CREDIT AND MONETARY POLICY: AN AUSTRALIAN SVAR

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Abstract

Credit is an important macroeconomic variable that helps to drive economic activity and is also dependent on economic activity. This paper estimates a small structural vector autoregression (SVAR) model for Australia to examine the intertwined relationships of credit with other key macroeconomic variables. At short horizons, shocks to the interest rate, the exchange rate, and past shocks to credit are found to be important for credit growth. Over longer horizons, shocks to output, inflation and commodity prices play a greater role.

The response of credit to changes in monetary policy is found to be relatively slow, similar to that of inflation and slower than that of output. The model suggests that an unexpected 25 basis point increase in the interest rate results in the level of credit being almost half of a percentage point lower than it otherwise would have been after a bit over one year, and almost 1 per cent lower after four years.

Estimates from the model indicate that in responding to the macroeconomic consequences of a credit shock, monetary policy appears to stabilise the economy effectively. As a result of monetary policy's response, output and the exchange rate are barely affected by a credit shock. The credit shock results in higher inflation for about two years, but it would be higher still over this period in the absence of a monetary policy response. Changes in credit are also moderated as a result of monetary policy's response.

JEL Classification Numbers: E51

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1. Introduction

Credit is an important macroeconomic variable that both helps to drive economic activity and is also dependent on economic activity. Expenditure financed by credit growth will boost output, but at the same time strong output growth can stimulate the demand for credit to finance further expenditure (such as investment). This paper estimates a small structural vector autoregression (SVAR) model to examine the relationships between credit and other key macroeconomic variables.

The SVAR methodology is used in this paper because it can account for endogenous relationships, and can summarise the empirical relationships without placing too many restrictions on the data. While a SVAR model is compatible with many different economic theories, the estimates can be sensitive to the set-up of the model. For this reason, this paper gives special attention to the robustness of the results.

Particular attention is paid to the interaction between credit and monetary policy. This relationship has mostly been viewed through the lens of the 'credit channel', whereby monetary policy changes cause financial institutions to alter the volume of loans that they issue.[1] This is a story about the supply of credit. Changes in monetary policy also affect the demand for credit. Both sides of the story suggest that tighter monetary policy will be associated with weaker credit growth. On the other hand, the interest rate responds to the macroeconomic consequences of credit growth. Rapid growth of credit could prove to be inflationary, and so elicit a response by the central bank. In this case stronger credit growth will be associated with higher interest rates.

Australian credit has been the subject of many studies, though none have used an economy-wide model to investigate the simultaneous relationships of aggregate

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[1] Bernanke and Gertler (1995) and Mishkin (1996) provide a more extensive discussion of the credit channel.

credit with economic activity and monetary policy. In an early contribution, Bullock, Morris and Stevens (1989) examined the ability of various financial indicators to lead real private demand. They found that lending and credit aggregates appeared to lag rather than lead changes in activity. Stevens and Thorp (1989), using more rigorous statistical techniques, were largely supportive of these findings. In later work, Tallman and Chandra (1996, 1997) argued that financial aggregates held little or no predictive power for other macroeconomic series.

However, Blundell-Wignall and Gizycki (1992) suggested that the conclusions of Bullock *et al* (1989) and Stevens and Thorp (1989) may not hold after the financial reforms of the 1980s. For the period 1984–1991, they showed that business credit led business investment, while overall credit was found to have a two-way relationship with GDP. While Bullock *et al* and Stevens and Thorp did cover some of the deregulation period, Blundell-Wignall and Gizycki contended that it was not sufficient to fully capture the change in dynamics.

Blundell-Wignall and Gizycki additionally argued that credit rationing had not been important in Australia because the supply of loans had consistently exceeded demand. This suggests that a supply-driven credit channel may not have been particularly strong in Australia. Suzuki (2004) supported this view for bank loans using a VAR.

In contrast, Tallman and Bharucha (2000) argued that supply considerations can be important, at least at a more disaggregated level and during particular episodes. They found that after the distress of the early 1990s recession, the major banks pulled back on risky commercial lending. They noted that this reallocation was more marked in the banks that were under the most financial stress.

Most international studies considering the relationship between credit and monetary policy have focused on the credit channel, and so have been limited to bank credit or other components of the aggregate. Two notable studies are Romer and Romer (1990) and Bernanke and Blinder (1992). Both found that contractionary monetary policy shocks reduced the level of US bank loans, albeit with a considerable lag of about 6–12 months. In fact, both studies found that immediately after the shock the level of bank loans actually *increased*. A possible explanation is that firms initially borrowed to smooth the impact of a downturn.

A lagged response of credit was also found for the Netherlands by Garretsen and Swank (1998).

However, a lagged response is by no means a universal finding. For example, Safaei and Cameron (2003) found an immediate impact of monetary policy on Canadian bank credit. For the US, Gertler and Gilchrist (1993) found a similar instantaneous response, contrasting with Bernanke and Blinder (1992) and Romer and Romer (1990).

The remainder of this study is structured as follows. In Section 2 there is a discussion of the variables included in the model, and the assumptions made to identify the SVAR. The results are presented in Section 3. The preferred model is outlined and then used to examine the consequences of shocks to the interest rate and to credit. The robustness of the findings to alternative specifications is considered. This is followed by some concluding remarks in Section 4.

2. The Set-up of the SVAR

2.1 Variables Included in the SVAR

The form of the structural vector autoregression (SVAR) used in this paper reflects the fact that Australia is a small, relatively open, economy for which external shocks can be an important driver. A key decision is how many variables to include in the model. This paper follows Brischetto and Voss (1999) in using a small-scale model, including two variables for the external sector, and five for the domestic sector. While a larger SVAR, such as the 11-variable model in Dungey and Pagan (2000), would allow for richer interactions, a more parsimonious model with more degrees of freedom is likely to be easier to estimate and more stable. The 7-variable SVAR used here seems to provide a good compromise between these trade-offs and is still capable of capturing the key macroeconomic interactions. Dungey and Pagan (2000) provide a survey of other VAR studies of the Australian economy. A brief description of the SVAR methodology, which may be of particular interest to readers not familiar with this technique, is contained in Appendix A.

The role of the external sector is captured by real commodity prices (commodity prices in US dollars deflated by the US CPI, *comm*) and real US GDP (*usgdp*). The domestic sector is captured by: real Australian GDP (*gdp*), quarterly inflation (π), real credit (nominal credit deflated by the CPI, *cred*), the cash rate (i), and the real trade-weighted exchange rate index (*twi*).[2]

Commodity prices are included because they contain information about the world business cycle and are likely to be particularly relevant to a commodity-exporting country such as Australia. The inclusion of commodity prices has also been found to help resolve the 'price puzzle' in VARs, that is, the finding that the price level tends to increase in response to a contractionary monetary policy shock. Commodity prices are thought to control for policy-makers' expectations of future inflation, seemingly the missing factor responsible for the 'price puzzle' (for a survey, see Christiano, Eichenbaum and Evans 1998). Australian VAR studies capture commodity prices in a number of different ways. Suzuki (2004) includes commodity prices, while in Dungey and Pagan (2000) the terms of trade play a similar role. Brischetto and Voss (1999) include world oil prices.

Many papers have found that the global business cycle is an important driver of domestic activity. US GDP is included here as it has been shown to have a particularly strong relationship with Australian activity (see, for example, Gruen and Shuetrim 1994; de Roos and Russell 1996; Beechey *et al* 2000). While US GDP has been used by other recent Australian VAR studies to represent world economic activity, such as Dungey and Pagan (2000) and Suzuki (2004), the US federal funds interest rate has also been used (Brischetto and Voss 1999).

The inclusion of GDP to represent domestic activity is standard. Inflation is included, following Dungey and Pagan (2000), rather than the price level as in Brischetto and Voss (1999). There are no nominal level variables in the model and so the rate of change of prices seems to be a more logical variable to interact with real variables and a nominal interest rate. In particular, for over half of the sample the objective of monetary policy has been an inflation target.

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2 This study uses the credit series revised by the Reserve Bank in 2004 to ensure better coverage of the securitisation of loans, which has been a major innovation in the credit market over the past few years (RBA 2004).

No Australian VAR studies have included total credit. Suzuki (2004) is closest with the inclusion of bank lending. Brischetto and Voss (1999) include a monetary aggregate, while Dungey and Pagan (2000) include neither monetary nor credit aggregates.

The overnight cash rate is included as this has been the chief instrument of monetary policy since the float of the dollar in December 1983 (Grenville 1997 and Dotsey 1987). Brischetto and Voss (1999), Dungey and Pagan (2000) and Suzuki (2004) also include the cash rate, but Haug, Karagedikli and Ranchhod (2003) use a 90-day interest rate to be consistent with New Zealand, the other country in their study.

The real exchange rate is also viewed as an important measure of Australian economic conditions. Sims (1992) suggested that the inclusion of the exchange rate can also help to resolve the price puzzle. Dungey and Pagan (2000) also use this variable, while Brischetto and Voss (1999) and Suzuki (2004) both use the US dollar bilateral exchange rate. The real trade-weighted exchange rate used in this paper captures a broader relationship and is more appropriate to interact with other real variables. Throughout the paper, the 'exchange rate' and 'trade-weighted index' will be taken to mean the real trade-weighted exchange rate index.

All data are quarterly; the sources and further details are given in Appendix B.

2.2 Identification

Structural shocks in a SVAR can be identified by placing some restrictions on contemporaneous relationships. There are few simple theoretical macroeconomic models that explicitly include credit, and seemingly none that determine the timing of effects needed for identification in a SVAR. Therefore previous studies and stylised facts are used to determine the identification restrictions outlined in this section.

The restrictions placed on the contemporaneous relationships among the variables are characterised by Equation (1), which is the left-hand side of the standard SVAR representation (Equation (A2) in Appendix A).

$$BX_t \equiv \begin{bmatrix} 1 & & & & & & \\ b_{21} & 1 & & & & & \\ b_{31} & b_{32} & 1 & b_{34} & b_{35} & & \\ b_{41} & & b_{43} & 1 & & & \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 & b_{56} & \\ b_{61} & & & & b_{65} & 1 & b_{67} \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & 1 \end{bmatrix} \begin{bmatrix} comm_t \\ usgdp_t \\ gdp_t \\ \pi_t \\ cred_t \\ i_t \\ twi_t \end{bmatrix} \qquad (1)$$

The (non-zero) coefficients b_{ij} in Equation (1) indicate that variable j affects variable i instantaneously (for example, b_{21} is the instantaneous impact of commodity prices on US GDP). The coefficients on the diagonal are normalised to one, while the blank entries indicate that those entries in the matrix are constrained to be zero. The assumptions embodied in Equation (1) exactly identify the system.

The transmission of international shocks to the domestic economy can be very rapid. For example, an increase in commodity prices results in an immediate increase in the value of Australian exports, and hence domestic income. Therefore, apart from two exceptions, it is assumed that all foreign variables affect all domestic variables contemporaneously. The first exception prevents an immediate effect of US GDP on monetary policy (that is, the cash rate). This assumption reflects the informational lags faced by policy-makers and is also employed in an open-economy SVAR by Kim and Roubini (2000). The second exception prevents an immediate effect of US GDP on inflation, since the domestic inflationary consequences of world economic activity would normally be thought to be transmitted indirectly through domestic activity.

The domestic variables are deemed not to affect the international variables, reflecting the relatively small size of Australia's economy.

Australian real GDP is assumed to be affected contemporaneously by inflation and credit. Output might respond contemporaneously to inflation because nominal incomes, and so spending, may be fixed in the short term. Alternatively, this assumption can be motivated by the Lucas-Phelps imperfect information model, in which producers face a signal extraction problem. Contemporaneously, producers only observe their own price, and so are unsure whether an increase in their price reflects inflationary pressures or an increase in demand. As a result, they increase production, even if the price increase is purely inflationary. This increase in production could occur quite quickly.[3] The contemporaneous response of output to credit follows Safaei and Cameron (2003) and reflects a quick pass-through of credit to aggregate demand. Given the cost of borrowing, credit will typically be spent as soon as the funds are obtained, immediately adding to aggregate demand.

Equation (1) allows for the possibility of a contemporaneous response of inflation to output. This assumption is common in domestic (Brischetto and Voss 1999; Dungey and Pagan 2000) and international (Bernanke and Blinder 1992) studies.[4] Other domestic variables are assumed to affect inflation only with a lag.

Credit is assumed to respond to output, inflation and the overnight cash rate, contemporaneously. The expectation of future activity is an important determinant of credit demand, as noted by Blundell-Wignall and Gizycki (1992). Current activity, as observed by individual agents, and interest rates, should give some indication of what future conditions hold. The contemporaneous interaction of credit with the interest rate and inflation is justified by the perception that borrowers and potential borrowers will respond quickly to the real cost of credit (the difference between the interest rate and the inflation rate). Note that these assumptions are in contrast to Safaei and Cameron (2003).

The overnight cash rate is assumed to respond contemporaneously only to commodity prices, credit, and the exchange rate. This is justified by information lags. Direct information on these variables is available within the quarter, unlike the other domestic variables. The exchange rate is assumed to respond contemporaneously to all variables, as is common in SVAR studies.

While this study uses the same number of variables as Brischetto and Voss (1999), and attempts to capture the same key macroeconomic interactions, as noted above, it uses a different set of variables to do so. Of particular note is that the SVAR in this paper includes credit, rather than a monetary aggregate as in Brischetto and Voss, in order to specifically understand the interaction of credit with other key macroeconomic variables.

[3] See Romer (2001) for a discussion of the Lucas-Phelps model.

[4] Brischetto and Voss and Bernanke and Blinder use the price level rather than inflation.

This paper also imposes an important restriction on the lagged structure of the model. Given that the Australian economy is small relative to the global economy, it is assumed that lags of the Australian variables have no effect on the international variables. This restriction was not imposed by Brischetto and Voss (1999) but has been used in other studies (for example, Dungey and Pagan 2000). Lags of all variables are included in the equations for the five domestic variables.

2.3 Non-stationarity

Unit root tests suggest that most, if not all, of the variables included in the model are non-stationary, $I(1)$, processes. These tests are available as an unpublished appendix upon request. This raises the issue of the appropriate estimation methodology. This paper follows the existing literature which typically estimates VARs in levels even when the variables are $I(1)$. Indeed, of the VAR studies referenced in this paper, only Haug *et al* (2003) use a vector error-correction model. The preference for VARs in levels can be explained, at least in part, by a reluctance to impose possibly incorrect restrictions on the model.[5] Even with $I(1)$ variables, the residuals will be stationary because of the inclusion of lagged levels of the variables in the VAR. Nevertheless, the possibility of spurious relationships between the $I(1)$ variables remains. Ensuring this is not the case is perhaps best achieved by confirming that the relationships summarised by the SVAR are plausible on economic grounds.

3. Estimation and Results

In the model, inflation is expressed as a quarterly percentage change and the cash rate is expressed in percentage points. All other variables are in logs. The model is estimated for the period that starts with the float of the Australian dollar, in 1983:Q4, and ends in 2003:Q4. This is a similar sample period to that used in most Australian VAR studies. Standard errors for the impulse response functions are calculated using the bootstrap procedure from Kilian (1998).

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5 See the discussion in Hamilton (1994), p 652.

3.1 Lag Length

Table 1 reports serial correlation tests using different lag lengths of the reduced form VAR. On the basis of these results it is not clear what is the appropriate lag length for the VAR. There is weak evidence of first or fourth order serial correlation for almost all lag lengths. Other Australian studies have tended toward shorter lag lengths; Dungey and Pagan (2000) used three lags and Suzuki (2004) used only two. One exception is Brischetto and Voss (1999), whose model contains six lags. A lag length of three was chosen for this study as this provides reasonable dynamics without shortening the estimation sample too much. Section 3.4 demonstrates that the main results are robust to the lag length chosen.

Table 1: Diagnostic Tests

Serial correlation tests for various lag lengths of the SVAR: p values

Lag	*comm*	*usgdp*	*gdp*	π	*cred*	*i*	*twi*
			First order serial correlation				
2	0.29	0.00	0.66	0.06	0.24	0.01	0.99
3	0.03	0.32	0.63	0.03	0.70	0.61	0.82
4	0.01	0.74	0.45	0.30	0.59	0.40	0.37
5	0.43	0.18	0.51	0.76	0.24	0.27	0.29
6	0.13	0.09	0.11	0.24	0.09	0.34	0.11
7	0.12	0.20	0.14	0.13	0.33	0.02	0.69
8	0.11	0.39	0.94	0.60	0.57	0.21	0.79
9	0.53	0.56	0.04	0.24	0.63	0.03	0.05
			Fourth order serial correlation				
2	0.15	0.01	0.04	0.01	0.03	0.08	0.02
3	0.01	0.39	0.02	0.12	0.06	0.50	0.00
4	0.04	0.35	0.13	0.24	0.39	0.69	0.00
5	0.79	0.32	0.65	0.05	0.10	0.60	0.03
6	0.26	0.20	0.14	0.16	0.24	0.08	0.29
7	0.09	0.49	0.07	0.25	0.24	0.02	0.65
8	0.38	0.49	0.92	0.33	0.52	0.67	0.94
9	0.61	0.62	0.25	0.04	0.08	0.01	0.00

3.2 Impulse Responses and Variance Decomposition

Impulse responses provide a useful summary of the relationships implied by the large number of estimated coefficients in the VAR. The impulse responses can be constructed for shocks to any of the variables in the model. In this paper, only the impulse responses for shocks to the cash rate and credit are presented. VAR studies often highlight the response of the economy to monetary shocks, and so impulse responses to a cash rate shock allow a useful comparison with previous studies and a check on the properties of the model. The impulse responses for shocks to credit, and the cash rate, help to highlight the interaction of credit with the rest of the economy.

Figure 1 shows the impulse responses to a structural cash rate shock that increases the interest rate by 25 basis points.[6] These show the deviation of each variable from its baseline. Given that all variables, other than the (quarterly) rate of inflation and the cash rate, are in log form, multiplication by 100 yields the approximate percentage deviation from baseline. The dashed lines are 90 per cent confidence intervals derived using the technique of Kilian (1998).

The shock to the cash rate leads to an instantaneous appreciation of the exchange rate of almost 1 per cent. The increase in the cash rate results in a very small contemporaneous fall in credit which in turn leads to a small fall in GDP and a very small pick-up in inflation.

After the initial shock, the cash rate steadily declines until it is roughly back to baseline three quarters after the shock. It continues to decline for three more years – at which time it is around 25 basis points below baseline – in response to the paths of the other variables, notably the declines in inflation and output. It then gradually picks up.

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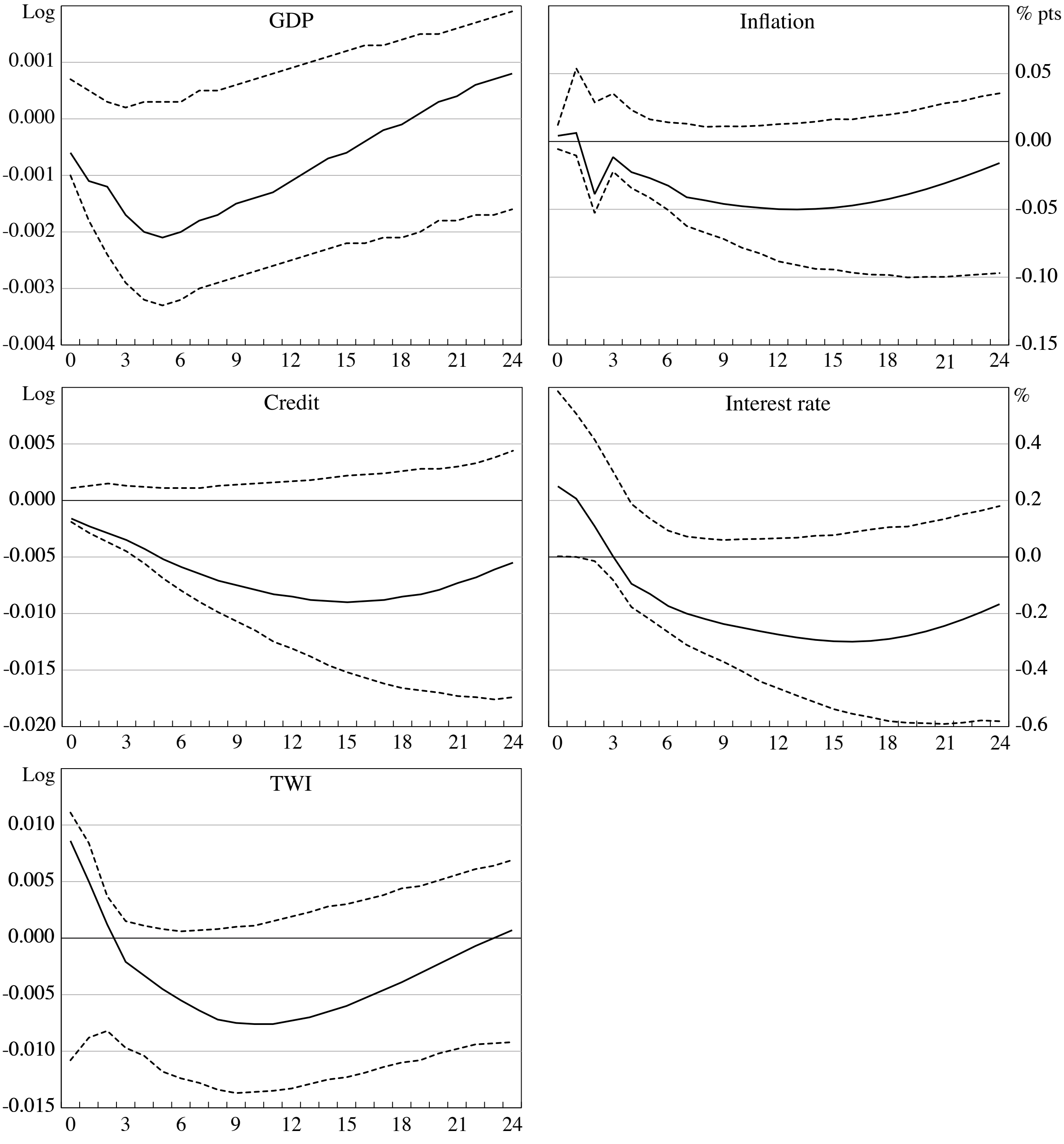
[6] This paper presents impulse responses for reduced form interest rate shocks of 25 basis points, rather than structural shocks of a given magnitude, as often used in VAR studies. This makes comparisons across different specifications straightforward as the initial movement in the interest rate is always the same magnitude. Because of the contemporaneous relationships, the structural shock that results in a 25 basis point reduced form shock is larger – 57 basis points for this specification. The way this is determined is by scaling the structural shock to the interest rate, which is the sixth element of u_t, so that the sixth element of the vector ε_t in Equation (A1) in Appendix A is '+0.25', as determined by the relationship $B\varepsilon_t = u_t$.

Figure 1: Impulse Response to a Cash Rate Shock



GDP declines steadily in the year after the shock, to be about 0.2 per cent lower after five quarters. Following a volatile estimated response in the first year, inflation steadily declines. The maximal response of inflation is about three years after the shock when the quarterly rate of inflation is 0.05 percentage points lower than baseline. The relatively slow response of inflation to a cash rate shock is a well-established result. The timing of the maximum impact on output and inflation is broadly consistent with previous studies for Australia (Brischetto and Voss 1999; Dungey and Pagan 2000).

Credit responds more slowly to the cash rate shock than does GDP. In fact the timing of its response is more akin to that of inflation. Credit is 0.5 per cent below counterfactual levels after five quarters. It continues to fall until it is almost 1 per cent lower after four years, before it begins to recover. It is interesting to note that while the initial response is small, credit appears to respond immediately to the cash rate shock. In contrast, as noted in Section 1, many studies have found that credit only declines in response to an interest rate rise with a lag. Often these studies have used only bank credit, because they have focused on the credit channel. Nevertheless, the immediate response of credit to monetary policy in this SVAR was found to be robust to using only the component of credit provided by banks.

Following the initial appreciation, the exchange rate depreciates, consistent with uncovered interest rate parity. However, it should be noted that the Killian-bootstrapped 90 per cent confidence intervals for all of the impulse response functions are quite wide, so that none of the results are statistically significant at conventional confidence levels. While the impulse responses are not statistically significant, the point estimates are still economically significant, and numerically and qualitatively plausible.

The effect on GDP reported here is somewhat larger than that reported in other studies, for example Dungey and Pagan (2000) and Brischetto and Voss (1999). However, due to the size of the standard errors, there is scope to reconcile the results. By and large, the results for other variables fall within the range that has been established elsewhere.

An alternative method of interpreting the properties of the model is with a variance decomposition. This reports the proportions of the error of forecasts, generated by the SVAR, that are attributable to shocks to each of the variables in the model. The variance decompositions for four different forecast horizons (one quarter, and one, three and six years) are reported in Table 2. Each column reports, for a different domestic variable, the proportion of the forecast error that is explained by structural shocks to each of the seven explanatory variables, listed on the left-hand side of the table (so, for a given time horizon, the entries in a given column sum to one, subject to small differences for rounding).

Table 2: Variance Decomposition

Innovation	**Forecast (quarters)**	**Proportion of forecast error variance for variable**				
		gdp	π	*cred*	*i*	*twi*
comm	1	0.00	0.00	0.03	0.00	0.06
	4	0.07	0.11	0.01	0.04	0.11
	12	0.10	0.22	0.04	0.03	0.24
	24	0.28	0.45	0.44	0.32	0.18
usgdp	1	0.14	0.00	0.03	0.00	0.00
	4	0.27	0.03	0.17	0.00	0.03
	12	0.52	0.05	0.12	0.03	0.18
	24	0.61	0.10	0.05	0.13	0.28
gdp	1	0.57	0.02	0.01	0.01	0.01
	4	0.32	0.03	0.06	0.01	0.04
	12	0.14	0.10	0.15	0.08	0.17
	24	0.04	0.09	0.12	0.11	0.16
π	1	0.18	0.97	0.01	0.02	0.04
	4	0.21	0.67	0.05	0.19	0.02
	12	0.15	0.42	0.29	0.37	0.13
	24	0.05	0.26	0.24	0.27	0.17
cred	1	0.04	0.00	0.39	0.43	0.15
	4	0.01	0.07	0.19	0.43	0.10
	12	0.00	0.03	0.03	0.15	0.02
	24	0.00	0.01	0.01	0.03	0.01
i	1	0.04	0.00	0.34	0.34	0.27
	4	0.08	0.06	0.24	0.20	0.15
	12	0.08	0.11	0.23	0.18	0.11
	24	0.02	0.07	0.11	0.10	0.10
twi	1	0.02	0.00	0.20	0.20	0.46
	4	0.05	0.03	0.28	0.14	0.55
	12	0.01	0.06	0.14	0.17	0.14
	24	0.01	0.02	0.03	0.04	0.09

In the short run, shocks to inflation and GDP's own shocks are important for GDP forecast errors. But as the horizon lengthens, the exogenous global variables, US GDP and commodity prices, play a greater role. This is consistent with previous studies, such as Brischetto and Voss (1999), Dungey and Pagan (2000) and Kim and Roubini (2000). For inflation, its own shocks are responsible for almost all of the short-term forecast error. Over longer horizons, shocks to commodity prices are increasingly important. Shocks to the interest rate have been only a small part of GDP and inflation forecast errors. This too is consistent with many other studies. It is also eminently sensible that an arguably stationary variable such as interest rates has little influence on a trending variable such as GDP in the long run.

Over short horizons, the forecast errors for credit are explained by shocks to credit itself, the interest rate and the exchange rate. Not surprisingly, at longer horizons shocks to major macroeconomic variables – output, inflation and commodity prices – play a greater role. This finding is related to a broader pattern observed in these decompositions. Table 2 shows that innovations to the international variables become more important as time passes across the spectrum of domestic variables. This reflects the role that these exogenous factors play in determining the long-run values of the domestic variables in this type of model.

3.3 The Impact of Monetary Policy and Credit Shocks

Standard impulse response functions describe the response of the system to an exogenous shock, say to the interest rate, but with the paths of all variables, including the shocked variable, endogenously determined. It is this endogenous determination that results in the interest rate in Figure 1 declining after the initial shock to be below baseline after one year. So these impulse responses jointly summarise the response of the variables to an initial cash rate shock *and* the ongoing endogenous response of the cash rate. In many regards, understanding the impact of the systematic component of policy, that is the part that is the endogenous response to observable changes in the economy, is of greater interest (McCallum 1999).

One method to examine this systematic component of policy is to compare the impulse responses when policy responds endogenously to the case in which monetary policy is passive, and so the interest rate remains constant at the initial shocked level. This exercise is of course subject to the Lucas critique given that the behaviour embodied in the equations for the other variables has been estimated when monetary policy has been responsive. Nevertheless, other studies have adopted similar strategies, accepting the problems associated with this exercise.[7] Sims and Zha and Bernanke *et al* noted that this experiment implies that the public are surprised by the passivity of interest rates and interpret this as random deviations from the underlying model. As a result, the plausibility of this experiment diminishes at longer time horizons.

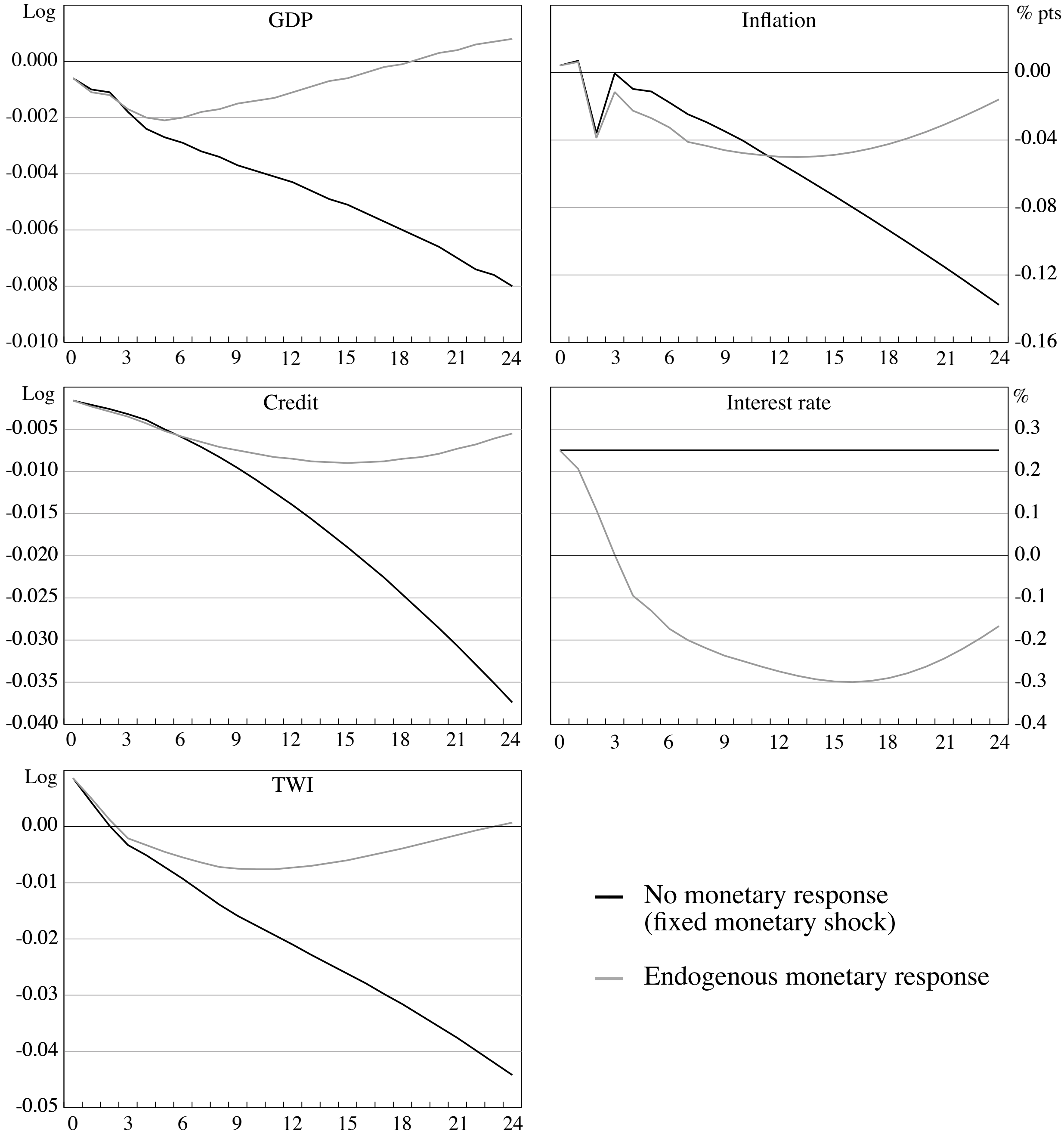
Figure 2 presents these constrained impulse responses (passive monetary policy), along with the unconstrained impulse responses (endogenous monetary policy) from Figure 1, for a structural interest rate shock that increases the cash rate by 25 basis points.

For the first year the constrained and unconstrained impulse responses are almost identical (other than for the interest rate, of course). Thereafter, they begin to deviate. This demonstrates that much of the behaviour of the other variables in the first year is dictated by the initial shock, with the subsequent endogenous response of the interest rate over the first year doing little to unwind these effects. But after the first year the easing in policy from the endogenous response of the cash rate clearly does have an effect, with GDP, inflation, credit and the exchange rate all returning toward baseline. Notably, of all the variables, inflation and credit have the slowest divergence between the constrained and unconstrained impulse responses. This highlights the relatively long lags with which monetary policy affects both inflation and credit.

This technique of comparing the impulse responses when monetary policy is constrained and responds endogenously is also particularly useful for elaborating on the relationship between credit and monetary policy. In particular, it can be used to examine the implications of monetary policy's reaction to a credit shock. Sims and Zha (1998) and Brischetto and Voss (1999) also investigate the

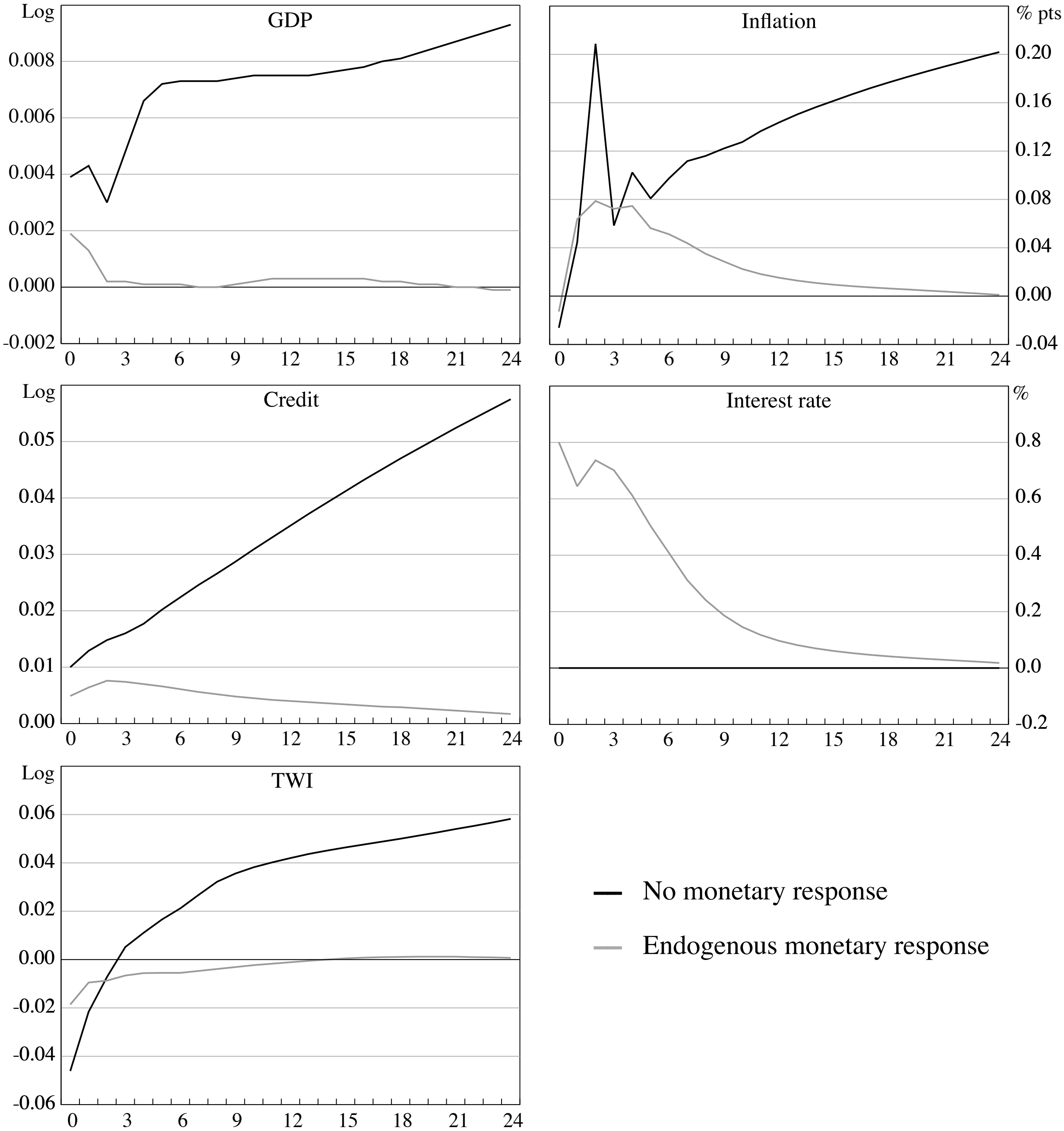
7 Examples are Sims and Zha (1998), Brischetto and Voss (1999) and Bernanke, Gertler and Watson (1997). However, there is a slight difference between the exercise performed in this section and the exercise performed by Sims and Zha. Sims and Zha assume that the monetary variables still respond to their own lags, so the policy variables are not above (or below, depending on the shock) counterfactual values by a fixed constant.

Figure 2: Impulse Response to a Cash Rate Shock



consequences of constraining monetary policy in the face of a shock to a non-policy variable. Figure 3 plots the impulse responses for a structural shock of a 1 per cent increase in credit both with passive (constrained), and endogenous (unconstrained), monetary policy. (In this scenario the impulse responses are based on the same size structural shock, rather than the same size reduced form shock as for the cash rate shock in Figures 1 and 2. This allows the impact of the instantaneous response of monetary policy to be considered).

Figure 3: Impulse Response to a Credit Shock



The impulse response for endogenous monetary policy shows that the credit shock leads to a sizeable increase in the interest rate (the constrained interest rate impulse response is zero by definition). It should be noted though, that this does not imply that monetary policy responds directly to credit movements in and of themselves. Rather, the endogenous changes in monetary policy are the response to all of the variables in the system, notably inflation and output.

The endogenous setting of monetary policy is seemingly quite effective at mitigating the impact of credit shocks. The effects of monetary policy in this case are particularly marked for GDP and the exchange rate, with both experiencing substantially smaller deviations from baseline when policy responds. While inflation picks up in response to the credit shock even when the interest rate is increased, the response is more muted as a result of the policy response.

3.4 Robustness

SVARs can be quite sensitive to the assumptions used in their estimation; see for example Stock and Watson (1996, 2001). In particular, changes to the sample length and the number of lags in the VAR can have large effects. The robustness of the estimates to these factors is considered in this section.

The impulse responses for a structural interest rate shock that increases the cash rate by a 25 basis point reduced form shock to the cash rate for the original specification with three lags, and SVAR models that include four and five lags (but use the same identification restrictions), are shown in Figure 4. The contemporaneous endogenous response of the cash rate differs between these specifications and so a different structural shock must be applied in each case to deliver the 25 basis point reduced form shock.[8] In contrast to the sensitivity of some VAR models to the lag length, Figure 4 demonstrates that the SVAR used in this paper is quite robust to the lag length. In particular, the impulse responses for all variables have broadly the same shape and very similar timing.

The sample period used to estimate the SVAR covers some major changes in the Australian economy, notably reform in the financial sector and the adoption of inflation targeting. The robustness of the results with respect to the sample period is tested by estimating the model for two truncated samples. The first sub-sample removes the first two years (and so covers 1985:Q4–2003:Q4) while the second removes the last two years (1983:Q4–2001:Q4). Shorter sub-samples are not really practical because of the large number of parameters to estimate. The impulse responses to a monetary shock for the standard SVAR estimated over these sub-samples are shown in Figure 5, along with the impulse response based

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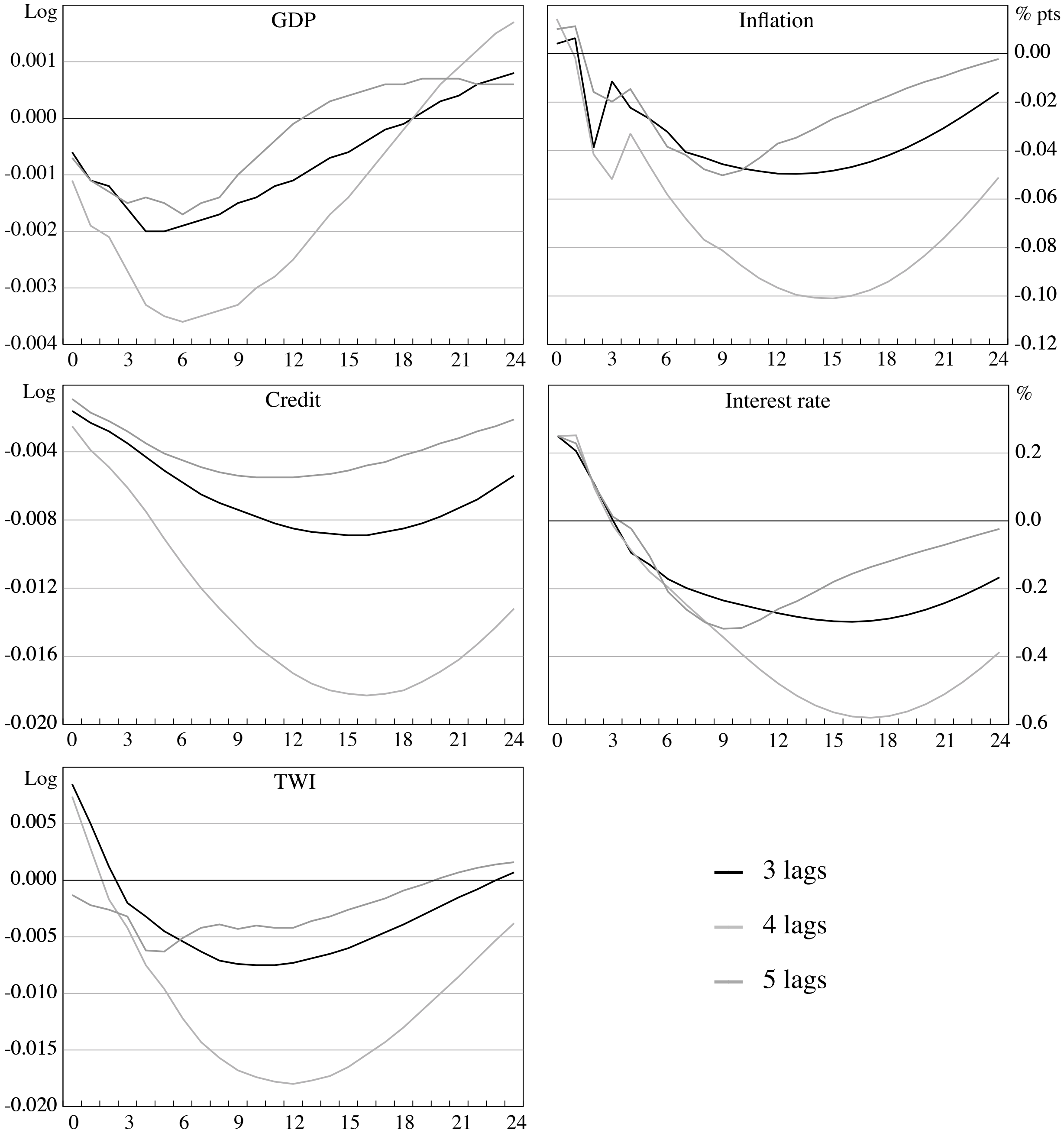
[8] For the models with 3, 4 and 5 lags the structural shocks are, respectively, 57, 82 and 28 basis points.

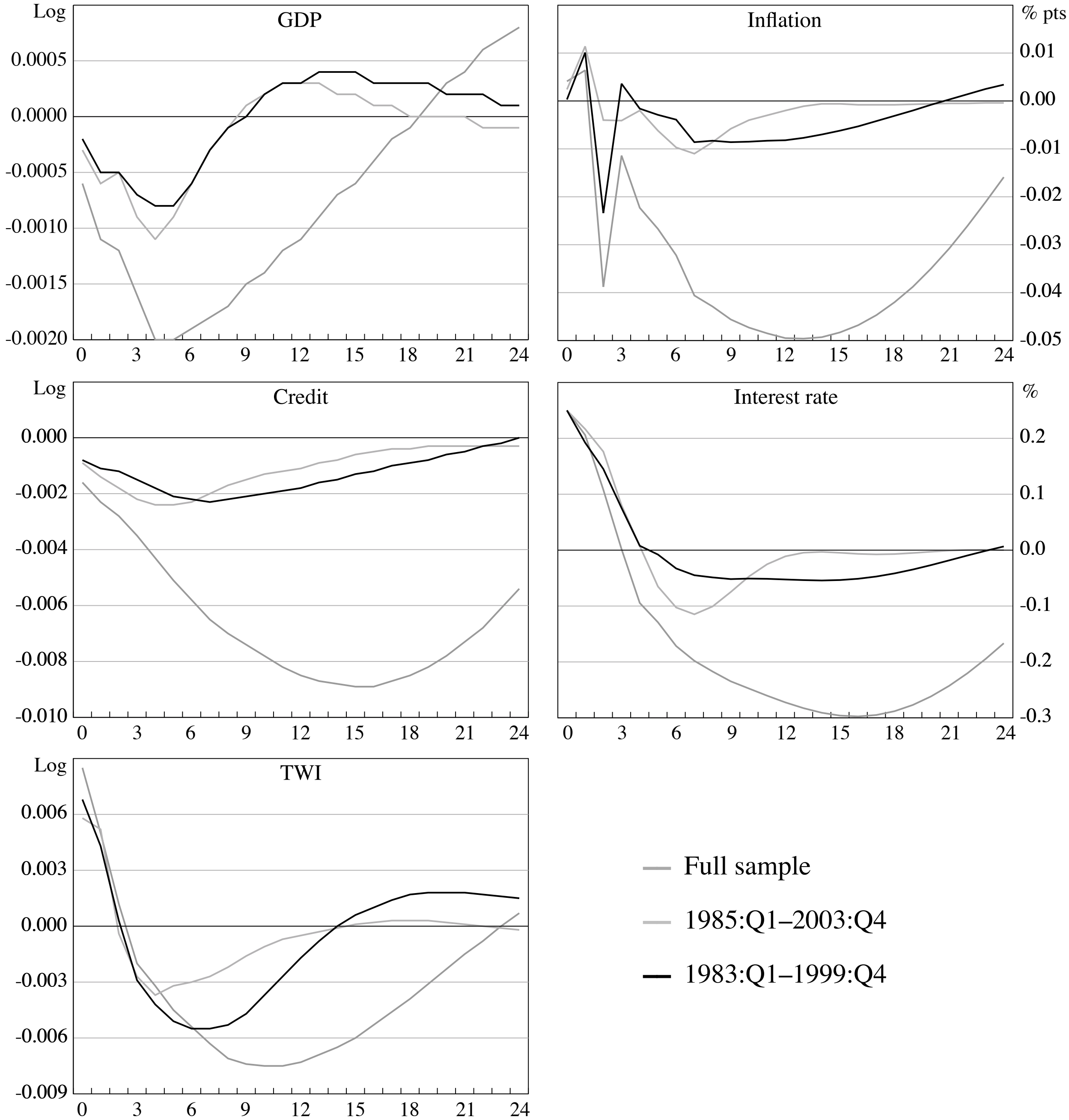
Figure 4: Impulse Response to a Cash Rate Shock



on the full sample. Each model is subject to a structural interest rate shock that increases the cash rate by 25 basis points.[9] The broad patterns are similar under the three specifications, though the model is more sensitive to the sample period than it was to the lag length. The effects of the interest rate shock on GDP, inflation

9 Again, the structural shock which results in a 25 basis point reduced form shock differs in each model. In the 1985:Q4–2003:Q4 and 1983:Q4–2001:Q4 samples it is 32 and 42 basis points, respectively; slightly smaller than 57 basis points in the full sample.

Figure 5: Impulse Response to a Cash Rate Shock



and credit are not as persistent in the two sub-samples. What is common to the two two-year blocks that are excluded to form the sub-samples is that real credit was accelerating very strongly. Further, the muted response of GDP and inflation to an interest rate shock when estimating from 1985:Q4 appears to be influenced by excluding the sharp rise in the cash rate in 1984–1985, which was followed by declines in GDP and inflation. Nonetheless, the sign and timing of the response is reasonably robust to the sample length, especially in comparison to the sensitivity that other authors, including Brischetto and Voss (1999), have found.

The robustness of the model along other dimensions was also examined, though these are not reported for brevity. When the data are detrended, as in Dungey and Pagan (2000), the effects of a monetary policy shock tend to be more persistent, though the efficacy of monetary policy in dealing with credit shocks is almost identical to the results presented in this paper. Similar conclusions are reached when the first difference of the levels series are used in place of the levels data.

4. Conclusion

This paper uses a structural vector autoregression (SVAR) model to examine the endogenous relationships between credit and other key macroeconomic variables, in particular monetary policy. Variance decompositions indicate that, at short horizons, shocks to the interest rate, the exchange rate, and past shocks to credit are found to be important in explaining movements in credit. Over longer horizons, shocks to output, inflation and commodity prices are found to play a greater role. For the domestic variables in general, the exogenous international variables are responsible for a large proportion of forecast errors at longer horizons.

The model suggests that a shock to the interest rate, increasing it by 25 basis points, results in the level of credit being almost half of a percentage point lower after four quarters. If monetary policy subsequently reacts in a manner consistent with its past behaviour, credit continues to decline for about four years, when it is almost 1 per cent lower than the counterfactual level. It then slowly retraces this decline. The timing of the response of credit appears to be similar to that of inflation; the response of output is more rapid, reaching the maximum response after about five quarters. The response of the other domestic variables accords with responses found elsewhere.

The SVAR estimates suggest that in response to a shock to credit, monetary policy plays an effective role in stabilising the economy. The impact of the credit shock on output and the exchange rate are almost completely offset by the response of monetary policy. Monetary policy does not completely counteract higher inflation, which is above baseline for about three years after the shock to credit. But inflation would be higher still over this period if monetary policy was passive to the macroeconomic consequences of the credit shock. Changes in credit are also moderated as a result of monetary policy's response.

The model is robust to changes in the lag length, but slightly less so to changes in the sample period. The sample period spans financial deregulation and the adoption of inflation targeting. It is then perhaps not surprising that the SVAR, which summarises the average dynamic properties of the data over the sample period, is somewhat sensitive to this. A further caveat is that the Killian-bootstrapped confidence intervals are relatively wide, making conclusive statements difficult. Nonetheless, the model presents plausible economic interactions, both in their timing and magnitude.

Appendix A: The SVAR Methodology

This appendix briefly outlines the structural vector autoregression (SVAR) methodology. For a more detailed exposition, the reader is referred to Chapter 11 of Hamilton (1994). Consider the following reduced-form representation of the system:

$$X_t = C(L)X_t + \varepsilon_t \tag{A1}$$

where:

$$E(\varepsilon_t \varepsilon_t') = \Omega$$
$$E(\varepsilon_t \varepsilon_{t+s}') = 0, \forall s \neq 0$$

X_t is a vector of macroeconomic variables, C is a polynomial function of order p and L is the lag operator.

Now consider a square matrix T such that $(T^{-1})(T^{-1})' = \Omega$, so $T\Omega T' = I$, the identity matrix.[10] Define $T = AB$, where A is diagonal and B's diagonal contains only ones. The matrix A has the same lead diagonal as T, but zeros elsewhere, while B is formed by dividing each row of T by the lead diagonal element of that row. Multiplying Equation (A1) by B gives the structural VAR representation:

$$BX_t = BC(L)X_t + u_t \tag{A2}$$

where the matrix B is the contemporaneous relationships between the variables and $B\varepsilon_t = u_t$. The covariance matrix of the errors from Equation (A2) is given by:

$$E(u_t u_t') = E(B\varepsilon_t \varepsilon_t' B') = (A^{-1})(A^{-1})' = D \tag{A3}$$

Note that because A is diagonal, so too is D. Therefore, u_t can be interpreted as a vector of structural shocks, defined as a shock to a particular variable that is orthogonal to other shocks in the economy. In the reduced form, that is Equation (A1), the disturbances, ε_t, could be the result of structural shocks to other variables. For example, unexpected changes to the exchange rate could be caused by contemporaneous disturbances to, say, the interest rate. The matrix B filters the reduced form shocks so that the structural shocks can be identified.

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[10] This can be done if the random shocks are linearly independent. Consider any conformable non-zero vector a. $a'\Omega a = a'E(\varepsilon_t \varepsilon_t')a = E(a'\varepsilon_t \varepsilon_t' a) > 0$, and so Ω is positive definite, thus invertible, and therefore there exists at least one such matrix, T.

The matrix B can be solved for by first running the VAR represented in Equation (A1) to obtain an estimate of Ω. From this estimate, B and A can be calculated from the equation $((AB)^{-1})((AB)^{-1})' = (T^{-1})(T^{-1})' = \Omega$ if sufficient restrictions are imposed on these two matrices. Suppose that there are k variables in the system, so there are k^2 degrees of freedom in A and B. Because Ω is a symmetric matrix, there are only $\frac{k^2+k}{2}$ unknowns, so at least $\frac{k^2-k}{2}$ restrictions need to be imposed. These restrictions typically, but not always, take the form of restricting B's off-diagonal elements to be equal to zero, and as such constitute restrictions on the contemporaneous affect of one variable on another. Some studies choose a Choleski decomposition of Ω, resulting in a temporal ordering of the variables. This is referred to as a recursive VAR. An alternative, followed here, is to allow a more elaborate set of restrictions guided by economic theory. This is referred to as a SVAR.

Appendix B: Data Descriptions and Sources

Real commodity prices (*comm*): Index of commodity prices in US dollars (Reserve Bank of Australia), deflated by the United States underlying CPI (Datastream code: USCPXFDEE).

US gross domestic product (*usgdp*): The natural logarithm of seasonally adjusted quarterly real US GDP (Datasteam code: USGDP...D).

Australian gross domestic product (*gdp*): The natural logarithm of seasonally adjusted quarterly real Australian GDP (ABS Cat No 5206.0).

Real break-adjusted credit (*cred*): The natural logarithm of seasonally adjusted break-adjusted Australian credit (Reserve Bank of Australia, *Bulletin* Table D.2) deflated by the weighted median consumer price index excluding taxes and charges (Reserve Bank of Australia). Break adjustment occurs for various reasons (for example, the securitisation of loans). The quarterly credit series is constructed as for the last month of the quarter. Credit is defined as 'lending and credit to the private non-finance sector (including public trading enterprises) or, where stated, the government sector, by those financial intermediaries whose liabilities are included in broad money'.

Inflation (π): Quarterly inflation of the weighted median consumer price index excluding taxes and interest (Reserve Bank of Australia).

Overnight cash rate (*i*): Overnight cash rate, averaged over the quarter. Nominal official cash rate until June 1998, and then the interbank overnight rate (Reserve Bank of Australia).

Real trade-weighted index (*twi*): Real trade-weighted exchange rate index (Reserve Bank of Australia).

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