# A STRUCTURAL VAR MODEL OF THE AUSTRALIAN ECONOMY*

Mardi Dungey
Department of Economics and Finance
La Trobe University
Bundoora, Victoria, 3083
Australia
ph: 03 9479 1514
fax: 03 9479 1654
email: m.dungey@latrobe.edu.au

Adrian Pagan
Department of Economics
Research School of Social Sciences
Australian National University
Acton, ACT, 0200
Australia
ph: 02 6249 2216
fax: 02 6249 0182
email: arpagan@coombs.anu.edu.au

We develop an eleven variable structural VAR for the Australian economy over the period 1980 to 1998. The VAR methodology has only relatively recently been applied in the Australian context, despite its popularity in quantitative macroeconomics internationally. Our model includes an overseas sector which distinguishes between goods and asset markets so as to disentangle the effects of shocks emanating from each source. We utilize our model to dissect the Australian growth cycle into its separate influences and to study the Asian crisis. Throughout there is a strong emphasis upon identifying the impact of monetary policy.

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## I. Introduction

Quantitative macroeconomic research in Australia has tended to either revolve around large and medium scale models or to be of the single equation variety. Thus there has been a sequence of models constructed by both the RBA and Treasury with names like RBA79, NIF-10, TRYM etc., as well as a series of models inspired by Chris Murphy, such as AMPS, the AEM model and (currently) MM2. Single equation research has appeared on a variety of topics and in a number of locations. In many instances both modes of analysis are employed to deal with similar questions. To illustrate this fact, take the question of the impact of monetary policy upon output and inflation. Simulations have been performed to assess this question with the system models mentioned above. As well there have also been single-equation studies like Gruen and Shuetrim (1994). The latter study illustrates one of the main difficulties with single-equation approaches to analysing monetary policy effects, namely that many of the variables appearing on the RHS of the equation are also affected by an interest rate change, so that only a partial measure of the impact of policy is found. In order to capture the systems dimension, but at the same time retaining a single-equation flavour to estimation, the overseas literature tends to proceed with a relatively small structural vector autoregressive (SVAR) model of the economy e.g. see Bernanke and Blinder (1992) and Sims (1992) for the U.S.. SVAR models have the distinctive feature that each structural equation is "saturated" with lagged variables i.e. the dynamics are essentially unrestricted.

SVAR-type research is still in its infancy in Australia, although recently there has been an expansion of interest in the methodology. It might be asked why one would want to work with an SVAR model rather than one of the established system models mentioned above. Two reasons can be given. First, for many purposes one does not need to explain the very large number of variables which models such as TRYM determine. By and large SVAR models explain only a small number of variables that are considered critical either for the analysis of policy or the performance of an economy. Second, models such as TRYM utilize strong restrictions upon the data which are rarely tested for their validity. Thus assumptions such as rational expectations and uncovered interest parity are generally invoked, while quite simple dynamics are assumed in the structural equations. Consequently, because features such as uncovered interest parity and rational expectations operate to impose restrictions upon dynamics in models such as TRYM, while an SVAR model places few restrictions upon the dynamics, the latter may have some advantages. In particular, an SVAR model may be compatible with quite a wide variety of hypotheses regarding the formation of expectations, since adaptive expectations and fully rational expectations really only differ in the weights applied to the variables representing dynamics in the reduced form of the system – the latter point being clear from the analysis of rational expectation models in Hansen and Sargent (1981) and a real business cycle model in King, Plosser and Rebelo (1988). Of course this generality is not realized without some assumptions - no regime changes and expectations formed in a linear way are the two obvious ones. Nevertheless, many of these assumptions are also common to models such as TRYM.

None of the advantages just mentioned comes without a cost and the cost derives from the fact that SVAR models are generally made recursive in contemporaneous variables and rarely impose any restrictions upon the dynamics in their implied structural equations. In contrast, a model such as MM2 may be block recursive, but its dynamic structure is heavily constrained, in that only a few lagged variables appear in any structural equation. This means that SVAR models have huge numbers of parameters and the structural equations underlying them are hard to interpret. This is unfortunate since it seems sensible to build upon results known from single-equation research. Accordingly, these considerations point to the need for a “third way” of modelling systems which involves the utilization of plausible exclusion restrictions upon the dynamics contained in each structural equation, so as to allow for easier interpretation of the system. Such exclusion restrictions have always been used in producing a recursive contemporaneous structure and it seems sensible to extend that philosophy to dynamics. At the same time one does not want to produce structural equations with little dynamics in them; the maintained position should be to have very general dynamic structure unless there are some good reasons for simplifying it. Mostly these reasons will relate to economic decisions but they could also come from statistical tests. Illustrating this “third way”of modelling is a major theme of the paper.

Section II of the paper distinguishes between vector autoregressions (VARs) and SVARs, discusses the Australian research in this area, and outlines what our general approach will be. In line with the discussion above our philosophy will be to have a bias towards keeping the dynamics as general as possible but always with an eye towards a potential simplification. Section III then sets out the individual structural equations of our 11 variable SVAR model of the Australian economy. Section IV looks at the effects on the Australian economy of five types of shocks – U.S. GDP, terms of trade, U.S. equity prices, an aggregate demand shock and a cash rate shock. Finally, section V adopts the estimated SVAR in decomposing the growth cycle in GDP into the shocks that drive it, as well as providing an account of the first 15 months of the Asia crisis and some analysis of the factors driving the Australian growth cycle.

## II. History, Definitions and Model Philosophy

It is necessary to first differentiate between a VAR and an SVAR. The Cowles Commission distinguished between a reduced form and a structure. The reduced form related endogenous variables to lagged endogenous (predetermined) variables and exogenous variables, while the structure did the same, but also allowed for a contemporaneous interaction between the endogenous variables. Moreover, very few variables entered each structural equation, at least compared with the large number in the reduced form equations. In the literature we are concerned with, the VAR is the equivalent of the reduced form, in that each variable is related to lags of all other variables in the system but there are no contemporaneous interactions. An SVAR allows for some contemporaneous relations.

### (i) Australian Studies

VARs are often used for forecasting and a number of these have been proposed either to forecast the Australian economy or parts of it. For example Trevor and Thorp

(1988) looked at a relatively large VAR with limited international influences. The model maintained by Peter Summers at the Melbourne Institute has a much stronger emphasis on the latter. The current version of the Melbourne Institute model contains six U.S. variables to represent international conditions as well as nine variables to capture domestic variables.[1] There have been fewer SVAR studies of the macroeconomy in Australia. Orden and Fisher (1993) present one with the same four variables that enter into many U.S. studies- money, output, prices and an interest rate. Given the openness of the Australian economy, such a reduced set of variables is not very attractive. Smith and Murphy (1994) construct an SVAR with money, output, unemployment, real wages, world interest rates, the terms of trade and world output. Notably absent from the system is a domestic interest rate and the exchange rate, although it seems as if the terms of trade was regarded as a proxy for the exchange rate, given the perception that the $A is a commodity currency[2]. Mostly the system served to effect a comparison with the AEM model. Notable conclusions from it were that shocks to world output and money were very weak determinants of domestic output and demand shocks were by far the most important contributor. Monetary policy had little effect upon output when measured by the SVAR, as contrasted with a rather strong effect in the AEM model for two to nine quarters ahead.

Huh (1999) constructed a five variable system using interest rates, real GDP, the nominal exchange rate, prices and money supply. This model is applied to the open economy using the assumption that uncovered interest parity holds. The assumption of some form of uncovered interest parity is relatively common in larger structural models, such as MM2 and TRYM, but less so in SVARs. Huh also concludes that world shocks are relatively unimportant in explaining Australian output. Moreno (1992) constructed a small model of the Australian economy with four variables - oil prices, labour supply, real GDP and prices - mainly with the intention of quantifying the relative importance of demand and supply side shocks. Moreno found supply side shocks to be all important, but again the absence of international variables reduces its appeal. In contrast, Weber (1994)

[1] As Summers (1999) notes the set of variables chosen was influenced by an earlier version of this paper.
[2]This observation derives from a comparison of the published paper and an earlier work, Murphy and Smith (1990), which did include both the terms of trade and the exchange rate.

specifically includes the overseas sector in order to consider the origin of the 1990s recession in Australia. His study includes 5 variables; foreign output, a foreign interest rate, domestic money supply, prices and domestic output. One of the limitations of the study is the treatment of monetary policy as pertaining to the control of the money supply; a specification that has been inaccurate at least since 1990 (see MacFarlane (1999) for example). Consequently, monetary policy may not be well represented in it.

A recent entrant to the literature is Brischetto and Voss (1999), who applied Kim and Roubini's (1999) model to the Australian economy. This paper, written after the first version of ours had appeared, has some variables in common with ours; it includes real output, foreign interest rates (although these are nominal as opposed to our real rates) and the domestic interest rate. The Kim and Roubini model also includes oil prices, domestic prices, domestic money supply and the bilateral exchange rate, but Brischetto and Voss find that a five variable model encompassing foreign interest rates, real output, domestic prices, the domestic interest rate, and a bilateral exchange rate produces similar results. In this respect the structure of their model is somewhat similar to that of Weber (1994), but with the important inclusions of a domestic interest rates and the exchange rate. Other SVAR studies of the Australian economy have either tended to focus upon various sub-sectors of the economy or have excluded a monetary policy instrument e.g. Otto (1995) is interested in the current account, Otto (1999) examines the Solow residual, Lowe (1992) looks at domestic and foreign real exchange rates and unemployment and Fisher (1996) uses output, the terms of trade and the exchange rate (with these being defined relative to international variables).

**(ii) Modelling Philosophy**

To begin the construction of an SVAR one has to decide what would be the minimal set of variables to model and which might be regarded as capturing the principal interactions in the Australian economy. No model can capture them all; even models such as TRYM and MM2 omit certain variables. Nevertheless, we believe that it is hard to reduce the relevant set of variables below eleven – a measure of foreign output, the terms of trade, foreign real interest rates, exports, real foreign asset prices, real domestic asset prices, domestic aggregate demand, domestic output, inflation, a monetary policy instrument and a real exchange rate. These variables capture most of the important interactions within and between commodity and financial markets, as well as the influences upon monetary policy. Each of the variables above will be connected with a structural equation that has a shock associated with it and these may then be given names such as an aggregate demand shock. It is clear that this list may not be sufficient if one wishes to ask questions of the model that do not directly map into any of the shocks that have been distinguished. For example, since fiscal policy is essentially subsumed into aggregate demand, there is no way of knowing what fraction of an aggregate demand shock is due to it. Other examples are that productivity and unit labour cost shocks will both show up in inflation shocks while tariff cuts are lost in output shocks. These ambiguities do not signify any failure on our part to have a model of the Australian economy, but rather that it is not disaggregated enough for us to perform certain analyses. This is as true of TRYM and MM2 as it is of our model e.g. an analysis of the introduction of a GST has required substantial modification of both of these models.

Some mention has to be made of the difference between our “third way” of constructing SVAR’s and the traditional one. There are three strands to our approach. The first is to recognize that, for a small economy such as Australia, it would make no sense for Australian variables to influence those in the rest of the world. This means that there will be two blocks of structural equations (rest of world and Australia) with the variables appearing in the second (Australian) block being completely absent in the first (rest-of-world).[3] Our second strategy is to eliminate a variable and all its lags from a particular structural equation if we feel that its absence is plausible e.g. the equation for aggregate demand does not involve either the rest of the world output or asset prices. Finally, some equations are simplified to reflect single-equation research that has become widely accepted as a useful characterization of the series being modelled. Examples of the latter would be that the inflation equation is driven by an output gap, international prices and the exchange rate, while in the output equation the cash rate only has an influence after two quarters has elapsed – see Gruen and Shuetrim (1994) for the latter.

[3] This feature was present in the 1996 version of this paper and has become the accepted norm as a result of Cushman and Zha (1997) using the same strategy for Canada and the U.S.

Our modelling strategy also requires some comment upon the nature of the processes generating the data. In line with models such as TRYM and MM2 we conceive of variables such as foreign and domestic output as growing along a steady state growth path. Hence, we first deterministically detrend such variables so as to focus upon the growth cycle and to construct "output gaps". In fact, we detrend all the eleven variables mentioned earlier, with the exception of inflation. In the next section we indicate why this is so. For variables such as the real exchange rate and the terms of trade such adjustments may not be surprising, as it is hard to account for relative productivity shocks and changes in preferences, but detrending would be more unusual for a variable such as the cash rate.

We also view departures from the trend growth rate as transient. This is in line with the best-known SVAR studies done on U.S. data e.g. Sims (1980) and Bernanke and Blinder (1992). Therefore, shocks may have persistent effects but no permanent ones. To discuss this issue in a little more detail take the following two equations

$$y_{1t} = a_1 y_{1t-1} + e_{1t} \qquad (1)$$

$$y_{2t} = b_{11} y_{1t-1} + b_{12} y_{2t-1} + e_{2t}, \qquad (2)$$

where $y_{1t}$ is foreign output and $y_{2t}$ is Australian output. The recursive structure between overseas and domestic variables identified earlier has been imposed here. If the foreign output shock was permanent then $a_1$=1 and, if co-integration held between domestic and world output, then $b_{11} = -b_{12}$. In our work the parameters $a_1$, $b_{11}$ and $b_{12}$ are freely estimated, so we are being agnostic about whether shocks are permanent and whether there is co-integration. In our estimated model the point estimates of the equivalent of $a_1$ are less than unity. For some purposes, one might want to impose the restrictions which ensure that there are permanent shocks and co-integration, but we see no compelling reason to do so. If such shocks are present in the data then we would expect to get an $a_1$ close to unity, and they will show up in our estimates as being very persistent i.e. the impulse responses we compute would be close to what one would get with a permanent shock, at least for ten or so quarters. It would be possible to re-formulate our system so that some shocks were permanent, for example as in Garratt, Lee, Pesaran and Shin

(1999), but we think it is more important to focus upon constructing a system that captures the interactions within the economy then to spend time on an issue which is of second order importance.

**III. The Model**

In this paper we describe the construction of the structural equations of our SVAR model of the Australian economy. We first need data to proxy the eleven variables that were distinguished earlier. Our choices are as follows: the log of U.S. GDP (LUSGDP), a real U.S. interest rate (RUS), the log of the terms of trade (LTOT), the log of the ratio of the Dow Jones Index to the U.S. CPI (LUSQ), the log of real exports (LEXPT), the log of the ratio of the All Ordinaries Index to the Australian Implicit Price Deflator for Plant and Equipment (LAUSQ), the log of real Australian gross national expenditure (LGNE), the log of real Australian GDP (LGDP), the quarterly inflation rate (INF), the cash rate (CASH), and the log of the real trade-weighted index of the Australian dollar (LRTWI). Exact definitions of these variables and how they are measured are provided in the appendix. The estimation period was 1980 Q1 to 1998 Q3. The length of the estimation period was selected in recognition of the fact that the exchange rate regime started to become more flexible in 1977 with the advent of a crawling peg system. Hence the exchange rate regime was no longer a fixed one and we might expect that there would be some shift in structural relations if a longer time period was chosen. Moreno (1992) estimates from essentially the same starting point.

Our objective is to build an SVAR model with the variables mentioned above, incorporating such restrictions upon the interactions and dynamics as are needed to produce sensible responses, while at the same time emulating some of the longer run restrictions of the models popularised by Murphy. Regarding the latter, we begin with the idea that the VAR should describe behaviour away from some deterministic growth path. In Murphy’s models this path is given by the sum of the rate of growth of total factor productivity and population. Moreover, all variables such as foreign demand are assumed to grow at the same rate in the long run. We don't impose such a balanced growth path but rather allow a variety of growth rates by working with data that has been detrended via a regression on a constant and a deterministic trend. One reason for doing this is that the rate of migration and the participation rate have varied a good deal in Australian history and this makes for an element of endogeneity in population growth.

If the SVAR has stable roots (and ours has), in the long-run all variables grow according to these estimated trend paths, since any temporary shock dies away and the system resumes its deterministic trend. It would be preferable if variables such as the real foreign interest rate, the cash rate, and the real exchange rate did not exhibit a long-term trend, but over the data period chosen this does not seem to be true, in the sense that the trend variable is non-zero when placed in equations describing them. A similar situation occurs in a number of equations in Murphy's models, where trend variables feature over the estimation period but are set to zero when performing simulations and forecasts. Hence, it is best to think of our model as describing the dynamics around a steady state that has to be set by the user.

Restrictions that we place upon the system are of three types. Firstly, we see the system as block recursive between the foreign and domestic components. Thus we allow no feedback from domestic variables to the five foreign variables. This is done by having no contemporaneous or lagged domestic variables appearing in the four equations describing the evolution of the foreign block. Secondly, we impose some recursive structure upon the system. This is a much more contentious issue, but such choices are made with all models and are unavoidable. Our recursive system will be {LUSGDP, LTOT, RUS, LUSQ, LEXPT, LAUSQ, LGNE, LGDP, INF, CASH, LRTWI}. A brief description of the rationale for this structure is given later when we discuss the individual equations.

Finally, some restrictions are placed upon the lag structure. Generally, we work with a VAR(3) ie 3 lags of variables appear in each equation, but sometimes we have either excluded all or specific lags on a particular variable. An example of the former would be the absence of the real foreign interest rate in all equations for the domestic sector, except that describing the exchange rate. The logic of this choice is that the structural equations being represented would correspond to concepts such as the IS and

Phillips curves, and there is no reason to expect such a variable to be present in them. An example of excluding specific lags is the absence of CASH(t-1) from the LGNE, LGDP and INF equations.[4] We are not the first to do this; Gruen and Shuetrim (1994) do so in their single equation regression linking LGDP and the cash rate. Again it should be stressed that our objective is to see if plausible responses can be obtained by placing a minimal number of restrictions upon the system, provided that these agree with some theory or evoke assent. Given this orientation, it is perhaps not surprising that instances exist in which the responses produced by our system are hard to rationalize, but that is a cost that must be borne, and which further improvements on the model might be aimed at eliminating.

We now proceed to an explanation of the format of the individual equations. Tables 1 and 2 summarize their structure. To read these tables one should treat the rows as showing the dependent variable in each structural equation and the columns as showing the other variables appearing in it. An * indicates that a variable is present. Since the SVAR we look at later is of third order, but the third lag is either completely excluded or included, there are only two possibilities regarding the lag structure attached to variables in any equation. If the variable is excluded completely, Table 2 records a blank. If all lags appear then a single * is used, whereas a lag starting with a two period delay is signalled by a dual *.

**(i) The Overseas Sector**

In the foreign sector output (LUSGDP) is taken to depend upon lags of the foreign real interest rate and the foreign Q ratio (LUSQ) but not the terms of trade (LTOT). Although it might be desirable to expand the foreign specification to allow for the impact of commodity price shocks upon LUSGDP, it seems unlikely that these would be adequately measured by the Australian terms of trade. Since the sole purpose of the foreign sector is to separate out shocks to USGDP growth that have terms of trade, export and foreign asset market effects from those that don't, it was decided to keep the overseas

[4] The reason is the wide-spread belief that monetary policy has no noticeable impact on either real or nominal quantities for at least six months. It should be noted that tests for whether the associated coefficients are zero easily accept that hypothesis.

sector as simple as possible. It is to be noted that existing Australian models do not feature our decomposition; foreign output, real interest rates and the terms of trade are simply treated as fixed and are then varied independently of one another in simulations.

We assume that LTOT responds to foreign output and real interest rates (RUS), although the last is only with a lag. Commodity markets are probably sensitive to monetary policy developments as well as to the demand changes summarized by the LUSGDP variable, and may well react in a dynamically different way to the individual stimuli. This is particularly true in recent years as commodities have effectively become part of the portfolio of many institutional investors. The foreign real interest rate and LUSQ respond to foreign GDP movements. LUSQ is also considered to contemporaneously respond to the real U.S. interest rate. The inclusion of LUSQ in the system reflects the work of de Roos and Russell (1996) who examined the impact of overseas asset prices on the Australian economy. Exports react to USGDP and the terms of trade, both contemporaneously and with a lag.

The U.S. real interest rate equation is probably mis-specified as it implies that the Fed varies the real interest rate solely in response to an output gap. If one thinks of the literature on "Taylor rules", it would be expected that the real interest rate would also respond to the inflation rate, while the existing U.S. SVAR literature would further augment the rule with some measure of commodity price inflation (following Sims (1992)). Adding extra variables to the system to incorporate such effects was not an attractive option. Although the LTOT variable does react to commodity prices, and is already present in the system, it is a relative price, and so it is hard to use it as a foreign price measure. Moreover, it is unlikely that it summarises the commodity prices of concern to the U.S. and European monetary authorities and investors. We found it necessary to detrend the real U.S. rate and it is possible that this detrending compensates for those omitted variables. The implication of this specification problem is that we are unlikely to have captured a pure foreign real interest rate shock very precisely. However, as our interest in introducing it into the system was simply to separate these from pure GDP and equity price shocks, and the latter is done by conditioning upon the actual real rate, this simple strategy seems satisfactory.

Table 1: Contemporaneous Structure of System

| | USGDP | TOT | RUS | USQ | EXPT | AUSQ | GNE | GDP | INF | CASH | RTWI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| USGDP | * | | | | | | | | | | |
| TOT | * | * | | | | | | | | | |
| RUS | * | | * | | | | | | | | |
| USQ | * | | * | * | | | | | | | |
| EXPT | * | * | | | * | | | | | | |
| AUSQ | * | * | | * | | * | | | | | |
| GNE | | * | | | | * | * | | | | |
| GDP | * | * | | | * | * | * | * | | | |
| INF | | * | | | | | * | | * | | |
| CASH | | | | | | | * | | * | * | |
| RTWI | * | * | * | * | | * | * | * | * | * | * |

Table 2: Lag Structure of System

| | USGDP | TOT | RUS | USQ | EXPT | AUSQ | GNE | GDP | INF | CASH | RTWI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| USGDP | * | | * | | | | | | | | |
| TOT | * | * | * | | | | | | | | |
| RUS | * | | * | | | | | | | | |
| USQ | * | | * | * | | | | | | | |
| EXPT | * | * | | | * | | | | | | |
| AUSQ | * | * | * | * | | * | * | * | * | * | * |
| GNE | | * | | | | * | * | * | * | ** | * |
| GDP | * | * | | | * | * | * | * | * | ** | * |
| INF | | * | | | | | * | | * | | * |
| CASH | | | | | | | * | | * | * | * |
| RTWI | * | * | * | * | | * | * | * | * | * | * |

*Indicates that all lags of the variable appear in the equation

** Indicates that only lags subsequent to the first lag of this variable appear in the equation.

We also detrend the real U.S. Q ratio. Because the change in this ratio represents the real return to equity, if the inflation rate is close to the risk-free interest rate then the change in this ratio could be regarded as approximately the equity premium. As one knows from the "equity premium puzzle" literature it is very difficult to explain such a quantity, leading us to treat it as a constant here which gets removed by a deterministic detrending.

**(ii) The Domestic Sector**

The quick transmission of U.S. asset prices to Australian asset prices noted by de Roos and Russell (1996) is captured by placing the Australian Q ratio at the top of the Australian block. Shocks to this equation might be regarded as events that impinge upon the profitability of Australian capital and which are not connected with world events e.g. movements in unit labour costs that are not predictable using any variables in the LAUSQ equation. Gross National Expenditure (LGNE) is taken to be determined prior to Gross Domestic Product (LGDP) by conceiving of LGNE as a measure of aggregate demand and LGDP as output. As LGNE includes spending on imports it is likely that LGNE and LGDP react differently to variables such as the exchange rate, and it is therefore interesting to have it as a separate variable in the system. This structure is similar to that of Otto (1995); his VAR includes the terms of trade, real GDP and the balance of trade(BT). But, because LGNE-LGDP =log[1+(BT/GDP)] ≅ BT/GDP, whenever LGNE and LGDP are present in the same equation one can equivalently think of the two variables as LGDP and (BT/GDP).

Shocks to the LGNE equation will be taken to represent aggregate demand shocks. The remaining variables present in the LGNE equation are LTOT, LAUSQ, LGDP, INF, the cash rate and LRTWI; only LAUSQ and the LTOT effects are contemporaneous. Foreign variables are excluded from aggregate demand decisions. This could be challenged since expectations might be taken to be a function of all information, both domestic and foreign. However, it seems more plausible that expenditure decisions will be taken largely in light of the change in domestic variables such as LAUSQ. LUSGDP does appear in the structural equation for LGDP to reflect possible influences from worldwide productivity shocks. Apart from these factors the most noticeable feature of the GNE and GDP equations is that the cash rate only operates after two quarters. This time delay derives from the single equation work of Gruen and Shuetrim (1994).

Derivation of the inflation (INF) equation is best done in two steps. First, there is an equation capturing the mark up of prices over costs, which translates into inflation being a weighted average of items such as the growth in wages and import prices. Second, a Phillips curve relates wages growth to expected inflation and the pressure of demand. Assuming that expected inflation is a combination of current and lagged inflation rates, with weights that are unknown, the two variable system can be reduced to a single equation for inflation, making the latter a function of the pressure of demand and other factors. We depart from the existing single equation literature in using a GNE gap as a measure of demand pressure. Since GNE is trend adjusted we can think of the equation in Tables 1 and 2 as one in which inflation responds to demand pressure as indicated by a gap between actual and trend GNE. Import price movements would have to be proxied by other variables such as the real exchange rate and the terms of trade; neither variable quite captures import price movements and this has to be regarded as a limitation in the system. Note that we have chosen to place inflation rather than the level of prices into the system. In doing so we have to be content with an implicit explanation of the price level. Under certain assumptions the nominal anchor for the system can be regarded as the level of foreign prices. Since such a variable does not appear in our system, it would need to be added if it was felt desirable to be able to explain the price level. It is possible that omission of such a term may mean that our explanation of inflation is not as good as that for real variables. Indeed, there is some evidence - de Brouwer and Ericsson (1998) - that inflation rates depend upon the past level of prices. Shocks to this inflation equation are conventionally labelled aggregate supply e.g. see Gali (1992), as they represent movements in inflation that are not due to demand pressure. But, as seen from our sketch above, this is not quite accurate, since the shock in the inflation equation is actually a combination of those accompanying the mark-up and wage equations, although we will retain the conventional interpretation. There may be other sources of supply shocks, for example Otto (1995) identifies changes in the terms of trade as supply shocks.

The cash rate (CASH) represents the responses of the monetary authorities to contemporaneous and lagged developments in the Australian economy.[5] Of course this does not mean that overseas variables do not influence Australian monetary policy; they do, but only indirectly either through their impact on domestic variables or the exchange rate. The statement above points to a monetary policy rule of the Taylor-type, but it is a statement of objectives rather than the information used in reaching these objectives. In particular, it seems likely that some attention is paid by the RBA to the degree of competitiveness of the Australian economy as reflected in a real exchange rate i.e. monetary conditions are likely to be assessed in the light of the real exchange rate relative to some norm. It is equally unlikely that the authorities would solely react to contemporaneous movements in such a variable and the relevant norm may well be some average of the past values. By including three lags of the real exchange rate in the equation we are essentially performing such smoothing. Again, if one thinks of this equation as a policy rule it is unlikely that it can adequately represent actual decisions by the RBA, owing to the fact that the target inflation rate almost certainly shifted from the 1980s to the 1990s. To some extent the detrending we perform upon the cash rate compensates for the latter change and may explain why such an operation is needed.

Finally, the real exchange rate (LRTWI) equation is primarily set up to allow for the possibility of uncovered interest parity (UIP), in that the real exchange rate is a function, *inter alia*, of the cash rate (representing a short term interest rate on risk free assets), the domestic inflation rate and the foreign real interest rate.[6] Due to the presence of lagged LRTWI in the equation it is possible for the equation to be re-expressed in terms of the change in LRTWI and for the coefficients of the two real interest rates to be equal and opposite, if that was consonant with the data. Such a configuration would

[5] Note that because of the presence of inflation on the RHS of this equation one could re-interpret it as describing the real cash rate.

[6] A referee has observed that UIP involves equating the difference between the logs of the current real exchange rate and its expected future value with the current real interest differential. To reconcile this comment with our formulation it needs to be recognised that the expected real exchange rate is conditioned

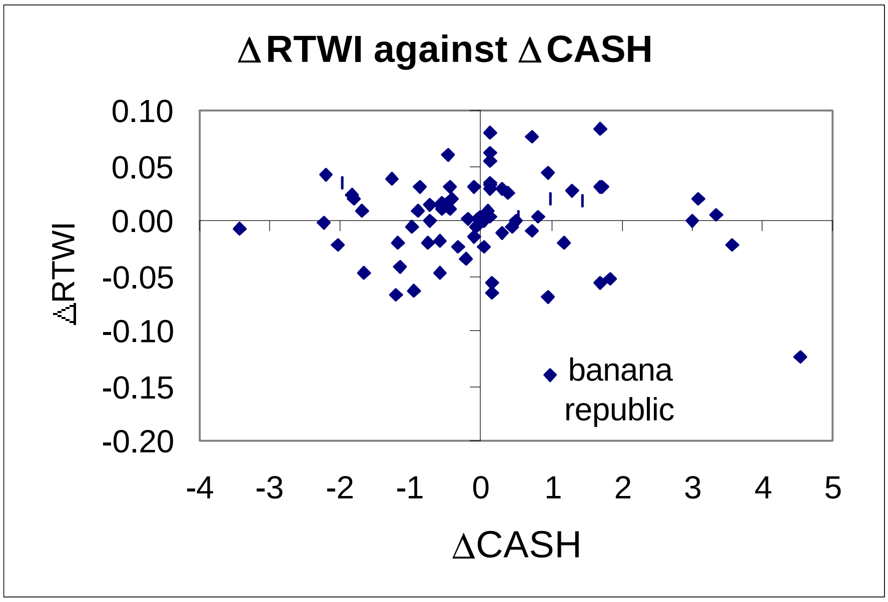
produce UIP. In practice UIP is a rather controversial assumption in Australian macro models e.g. see Gruen and Smith (1994), but the equation is set up in such a way as to allow it to hold if the data supports the hypothesis. In this way our model potentially departs from those in the Murphy class which impose UIP.

There are two further aspects of the LRTWI equation which require comment. These involve the addition of some dummy variables and the imposition of a constraint. First, dummy variables are added to account for observations in the second quarter of 1985 and the third quarter of 1986. Regarding the former, between the March and June quarters of 1985 the cash rate series jumped by 300 basis points, much larger than any other movement in the series, and this was at least partly due to extreme variations in the daily cash rate at that time, although there is no doubt that there may have been some tightening of policy since the increase was largely maintained over subsequent quarters. Owing to liquidity problems the daily cash rate actually rose to 32% for a number of days. This problem did not arise in earlier versions of the model where we were able to access the now discontinued authorised-dealers rate for this market. The second dummy, in the third quarter of 1986, accounts for the flow-on effects of the infamous ‘banana republic’ statement by former Treasurer Paul Keating. These dummy variables are important as the two observations are very influential in determining the sign and magnitude of the response of the exchange rate to a shift in the cash rate. To see this consider the regression of the change in LRTWI (ΔLRTWI) upon the change in the cash rate (ΔCASH). This produces a *negative* relation rather than the positive one that might be expected. Cross plotting ΔLRTWI against ΔCASH in figure 1 shows very clearly that the reason for a negative relation is the largest value for ΔCASH, and this is the observation in 1985Q2. Also apparent on the graph is the large depreciation of the exchange rate triggered by the “banana republic” speech. Inserting the dummy variable corresponding to that event into the relation does not change the sign of the coefficient but it does influence its magnitude quite substantially.

upon all contemporaneous and lagged information and that will induce such variables to appear in any equation describing RTWI.

Our second modification to the LRTWI equation involves the imposition of the constraint that the LGDP and LGNE terms have coefficients of the same magnitude but opposite sign; hence it is the ratio of the balance of trade to GDP that influences the Australian dollar exchange rate. This is in accord with previous single equation work by Blundell-Wignall, Fahrer and Heath (1993) and Tarditi (1996) who have the ratio of the current account to GDP as an influence.

Figure 1:




**(iii) Specification Tests on the Equations**

The set of specification tests in MICROFIT 4 – Pesaran and Pesaran (1997) - were applied to each of the equations used in the SVAR. These tests are for fourth order serial correlation in the residuals; the RESET test; the Jarque-Bera test for normality; and a test for heteroskedasticity. With the exceptions to be discussed below, all equations pass these four tests.

The terms of trade equation shows some serial correlation (p value .03). The serial correlation test involves testing if the four lagged residuals from the equation are significant in the regression which has the residuals as dependent variable and those variables as well as three lags of detrended LUSGDP, LTOT and RUS and the contemporaneous value of detrended LUSGDP as regressors. Investigation of this test found that it was significant only because of the presence of RUS(-3) in the diagnostic regression. This extreme sensitivity is always a problem in regressions with a large number of regressors relative to the number of observations. Since RUS(-3) is insignificant in the basic LTOT regression it seems that this is likely to be a spurious effect.

As foreshadowed earlier the RUS equation is not well specified and exhibits quite a lot of serial correlation. Adding extra lags of RUS and LUSGDP (as well as LUSQ) into it does not eliminate this serial correlation. When discussing this equation in section III (i) we noted that it was not likely to be a good description of U.S. monetary policy but also indicated why we felt this was not a serious problem for our investigation.

A number of other equations fail normality tests - specifically those for CASH, LUSQ and INF. The causes of the failure for the first two are easily identified - the large movements in the cash rate for 1985Q2 noted earlier and the stock market crash in 1987Q3. Inserting dummy variables into the equations for CASH and LUSQ to account for those time points eliminates the non-normality. It is harder to trace the problem with the INF equation. This is a quarterly inflation series and there are some large movements in it in the mid 1980s which seem to be the source of the non-normality; specifically there is a large increase in quarterly inflation in 1981Q4 and a decline in 1984Q1. One possibility is that the first was the effects of the large wage movements in the early 1980's due to the mining boom while the second may have come from the introduction of the Accord and a delayed reaction to the wage freeze of 1982. The presence of non-normality might impact upon information provided from model simulations but there seems little we can do about it as the non-normality is due to a few observations and so hard to capture effectively with any density.

## IV. The Results

Traditionally, the most important means of analysing an estimated structural VAR has been through the impulse responses of the system (Hall (1995)). The impulse response function represents the dynamic response of a particular variable in the system to a shock ("error") in one of the structural form equations. For example, a shock in the USGDP equation has an effect on GDP contemporaneously, one period into the future, etc, and these represent impulse responses. Any variable can be expressed as a combination of the current and all past errors in the equations, with weights given by the impulse responses.[7] Therefore, the evolution of a variable such as LGDP is governed by the eleven shocks which enter the system. Some of the shocks influencing the evolution of LGDP are readily interpretable, e.g. those to LUSGDP, LTOT, LEXPT, LUSQ, LAUSQ, LGNE and INF, but others are more difficult. Shocks to LRTWI are those forces which cannot be captured by factors in the VAR e.g. changes in "confidence" about the Australian dollar. It is difficult to classify such shocks as demand or supply related, and this can be important for debates over the causes of business cycles. GDP shocks themselves are also difficult to classify. They represent a change in expenditure on domestic product not matched by a rise in aggregate domestic demand (GNE). Because we have controlled for export shocks separately, the LGDP shock must therefore arise from the residual item in the identity connecting GDP, GNE and EXPT i.e. imports. Consequently, tariff changes would be one interpretation.

Ninety percent confidence intervals have been estimated for the impulse response functions using the 'bootstrap-after-bootstrap' approach of Kilian (1998). This aims to correct for some undesirable features of bootstrapped confidence intervals when the simulations are performed with a biased (but consistent) estimator of the true parameters of the system $q$. It seeks to transform the biased estimator $\hat{q}_{D}$ obtained by OLS into another estimator, $\hat{q}$, which has smaller bias. It is the latter which is used to calibrate the system for the bootstrap simulations; here we have used 1000 simulations. It is worth noting that the error bands we present are 90% confidence intervals, not the 2 standard error bands commonly presented in the VAR literature.

The sizes of shocks applied to VAR systems are traditionally measured in one of two ways; either as a one unit or as a one standard deviation shock to the error. This

[7] Hamilton (1994) provides a good explanation of the formal connections.

paper adopts the one standard deviation shock, as the choice is purely one of convenience. Table 3 records the sizes of the shocks to each equation. Some of these are very large and one should bear this in mind when assessing the magnitudes of responses.

Table 3:Size of One Standard Deviation Shocks (as Percentages)

| | | | | | |
|---|---|---|---|---|---|
| USGDP | 0.8% | EXPT | 4.2% | INF | 0.8% |
| TOT | 2.4% | AUSQ | 5.3% | CASH | 1.4% p.a. |
| RUS | 1.3% p.a. | GNE | 1.3% | RTWI | 2.4% |
| USQ | 8.4% p.a. | GDP | 0.4% | | |

**(i) A USGDP Shock**

The effects of this shock on Australian GDP are shown in figure 2; the response for GNE is very similar. A positive shock to LUSGDP results in growth in the Australian economy for some three years. Activity in the Australian economy then begins to drop off in response to the tighter monetary policy invoked when the economy began to expand (figure 3), with the cash rate rising quickly in response to the improvement in activity. Unlike Gruen and Shuetrim (1994) the peak response in domestic activity to an overseas activity shock does not occur in the first quarter, but after six. While the terms of trade effect of a LUSGDP shock is positive, the overall response of LRTWI is a depreciation of the Australian currency. The maximum depreciation is of the order of 1.6%.

**(ii) A Terms of Trade Shock**

A terms of trade increase could originate from a rise in the price of exports or a fall in the price of imports. Generally, emphasis has been placed upon export price changes in the Australian context, as this has been the historical experience for most of the period we are concerned with. More recently, however, import price fluctuations have been important. Long and Pitchford (1993) deal with the differing impacts of the two types of terms of trade shocks on income in some detail. The impulse responses coming from the model presented in figures 4 to 9 are consistent with improvements being due to export price increases as there is no sign of the exchange rate depreciation generally associated with a shift in preference to imports. The exchange rate appreciates quite strongly in response to the positive terms of trade shock, and this feeds through to lower inflation, an effect also noted in Gruen and Shuetrim and Gruen and Dwyer (1995). The strong increase in cash rates starting from the third quarter after the shock is in response to increases in domestic activity. Both LGDP and LGNE respond positively to the shock. However, as the confidence intervals show, there is no certainty that LGDP will increase initially[8].

**(iii) A Shock to USQ**

Figures 10-13 show the responses to a positive shock in LUSQ. This shock is strongly transmitted into the LAUSQ variable and thereby produces an increased incentive for investment and a possible rise in household consumption due to a change in wealth. The corresponding increase in domestic activity leads to an increase in the inflation rate. Consequently, the cash rate rises quickly to staunch any inflationary tendencies. Two years after the shock the inflation rate is around 2.5% above trend level and cash rates have risen 2.9%. The cash rate continues to rise until some 12 months after economic activity begins to fall. In this scenario the exchange rate appreciates in response to the higher domestic interest rates. The impact of a shock to LAUSQ in the system is similar to that of LUSQ.

**(iv) A GNE Shock**

A demand shock to the Australian economy is effected through variation in the GNE equation error term. The impulse responses display what would be the conventional wisdom about such an event, with output and inflation rising, the real exchange rate depreciating, and the cash rate rising quite strongly (Figures 14-17 ). The initial responses in the cash rate and GDP are statistically significant although there is some chance of observing a decline in inflation or appreciation in the exchange rate as a consequence of the LGNE shock. One year after the 1.3% shock to GNE, GNE has risen by 3.7%, GDP

[8] In an earlier version of this paper GDP declined in response to the terms of trade shock.

Impulse Response Functions to a one Standard Deviation Shock in USGDP

Figure 1:

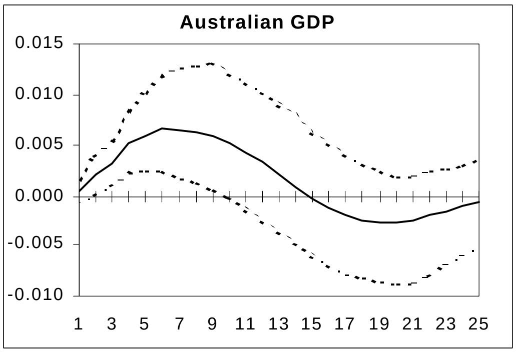
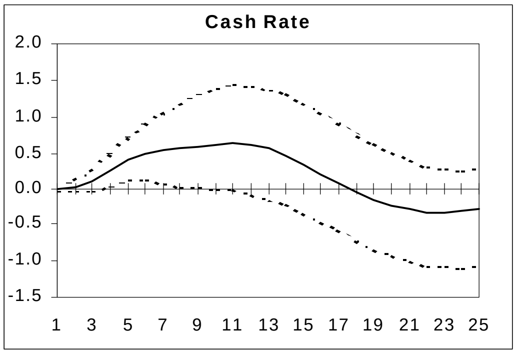



Figure 2:




Impulse Response Functions to a one Standard Deviation Shock in TOT

Figure 4:

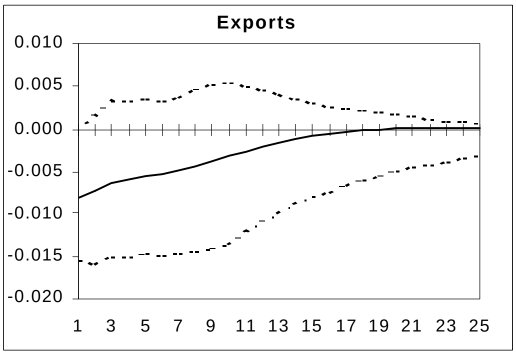



Figure 5:

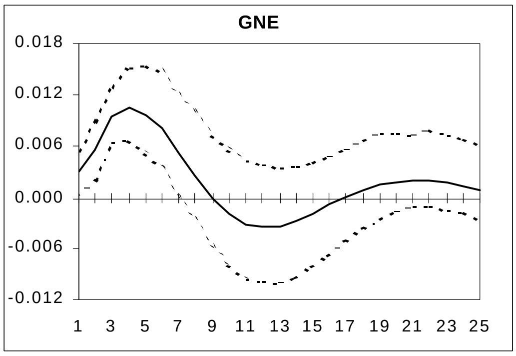



Figure 6:

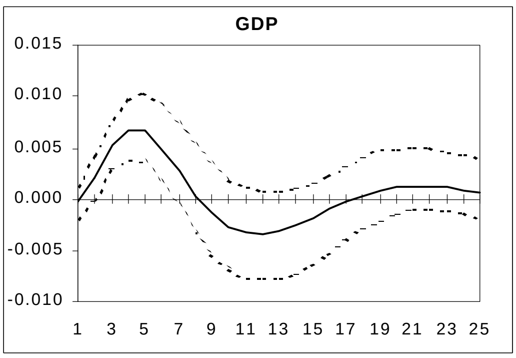



Figure 7:

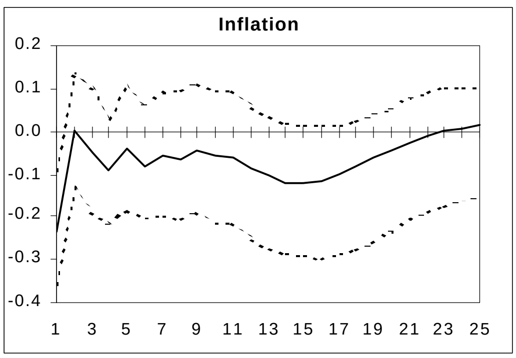


Figure 8:

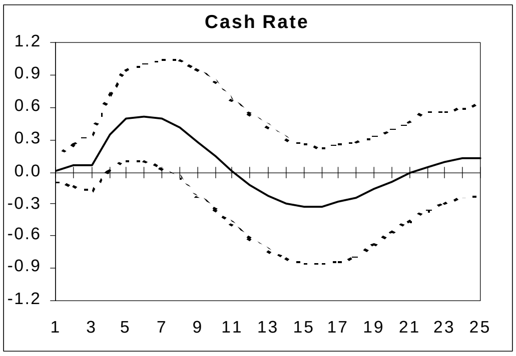
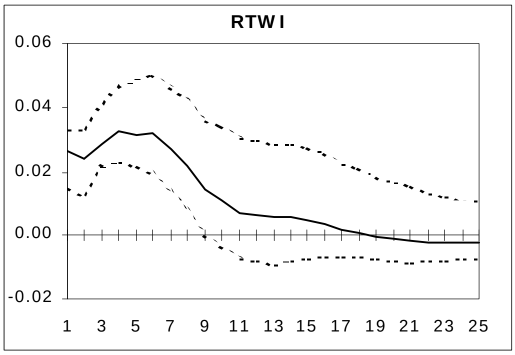



Figure 9:




Impulse Response Functions to a one Standard Deviation shock in USQ

Figure 10:

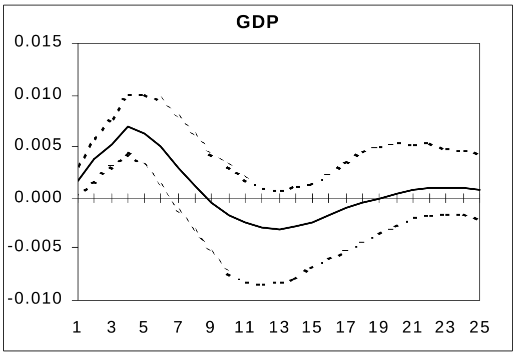



Figure 11:

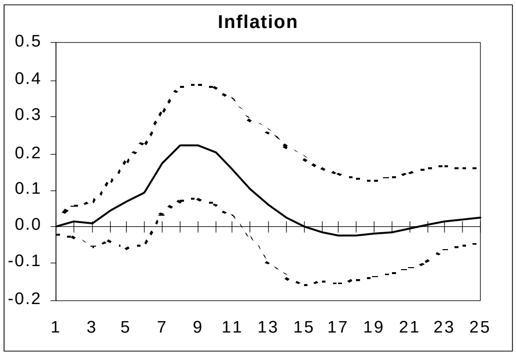



Figure 12:

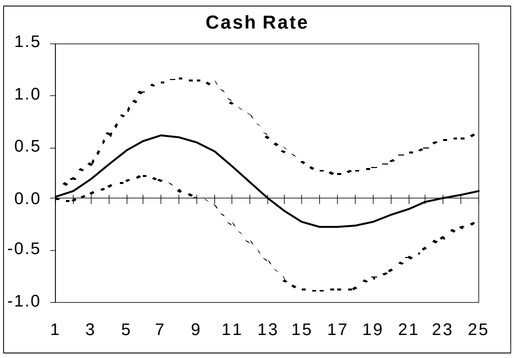



Figure 13:

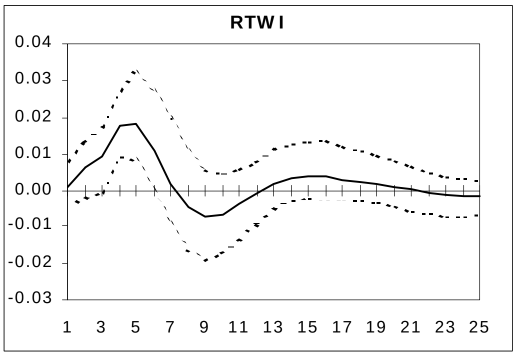


Figure 14:

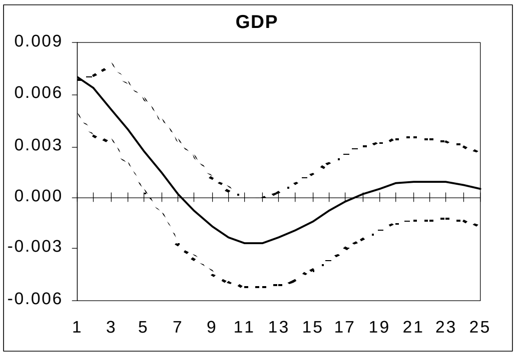



Figure 15:

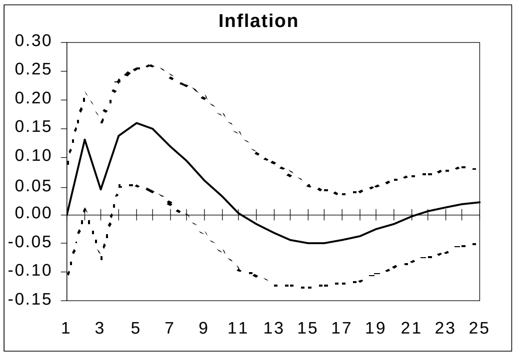



Figure 16:

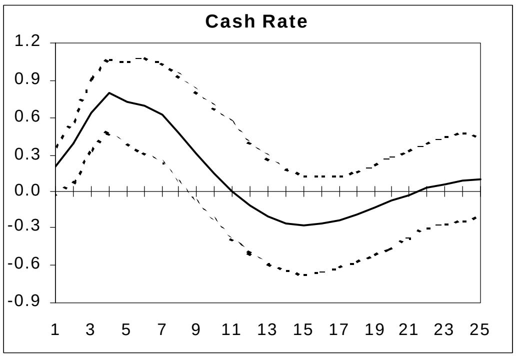
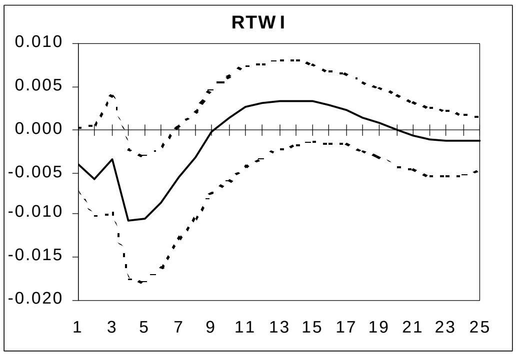



Figure 17:




Impulse Response Functions to a one Standard Deviation Shock in CASH

Figure 18:

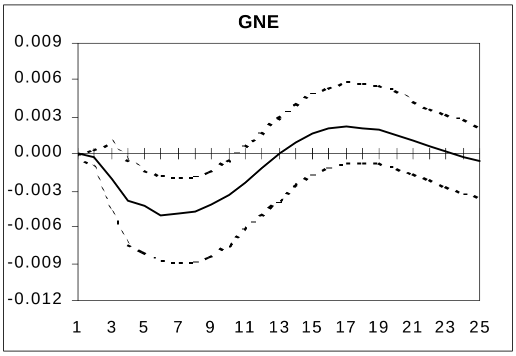



Figure 19:

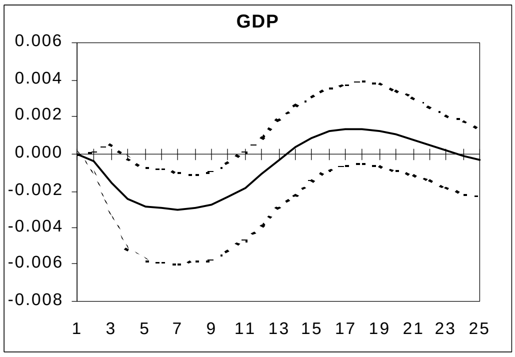


Figure 20:

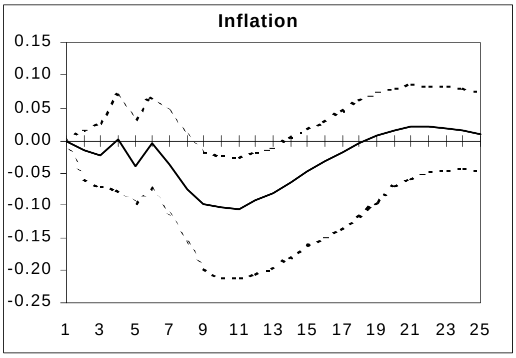
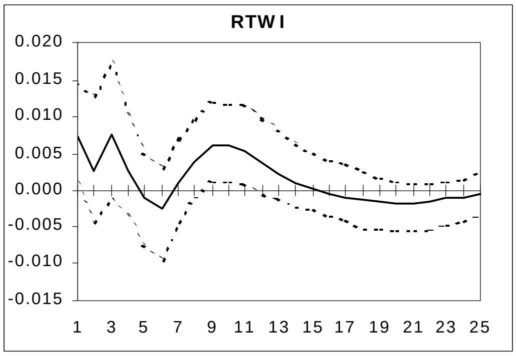



Figure 21:




has risen by 2.3%, and inflation is 1.3% higher per annum; the relative movements in GNE and GDP mean that the balance of trade declines as a fraction of GDP. The implied sacrifice ratio is 1.8, slightly below the range of values reported in Stevens (1992).

**(v) A Cash Rate Shock**

The final shock to be examined is an unanticipated increase in the domestic cash rate (Figures 18-21). As expected the higher cash rate results in decreased real domestic activity and inflation. The impact on GNE is much stronger than that on GDP, reflecting the fact that some of the reduced demand will be absorbed by a decline in imports. Theoretically an initial appreciation would be expected in response to an unanticipated increase in the cash rate; what happens after that reflects the response of the economy and any further policy actions with respect to the cash rate. In our estimated model the appreciation is sustained for the first four quarters after the shock, although it is statistically insignificant. Thereafter a depreciation occurs, which is responsible for an interruption in the rate of fall in inflation, before the earlier pattern of an appreciating exchange rate, declining inflation, and falling activity resumes. As we would expect, the response of inflation to the cash rate shock lags that of output. It is interesting to observe that, in general, it has been difficult to detect the effects of monetary actions in VAR studies. Indeed, a whole literature has grown up around the issue of how one might specify a model to identify these shocks, including the vigorous debate between Rudebusch (1998a,b) and Sims (1998) on the appropriate means of doing so. A pleasing aspect of this study is that we have identified monetary policy responses using only the instrument of monetary policy in our specification, rather than including other non-monetary policy variables such as money supply or reserves (as is the case for Weber (1994) and Brischetto and Voss (1999)).

**V. Historical Analysis of The Australian Growth Cycle**

It is often desirable to be able to provide an explanation of the growth cycle over some historical period. The estimated SVAR can be used for this purpose. Assuming the variable of interest is detrended output, y(t), the SVAR can be converted to its moving average representation,

$$y(t) = \text{initial conditions} + \sum_{j=0}^{t-1} \sum_{k=1}^{11} c_{jk} e_k (t - j), \qquad (3)$$

where $c_{jk}$ is the j'th impulse response associated with the k'th shock, and there are eleven shocks in our system. Figures 22 to 26 show the contributions of LUSGDP, LTOT, LUSQ, LGNE and CASH shocks to the growth cycle in GDP over the sample period. In the early years, up to around 1983, the initial conditions (not shown) also make a substantial contribution to the explanation of any particular observation – so that our comments are largely reserved for the period after 1983. The zero line corresponds to trend growth being achieved, so that a negative value for a particular component means that this shock is causing output to move below trend.[9] Ideally one would want the economy at the zero line all the time. Peaks and troughs in detrended output make the Australian growth cycle clearly evident in the charts.

In the early part of the sample the main driving forces behind GDP is LUSGDP and LUSQ with demand shocks assuming a substantial role post-1987. The pattern of domestic output broadly follows that of LUSGDP, with some exceptions. Following the 1987 stock market crash the contribution of LUSGDP is subdued, although still positive, but this is more than compensated for by the lagged response of expenditures to domestic asset prices, whose origin is the strong foreign asset price movements prior to October 1987 (as seen by the influence of the LUSQ shocks). The overall effect is for Australian

[9] The trend growth rate in GDP for the sample is 3.2% per annum.

GDP to grow strongly above trend. Eventually the LUSGDP and LUSQ influences die out and are replaced by favourable terms of trade and demand shocks. The *initiation* of the early 1990s recession seems to derive from a combination of demand, terms of trade and cash shocks. Foreign output offsets these for a while. Exactly what the nature of the negative demand shocks is cannot be determined from the current model, but tighter fiscal policy is a possibility. Once the recession is established in the Australian economy it is primarily driven by the international economy. The end of the recession in 1994 comes with an expansion in domestic demand accompanied by a small improvement in international conditions and the terms of trade. The earlier cycles are interesting. The 1986 slowdown is generally attributed to terms of trade effects and that is evident here.

Contributions of components to GDP over the sample period:
( solid line is GDP, dashed line the contributing series)

Figure 22:

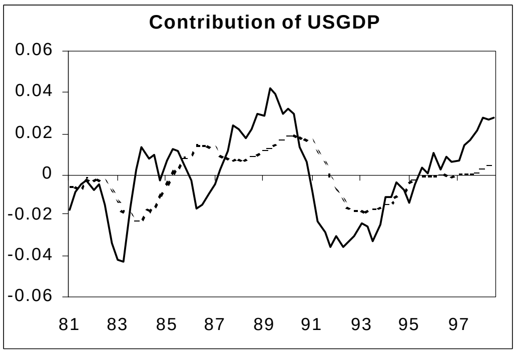



Figure 23:

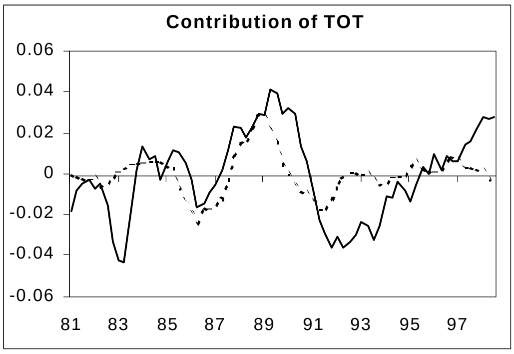



Figure 24:

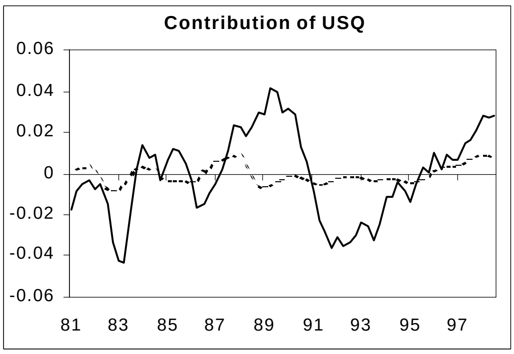



Figure 25:

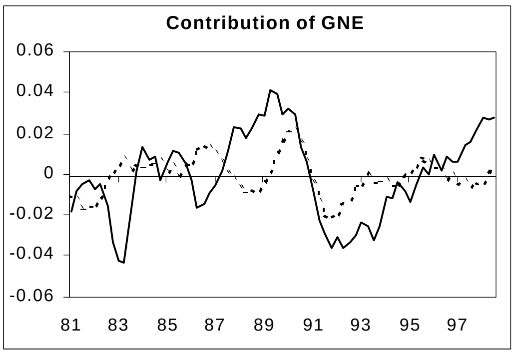


Figure 26:

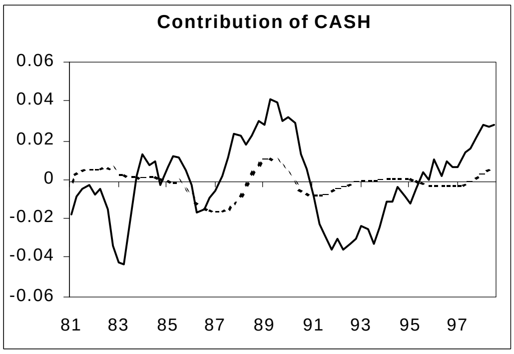
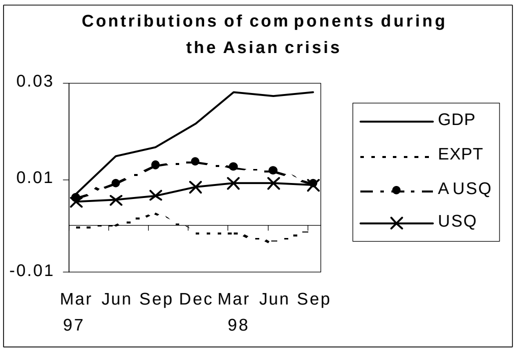



Figure 27:




Finally it is of interest to study the impact of the Asian crisis through the model. The decomposition covers approximately fifteen months of this crisis, taking the starting point to be mid-1997. Figure 27 shows the historical decomposition of the output growth cycle in this period, highlighting the contributions of LEXPT, LAUSQ, and LUSQ shocks. As anticipated by both policy makers and market economists, a negative contribution from exports was recorded against Australian GDP with some delay after the shock. The impact of the export decline on GDP was relatively small, accounting for at most a 0.35% decline in GDP in June 1998. Such an effect is comparable with the 0.38% negative impact of exports in June 1986 during the 1986 slowdown. The strong growth observed in the Australian economy despite the Asian crisis can be attributed in the main to the above trend performance of foreign and domestic asset prices.

**(i) The impact of monetary policy**

The effects of the cash rate shock shown in Figure 26 do not fully capture the impact of ‘monetary policy’. To see this consider a shock to LUSGDP. This will drive up LGNE and LGDP, the cash rate will respond, and this in turn will impact upon LGDP. There are therefore two effects on LGDP of the LUSGDP shock; a *direct* one and an *indirect* (or induced) one coming from the way in which the cash rate is varied in response to domestic economic conditions. To measure the impact of *monetary policy* we therefore need to add together these indirect effects on to the direct effects of cash rate shocks.

To understand the way in which we isolate the indirect effects it needs to be realized that, if there were no feedback relations in the interest rate equation, i.e. only lags of the cash rate itself remained in the equation, then all indirect effects would be zero. This suggests that results from a model in which the feedback rule is suppressed will enable us to isolate the direct and indirect contributions. Formally, we compute impulse responses from a VAR in which the only variables in the cash rate equation are the lagged cash rate variables (the parameters of the system remain the same except that all variables in the cash rate equation are given zero coefficients unless they are lagged cash rate variables). These are designated as $b_k(t)$, allowing predictions of the variable of interest with the monetary policy feedback suppressed to be written as $y^*(t)$, where

$$y^*(t) = initial\ conditions + \sum_{j=0}^{t-1}\sum_{k=1}^{11} b_{jk} e_k(t-j) \qquad (4)$$

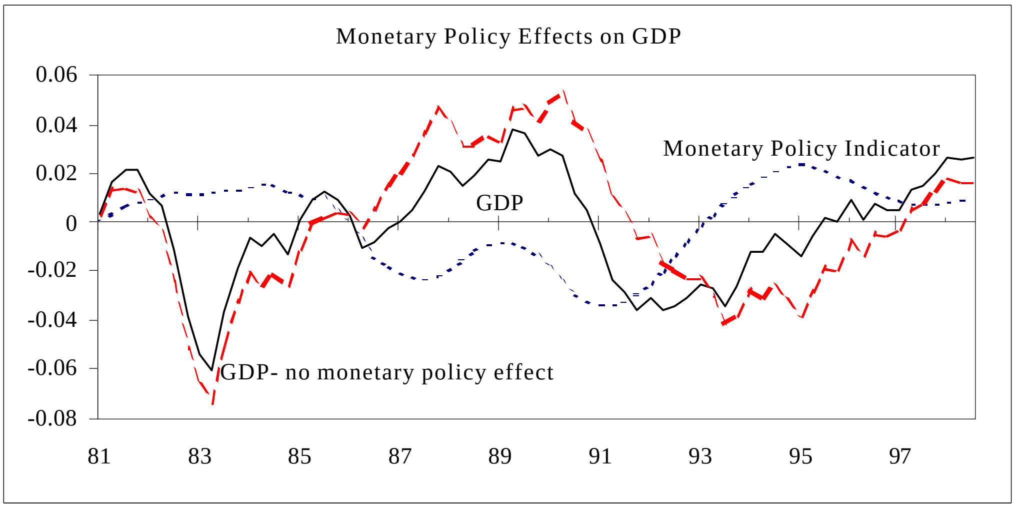
Subtracting (4) from (3) gives the effect on output of monetary policy that comes from feedback in the monetary rule. Therefore, the total effect of monetary policy upon *y(t)* is given by subtracting (4) from (3) and adding back in the effects of cash rate shocks i.e.

$$\text{MPI}_t = \sum_{j=0}^{t-1} b_j e_{10}(t-j) + \sum_{j=0}^{t-1}\sum_{k=1}^{11} (c_{jk} - b_{jk}) e_k(t-j) \qquad (5)$$

with $e_{10}(t)$ being the cash rate shock. In (5) the first term gives the impact of monetary shocks and the second the effects due to feedback. $\text{MPI}_t$ is a *Monetary Policy Index* since it shows how much monetary policy is adding or subtracting to trend adjusted GDP at any point in time. If it is positive then policy might be labelled expansionary, although one would also want to look at the sign of $\Delta\text{MPI}_t$ . About 85% of the variability in MPI is due to feedback effects, showing how important it is to add these to the shocks to get a complete picture of the impact of monetary policy.

Figure 28 plots the value of trend-adjusted GDP and the value it would have been in the complete absence of monetary policy; the difference between these is the $\text{MPI}_t$. A question that might be asked is whether monetary policy is countercyclical. It is not easy to give a formal answer to this question. A tough criterion to satisfy would be to demand that the MPI curve intersect the time axis at the same point as the curve for $y_t$ does, but with opposite slope, since at that point output switches from being above (below) trend to below (above) trend and ideally policy should switch as well.[10] It is clear that this rarely happens. Nevertheless, the graphs do suggest that policy has largely performed in what one would think of as a counter-cyclical fashion in that it has added output in contractions and reduced it in expansions. A weaker test therefore might be to inquire whether the actual path followed by $y_t$ differs in its nature from the series $z_t = y_t - MPI_t$ ; this latter series is what detrended GDP would have been if monetary policy did not operate. Fitting an AR(1) to each series produces AR(1) coefficients of $\rho_y$=.924, $\rho_z$=.952, and standard deviation of innovations of $\sigma_y$=.023 and $\sigma_z$=.029. Thus monetary policy returns output to trend quicker, and the variance around trend is lower, which would seem to qualify it as stabilizing. However, it is also clear that these effects are not large.

Figure 28:




[10] Note that cash rates rose in the second part of 1994 but the lagged response of monetary policy meant that this change did not impact on output until almost a year later. There is obviously an issue about whether one only calls the policy as contractionary or expansionary at the time it operates upon output or whether it would be best to give it that description at the time policy changed. Clearly a forward-looking monetary authority should change the stance of monetary policy well in advance of when the changed policy has an impact. For assessing the intent of a policy change would probably want to utilize the latter definition.

In many ways the results just established are what might have been expected. Since policy takes two quarters to impact upon output and a growth recession lasts a minimum of three (with an average of around 6) quarters, unless the growth recession can be predicted sufficiently far in advance, the economy will be well into a growth recession before policy moves to offset it. The late reaction of policy is clearly evident in Figure 28, where it has often added to growth during expansions and subtracted from it during recessions. For example, monetary policy was too loose when the economy was emerging from the early 1980s recession, and it did not begin to constrain the economy until 1986, while the evidence on the early 1990s recession suggests that tight monetary policy was held longer than was optimal. It is interesting to observe that monetary policy took a maximum of 3.7% from GDP in the March quarter of 1991 and added a record 2.4% on to it in the March quarter of 1995. Monetary policy has been expansionary from mid-1993 according to this decomposition, although it has become less so after 1995Q2. Negative contributions from RUS, and to a lesser extent TOT, seem to be responsible for the minor slowdown in 1995/96, something that has often been attributed to monetary policy. Our decomposition suggests that, while policy certainly tightened, it continued to produce a positive contribution to output.

**(ii) Analysing the Contribution of Foreign Shocks to the Growth Cycle**

Traditionally impulse response analysis has been supplemented with a variance decomposition of forecast errors at various time horizons. Sometimes these decompositions are interpreted as providing information about the drivers of the economic cycle. However, the connection is rather tenuous, since it is hard to relate a forecast decomposition to features of the cycle. Consequently, it seems more satisfactory to try to perform a direct analysis of how shocks affect the nature of the average growth cycle. In particular we are interested in how the shocks originating from overseas impact upon the Australian growth cycle.

We first need to define what we mean by a growth cycle. Figure 28 gave a graph of detrended GDP. There are noticeable peaks and troughs in this series and the periods between these peaks and troughs then qualify as periods that may be termed as either an expansion or a contraction (the phases) of the growth cycle. Although a visual inspection of figure 28 does provide some striking peaks and troughs, there are also some that would be regarded as more questionable, because the period of time between them seems to be too small to be regarded as marking out a genuine phase. For example, it seems unlikely that being below trend for one or two periods would make an analyst call a growth recession. Therefore, some rules need to be applied in order to sort out the "true" peaks and troughs from the "false" ones. This process is a familiar when dating cycles in the level of output - the classical cycle. In that context a standard set of rules has slowly evolved to perform this task and these form the basis of the NBER's dating of the U.S. business cycle. In particular, phases of the classical cycle must be at least 2 quarters long and the complete cycle must be at least 5 quarters. It is tempting to apply the same rules to establish a growth cycle but we feel that this would be inappropriate. At its most basic one could observe that the recording of two periods of negative growth (often taken to signal a recession in the classical cycle) is a very rare event compared to two periods of below-trend growth. Accordingly, we took the BBQ computer program described in Harding and Pagan (1999), which implements NBER ideas for the classical cycle, and modified it so as to impose the requirement that a phase of the growth cycle must be at least 3 quarters in duration, while the complete cycle must be at least six quarters. We term the modified program BBQG. When we apply this to Australian data the growth cycle dates match up quite closely with what one would have thought to be the obvious set from a visual inspection of figure 28.

Once the growth cycle turning points have been identified we need to measure its characteristics in some way. In Harding and Pagan four measures were proposed- the duration of the phases, their amplitudes, their cumulated movements, and their shapes. Because the length of the growth cycle tends to be rather robust to changes in the process generating it (unlike the classical cycle), and the shapes do not change because all our models are linear, the two indices that we focus upon are the amplitudes and cumulated movements.

With the modification just described we simulate data from our SVAR and then pass it through BBQG to produce the characteristics of the average growth cycle. The first column of Table 4 shows what the latter are for Australian quarterly GDP data over the period 1959/3-1997/1. The second column gives the average growth cycle characteristics from our simulated SVAR while the remaining columns report results from the following two experiments which investigate how the growth cycle changes if various shocks are absent.

(i) Cutting off all external shocks by setting them to zero. External here means USGDP, RUS, TOT, USQ and EXPT.

(ii) Cutting off USGDP shocks only.

The average cycle characteristics recorded in Table 4 are based on 1000 simulations. It is apparent that the simulated growth cycles are symmetric because the errors have been assumed to be symmetric and the models are linear; this also seems to be true of the data. Suppression of the foreign sector makes a great deal of difference to the Australian cycle showing just how important foreign influences are. It is not true however that it is solely due to USGDP shocks; if these did not occur then there would be some amelioration of the cycle, but well below the reduction obtained by suppressing all foreign elements. Our decomposition aims to separate out pure U.S. GDP shocks from pure financial shocks and it is apparent that the latter are the most important.

Table 4: Actual and Simulated Growth Cycle Amplitudes and Cumulated Movements

| | Actual | Fitted | Foreign shocks absent | UGDP shocks absent |
|---|---|---|---|---|
| AMPLITUDE | | | | |
| Recession | -0.0633 | -0.0614 | -0.0320 | -0.0530 |
| Expansion | 0.0647 | 0.0614 | 0.0320 | 0.0529 |
| CUMULATED | | | | |
| Recession | -0.3394 | -0.2986 | -0.1471 | -0.2343 |
| Expansion | 0.5983 | 0.2986 | 0.1419 | 0.2398 |

## VI. Conclusion

In this paper we have developed a VAR model of the Australian economy which seems to both capture most of the observed features of the real economy over time and behaves broadly as expected in response to various shocks. The feature which differentiates this work from its predecessors is the inclusion of a more complete overseas sector and asset markets. Historical decompositions are used to consider the structure of the business cycle over the period from 1980 to 1997, showing that, although overseas activity is generally a substantial contributor to domestic activity, the cycles are not fully synchronised. In particular, the start of the 1990s recession can be characterised as due to falls in domestic demand and tight monetary conditions, although the recession was then sustained by weak overseas activity. The negative influence of the Asian crisis on exports emerges from our decomposition, but also apparent was the way in which it was offset by buoyant conditions stemming from asset markets. An analysis of the business cycle characteristics of the simulated series from the SVAR shows that the system does quite well in matching the average Australian growth cycle. Further, simulations of the system were used to demonstrate that the overseas sector is important in obtaining those characteristics and that both foreign output and asset price effects play a major role in the Australian growth cycle. Throughout, the influence of monetary policy on the economy is seen to contribute to stabilizing activity, although the effects are not large.

## Appendix: Data Description and Sources

The data used in the VAR are quarterly from 1980Q1 to 1998Q3 as described below. All data were extracted as at October 1999.

| | |
|---|---|
| USGDP | U.S. real Gross Domestic Product obtained from Datastream [USGDP...D]. |
| TOT | The National Accounts terms of trade for merchandise goods series, obtained from the DX database [BTBQ.ATCHX130]. |

RUS — The quarterly 90 day U.S. Treasury Bill rate was obtained from Datastream [USESTBIL] by averaging the monthly series. This nominal series was deflated using the U.S. CPI data [USI64…F].

USQ — The quarterly average of the monthly Q ratio obtained by dividing the quarterly average of the Dow Jones Index from Datastream [USDJINDUS] by the U.S. CPI obtained from Datastream [USI64…F]. An alternative measure would be to replace the Dow Jones Index by the S&P500 Index from Datastream but there was little difference in results when this was done.

EXPT — Real Seasonally Adjusted Chain-Weighted Exports obtained from Datastream [AUEXPGSVD].

AUSQ — The Q ratio obtained by dividing the quarterly average of the monthly All Ordinaries Index by the Implicit Price Deflator for Plant and Equipment; both series were obtained from Datastream [AUSHRPRC/AU001060E].

GDP — Real Seasonally Adjusted Chain-Weighted Gross Domestic Product obtained from Datastream [AUGDP…D].

GNE — Real Seasonally Adjusted Chain-Weighted Gross National Expenditure obtained from Datastream [AUGNE…D].

INF — The 'target' inflation rate, compiled as a spliced series of the headline inflation rate from the DX database [RSRQ.UI90C90110001] and the Acquisition series available from the Reserve Bank to cover the period when the headline CPI included interest rate costs as a measure of mortgage expenses.

CASH — The quarterly average of the 11am cash rate series published by the RBA in Bulletin Table F.1. This was obtained from Datastream [AUCASH11F].

RTWI — Quarterly real Trade-Weighted Index of the Australian dollar supplied by the Reserve Bank of Australia as used in Blundell-Wignall, Fahrer and Heath (1993).

**References:**

Bernanke, B.S. and Blinder A.S. (1992), 'The Federal Funds Rate and the Channels of Monetary Transmission', *American Economic Review* **82**, 901-21.

Blundell-Wignall A., Fahrer J., and Heath, A. (1993),. 'Major influences on the Australian Dollar Exchange Rate' in A. Blundell-Wignall (ed), *The Exchange Rate, International trade and the Balance of Payments*, Reserve Bank of Australia, Sydney, 30-78.

Brischetto, A. and Voss G. (1999), 'A Structural Vector Autoregression Model of Monetary Policy in Australia' mimeo, Reserve Bank of Australia.

Cushman, D.O. and Zha, T.A. (1997), 'Identifying Monetary Policy in a Small Open Economy Under Flexible Exchange Rates', *Journal of Monetary Economics* **39**, 433–448.

de Brouwer, G. and Ericsson, N.R. (1998), 'Modelling Inflation in Australia' *Journal of Business and Economic Statistics* **16**, 433-449.

de Roos, N. and Russell, B. (1996), 'Towards an Understanding of Australia's Co-Movement with Foreign Business Cycles' Reserve Bank of Australia Research Discussion Paper 9607.

Fisher, L.A. (1996), 'Sources of Exchange Rate and Price Level Fluctuations in Two Commodity Exporting Countries: Australia and New Zealand' *Economic Record* **72**, 345-58.

Fraser, B.W. (1995), 'Economic Trends Down Under' Speech given to Westpac European Economics Conference 13 June 1995, reprinted in *Reserve Bank of Australia Bulletin*, July 1995

Gali, J. (1992), 'How Well Does the IS-LM Model Fit Postwar U.S. Data?', *Quarterly Journal of Economics* **107**, 709-738.

Garratt, A., Lee, K., Pesaran, H.M. and Shin, Y. (1999), 'A Long Run Structural Macroeconometric Model of the UK' mimeo, University of Cambridge.

Gruen, D. and Dwyer, J. (1995), 'Are Terms of Trade Rises Inflationary?' Reserve Bank of Australia Research Discussion Paper 9508.

Gruen, D. and Shuetrim, G. (1994), 'Internationalisation and the Macroeconomy' in P. Lowe and J. Dwyer (eds), *International Integration of the Australian Economy*, Reserve Bank of Australia, Sydney, 309-363.

Gruen, D.W.R. and Smith, J. (1994), 'Excess Returns in a Small Open Economy' *Economic Record* **70**, 381-396.

Hall, S. (1995), 'Macroeconomics and a Bit More Reality' *Economic Journal* **105**, 974-88.

Hamilton, J. (1994), *Time Series Analysis*, Princeton University Press, Princeton.

Hansen, L.P. and Sargent, T.J. (1981), 'Formulating and Estimating Dynamic Linear Rational Expectations Models', in R.E. Lucas and T.J. Sargent (eds), *Rational Expectations and Econometric Practice*, University of Minnesota Press, Minneapolis.

Harding, D. and Pagan, A.R. (1999), 'Dissecting the Cycle' Melbourne Institute Working Paper No. 13/99.

Huh, H. (1999), 'How well does the Mundell-Fleming model fit Australian data since the collapse of Bretton Woods?' *Applied Economics* **31**, 397-407.

Ireland, P.N. (1996), 'The Role of Countercyclical Monetary Policy', *Journal of Political Economy* **104**, 704-723.

Kilian, L. (1998), 'Small-sample Confidence Intervals for Impulse Response Functions' *Review of Economics and Statistics* **80**, 218-30.

Kim, S. and Roubini, N. (1999), 'Exchange Rate Anomalies in the Industrial Countries: A Solution with a Structural VAR Approach', mimeo, University of Illinois, Urbana-Champaign.

King, R. G., Plosser, C. and Rebelo, S. (1988),.'Production, growth and business cycles I: The basic neoclassical model', *Journal of Monetary Economics* **21**, 195-232.

Long, N.V. and Pitchford, J.D. (1993), 'The Terms of Trade and Real Income in a Small Open Economy' In H. Herberg and N.V. Long, eds, *Trade, Welfare , and Economic Policies: Essays in Honour of Murray Kemp,* 367-78, Ann Arbor, University of Michigan Press.

Lowe, P. (1992), 'The Impact of Real and Nominal Shocks on Australian Real Exchange Rates' Reserve Bank of Australia Research Discussion Paper 9201.

MacFarlane, I. (1999), 'Australian Monetary Policy in the Last Quarter of the Twentieth Century' *The Economic Record* **75,** 213-224.

Moreno, R. (1992), 'Macroeconomic Shocks and Business Cycles in Australia' *Federal Reserve Bank of San Francisco Economic Review* **3**, 34-52.

Murphy, C. and Smith, J. (1990), 'Determinants of the Australian Real Exchange Rate', paper prepared for the Office of EPAC workshop on the exchange rate.

Orden, D. and Fisher, L.A. (1993), 'Financial Deregulation and the Dynamics of Money, Prices and Output in New Zealand and Australia', *Journal of Money, Credit and Banking* **25**, 273-92.

Otto, G. (1995), 'Terms of Trade Shocks and the Australian economy' University of New South Wales Economics Department Working Paper No. 95/23.

Otto, G. (1999), 'The Solow Residual for Australia: Technology Shocks or Factor Utilization?' *Economic Enquiry* **37**, 136-53.

Pesaran, M.H. and Pesaran, B. (1997), *Working with Microfit 4.0: Interactive Econometric Analysis*. Oxford University Press, Oxford.

Rudebusch, G. (1998a), 'Do Measures of Monetary Policy in a VAR Make Sense?' *International Economic Review* **39**, 907-31.

Rudebusch, G. (1998b), 'Do Measures of Monetary Policy in a VAR Make Sense? A Reply' *International Economic Review* **39**, 943-48.

Sims, C.A. (1998), 'Comment on Glenn Rudebusch's 'Do Measures of Monetary Policy in a VAR Make Sense?' *International Economic Review* **39**, 933-41.

Sims, C.A. (1992), 'Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy', *European Economic Review* **36**, 975-1000.

Sims, C.A. (1980), 'Macroeconomics and Reality' *Econometrica* **48**, 1-48.

Smith, J. and Murphy, C. (1994), 'Macroeconomic Fluctuations in the Australian Economy', *Economic Record* **70**, 133-149.

Stevens, G. (1992), 'Inflation and Disinflation in Australia: 1950-91' in A. Blundell-Wignall (ed), *Inflation Disinflation and Monetary Policy*, Reserve Bank of Australia, Sydney, 183-244.

Summers, P. (1999), 'For the Student: Macroeconomic Forecasting of the Melbourne Institute' *Australian Economic Review* **32**, 197-205.

Tarditi, A. (1996), 'Modelling the Australian Exchange Rate, Long Bond Yield and Inflationary Expectations' Reserve Bank of Australia Research Discussion Paper, no. 9608.

Trevor, R. and Thorp, S. (1988), 'VAR Forecasting Models of the Australian Economy: A Preliminary Analysis' *Australian Economic Papers* **27**, Supplement June 1988, 108-20

Weber, E.J. (1994), 'The role of money during the recession in Australia in 1990-92' *Journal of Applied Financial Economics* **4**, 355-361