous and lagged relationships in the model. Monetary policy effects are successfully identified in the model, and a simple experiment shows the potential importance of structural restrictions in modelling the outcomes for the economy.

APPENDIX ONE

Data Descriptions			
Variable	Description	Units	Reference Code*
<i>USGDP</i>	Real US GDP	\$US billion, chain-volume measure, 1996 prices (s.a.)	USGDP...D
<i>USP</i>	US Quarterly Inflation Rate Calculated from US Headline CPI	Index 1995=100, (s.a.)	USI64...F
<i>USR</i>	Federal Funds Rate	Annual rate	USFEDFUN
<i>IMP</i>	Quarterly inflation rate of Import Prices calculated from an Implicit Price Deflator for Imports index	Index 1999/2000 = 100 (s.a.)	ABS Cat No. 5206.0. Table 9
<i>EXP</i>	Quarterly inflation rate of Export Prices calculated from and Implicit Price Deflator for Export index	Index 1999/2000 = 100 (s.a.)	ABS Cat No. 5206.0. Table 9
<i>AUSQ</i>	All Ordinaries Share Price Index deflated by Total private gross fixed capital formation	Index Dec 1979 = 500 Index 1998/99 = 100 (s.a.)	AUSHRPRC ABS Cat No. 5206.0. Table 9
<i>GDP</i>	Real Australian GDP	\$AU million, chain volume measure, 1998/99 prices (s.a.)	AUGDP...D
<i>ULC</i>	Quarterly inflation rate calculated from a Non-Farm Unit Labour Cost Index [#]	Index 1986/87 = 100 (s.a.)	Federal Treasury Website
<i>UN</i>	Standardized Unemployment Rate	% (s.a)	AUOCSUN%E
<i>P[#]</i>	Australian Quarterly Inflation Calculated from Australian Headline CPI	Index 1995=100, (s.a.)	AUI64...F
<i>R</i>	Australian Cash Rate	Annual rate	AUCASH11F
<i>EXC</i>	Nominal Exchange Rate	Units of USD per one Australian Dollar	AUI..RF

*Codes refer to Thomson Financial DataStream codes unless otherwise noted.
'spliced' values for post-GST CPI obtained from the Econtech Website.

- Nominal non-farm unit labour costs are the ratio of nominal hourly labour costs (non-farm compensation of employees plus payroll tax and fringe benefits tax less employment subsidies, per hour worked by non-farm wage and salary earners) to average hourly productivity (real gross non-farm product per hour worked by all employed persons).

APPENDIX TWO

	Identification of Contemporaneous matrix A_0											
	<i>USY</i>	<i>USP</i>	<i>USR</i>	<i>IMP</i>	<i>EXP</i>	<i>AUSQ</i>	<i>GDP</i>	<i>ULC</i>	<i>UN</i>	<i>P</i>	<i>R</i>	<i>EXC</i>
<i>USY</i>	X	X	X	X	X	X	X					X
<i>USP</i>		X	X	X								X
<i>USR</i>			X			X						X
<i>IMP</i>				X						X		X
<i>EXP</i>					X							X
<i>AUSQ</i>						X						X
<i>GDP</i>						X	X	X	X	X	X	X
<i>ULC</i>								X	X	X		
<i>UN</i>								X	X			
<i>P</i>								X	X	X	X	X
<i>R</i>						X					X	X
<i>EXC</i>												X

	Identification of Lagged matrices A_l											
	<i>USY</i>	<i>USP</i>	<i>USR</i>	<i>IMP</i>	<i>EXP</i>	<i>AUSQ</i>	<i>GDP</i>	<i>ULC</i>	<i>UN</i>	<i>P</i>	<i>R</i>	<i>EXC</i>
<i>USY</i>	X	X	X	X	X	X	X				X	X
<i>USP</i>	X	X	X	X			X					X
<i>USR</i>	X1	X1	X			X					X	X
<i>IMP</i>				X			X				X	X
<i>EXP</i>					X		X	X	X	X	X	X
<i>AUSQ</i>						X	X	X	X	X		X
<i>GDP</i>							X	X	X	X	X	X
<i>ULC</i>							X	X	X	X	X	
<i>UN</i>								X	X	X	X	
<i>P</i>							X	X	X	X	X	X
<i>R</i>							X1	X1	X1	X1	X	X
<i>EXC</i>							X			X	X	X

(1 Denotes that the variable is omitted from the first lag, but present in those subsequent.)

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