The Output Composition Puzzle - compositional response of GDP to Australian monetary policy.

By Muheed Jamaldeen*

Abstract

The ‘output composition puzzle’ refers to economy-specific responses of components of GDP to domestic monetary policy. This paper analyses the compositional response of Australian output to domestic monetary policy using Structural Vector Auto Regression (SVAR) models estimated over the period 1986 to 2013 and makes a distinction between the sensitivity of each GDP component, and its contribution to GDP deviation. This study finds that investment is most sensitive (followed by net exports) to unanticipated increases in the cash rate, and also contributes the most to output deviation. However, this study also finds that net exports are a key driver of output reduction in the first year, and then play a role in dampening the investment contraction in subsequent years. This suggests that the exchange rate channel is particularly important for the transmission of Monetary Policy in Australia. In addition, this study finds that within investment, new dwelling investment is the most sensitive to cash rate shocks. However, the rest of investment contributes more to contractions in output. In contrast, durable consumption appears to be slightly more sensitive than its non-durable counterpart in the first year. Interestingly, this study does not show evidence of a statistically significant ‘price puzzle’ or other puzzles encountered in other SVAR studies.

Keywords: monetary policy, output composition, Structural Vector Auto Regression.

JEL classification: E52, E27, E20

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1 Introduction

Australian monetary policy has evolved considerably over the last few decades. The introduction of inflation targeting in 1993, accompanied by central banking independence has brought monetary policy to the forefront of economic management. Early studies such as Friedman and Schwartz (1963) postulated that monetary policy changes drive changes in output. These views were reaffirmed by more recent studies such as Romer and Romer (1999) and Christiano, Eichenbaum and Evans (1994). As a result of these research efforts and many others, there is general consensus amongst economists that in the short-run monetary policy can significantly influence the real economy (Bernanke and Gertler (1995)). With a few notable exceptions, there has been limited research into the monetary policy impact on disaggregated GDP. Focusing only on aggregate GDP would leave out important information regarding the differential dynamic responses of GDP components to changes in monetary policy.

Given the ability of monetary policy to influence output in the short run, it is vital to understand how and why output behaves in this way. Studies that explicitly explore the monetary transmission mechanism answer the question ‘why’. This paper attempts to answer the question ‘how’ output responds the way it does by exploring the differences in the responses of its key components. Answering the question ‘how’ would provide the monetary authority with information about the sectors of the economy and the key agent behaviour that deserves the central bank’s particular attention.

Angeloni et al (2003) examine differences between the US and the Euro Zone in terms of their compositional GDP responses to monetary policy. They refer to the economy-specific response of the components of GDP as ‘the output composition puzzle’. The response is deemed a ‘puzzle’ because even though the conventional understanding is that investment responds to interest rate changes (thereby contracting output); the authors find that it is in fact consumption in the US, and investment in the Euro Zone that contributes the most to GDP deviation. This paper adds to the literature on the output composition puzzle, by examining the response of disaggregated GDP to Australian monetary policy using a Structural Vector Auto Regression (SVAR) model of the economy. The nature of the disaggregated GDP response to monetary policy may provide policy makers greater insight into structural properties of the economy (such as institutional arrangements) that influence the GDP response.
2 Literature review

Since Sims (1980) introduced Vector Auto Regression, it has become a popular econometric method used to model interactions in the macro-economy. However, it is not without its critics. Initially, identification of VAR models used a recursive causal ordering of the variables. Cooley and Le Roy (1985) criticised this inherently arbitrary atheoretical approach because it depended on the ordering of the variables. This could lead to findings of reverse causation between some of the variables according to the ordering employed. In response to this criticism, Bernanke (1986) and Sims (1986) introduced Structural VARs (SVARs) which utilised non-recursive identification of the structural matrices instead.

Studies such as Bernanke and Gertler (1995), Radatz and Rigobon (2003), and Erceg and Levin (2002) utilise disaggregated GDP in SVAR models of the US economy. However, none of these studies analyse the ‘output composition puzzle’ per se. These papers focus on specific elements of GDP, in relation to specific research questions.

The term ‘output composition puzzle’ was first coined by Angeloni et al (2003). The puzzle refers to the difference in the compositional response of GDP to domestic monetary policy in different countries. They conduct a comparative study of the US and the Euro Zone area, in which they compare the disaggregated GDP response (to domestic monetary policy shocks) of the two areas, to illuminate differences in consumer and investor behaviour between the two regions. They use three methodologies: SVAR models, large macroeconomic structural equation models, and Dynamic Stochastic General Equilibrium (DSGE) models. In addition to utilising existing large scale structural equation models for the US and, Euro Zone; the authors construct country-level SVARs for the Euro Zone, and area SVARs for the US, and Euro Zone.

They find that large scale structural equation models for the US and Euro zone produce similar results to the SVAR models. Consumption contributes most to output loss in the US, while investment plays this role in the Euro Zone. From an empirical point of view, they find these two methodologies are sufficient to observe which component is dominant. However, both methodologies are insufficient to ascertain the reason for this difference between the US and the Euro Zone. For this they employ DSGE models to replicate the empirical results with an attempt to trace back the structural features of each economy that cause this difference. A DSGE model is not employed in this paper because it is not a comparative study with another economy and does not seek to explain the ‘output composition puzzle’. Instead, this paper attempts to empirically characterise the compositional response of Australian GDP to domestic monetary policy. The 2003 study concludes that the DSGE model has difficulty accounting for the puzzle. The authors conclude by making a tentative assessment
that consumers are responsible for the differences. Unfortunately they do not have a compelling explanation for why this is the case. They posit that disposable income may be less responsive to monetary changes in the Euro Zone than in the US, and argue that is likely to be due to the fact that the social safety net in Europe is stronger. Though not reported, Angeloni et al (2003)\(^2\) also construct a model for the UK, and find that consumption contributes the most to GDP contractions in that economy.


### 3 General specifications

Since VAR and SVAR were introduced in the 1980s, the technique has been widely applied in the literature. For that reason, a technical discussion on the methodology is avoided and readers unfamiliar with the technique are encouraged to refer to Hamilton (1994) for a rigorous exposition.

The variables\(^3\) considered in this study can be classified as follows:

- **External sector variables**: US real GDP, Commodity prices
- **Domestic variables**: trimmed mean inflation, cash rate, M1 monetary aggregate, real trade weighted index
- **Disaggregated components of domestic GDP**.

**External sector variables**

*US Gross Domestic Product (US GDP)*

Studies such as Gruen and Shuetrim (1994), de Roos and Russel (1996) and Beechey et al (2000) find that US GDP has a strong relationship with Australian economic activity. Given its size and close relationship to the Australian economy, shocks to US GDP can also be interpreted as shocks to demand for Australian exports over the sample period being estimated.


\(^3\) All variables, except inflation, and cash rate are in logs. The models are estimated in levels.
Commodity Prices (Comp)

The inclusion of commodity prices in a stylised model is particularly important for the Australian economy because commodities make up the majority of Australian export income, and have a significant impact on the economy. Furthermore, commodity prices are also thought to account for the forward-looking nature of the monetary authority. Sims (1992) posits that commodity prices act as an information signal to the central bank regarding future inflation. This property is thought to resolve the ‘price puzzle’ often encountered in the SVAR literature.

Domestic sector variables

Trimmed mean inflation rate (Infl)

Including a measure of price is standard in studies that investigate economic activity. Following Dungey and Pagan (2000), this paper includes the inflation rate instead of the price level. However, instead of CPI inflation, this study includes – trimmed mean inflation; a key measure of underlying inflation. This is because the RBA in its 1996 statement for the conduct of monetary policy (and numerous bulletins since) highlights the importance of underlying measures of inflation. In addition, this series has the advantage of being less volatile compared to other alternatives.

Monetary aggregate (M1)

This paper follows in the footsteps of studies such as Huh (1999), Cushman and Zha (1997) and Kim and Roubini (2000) by including a narrowly defined monetary aggregate – M1. This variable is included in the model for two reasons. Firstly, even though a monetary aggregate does not reflect the stance of monetary policy since the advent of inflation targeting, it did have a weak role prior to that. Secondly, and crucially, it is included with the intention of capturing the monetary interactions within the Australian economy.

Interest rate (Int)

The quarterly average of the interbank cash rate is used in this study to represent the monetary policy instrument. Grenville (1997) and Dotsey (1987) contend that the cash rate is the chief instrument of monetary policy since the floating of the AUD in December 1983.

Real trade weighted index (Rtwi)

Given that Australia is a small open economy and given its export profile, the real exchange rate is an important indicator of Australian economic conditions. Studies such as Brischetto and Voss (1999) and Suzuki (2004) use the US dollar bilateral nominal exchange rate for this purpose. The real trade weighted index is more appropriate because it takes into account Australia’s broad relationship with its major trading partners.
and not just the US. Hence it is more reflective of Australia’s integration in the global economy. Furthermore, since the real exchange rate incorporates the foreign price level as well as the nominal exchange rate, it is more reflective of Australia’s international competitiveness. The RBA is likely to make some assessment of Australia’s international competitiveness in its monetary policy decisions. This is best captured by the real exchange rate. For these reasons, this study utilises the real trade weighted index in line with Dungey and Pagan (2000).

**Model 1: Disaggregated GDP components**

The disaggregation of real GDP in Model 1 follows the standard accounting identity decomposition of five components. All real GDP components enter the model in logs.

- total household consumption (C)
- private and public investment (Invst)
- government consumption expenditure (G)
- exports (Ex); and
- imports (Im).

Angeloni *et al* (2003) model only consumption and investment. They include government expenditure and net exports into a residual term defined ‘rest of GDP’. They argue that this is a parsimonious shortcut to implicitly impose the constraint of the accounting identity. Since Australia is a small open economy and because net exports play an important role, this paper splits ‘rest of GDP’ into its components, in order to capture the potential impact that monetary policy may have on net exports. This also has the added advantage of familiarity with the standard textbook decomposition of GDP.

**Model 2: Disaggregated GDP components**

While Models 1 will be based on the accounting identity, Model 2 will delve deeper into the compositional response of household consumption and investment. Following Erceg and Levin (2002), and Bernanke and Gertler (1995), Household consumption is disaggregated into durable consumption (Durc) and non-durable consumption (Non-Durc), and all sector investment is disaggregated into new dwelling investment (House) and rest of investment (Rest-Invest). Non-durable consumption (Non-Durc) is total household final consumption

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4 The nominal trade weighted index was considered, but not chosen because it does not have information on relative prices, which are key to understanding the response of net exports to changes in monetary policy via the exchange rate channel.

5 Note that throughout this study the real exchange rate and real trade weighted index will be used interchangeably.
Expenditure minus clothing, footwear, furnishings and purchase of vehicles. Rest of investment (Rest-Invest) is all sector investment minus new dwelling investment. Hence, it includes the remainder of private and public investment. In order to retain the accounting identity, government consumption expenditure, exports, and imports are also included in the model. Again, all real GDP components enter the model in logs. The consumption decomposition intends to explore whether goods that have a longer life (durables) respond differently to monetary policy. The investment disaggregation attempts to explore the extent and timing of the new dwelling investment response.

4 Model 1

Model 1 is an 11-variable VAR model estimated in levels over the period 1986:03 to 2012:03. This sample period was chosen due to availability of trimmed mean inflation data, and to exclude data volatility subsequent to the floating of the Australian dollar. In addition to consumption, investment, government expenditure, exports, and imports; all external and, domestic sector variables are included. The model is large given the sample size. However, this enables the modeller to minimise Omitted Variable Bias (OVB) to which small SVARs are often subject. Thus, the large dimensions of the model intend to capture the important interactions within the Australian economy in an attempt to avoid OVB.

4.1 Model specifics

A constant term is included to account for the mean of the series in the VAR. An impulse dummies for 2002:04 is included in the M1 equation to account for an outlier in the series.

Lag length tests suggest an order 1 or 5 lags. Since the data is quarterly, to ensure that the model is not over-parameterised (while maintaining reasonable degrees of freedom), a lag order of four is selected after concurrently considering lag length criterion, autocorrelation tests and stability of the model. The autocorrelation tests were conducted on the reduced form VAR of four lags. Most equations do not show evidence of first or fourth order autocorrelation.

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6 This follows the definition in studies such as Fisher and Voss (2004) and Tan and Voss (2000)
7 See Christiano et al (1998) and Sims (1992) for a discussion on the susceptibility of small VARs to OVB.
8 See Hamilton (1994)
9 Akaike's Information Criteria (AIC) suggests five lags, while Schwarz (or Bayesian) Information Criterion (SC) and the Hannan-Quin Criterion (HQ) suggest one when estimated with a maximum of five lags.
10 M1 (weak first order), and Import (fourth order) equations exhibit some autocorrelation. However, increasing the lag order of the VAR is not feasible given the number of observations and parameters. Moreover, the five lag VAR does not reduce autocorrelation, and the impulse responses are noisy and unusable. Autocorrelation test results are available on request and are not reported for the sake of brevity.
Stability and stationarity

Unit Root tests suggest that most variables are non-stationary I(1) processes. This paper follows the work of the majority of SVAR studies and estimates the reduced form VAR in levels. Even though the VECM approach would improve the efficiency of the estimates, it was avoided for four reasons. Firstly, in line with Sims (1980) and Sims, Stock and Watson (1990), estimation in levels still provides consistent estimates and avoids discarding relevant information about possible long-run relationships between the variables in the model. Secondly, it is the most common approach in the SVAR literature and hence has the advantage of comparability of identifying restrictions and results (Brischetto and Voss, 1999). Thirdly, estimation in levels is adopted to not enforce possibly incorrect restrictions on the model (Hamilton, 1994). Fourthly, even if some of the variables are integrated, stability of the VAR would imply system stationarity thus making the impulse responses valid.

The stability of the VAR process is assessed to ascertain the reliability of the estimates from the model. A VAR process is considered stable if its reverse characteristic polynomial has no roots in or on the complex unit circle; and importantly, stability implies a stationary VAR (Lutkephol, 2006).

4.2 Identification

To recover the structural parameters (A and B matrices) from the reduced form VAR (and estimate an SVAR), restrictions need to be imposed on the matrices describing the contemporaneous relationships, thereby overcoming the identification problem. This paper adopts a non-recursive identification structure as there are clearly identifiable relationships between the system variables.

Where K is the number of variables; K (K-1)/2 restrictions need to be imposed (on the A matrix) for just-identification. In this case, that amounts to 55 restrictions in addition to those imposed on the B matrix. On theoretical grounds, 77 restrictions are imposed on the contemporaneous relationships between the variables. The A matrix describes the contemporaneous relationships between the 11 variables in the Y vector of dependent variables. Some domestic sector equations are discussed in detail below. The 0s restrict the corresponding system variable from having a contemporaneous impact on that equation. The B matrix, which describes the contemporaneous relationships between the structural shocks (Bεt), is set to a diagonal of freely estimated parameters with no contemporaneous relationships.

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11 Unit root tests are available on request. Not reported for the sake of brevity.
12 A VAR (p) process is stable if its reverse characteristic polynomial has no roots in or on the complex unit circle. This implies stationarity. See Lutkephol (2006).
13 See Appendix for modulus of Eigen values of the reverse characteristic polynomial.
External sector

Both equations from the external sector have no domestic variables affecting them. Such a lag structure has become a standard assumption in the small-open-economy SVAR literature and is referred to as "block exogeneity". This reflects Australia’s small open economy status, which implies that it cannot affect external sector variables. US GDP contemporaneously impacts Commodity Prices to stylise the demand side shocks to commodity prices. Commodity prices are assumed to have an instantaneous impact on all domestic equations (except the monetary aggregate), due to their expeditious impact on the Australian economy.

GDP components

There are two key assumptions for these equations. Firstly, with the exception of government consumption expenditure, both external variables are allowed to contemporaneously affect Australian GDP. It is therefore assumed that global economic conditions contemporaneously impact the Australian economy. This approach is common in most Australian SVAR studies, due to the small and open nature of Australia’s economy. Secondly, following Raddatz and Rigobon (2003), it is assumed that shocks to individual components of GDP take at least one quarter to affect the other components.

Domestic sector

\[ \text{Inflytm}_t = a_{\text{Comp}} \text{Comp}_t + a_{C} C_t + a_{\text{Invst}} \text{Invst}_t + a_{G} G_t + a_{\text{Ex}} \text{Ex}_t + a_{\text{M}} \text{M}_t + \sum_{j=1}^{1} \Gamma_j Y_{t-j} + b_{\text{Inflytm}} \text{Inflytm} \]  

(1.1)

It is assumed that inflation is contemporaneously impacted by commodity prices and Australian GDP only. Commodity prices transmit into the economy rapidly given their dominance in Australia’s export profile. For instance, an increase in commodity prices is likely to impact on Australian firms’ marginal cost (just as they affect foreign firms’). Of course, they also do impact income, demand, and thereby output, but we cannot be sure which effect dominates.

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14 Since the government faces information lags and because spending decisions are made ahead of time it is assumed that external sector variables do not contemporaneously impact Australian government’s spending decisions.
It is unlikely that an increase in U.S. GDP will contemporaneously impact domestic inflation. However, it is reasonable to assume that Australian GDP would contemporaneously impact inflation. This assumption is common in both international (see Bernanke and Blinder 1992, Kim and Roubini 2000) and domestic SVAR studies (see Brischetto and Voss 1999; Dungey and Pagan 2000; Dungey and Fry 2003; Berkelmans 2005).

\[ M_1 = a_1 C + a_2 \text{Invst} + a_3 G + a_4 \text{Ex} + a_5 \text{Inflym} + a_6 \text{Int} + \sum_{j=1}^{4} \Gamma_j Y_{t-j} + b \varepsilon_M \]  (1.2)

Although excluded from some studies, a monetary aggregate is included in this study to capture the monetary interactions within the economy. This is in line with SVAR studies such as Brischetto and Voss (1999), Kim and Roubini (2000) and Cushman and Zha (1997), which allow GDP, inflation and the interest rate to have a contemporaneous impact on the monetary aggregate, thus specifying the equation as a standard money demand equation.

\[ \text{Int}_t = a_1 \text{Comp} + a_2 M_1 + \sum_{j=1}^{4} \Gamma_j Y_{t-j} + b \varepsilon_{\text{Int}} \]  (1.3)

The interest rate equation is interpreted as the policy reaction function of the RBA and it is assumed that the cash rate is representative of the monetary policy stance of the RBA. However, it is important to note that this specification is limited, in that the monetary authority is assumed to not respond to any other variables other than those specified. This is one of the shortcomings of the SVAR framework as it is likely that the RBA has a whole range of variables in its information set that it uses to make monetary policy decisions.

Modern monetary policy is complex and has numerous components to it. Hoover and Jorda (2001) succinctly summarise these components and their interactions as shown below.

<table>
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<th>Table 1. Components of monetary policy</th>
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<td><strong>Public</strong></td>
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<td><strong>Anticipated</strong></td>
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In the context of the SVAR framework, the monetary policy shock only captures the unanticipated and unsystematic (exogenous) component of monetary policy. It is therefore important to note that the conclusions derived from SVAR studies largely relate to unanticipated unsystematic monetary policy shocks.
This paper adopts information timing restrictions for the cash rate equation, and assumes that the monetary authority is allowed to contemporaneously react to as much information available at the time (M1 and commodity prices). Hence, any information not available at the time of the decision will be excluded from the contemporaneous relationships and only be available in lags. Although exchange rate information would be contemporaneously available, inflation information is not, and therefore real exchange data would not be available. As Dungey and Pagan (2000) argue, even though the RBA would pay attention to Australia’s international competitiveness (as captured by the real trade weighted index), it is unlikely that the RBA would react to contemporaneous movements in such a variable and the relevant norm may well be some average of the past values. For this reason, the real exchange rate enters the equation in lag only.

Moreover, in line with Sims (1992) it is assumed that commodity prices represent the inflationary expectations and forward-looking behaviour of the monetary authority.

$$R_{twi} = a_{USgdp} + a_{Comp} + a_C + a_{Invst} + a_G + a_{Ex} + a_{Infltm} + a_{M1} + a_{Int} + \sum_{j=1}^{G} Y_{j} + b \epsilon_{Ex \ Im}$$  

(1.4)

Finally, the real exchange rate is assumed to respond contemporaneously (as well as with lags) to all the domestic and foreign variables, reflecting the precision and speed with which information feeds into the exchange rate market. This is a standard assumption in most SVAR studies, both domestic and international.

**Results**

Given the identification of the structural matrices, the estimated coefficients and standard errors of the A matrix of the SVAR are reported below. Broadly speaking, the signs of most coefficients appear to be consistent with economic theory, and the standard errors imply that most estimates are significant. The non-recursive identification adopted for Model 1 is 22 more restrictions than required for just-identification. As is often the case with large SVAR models with restrictions based on economic theory, the LR test\(^{15}\) for over-identification suggests that, in comparison to a just-identified model, the restrictions are not vastly supported by the data. However, as shown in Section 6, this does not affect the overall conclusion of this paper as the impulse responses are largely robust to alternative identification schemes (such as recursive identification). The non-recursive identification is adopted since it is not arbitrary, not affected by the ordering of the variables, and produces more sensible impulse responses.

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\(^{15}\) SVAR is over-identified with 21 degrees of freedom. LR Test: Chi\(^2\)(21): 71.19, Prob:0.00
Table 2. A matrix estimates and standard errors

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A matrix standard errors

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<td>0.00</td>
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</tr>
<tr>
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<td>0.00</td>
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<tr>
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<td>1.99</td>
<td>4.48</td>
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<td>0.00</td>
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<td>1.17</td>
<td>0.23</td>
<td>0.59</td>
<td>0.25</td>
<td>0.51</td>
<td>0.01</td>
<td>0.00</td>
<td>0.02</td>
<td>0.00</td>
</tr>
<tr>
<td>0.00</td>
<td>2.14</td>
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<td>0.00</td>
<td>0.00</td>
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<tr>
<td>0.58</td>
<td>0.04</td>
<td>0.53</td>
<td>0.12</td>
<td>0.25</td>
<td>0.11</td>
<td>0.17</td>
<td>0.01</td>
<td>0.08</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Computed using MLE Scoring Algorithm (see Amisano & Giannini (1992)).

Impulse responses

Having estimated the SVAR model, the impulse responses to an unanticipated unsystematic cash rate shock of 17 basis points is reported below.

The impulse response for private consumption is sluggish and takes around two years to reach its full effect. One possible explanation for the sluggish response is the interplay of substitution and wealth effects of consumption. An increase in the cash rate would increase the cost of consumer borrowing and debt servicing, causing consumers to substitute away from consumption (substitution effect). It is also plausible that monetary contraction would increase the return to a given stock of savings (wealth effect). Via the wealth effect it is probable that consumers increase current and future consumption. The ultimate impact on consumption therefore depends on the relative magnitude of the substitution and wealth effects. In this case it appears that the wealth effect has some impact in the first year after the shock.

The investment response is also quite sluggish. The maximum effect of the investment response is reached in the fifth quarter, and is much larger than the contraction in consumption. The sluggish response is likely to be because firms are unable to change their investment plans in response to an unanticipated cash rate innovation.

16 Since the GDP components are in logs, their impulse response can be converted percentages.
(which is precisely what an SVAR innovation represents). Moreover, if firms have priced in an unexpected increase in their cost of capital (in the form of capital risk), most firms are likely to proceed with the project anyway. Similar behaviour is observed by Bernanke and Gertler (1995) for the US economy\(^\text{17}\).

Given that the government consumption expenditure equation is not fully specified (since this is not a study examining Fiscal Policy such as Dungey and Fry (2003)), one cannot draw too many conclusions from its impulse response. Overall, as one would expect, the impulse response suggests that there is only marginal deviation in government consumption expenditure.

The impulse responses of exports and imports are easier to understand when viewed alongside the response of the real exchange rate. The real exchange rate appreciates instantaneously by 0.19% due to the interest rate shock. This overshooting of the exchange rate is consistent with the Uncovered Interest Parity (UIP) rule\(^\text{18}\) with expectations. Moreover, the response is indicative of price rigidities in the short run. Interestingly, the response does not reveal any evidence of the "exchange rate puzzle\(^\text{19}\)" or the "forward premium puzzle\(^\text{20}\)" that appear in some studies.

Due to the AUD appreciation, imports reach their peak increase in the third quarter. Exports, decline from quarters 2 to 6; subsequently returning to the baseline. Overall, this implies that net exports would fall within the first year of the cash rate innovation. Subsequently, the real AUD begins to return to its baseline, driving exports up and imports down. This result is consistent with the ‘J-curve’ representation of the net exports response to exchange rate shocks. Importantly, the increase in net exports offsets part of the contractionary impact of investment.

The impulse response of inflation is sluggish, and the maximum effect of the monetary policy contraction is only felt in the 10\(^\text{th}\) quarter. Interestingly, the inflation response does not reveal statistically significant evidence of what is known as the ‘price puzzle’ - a consistent increase in inflation subsequent to an interest rate increase. This suggests that the monetary policy shock has been sufficiently indentified. Similar to what Sims (1992) observes it is likely that commodity prices play a role in eradicating the price puzzle prevalent in most SVAR studies.

\(^{17}\) They use inventory investment in the model and hence interpret it as inventory build-up.

\(^{18}\) See Blanchard and Sheen (2007) pp. 423 for a comprehensive discussion of the UIP with expectation which accounts for the overshooting.

\(^{19}\) Immediate depreciation of the exchange rate following an increase in the interest rate.

\(^{20}\) Persistent appreciation of the exchange rate following a monetary policy contraction.
The response of the monetary aggregate (M1) is consistent with economic theory. The disturbance to the cash rate results in an instantaneous fall in money supply. The response closely follows the cash rate and returns to the baseline once the cash rate innovation has died out. Interestingly, the model does not exhibit the 'Liquidity Puzzle' which is apparent in some SVAR studies.\footnote{The presence of the "liquidity puzzle" (or lack thereof) does not however negate the validity of the monetary policy function, because the monetary aggregate, however narrowly defined, does not represent the monetary policy stance in Australia during the majority of the sample period.}

\textbf{Figure 1. Impulse responses to contractionary monetary policy – Model 1}

The vertical axis shows deviations from the baseline level prior to the cash rate innovation, while the horizontal axis shows the number of quarters after the disturbance. The solid lines represent point estimates of the impulse responses, while the dotted lines are 95\% confidence intervals based on Hall’s (1992) bootstrap method utilising 250 bootstrap replications. Note that US GDP and Commodity Prices do not have impulse responses as the cash rate does not enter either equation.
4.3 Sensitivity vs. Contribution

The impulse responses from Model 1 reflect the extent to which each GDP component diverges from its baseline due to a monetary policy shock. In other words, the impulse responses show the sensitivity to an increase in the cash rate. The sensitivity to a monetary policy shock does not necessarily mean that the output response is driven by the most sensitive component. For instance, a component might be highly sensitive, but only make up a small share of GDP, and therefore have a limited impact on economic activity. It is therefore important to distinguish between 'sensitivity to shocks' and 'contribution to GDP contraction'.

In the standard SVAR framework, the reduced form residuals are converted to structural shocks by imposing the identifying restriction matrices $A$ and $B$. This implies that the Wold moving average form of the VAR can be written as a function of the structural shocks.

$$ y_t = \Phi_0 A^{-1} B \varepsilon_t + \Phi_1 A^{-1} B \varepsilon_{t-1} + \Phi_2 A^{-1} B \varepsilon_{t-2} + \ldots. $$

Based on the above exposition, the impulse response function (IRF) can be derived as follows.

$$ IRF_j = \frac{\partial y_{t+j}}{\partial \varepsilon_{j,t}} = \Phi_j a_{j}, b_{j} $$

Where $a_j$ is the $j^{th}$ column of the $A^{-1}$ matrix that represents the contemporaneous relationships between the system variables and $b_{j}$ is the elements of the matrix describing the contemporaneous relationships of the structural shocks. Since all GDP components are in logs we can rewrite this as follows:

$$ IRF_k = \frac{\partial \log y_{k,t+j}}{\partial \varepsilon_{j,t}} = \frac{\partial y_{k,t+j}}{\partial \varepsilon_{j,t}} \frac{1}{y_k}, \text{ where } y_k = C, \text{ Invst, G, Ex, Im} $$

By the national accounting identity, it is therefore possible to recover total output by aggregating each GDP component’s IRF after weighting the response by its share of GDP\(^{22}\).

$$ \frac{\partial \log GDP_{k,t+j}}{\partial \varepsilon_{j,t}} = \frac{\partial GDP_{k,t+j}}{\partial \varepsilon_{j,t}} \frac{1}{GDP} = \sum_k \frac{\partial y_{k,t+j}}{\partial \varepsilon_{j,t}} \frac{1}{y_k} GDP_k $$

In other words, the Weighted Impulse Response Function (WIRF) can be used to recover total output, and thereby examine which component contributes most to output contractions. The figure below shows IRFs and WIRFs. Net-exports are computed as the difference in the exports, and imports responses. Implied GDP is calculated as the sum of the WIRFs of the GDP components.

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\(^{22}\) 2012:03 shares of GDP are used to compute the WIRFs. C = 54%, I = 29%, G = 18%, Ex = 22%, and Im = 21%
Figure 2. Un-weighted IRF vs. Weighted IRF: Model 1

Figure 2 shows the importance of distinguishing between sensitivity, and contribution. It is clear that the combination of the fall in net exports and investment drives down output till the fifth quarter. The subsequent increase in net exports (driven by the falling real exchange rate) offsets the contractionary effect of investment till the 12th quarter. It is also clear that investment, and net exports are highly sensitive to cash rate shocks. The implied GDP response reaches a sustained trough in the first and second years. This is broadly consistent with Australian SVAR studies such as Dungey and Pagan (2000), and Brischetto and Voss (1999).

The WIRFs can also be used to calculate the Cumulative Contribution Ratio (CCR) which shows the composition of GDP variation due to the monetary policy shock. Angeloni et al (2003), Fujiwara (2003), and Linde (2003) use a similar measure because they argue that it smooths out some of the possible noise in the responses, particularly in the initial periods. Moreover, it can show the net impact after accounting for variables such as net exports that have a positive impact on GDP. Let C<sub>k,h</sub> be defined as:

\[
C_{k,h} = \frac{\sum_{s=1}^{h} \frac{\partial y_k}{\partial \varepsilon_j} y_k \frac{1}{y_k} y_k \frac{1}{y_k} y_k \frac{1}{y_k}}{\sum_{s=1}^{h} \sum_{j} \frac{\partial y_k}{\partial \varepsilon_j} y_k \frac{1}{y_k}} = \frac{\sum_{s=1}^{h} \frac{\partial y_k}{\partial \varepsilon_j} y_k \frac{1}{y_k}}{\sum_{s=1}^{h} \frac{1}{y_k} \frac{\partial y_k}{\partial \varepsilon_j}} = \frac{\sum_{s=1}^{h} \text{WIRF}_s}{\sum_{s=1}^{h} \text{IRF}_{\text{Implied GDP}}} \quad (1.9)
\]

This gives the fraction of the variation in GDP attributable to GDP component k cumulated over h quarters. Thus, $CCR_{k,h}$ can be computed as follows:

\[
CCR_{k,h} = \left| \frac{C_{k,h}}{\sum_k C_{k,h}} \right| \quad (1.10)
\]

The table below shows the CCRs based on the point estimates, and upper and lower error bands (given in parentheses). Within the first year, investment, and net exports contribute the most to deviations in output. This indicates that the exchange rate channel of monetary policy transmission is important in the short run, and

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23 They refer to it as the "contribution ratio".
24 Note that CCR is bounded between 0 and 1.
(based on the CCRs in parentheses) may be important beyond the first year. However, over time, consumption grows in importance.

**Table 3. Cumulative Contribution Ratios (CCR)**

<table>
<thead>
<tr>
<th>Horizon (h)</th>
<th>Household consumption</th>
<th>Investment</th>
<th>Government consumption</th>
<th>Net exports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(9%)</td>
<td>(73%)</td>
<td>(4%)</td>
<td>(14%)</td>
</tr>
<tr>
<td>4</td>
<td>(12%)</td>
<td>(62%)</td>
<td>(6%)</td>
<td>(19%)</td>
</tr>
<tr>
<td>8</td>
<td>(13%)</td>
<td>(69%)</td>
<td>(6%)</td>
<td>(12%)</td>
</tr>
<tr>
<td>12</td>
<td>(17%)</td>
<td>(61%)</td>
<td>(9%)</td>
<td>(13%)</td>
</tr>
<tr>
<td>16</td>
<td>(21%)</td>
<td>(52%)</td>
<td>(10%)</td>
<td>(17%)</td>
</tr>
<tr>
<td>20</td>
<td>(23%)</td>
<td>(44%)</td>
<td>(12%)</td>
<td>(21%)</td>
</tr>
</tbody>
</table>

**5 Model 2**

In order to better understand the driving forces of the consumption, and investment responses, Model 2 disaggregates consumption into durable and non-durable consumption, and investment into new dwelling and rest of investment. To preserve the accounting identity, government consumption expenditure, exports, and imports are retained in this model. All external and domestic sector variables are included as before. Given that this model has 13 variables (as opposed to 11 in the previous model) the lag length was reduced to three, in order to preserve degrees of freedom. The usual diagnostic tests of autocorrelation, and stability were conducted on the reduced form VAR of three lags. The results were largely similar to Model 1, suggesting reasonable specification. Other aspects, such as the sample period, deterministic terms, lag structure, and non-recursive identification scheme are unchanged from Model 1.

The following figure shows the impulse responses due to an unanticipated monetary policy shock of 34 basis points. The impulses show that new dwelling investment is the most sensitive component to the rate increase in this model. This is likely to be due to the cash rate being transmitted through to lending in the housing market. It is therefore unsurprising that markets and commentators pay close attention to developments in the housing market. In contrast, durable consumption appears to be slightly more sensitive than its non-durable counterpart in the first year. However, the responses are broadly similar from the second year onwards. This is likely to be because consumers do not rely heavily on credit for durable consumption, and as such the transmission of monetary policy to consumer credit is likely to be limited. The wealth effect (through cash deposits) is likely to have a greater impact on consumption. This is evident in the sluggish durable and non-durables response, which was also observed in aggregate consumption in Model 1. Driven by real exchange rate deviations, net exports exhibit the ‘J curve’ representation, which is also similar to Model 1.
The responses of the domestic variables appear to be consistent with those obtained from the previous model. However, the point estimates of the inflation response reveal a small, albeit statistically insignificant ‘price puzzle’. The response of the monetary aggregate and real exchange rate respectively reveals no evidence of the ‘liquidity puzzle’ or the ‘exchange rate puzzle’. This suggests that Model 2 has been reasonably well specified, and the cash rate innovation sufficiently identified.

Figure 3. Impulse responses to contractionary monetary policy: Model 2

The vertical axis shows deviations from the baseline level prior to the cash rate innovation, while the horizontal axis shows the number of quarters after the disturbance. The solid lines represent point estimates of the impulse responses, while the dashed lines are 95% confidence intervals based on Hall’s (1992) bootstrap method utilising 250 bootstrap replications. Note that US GDP and Commodity Prices do not have impulse responses as the cash rate does not enter either equation.
5.1 Sensitivity vs. Contribution

Similar to the approach adopted for Model 1, the weighted impulse responses of consumption and investment components are computed to distinguish sensitivity from contribution to contractions in their respective aggregates. As such, the weights are shares of the respective aggregate in 2012\textsuperscript{26}.

The figure below demonstrates that even though durables and non-durables are relatively similar in their sensitivity to monetary policy shocks, non-durables contribute the most to the contraction in aggregate consumption. New dwelling investment is significantly more responsive to monetary policy shocks than the rest of investment. However, non-new dwelling investment makes a much greater contribution to contraction in aggregate investment. This suggests that even though the housing market is highly sensitive to cash rate shocks, the RBA should not rely heavily on the housing investment to transmit monetary policy to the economy.

**Figure 4.** Un-weighted IRF vs. Weighted IRF: Model 2

![Graphs showing un-weighted and weighted impulse responses for consumption and investment](image)

6 Robustness

SVAR models are popular frameworks used for Macroeconomic analysis. However, just like any econometric model, the results are only as good as the model itself. It is therefore imperative to test the sensitivity of the baseline results to alternative econometric specifications. Lag length of the VAR, identification, deterministic terms, and sample period are each altered to test the robustness of Model 1 impulse responses\textsuperscript{27}.

\textsuperscript{26} Durables are 11% of aggregate consumption. New dwellings are 10% of aggregate investment.

\textsuperscript{27} Model 2 was tested, and yielded similar robustness to Model 1. Not reported for the sake of brevity.
The figure below shows the impulse responses to a range of sensitivity checks: 2 and 3 lag VARs, an alternative identification scheme - Choleski decomposition (recursive identification\(^28\)), a trend term in the baseline VAR (since some of the series appear to be trending), and a 3 lag VAR\(^29\) restricted to the sample period 1994:01 to 2012:03 (post inflation targeting period).

**Figure 5. Testing robustness of impulse responses**

Broadly speaking, the responses of the GDP components are relatively consistent across all five estimated VARs. In particular, investment and imports appear to be the most sensitive. In terms of the direction of the investment and imports responses, the sub-sample model (with 3 lags) appears to be the only anomaly. However, the extent of the deviation appears consistent with other models. Interestingly, nearly all the models (except the recursive and 2 lag VARs) do not reveal substantial evidence of the ‘price puzzle’. It is likely that this is due to the inclusion of commodity prices, identification scheme of the cash rate innovation, and the

\(^{28}\) The ordering of the variables is identical to that in Model 1.

\(^{29}\) Given the reduced sample size, the number of lags had to be reduced for the SVAR to be estimated.
sample period\(^3\). The responses of the monetary aggregate do not reveal strong evidence of the ‘liquidity puzzle’ either. There is some inconsistency in the responses of the real exchange rate (mainly the sub-sample model). However there is no evidence of the ‘exchange rate puzzle’ as all responses are positive following the cash rate innovation. Broadly speaking, these sensitivity simulations suggest that the impulse responses obtained from the baseline Model 1 are generally robust, and therefore one can be reasonably confident of the results obtained.

7 Conclusion

Angeloni et al (2003) examine differences between the US and the Euro Zone in terms of their compositional responses of GDP to domestic monetary policy. They refer to the economy-specific response of the components of GDP as ‘the output composition puzzle’. The response is deemed a ‘puzzle’ because, even though the conventional understanding is that investment responds to interest rate changes (thereby changing output); the authors find that it is in fact consumption in the US (and UK), and investment in the Euro Zone that contributes the most to GDP deviation. This paper examines the output composition puzzle for Australia using two Structural Vector Auto Regression (SVAR) models.

Model 1 is an eleven variable SVAR containing consumption, investment, government consumption expenditure, exports, and imports. It is estimated over the period 1986:03 to 2012:03 due to constraints imposed by the availability of underlying inflation data, and parameter instability in the periods subsequent to floating of the currency. This paper makes a distinction between the sensitivity of each GDP component, and its contribution to GDP deviation. Sensitivity is measured by the impulse responses, while contribution is measured by weighted impulses, and Cumulative Contribution Ratios (CCR). Several interesting findings emerge. Overall, investment (followed by net exports) is most sensitive to unanticipated increases in the cash rate. However, the investment response is sluggish, and takes a few quarters to reach its maximum effect. The sluggish response is likely to be because firms are unable to change their investment plans in response to an unanticipated cash rate innovation (which is precisely what an SVAR innovation represents). If firms have priced in an unexpected increase in their cost of capital (in the form of capital risk) then they are likely to proceed with the project anyway.

Within the first year, net exports are found to be a key driver of output reduction, contributing to nearly 15% of output reduction. However, two to three years after the cash rate increase, net exports increase (due to the

\(^{30}\) Dropping the commodity price term causes a large puzzle. The non-recursive identification results in a small puzzle (as shown above). Sample period before 1986 also results in the puzzle. However, the period before 1986 is unsuitable since the AUD was floated at the end of 1983; and the data is likely to result in parameter instability.
real exchange rate returning to its baseline) thereby reducing the contractionary impact of investment. This suggests that the exchange rate channel is particularly important for the transmission of Monetary Policy in Australia. Over a period of five years (due to its sheer size in the economy) consumption contributes around 23% to output deviations, while next exports contribute a similar share. However, overall, investment is found to contribute most to output deviations (44%). Interestingly, this model does not show evidence of the 'price puzzle' or other puzzles encountered in other SVAR studies. This is likely to be due to the inclusion of commodity prices, identification scheme, and the sample period.

Model 2 further disaggregates consumption (durables and non-durables), and investment (new dwelling investment and rest of investment) while retaining the other variables from Model 1 to preserve the accounting identity. This model finds that within investment, new dwelling investment is the most sensitive to cash rate shocks. However, the rest of investment contributes more to contractions in output. In contrast, durable consumption appears to be slightly more sensitive than its non-durable counterpart in the first year. However, the responses are broadly similar from the second year onwards. This is likely to be because, unlike the US, Australian consumers do not rely heavily on credit for durable consumption over the sample period, and as such the transmission of monetary policy to consumer credit is likely to be limited.

Five separate VARs were estimated to test the robustness of the results. Decreased lag length, alternative identification, inclusion of a trend term, and restricting the sample to the inflation targeting period (sub-sample analysis) were the variations tested. Broadly speaking, the responses of the GDP components are relatively consistent across all five estimated VARs. In particular, investment and imports appear to be the most sensitive. This suggests that the baseline results are relatively robust.

The results from this paper give key insights into the compositional response of GDP to Australian monetary policy. In particular, the results suggest that non-dwelling investment, and net exports should be the key focus of the monetary authorities since they largely drive the output response. Moreover, since net exports have a delayed positive effect on GDP, the monetary authorities need to be aware of the importance of the exchange rate transmission mechanism in dampening the maximum impact of contractions in investment. These aspects should be closely monitored to assess the impact of monetary policy.
8 Bibliography


Fujiiwara, I. (2003), "Output composition of monetary policy transmission in Japan", *Discussion Paper No. 03-07*, Graduate School of Economics and Osaka School of International Public Policy, Osaka University.


## Appendix

### Table 4. Data sources, and definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Units</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>US GDP</td>
<td>RBA index of commodity prices – all items</td>
<td>2000:01 = 100 (seasonally adjusted)</td>
<td>RBA, Table F1</td>
</tr>
<tr>
<td>Commodity prices</td>
<td>RBA index of commodity prices – all items</td>
<td>2008:01 = 100, US $</td>
<td>RBA, Table G5</td>
</tr>
<tr>
<td>Real GDP components</td>
<td>Consumption (C): Households; Final consumption expenditure;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Investment (Invst): All sectors; Gross fixed capital formation;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Government expenditure (G): General government; Final consumption expenditure;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exports (Ex): Exports of goods and services;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Imports (Im): Imports of goods and services;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>New dwelling investment (House): Private Gross fixed capital formation - Dwellings - New;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rest of investment (Rest-Invst): Invst less House. Derived by the author.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Durable consumption (Durc): Clothing and footwear plus, Furnishings and household equipment, plus Purchase of vehicles. Derived by the author.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Durable consumption (Non-Durc): Households; Final consumption expenditure minus durable consumption (i.e. C minus Durc). Derived by the author.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td>The RBA calculates the “Trimmed mean” by ordering all the Consumer Price Index components by their price change in the quarter and taking the expenditure-weighted average of the middle 70 per cent of these price changes.</td>
<td>year ended percentage change</td>
<td>RBA, Table G1</td>
</tr>
<tr>
<td>Monetary aggregate</td>
<td>M1 is defined as currency plus bank current deposits of the private non-bank sector.</td>
<td>AU $ billions</td>
<td>RBA, Table D3</td>
</tr>
<tr>
<td>Cash rate</td>
<td>The “Interbank rate” is a weighted average of the interest rates at which banks have borrowed and lent exchange settlement funds overnight. Monthly data is converted to quarterly data by the author.</td>
<td>percent per annum</td>
<td>RBA, Table F1</td>
</tr>
<tr>
<td>Real trade weighted index</td>
<td>The ‘Real trade-weighted index’ is the average value of the Australian dollar in relation to currencies of Australia’s trading partners adjusted for relative price levels, using core consumer price indices from these countries.</td>
<td>1995/01 = 100</td>
<td>RBA, Table F15</td>
</tr>
</tbody>
</table>

### Table 5. Stability tests

| VAR (4)       | 1.2 | 1.2 | 1.3 | 1.3 | 1.5 | 1.5 | 1.5 | 1.5 | 1.7 | 1.7 | 1.8 | 2.2 | 2.2 | 2.8 | 3.3 | 3.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.4 | 1.4 | 1.6 | 1.6 | 4.1 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.3 | 1.3 | 1.4 | 1.3 | 3.5 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| VAR (4) with trend | 1.2 | 1.2 | 1.3 | 1.3 | 1.6 | 1.4 | 1.5 | 1.5 | 1.8 | 1.7 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 |
| VAR (3)       | 1.4 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |
| VAR (3) sub sample | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.5 | 1.5 | 1.5 | 1.6 | 1.6 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| VAR (2) sub sample | 2.9 | 2.9 | 3.2 | 3.2 | 2.9 | 2.9 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |

Notes: The above table shows modulus of the eigenvalues of the reverse characteristic polynomial. These values need to be greater than one for the VAR to be stable, and imply stationarity (Lutekepohl (2004)). Values have been rounded to one decimal place for the sake of brevity. All values shown as 1.0 are greater than one.