On the differential impact of monetary policy across states/territories and its determinants in Australia: Evidence and new methodology from a small open economy

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10 June 2011

On the differential impact of monetary policy across states/territories and its determinants in Australia: Evidence and new methodology from a small open economy[1]

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Abstract

Monetary shocks largely affect economic activity in Western Australia. In smaller proportion, those shocks generate contractions in New South Wales, Victoria and South Australia, while economic activity in Queensland is significantly less affected. Finally, we develop a new approach to uncover the determinants of the differential state/territory responses to monetary shocks. Our estimation validates the theoretical assumptions that differences in industrial composition, exposure to international trade and household debt across states/territories are important determinants of these differences.

Jel categories: E00, E50, E52, E58

Key words: Monetary Policy, VEC, Australian states/territories

[1] The author would like to thank to Professor Mardi Dungey and Professor Adrian Pagan for their helpful comments.

1. Introduction

The impact of monetary policy in Australia has traditionally been studied at aggregate macro-level; however, it is unlikely that monetary policy decisions have uniform impact across Australian states/territories. The international empirical literature suggests that monetary policy actions may affect each state/territory differently and attributes this effect to regional differences in industrial composition, the proportion of household debt and sensitivity to exchange rate variations.

In the Australian context, economic structures in states/territories do indeed appear to exhibit differences. The economies of Western Australia (WA) and the Northern Territory (NT), for example, largely depend on the mining industry and international trade, whereas economies in New South Wales (NSW) and Victoria (VIC) are more dependent on manufacturing, property development, financial services and tourism industries, while Queensland (QLD) has a more diverse industrial composition.

South Australia (SA) and Tasmania (TAS) both have a large manufacturing industry and proportionally large agricultural, forestry and fishing industries with less exposure to international trade. The Australian Capital Territory (ACT) depends more on the public sector and the economy of the state of NSW which geographically surrounds the ACT.

The major concern regarding the differential impact of monetary policy is that while the Reserve Bank of Australia (RBA) mainly focuses on the aggregate gross domestic product (GDP) and aggregate consumer price index (CPI) to make monetary policy decisions, the impact of those policies may affect the economies of the states and territories differently.

In Figure 1, the evolution of the real gross state product (GSP) by state/territory is plotted for the period 1990-2009. Panel a) shows the real GSP for the smallest states/territories, indicating that while the real GSP of NT and ACT has grown substantially (about 25% and 15% respectively during this period), growth in TAS is only about 4%. The main cause of these differences is that in the period 1992 to 2009[2], the population grew by approximately 35% in NT and 17% in ACT, but by only some 7% in TAS.

In panel b) the real GSP of the large states/territories for the same period is plotted. QLD and WA show the largest growth in real GSP, which is driven also by population growth (around 46% and 35% respectively). On the other hand, NSW, VIC and SA exhibit a moderate real GSP growth due to smaller population growths of 19%, 22% and 11% respectively. This is because although international migration is positive for those states (particularly NSW and VIC), their interstate migration is negative.

These changes in population generally take place as economic conditions or standards of living change across states/territories. The most notable economic condition to impact economic growth and, as a consequence, migration paths across states/territories during this period was the mining boom, which was responsible for the movement of the labour force from NSW, VIC, SA and TAS to mining areas in WA, NT and QLD[3].

<Insert figure 1>

Given these structural economic differences across states/territories in Australia, the objective of this paper is to develop an empirical model to estimate the effect of monetary policy in Australia across state/territory economies. In addition, a novel approach to uncover the determinants of the different responses across states/territories to monetary shocks is proposed in Section 6.

[2] For information see ABS cat. 5220.0, Australian National Accounts: States, Household Income Account and Per Capita, Current Prices, Several Tables
[3] For detail on this issue see 3412.0 Migration, Australia, 2008-09. Trends in Net Interstate Migration (NIM)

2. Literature Review

One of the earliest investigations to address the issue of differential regional and/or state response to monetary policy was conducted by Carlino and Defina[4], using the United States (US) quarterly data from 1958 to 1992. The authors use a vector autoregressive (VAR) analysis to estimate the different state/region responses to monetary policy shocks. For state models, the authors estimate an independent VAR model for each state using the variables of the state's personal income growth; the personal income growth for the state's region less the state's income; each of the other regions' personal income growth; the change in the log of the relative price of energy; and the change in the federal funds rate.

Carlino and Defina[5] found that the individual state response is often different from the average response of its region, and from the response of other states in that region. They argue that the main reason for these differences is the diverse mix of interest-sensitive industries in each state. The main contribution of this paper is the finding that manufacturing-intensive states are more responsive to changes in monetary policy than less manufacturing-intensive states.

Arnold and Vrugt[6] investigated the differential regional effect of monetary policy in the Netherlands from 1973 to 1993 using a VAR model with annual data. In this model, the authors use four endogenous variables to estimate a separate VAR model for each region. These variables are the aggregated Dutch real production growth (subtracting the production of the region estimated), the CPI, the estimated real production growth of a particular region, and the short term nominal interest rate. The main results are consistent with most studies,

[4] Carlino and DeFina, The differential, pp. 572-87
[5] Carlino and DeFina, The differential, pp. 572-87
[6] Arnold and Vrugt, Regional effect, pp.123-34

indicating that there is a differential response across the Netherlands which is related to regional industrial composition.

Cortes and Kong[7] analysed the effect of monetary policy shocks on various regions in China using a vector error correction (VEC) model with annual data from 1980 to 2004. The model estimates one region or province at a time and is constructed with the following endogenous variables: the log of real GDP; the log of real provincial GDP; the bank lending rate; the log of real effective exchange rate; the log of CPI index; and the exogenous variable, the log of world GDP. In this model, two error correction vectors are used among the variables: the bank lending rate, the log of real provincial GDP, the log of real effective exchange rate and the log of CPI index. This study finds that coastal provinces respond more strongly to monetary policy shocks than landlocked areas.

More recently, Georgopoulos[8] studied the differential regional effect of monetary policy in Canada using a VEC model. This study used monthly data from 1976 to 2000. The only error correction vector in this model is constructed with the following variables: the log of the Canadian/US exchange rate (normalised); the US federal funds rate; the overnight money market rate; and the log of real commodity prices. The paper concludes that there is a differential effect of monetary policy across Canadian regions and identifies three sources for these responses: differences in interest-sensitive industries, differences in the contribution of exports to output, and differences in the proportion of firm sizes.

An important common ground in these studies is that in all cases the researchers used a VAR or VEC model to estimate the impulse response function (IRF) of an interest rate shock over the state or region output indicator, estimating one state or region at a time.

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[7] Cortes and Kong, Regional effects, pp. 15-28
[8] Georgopoulous, Measuring regional effects, pp. 2093-2113

3. Causes of the Different Effects of Monetary Policy across States/Regions

Carlino and Defina[9] state that the main causes of differential monetary policy response are differences in the industrial mix, following the notion that interest sensitivities across industries may interact with different industrial mixes across regions. Each industry presents differences in the proportion of the size of firms, the proportion of production of durable vs non-durable goods, the proportion of exports/imports and the proportion of debts with domestic institutions. In this section, we argue that differential state/territory responses may also arise due to differences across states/territories in mortgage debts as a percentage of disposable income, the proportion of exports/imports, and the proportion of state/territory debts. Although the causes of differential impact of monetary policy across states/regions have been previously examined, few empirical models have been used to explain this phenomenon.

3.1 Differences in the industrial mix across states/territories

In Table 1, the industrial composition across states/territories is reported. Some differences can be observed: the ACT has a very distinct industrial composition, because public administration accounts for around 37% of ACT's total GVA. NSW and VIC seem to have a very similar industrial composition, with both having a relatively large finance and insurance industry. However, VIC has a considerably larger manufacturing industry.

<Insert table1>

QLD has the most diversified industrial composition in Australia, with only the manufacturing industry marginally exceeding 10%, followed by construction (8.4%) and mining (7.7%). In SA, the largest industry is manufacturing, which accounts for around

[9] Carlino and DeFina, Do states respond, pp. 17-27

17.5%, while the agricultural, forestry and fishery industry accounts for 6.2%, which is more than 50% larger than the Australian average.

WA and NT have a similar industrial composition, with the largest sector in both cases being the mining industry (21.5% and 23% respectively). TAS has the largest agricultural, forestry and fishery industry in Australia, which accounts for 7.2% of its total industrial GVA; however, manufacturing is the largest industry in TAS, accounting for around 17.1% of total GVA. In regard to taxes and subsidies, WA and NT seem to have substantially lower tax minus subsidies as a percentage of total GVA (7.26% and 5.86% respectively).

3.2 Different proportions of household debt

Household mortgage repayments can be assessed at the state/territory level by examining them as a percentage of total disposable income (Figure 2). The maximum mortgage repayment as a percentage of total expenditure is 8.3% for NT, closely followed by NSW (8.1%) and VIC (7.5%). No survey data is available to confirm whether the percentage has increased in the last decade.

According to Figure 2, TAS households have the lowest mortgage/disposable income ratio (around 4.8%) suggesting a possible lower impact of contractionary monetary policy.

<Insert Figure 2>

3.3 Differential proportion of exports/imports across states/territories

It is expected that an increase in the interest rate would result in an appreciation of the domestic exchange rate, due to an increase in capital inflow which would decrease exports and increase imports. Different proportions of export as a percentage of GSP across states/territories may therefore be another reason to expect a different state effect on monetary policy.

Figure 3 shows that NSW and VIC have relatively low export proportions (around 8% and 9% respectively of real GSP). WA and NT have a much larger export share than all other states/territories, because exports constitute around 47% of respective real GSP in WA and 38% in NT. QLD, TAS and SA have a level of exports closer to the Australian average (around 18% for both QLD and TAS and 12% for SA).

<Insert Figure 3>

The only large difference in imports is observed in the state of TAS, where imports represent less than 3% of its GSP.

While the total trade as a percentage of real GSP provides important information for understanding the effect of monetary shocks across states/territories, trade composition also plays an important role in assessing the effect of monetary shocks. For example, we expect exports of manufacturing products to be more responsive to monetary shocks because they can be substituted in the short run, and we expect mining exports to be less responsive to those shocks because long term supply contracts dominate this industry.

4. Model Specifications

To model the impact of monetary policy across states/territories, we construct a structural vector error correction model (SVEC)[10] using a mix of stationary and non-stationary variables, incorporating the co-integration relationship among non-stationary variables. The modelling philosophy and sensitivity analysis are detailed in Appendix 3.

4.1 Identification and descriptions of variables

To provide an economic interpretation of the shocks, restrictions are imposed on the residual-covariance matrix of a reduced-form vector autoregression (VAR). We specify the

[10] For more details about the VEC see Appendix 1 or Enders, *Applied Econometric*, Ch. 6

model as the past and contemporaneous observations of the following endogenous vector-variables: the Australian real GDP $(AGDP_t)$, the weighted median of Australian CPI inflation rate $(ACPIPC_t)$, the official cash rate $(CASH_t)$, a proxy for real gross state product (GSP^*_{st}) for the state/territory s and the real trade-weighted index of the Australian dollar $(ATWI_t)$.

The real GSP^*_{st} is used as a proxy of real GSP, because the Australian Bureau of Statistics (ABS) does not produce the GSP indicator on a quarterly basis. The GSP^* is constructed for each state as the state final demand plus the state/territory exports minus the state/territory imports. The GSP^* is deflated by the appropriate city's CPI indexes[11].

In addition, following Dungey and Pagan[12], the small open economy assumption is specified in the model including the following exogenous vector-variables: the Australian terms of trade (TOT_t), the Australian commodity price index (COM_t), the United States (US) GDP $(USGDP_t)$, the US inflation $(USCPI_t)$ and the US interest rate $(USIR_t)$

All variables descriptions and sources are presented in Appendix 2. Seasonally adjusted variables are used where possible, e.g. GSP^*_{st}, $ACPIPC_t$, $USCPI_t$, and $USGDP_t$. However, the ABS does not produce CPI seasonally adjusted indexes, and therefore the weighted median CPI inflation rate is preferred because this indicator seems to correct the seasonal effect; it is also one of the underlying inflation indicators used by the RBA.

The linear system of equations presented was chosen based on three different blocks. The first block contains the world economy (exogenous variables), the second contains the

[11] The cities CPI index is used as a proxy for the states/territories CPIs because the ABS does not produce states/territories CPIs
[12] Dungey and Pagan, A structural VAR, pp. 321-42; Dungey and Pagan, Extending a SVAR, pp. 1-20

Australian economy ($AGDP_t$, $ACPIPC_t$ and $CASH_t$), and the third, the state/territory economy ($GSP*_{st}$). We expect that the world economy may affect both the Australian and state/territory economy, while the Australian economy and the state economy may be affected reciprocally; however, Australian and state/territory economies are too small to affect the world economy.

Restrictions are imposed only on the contemporaneous structure and are substantiated as the $AGDP_t$ equation being affected contemporaneously only by the exogenous variables and $ATWI_t$. The idea behind these restrictions is based on Brischetto and Voss[13], who stated that it would take at least one quarter for other domestic variables to impact $AGDP_t$. The $ACPIPC_t$ equation assumes that inflation is also affected contemporaneously by the $AGDP_t$ and $ATWI_t$; hence, an increase in demand for domestic goods, imports and/or exports can be observed by economic agents in the same quarter.

The $CASH_t$ equation is interpreted as the monetary policy reaction function of the RBA. Although in Dedola and Lippi[14] the $CASH_t$ equation is affected contemporaneously to both output and inflation, in our study the $CASH_t$ equation is only affected contemporaneously by $\Delta\log(ATWI_t)$ because only the international outputs can be seen in the same quarter in Australia by the RBA. The restriction assumptions here are that the RBA observes contemporaneously all exogenous variables and $ATWI_t$, looking at movements in international outputs, commodity prices and exchange rate. It is unlikely that the $AGDP_t$

[13] Brischetto and Voss, *A structural vector*, Discussion Paper
[14] Dedola and Lippi, The monetary transmission, pp. 1543-69

and $ACPIPC_t$ indicators can be observed contemporaneously, because the release of these indicators takes place two months after the RBA makes monetary decisions.

The $GSP*_{st}$ is only affected contemporaneously by $ATWI_t$. This is because the state/territory's exports and imports may be sensitive to changes in either export or import demand generated by exchange rate variations.

In line with most domestic studies such as Dungey and Pagan[15], and Brischetto and Voss[16], $ATWI_t$ is affected contemporaneously by all variables. This is because exchange markets operate daily and operators observe and arbitrage quickly in response to the release of any indicator from either the Australian economy or the international economy.

The restrictions applied result in an over-identified model, because there is one more zero parameter restriction than necessary to exactly identify the model. Consequently, the likelihood ratio test for over-identification is performed and the results show that in all models, the null hypothesis that restrictions are valid cannot be rejected on a conventional level, indicating that restrictions are reasonable.

4.2. SVEC model

To investigate the transmission of monetary policy shocks to macroeconomic variables, simultaneous econometric techniques are generally used. In contrast to vector autorregresive (VAR) models, which generally use only stationary variables, a vector error correction (VEC) can be specified in order to capture the long run dynamic of the model as long as some variables of the same order are co-integrated.

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[15] Dungey and Pagan, A structural VAR, pp. 321-42; Dungey and Pagan, Extending a SVAR, pp. 1-20
[16] Brischetto and Voss, *A structural vector*, Discussion Paper

The SVEC can be expressed in matrix form (for simplicity the constant term is omitted):

$$B_0 X_t = B_1 X_{t-j} + exogenous\_vectors + error\_correction\_term + \varepsilon_t \quad (1)$$

Where $j = 1,2,3$ and X_t is vector of endogenous variables:

$$X_t = \left[AGDP_t, ACCPI_t, CASH_t, GSP*_{st}, ATWI_t\right] \quad (2)$$

and

$$B_0 X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & -b_{15} \\ -b_{21} & 1 & 0 & 0 & -b_{25} \\ 0 & 0 & 1 & 0 & -b_{35} \\ 0 & 0 & 0 & 1 & -b_{45} \\ -b_{51} & -b_{52} & -b_{53} & -b_{54} & 1 \end{bmatrix} \begin{bmatrix} \Delta \log(AGDP_t) \\ ACPIPC_t \\ CASH_t \\ \Delta \log(GSP*_{st}) \\ \Delta \log(ATWI_t) \end{bmatrix} \quad (3)$$

$$ECM_{st} = \beta_0 + \log(AGDP_t) + \beta_1 \log(GDP*_{st}) + \beta_2 \log(ATWI_t) + \beta_3 t + \varepsilon_t \quad (4)$$

Note that to analyse the impact of monetary shock on the State/Territory Final Demand (SFD) and/or the state/territory exports, the variable $GSP*_{st}$ is substituted for the SFD and exports of the respective state/territory.

5. Impulse Response Function to Monetary Shocks

In terms of the largest states/territories, NSW and VIC appear to be quite responsive to monetary shocks, having a maximum drop in the GSP* growth rate of 2.1% and 2.7% respectively. The similar responses in those states may be attributed to their similar industrial composition, mortgage repayment as a percentage of disposable income and exposure to international trade. SA responses are slightly lower (1.9%), perhaps due to lower exposure to international trade and smaller mortgage repayments as a percentage of disposable income.

WA seems to be the state/territory that is most responsive to monetary shocks at almost 3%. This is not surprising, because WA has much larger exposure to international trade than any other state/territory.

The QLD response seems to be smaller (around 1.7%). The reason for this may be the more balanced industrial composition of QLD, which has a relatively large mining industry, yet the exposure to international trade is still relatively low.

The responses for TAS and NT are relatively small and are also statistically insignificant. This perhaps shows a weakness in our model in respect of capturing the responses of the smallest states/territories. In addition, a potential problem regarding Tasmanian data is the fact this state generally imports products throughout Victoria and NSW, although quarterly data is not available to introduce to our model.

<Insert figure 4>

5.1 State final demand and export responses to monetary shocks (SVEC)

In this section we disaggregate the impact of monetary shocks on real gross state product into the impact of state final demand and state exports. In particular, we substitute the variable $\Delta\log(GSP^*_{st})$ by either $\Delta\log(SFD_{st})$ or $\Delta\log(SX_{st})$ in Eqn. (1), an IRF of monetary shocks on these two variables for each state/territory.

<Insert table 2>

In Table 2, the results of these IRFs are shown. The largest response of real exports for states/territories generally takes place before the largest response of real SFD, suggesting that the exchange rate channel quickly responds to monetary shock, whereas it takes some time for domestic demand to respond. This is consistent with Bernanke and Blinder's[17] view of the lending channel, in which they argue that it takes time for the lending channel to react:

> 'Over time, however, the brunt of tight money is felt on loans, as banks terminate old loans and refuse to make new ones'.

Second, for SA and VIC, the response of real exports is much larger than the response of real SFD, implying that export sectors in those states are more sensitive to monetary shocks. This is most likely due to the export composition of both states, which feature proportionally large exports of vehicles, farm products and other manufacturing goods which are known to be very responsive to exchange rate appreciation.

Third, QLD and WA have more balanced responses between real exports and real SFD, indicating that mining export demand is fairly inelastic. As a consequence, the reduction in exports may only reflect the reduction in income generated by the appreciation of the Australian dollar rather than reduction in export demand.

The results for NT and TAS indicate that in both cases the response of real exports is larger than the response of real SFD; however, the large standard error in these estimations does not allow us a reasonable level of confidence about these results.

Finally, NSW is the only state in which the response of real SFD is greater than the response of real exports, which may be related to the fact that NSW primarily exports services.

6. Determinants of State/Territory Response to Monetary Shocks in Australia

[17] Bernanke and Blinder, Credit, money, and aggregate, pp. 435-39

In this section, we develop a new methodology to uncover the determinants of differential state/territory effects of monetary policy. To address this issue, we run two separate regressions (Eqn. (2) and (3)), using the IRF in our SVEC models as dependent variables, for both the response of state/territory real exports, and the response of real SFD as dependent variables. For these regressions, we use panel data using the IRF of seven states/territories through periods two to ten.

The decision to run two regressions is based on our previous finding, namely, that the IRF of the real export response takes place before the IRF of real SFD. This suggests that the 'exchange rate channel' is felt immediately after a monetary policy shock by exports due to a fast appreciation of the Australian dollar, but the effect on IRF of real SFD takes longer to generate a response.

In addition, it is our view that it takes time for the effect of the 'exchange rate channel' to spill over into the domestic economy. Specifically, our view is that the appreciation of domestic currency due to monetary shock contracts the state/territory real exporter's revenue. Over time, this contraction spills over to the real SFD because exporters have fewer dollars to spend in the state/territory economy.

6.1 Determinants of real exports state/territory IRF to monetary shocks

In Eqn. (2), an OLS regression is constructed for the determinants of real state/territory real exports responses to monetary shocks. On the left hand side (LHS), the variable $\mathrm{Re}\,spx_{st}$ is constructed as the IRF of $CASH_t$ on $\Delta\log(SX_{st})$ from our SVEC model estimated in Eqn. (1) for each state/territory using $\Delta\log(SX_{st})$ instead of $\Delta\log(GSP*_{st})$. The independent variable $MINX_s$ is the ratio of the state/territory mining exports and the total state/territory exports. Likewise, $SERVX_s$ is the ratio of the state/territory services exports and the total state/territory exports and $FARMX_s$ is the ratio of state/territory farm exports and total state/territory exports.

We also attempt to include a variable for the proportion of manufacturing exports but it is shown not to be statistically significant, most likely due to the high level of aggregation of the state/territory export data.

$$\mathrm{Re}\, spx_{st} = \beta_0 + \varsigma MINX_s + \eta SERVX_s + \kappa FARMX_s + \theta TIME_t + \rho IND_s + \varepsilon_{it}$$

(2) OLS Model 1

6.2 Determinants of real SFD IRF to monetary shocks

In Eqn. (3), the determinants of real SFD are modelled. The dependant variable $\mathrm{Re}\, spSFD_{st}$ is constructed as the IRF of $CASH_t$ on $\Delta \log(SFD_{st})$ from our SVEC model in Eqn. (1) using $\Delta \log(SFD_{st})$ specification instead of $\Delta \log(GSP^*_{st})$ for each state/territory model. The independent variables in this model are: $\mathrm{Re}\, spx_{s,t-1}$ which is nothing but the lag LHS of Eqn. (2): the mortgage repayment as a percentage of disposable income by state/territory $(MORG_s)$, the degree of openness to international trade measure as the state/territory exports plus imports as a percentage of GSP $(OPEN_s)$, the state/territory debt as a percentage of GSP $(SDEBT_s)$ and the GVA of manufacturing industry as a percentage of GSP (MAN_s).

In addition to these independent variables, the GVA as a percentage of GSP of the other largest industries in Australia, namely, financial and insurance, and mining and construction, were estimated in Model 1 but excluded as not being statistically significant at a conventional level.

$$\operatorname{Re} spSFD_{st} = \beta_0 + \phi \operatorname{Re} spx_{s,t-1} + \pi MORG_s + \psi OPEN_s + \sigma SDEBT_t + \chi MAN_s + \theta TIME_t + \rho IND_s + \varepsilon_{it}$$

(3) OLS Model 2

7. Results

In Table 3, the results from Eqn. (2) and (3) are shown. OLS Model 1 results show that an increase in the proportion of mining exports softens the negative IRF of the gross rate of state/territory exports to monetary shocks.

By contrast, the coefficient κ_i shows that an increase in the proportion of farm exports strengthens the negative IRF. Likewise, an increase in the proportion of services exports strengthens the negative IRF. OLS Model 2 results show that an increase in one period lag IRF of real gross rate of state/territory exports to monetary shocks strengthens the negative IRF of the real gross rate of the SFD to monetary shocks, supporting our view that the 'exchange channel' spills over to the state/territory SFD. The coefficient π_s indicates that an increase in mortgage proportion is associated with a strengthening of the negative IRF. Similarly, increases in international trade, state government debts and manufacturing proportions are associated with strengthening of the negative IRF.

We decided to estimate both models using OLS diagonal standard errors to correct for any form of heteroskedasticity. In addition, the Wooldridge test for autocorrelation in panel data was carried out, this giving the F-statistics 0.69 for OLS Model 1 and 0.16 for OLS Model 2. As a consequence, the null hypothesis of no autocorrelation cannot be rejected, disregarding the presence of serial correlation in our models.

The dependant variables in these models are data generated by the impulse response function, therefore the interpretation of the impact of the dependant variable must be taken with caution. This regression is experimental in the sense that there are no antecedents in the literature. Nevertheless, because our results seem to be consistent with economic theory regarding which factors generate a differential impact of monetary policy, we believe that, possible inference problems aside, our results cannot be ruled out. Perhaps in the future researchers can ratify these results with richer data sources, e.g. US data.

<Insert table 3>

8. Conclusions

In this paper, we developed a SVEC model to study the impact of monetary policy across states/territories. For the largest states/territories, we found that WA is the state/territory most affected by monetary shocks, probably because of its large exposure to international trade. VIC is also significantly affected by these shocks, its large manufacturing sector being the main reason for this result. NSW and SA are slightly less affected by monetary shocks, perhaps because of their smaller exposure to international trade. A significantly smaller impact is observed for QLD, although no particular reason for this emerges from our investigation. We believe this result is connected to the very diverse industrial and export composition of QLD.

Regarding the impact of monetary shocks on state/territory exports, the principal results are that exports in SA and VIC are severely affected by monetary shocks, probably due to the large composition of manufacturing and farm exports. In contrast, QLD exports are substantially less affected, perhaps due to the large proportion of coal and other mineral exports.

Observing the state/territory responses for both real exports and real SFD, we found that in general, real exports respond faster than real SFD to monetary shocks as a result of the quick appreciation of the domestic currency.

Finally, we developed a new approach to estimate the determinants of differential response to monetary shocks at state/territory level. In particular, we built two regressions to study the determinants of real exports and real SFD responses to monetary shocks in states/territories. We found that in line with economic literature, the determinants of real exports responses are negatively related to the share of farm and services exports, but are positively related to the share of mining exports.

We also found that real SFD responses are negatively related to mortgage repayment as a percentage of disposable income and the manufacturing GVA as a percentage of total GSP. In lower proportion, SFD responses are also negatively related to international trade as a percentage of GSP, the government state/territory debt as percentage of GSP and the lag of state/exports real exports' response to monetary shocks.

Appendix 1: Vector Autoregressive Model and Vector Error Correction Model

Following Enders[18], consider the simple bivariate system;

$$y_t = b_{10} - b_{12} z_t + \gamma_{11} y_{t-1} + \gamma_{12} z_{t-1} + \varepsilon_{yt} \qquad (5)$$

$$z_t = b_{20} - b_{21} z_t + \gamma_{21} y_{t-1} + \gamma_{22} z_{t-1} + \varepsilon_{zt} \qquad (6)$$

where we assume that both y_t and z_t follow a stationary process; ε_{yt} and ε_{zt} are white-noise disturbance with standard deviation σ_y and σ_z .

Equations (5) and (6) are not reduced-form because both y_t and z_t appear in both equations: however, we can re-write Eqn. (5) and (6) in matrix form as:

$$\begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix} \begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix} \qquad (7)$$

$$Bx_t = \Gamma_0 + \Gamma_1 x_{t-1} + \varepsilon_t \qquad (8)$$

Where: $B = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}$, $x_t = \begin{bmatrix} y_t \\ z_t \end{bmatrix}$, $\Gamma_0 = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix}$, $\Gamma_1 = \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix}$ and $\varepsilon_t = \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$

Pre-multiplying both sizes of Eqn. (8) by B^{-1} we obtain the VAR for x_t as:

$$x_t = A_0 + A_1 x_{t-1} + e_t \qquad (9)$$

Where: $A_0 = B^{-1}\Gamma_0$, $A_1 = B^{-1}\Gamma_1$ and $e_t = B^{-1}\varepsilon_t$

Therefore systems (5) and (6) can be written as:

$$y_t = a_{10} + a_{11} y_{t-1} + a_{12} z_{t-1} + e_{1t} \qquad (10)$$

[18] Enders, *Applied Econometric*, pp.291

$z_t = a_{10} + a_{21} y_{t-1} + a_{22} z_{t-1} + e_{2t}$ (11)

Note that $e_t = B^{-1}\varepsilon_t$ and therefore:

$e_{1t} = (\varepsilon_{yt} - b_{12}\varepsilon_{zt})/(1 - b_{12}b_{21})$ (12)

$e_{2t} = (\varepsilon_{zt} - b_{12}\varepsilon_{yt})/(1 - b_{12}b_{21})$ (13)

From previous analysis it is important to highlight that:

The errors in the standard VAR are composites of the two shocks as $e_t = B^{-1}\varepsilon_t$ and because ε_{yt} and ε_{zt} are white-noise processes it can be shown that e_{1t} and e_{2t} have zero mean, constant variance and are serially uncorrelated.

There are feedback effects on the structural VAR because both y_t and z_t, appear in both equations, and the structural VAR therefore cannot be estimated. However, the standard VAR can be estimated because this feedback effect disappears in the system and therefore the ordinary least square (OLS) can be used.

Because there are 4 parameters to be estimated in each equation of the structural VAR but only 3 in each equation of the standard VAR, the last is under-identified because it is not possible to recover all the information in the structural VAR.

Identification: One method to solve the problem of under-identification is to use a Cholesky system such as Sims[19]; that is, by imposing restrictions on the structural VAR such as the coefficient that accounts for the feedback (b_{12} and b_{21}) is 0 and Eqn. (12) and (13) become:

$e_{1t} = \varepsilon_{yt} - b_{12}\varepsilon_{zt}$ (14)

[19] Sims, Macroeconomics, pp. 1-48

$e_{2t} = \varepsilon_{zt}$ (15)

Equations (14) and (15) imply that forcing $b_{21} = 0$ gives us an exact identified model[20]

Impulse response function: An important property of the VAR model is that it allows us to represent the variable of our model in terms of the current and past values of the 2 shocks, that is, the model can be expressed as a vector moving average. For illustration purposes, the model can be written in a matrix as:

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} e_{yt} \\ e_{zt} \end{bmatrix} \quad (16)$$

The vector moving average representation of (15) can be written as:

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{z} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} e_{yt-i} \\ e_{zt-i} \end{bmatrix} \quad (17)$$

Eqn. (17) can be written in terms of ε_{yt} and ε_{zt} sequences and can also be combined with Eqn. (14) and (15) to obtain;

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{z} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} \phi_{11}(i) & \phi_{12}(i) \\ \phi_{21}(i) & \phi_{22}(i) \end{bmatrix} \begin{bmatrix} \varepsilon_{yt-i} \\ \varepsilon_{zt-i} \end{bmatrix} \quad (18)$$

Where: $\phi_i = \dfrac{A_1^i}{1 - b_{12}b_{21}} + \begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix}$ = impact multipliers

Or more compactly[21]

$$x_t = \mu - \sum_{i=0}^{\infty} \phi_i \varepsilon_{t-1} \quad (19)$$

[20] For more detail see Enders pp. 271 and 272
[21] For more detail see Enders p. 273

The coefficient of ϕ_i can be used to generate the effects of unexpected shocks ε_{yt} and ε_{zt} on the time path of y_t and z_t sequences.

Finally the accumulative effect of unit impulses in ε_{yt} and ε_{zt} can be obtained by the sum of the impact multipliers.

From Eqn. (5) and (6) we can derive the relationship between ε_t and the structural disturbance e_t as:

$$B\varepsilon_t = \Gamma e_t \quad (20)$$

where $\varepsilon_t = B^{-1}\Gamma e_t$ and the variance covariance matrix is then represented as $E(\varepsilon_t \varepsilon_t') = B^{-1}\Gamma E(e_t e_t')\Gamma B^{-1}$.

The VEC model is a restricted version of the VAR model, constructed from the use of non-stationary co-integrated variables. The co-integrated relationship is built into the specification model, restricting the long-run behaviour of the endogenous variables to converging to their co-integrated relationship, allowing for short- run adjustment dynamics.

Consider the two variable systems with one co-integrating equation and no lagged difference terms:

$$\Delta y_t = \beta z_t \quad (1)$$

The corresponding VEC model is:

$$\Delta z_{t,1} = a_1(y_{t-1} - \beta z_{t-1}) + \varepsilon_{t,1} \qquad (2)$$

$$\Delta y_{t,2} = a_2(y_{t-1} - \beta z_{t-1}) + \varepsilon_{t,2} \qquad (3)$$

where the right hand size of the equation is called the error correction term. In the long run, this term is zero; however, if either variable deviates from the long run equilibrium, the error correction term will be different from zero until the equilibrium is restored.

Appendix 2: Data Definition and Sources

The quarterly data used in the SVAR model is from September 1990 (first period of inflation targeting reported by the RBA) to December 2010.

<Insert table 4>

<Insert table 5>

Appendix 3: Modelling Philosophy and Sensitivity Analysis

Lag selection

To select the lag length of our SVEC model, we have to consider the trade-off between the fact that more lags of SVEC significantly decrease the degree of freedom, increasing estimation uncertainty, but that fewer lags reduce forecast accuracy. Consequently, the widely use Akaike Information Criterion (AIC) and Schwarz Criterion (SC) are used. For our model, the AIC selects three lags for all models, while the SC selects three lags in four out of eight states/territories; as a consequence, three lags are used.

Stationary, unit root and co-integration

The assumption of the VAR/SVEC model requires that all variables in the model must be stationary, or that the linear combinations of non-stationary but co-integrated variables must be stationary. The Augmented Dickey Fuller (ADF) unit root test reveals that the $ACPIPC_t$, $\log(COM_t)$, $CASH_t$ and $USIR_t$ are level stationary, while the variables $\log(AGDP_t)$, $\log(ATWI_t)$, $\log(USGDP_t)$, $\log(TOT_t)$ and $\log(GSP*_{st})$, (for all states/territories) appear to be only first-difference stationary. The Phillips-Person and the Kwiatkowski-Phillips-Schmidt-Shin unit root tests are also estimated, confirming previous results.

In line with Beechey et al.[22] and Dungey and Pagan[23], the co-integration relationship between Australian and US technologies is studied. In our models the co-integration between $\log(GSP*_{st})$ and the $\log(AGDP_t)$ should also be considered, as each GSP is a component of GDP. In testing for co-integration, we first use the VAR-Johansen co-integration (JC) test (for all state/territory models), among the following first difference stationary variables: the $\log(AGDP_t)$, $\log(ATWI_t)$, $\log(GSP*_{st})$ and $\log(USGDP_t)$. We follow the lead of Dungey and Pagan[24] whose study used a co-integration equation among the Australian GDP, the Australian real exchange rate and the gross national expenditure (GNE). Note that this study used another co-integration equation among the variables; the Australian real GDP, the US real GDP, the Australian real exports and the Australian real GNE. We also explored the possibility of co-integration between commodity prices and Australian term of trade finding that there is not co-integration between these variables in this period. The VAR-Johansen co-integration test results show that the number of co-integration equations suggested for each state/territory model varies from zero to three. This may indicate that the $\log(USGDP_t)$ is only co-integrated with some s of the $\log(GSP*_{st})$ or perhaps less likely, that the $\log(AGDP_t)$ is only co-integrated with some s of the $\log(GSP*_{st})$. Following the literature reviewed and for comparison purposes, our intention is to use the same model for each state/territory

[22] Beechey et al., *A small model*, Discussion Paper
[23] Dungey and Pagan, Extending a SVAR, pp. 1-20
[24] Dungey and Pagan, Extending a SVAR, pp. 1-20

estimation. Consequently, we exclude the exogenous variable, the $\log(USGDP_t)$ from the VAR equation to run a new VAR-JC test, to find that for most state/territory models this test suggests one co-integration equation among the $\log(AGDP_t)$, $\log(ATWI_t)$ and $\log(GSP^*_{st})$. In addition, we test whether any of these three variables could be excluded from the error correction model for each state/territory, to find that the χ^2 test rejects any of these three constraints. Consistent with this analysis, a SVEC model is specified using only one error correction term (ECT_{st}) among the variables: the $\log(AGDP_t)$, the $\log(ATWI_t)$ and the $\log(GSP^*_{st})$. Following Dungey and Pagan[25], we normalise the $\log(AGDP_t)$ and include a time trend in this equation.

Autocorrelation, heteroskedasticity and tests stability condition

To test for autocorrelation and heteroskedasticity, the residual serial correlation LM test and the VAR residual heteroskedasticity test are carried out and p-values results estimated. The null hypothesis of no serial correlation cannot be rejected at conventional levels for most of the first eight lags tested across all states/territories; therefore autocorrelation does not seem to be a problem in these models. The results are also confirmed by both the VAR residual cross-correlation (correlograms) and by VAR residual Portmanteau test for autocorrelation.

The VAR residual heteroskedasticity test is performed. In this test, all possible combinations of error term products are used as dependent variables. The null hypothesis of no heteroskedasticity cannot be rejected at 5% level for the joint hypothesis of all combinations for all states/territories using both models. In addition, it is observed that in the overwhelming majority of individual tests, the null hypothesis cannot be rejected even at

[25] Dungey and Pagan, Extending a SVAR, pp. 1-20

10%. The White heteroskedasticity test either using no cross terms and cross terms also confirms the previous results. Therefore, the hypothesis of heteroskedasticity in our model is discarded.

The stability condition[26] for the VEC model, with r co-integrating equation and k endogenous variables, requires that at most k-r roots should be equal to unity, while the other roots must lie inside the unit root circle. Consequently, the inverse roots of the characteristic AR polynomial test are performed for each state/territory model. These tests find that this condition is satisfied for all state/territory models.

[26] For more detail see Enders, *Applied Econometric*, p. 266.

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Table 1. Industry GVA as a Total Industrial GVA (average from 1990 to 2009

Industry*	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	Mean
Agriculture, forestry, etc.	2.7%	3.4%	4.7%	6.2%	4.2%	7.2%	3.5%	0.2%	4.0%
Mining	2.4%	2.6%	7.7%	3.0%	21.5%	2.5%	23.0%	0.2%	7.9%
Manufacturing	13.4%	17.3%	11.8%	17.5%	10.9%	17.1%	8.9%	2.4%	12.4%
Electricity, gas, etc.	3.0%	3.6%	2.7%	3.4%	3.1%	5.5%	2.9%	2.9%	3.4%
Construction	7.4%	6.6%	8.4%	6.6%	8.1%	5.9%	7.9%	7.6%	7.3%
Wholesale trade	6.1%	6.2%	5.5%	4.8%	4.7%	4.1%	2.8%	2.2%	4.5%
Retail trade	5.4%	5.3%	6.6%	5.7%	4.8%	6.5%	4.5%	4.4%	5.4%
Accommodation, cafes, etc.	3.2%	2.1%	3.7%	2.6%	1.9%	3.2%	3.3%	2.6%	2.8%
Transport and stores services	5.7%	5.2%	7.8%	6.0%	5.7%	6.7%	5.5%	4.2%	5.8%
Information and telecom.	4.7%	5.0%	3.4%	3.8%	2.6%	3.4%	2.6%	3.4%	3.6%
Finance and insurance	12.4%	10.2%	6.5%	7.5%	5.1%	6.7%	3.6%	5.1%	7.1%
Rental, hiring and real estate	3.7%	3.3%	3.8%	2.8%	3.8%	2.0%	2.5%	3.0%	3.1%
Professional, scientific, etc.	6.9%	6.1%	4.6%	4.7%	4.9%	2.7%	3.8%	6.3%	5.0%
Administrative services	3.1%	2.7%	2.2%	2.3%	2.2%	1.5%	1.8%	2.7%	2.3%
Public administration	5.5%	4.8%	6.5%	5.7%	4.3%	7.7%	10.5%	37.2%	10.3%
Education and training	5.1%	5.7%	4.9%	5.9%	4.0%	5.7%	4.5%	6.5%	5.3%
Health care and social assistance	6.2%	6.7%	6.1%	7.9%	5.6%	8.4%	5.2%	5.4%	6.4%
Arts and recreation services	1.1%	1.0%	0.8%	1.0%	0.7%	0.8%	1.2%	1.8%	1.1%
Others	2.4%	2.3%	2.6%	2.6%	2.0%	2.4%	2.1%	2.4%	2.3%
Taxes minus subsidies as % of total GVA	10.25%	10.20%	8.87%	9.67%	7.26%	9.54%	5.86%	7.43%	8.64%

Table 2 Response of $\Delta\log(SFD_{st}$Real SFD and Exports $\Delta\log(SX_{st})$to an Official Cash Rate Shock (100 bps)

State/ Territory	SFD Min	Quarter	Exports Min	Quarter
NSW	-0.023†	5	-0.028†	2
VIC	-0.022†	4	-0.074*	4
QLD	-0.014†	7	-0.022†	3
SA	-0.018†	4	-0.080*	2
WA	-0.031†	4	-0.038†	3
TAS	-0.009	7	-0.100	6
NT	-0.017	6	-0.090	4

Table 3 OLS Determinants of Monetary Shocks Responses

OLS Model 1		OLS Model 2	
Ind. Variables	Dep. Variable; State/Terr. Exports IRF	Ind.Variables	Dep. Variable: State/Terr. SFD
Constant	0.056* (0.031)	Constant	0.098*** (0.008)
ζ_s	0.071** (0.031)	ϕ_s	-0.039* (0.021)
η_s	-0.127*** (0.044)	π_s	-0.835*** (0.074)
κ_s	-0.307** (0.129)	ψ_s	-0.040*** (0.008)
θ_t	0.002* (0.001)	σ_s	-0.042*** (0.016)
ρ_s	-0.018*** (0.000)	χ_s	-0.307*** (0.032)
		θ_t	0.000*** (0.000)
		ρ_s	0.000 (0.000)
Observations	63	Observations	56
R^2	0.416	R^2	0.840
$adj.R^2$	0.365	$adj.R^2$	0.817

*,**,***Indicates coefficient is significantly different from zero at the 10%,5% and 1% level respectively.
The OLS white diagonal standard errors technique was used to control for any form of heteroskedasticity. For both models a Durbin Watson statitics close to two indicated not presence of autocorrelation.

Table 4 SVAR and SVEC Models, Variable Descriptions and Sources

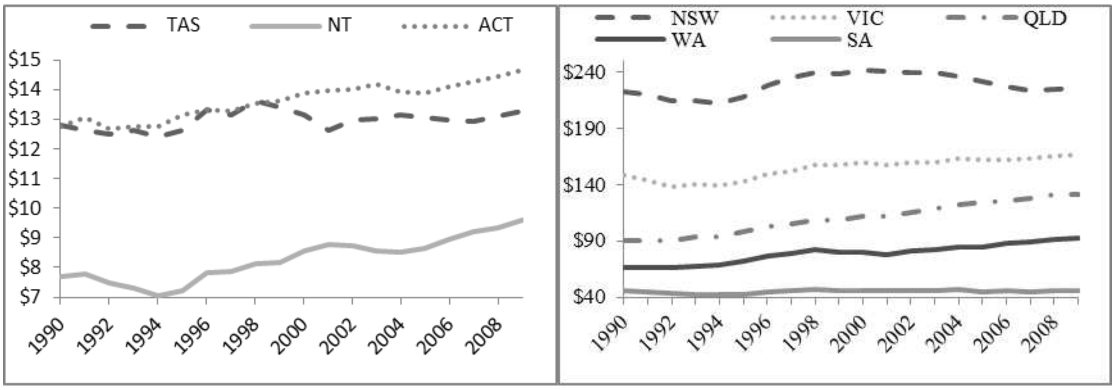
Variable	Description	Source
$AGDP_t$	Australian Real Gross Domestic Product* (seasonally adjusted).	ABS National Accounts
GSP^*_{st}	Real State Final Demand Plus State Export minus State Import (seasonally adjusted) for state/territory s.	ABS National Accounts
$ACPIPC_t$	Australian CPI, % change (Weighted Median).	RBA Prices and Inflation
$CASH_t$	Official Cash Rate.	RBA Interest Rate
$ATWI_t$	Real Trade-Weighted Index of Australian Dollar.	RBA Exchange Rate
TOT_t	Australian Term of Trade.	ABS National Accounts
$USGDP_t$	US Real Gross Domestic Product** (seasonally adjusted).	IMF, IFS
$USCPI_t$	US Consumer Price Index (seasonally adjusted).	IMF, IFS
$USIR_t$	US Interest Rate.	IMF, IFS
COM_t	Australian Commodity Prices Index (seasonally adjusted).	RBA Prices and Inflation
Δ	First Difference Operator.	
Log	Natural Logarithm.	

* Deflated by appropriate Consumer Price Index.
**Deflated by appropriate CPI by capital cities.

Table 5 OLS Models 1 and 2, Variable Descriptions and Sources

Variable	Description	Source
$MINX_s$	Ratio of mining exports and total exports of state/territory s (period 2002-2003)*	DFAT
$SERVX_s$	Ratio of service exports and total exports of state/territory s (period 2002-2003)*	DFAT
$FARMX_s$	Ratio of farm exports and total exports for state/territory s (period 2002-2003).*	DFAT
$MORG_s$	Ratio of household mortgage repayment and household disposable income for state/territory s (period 2003-2004).*	ABS National Accounts
$OPEN_s$	Ratio of state/territory exports plus imports and GSP for state/territory s (average over the period 1990-2009).*	ABS National Accounts
$SDEBT_s$	Ratio of state/territory debt and GSP for state/territory s (period 1990-1991).*	ABS National Accounts
MAN_s	Ratio of state/territory GVA of manufacturing industry and GSP for state/territory s (average over the period 1990-2009).	Australian Bureau of Statistics
$\mathrm{Re}\,spx_{st}$	The IRF of exports to a monetary shock by state/territory (Eqn. (2) using EX_{st}) from the second to tenth quarters.	
$\mathrm{Re}\,spSFD_{st}$	The IRF of SFD to a monetary shock by state/territory (Eqn. (2) using SFD_{st}) from the second to tenth quarters.	

*These periods are used as proxies for the average of the sample period (1990-2009) because this data is only available from period 2000 and beyond.



Panel a) Panel b)

Figure 1. Real GSP by State/Territory, 1990-2009 (A$'000 Millions)

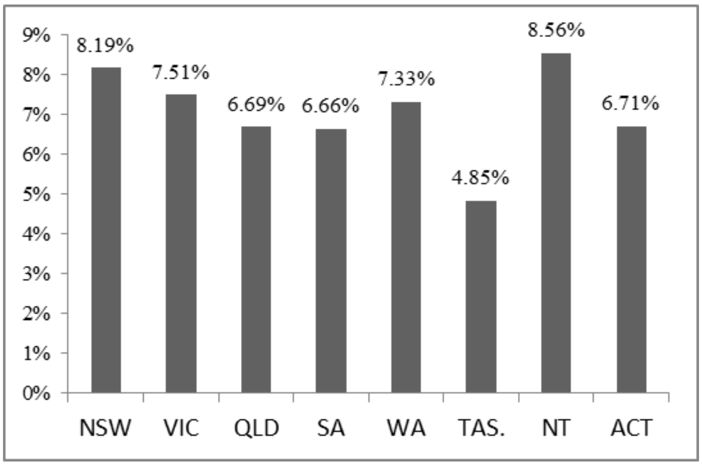
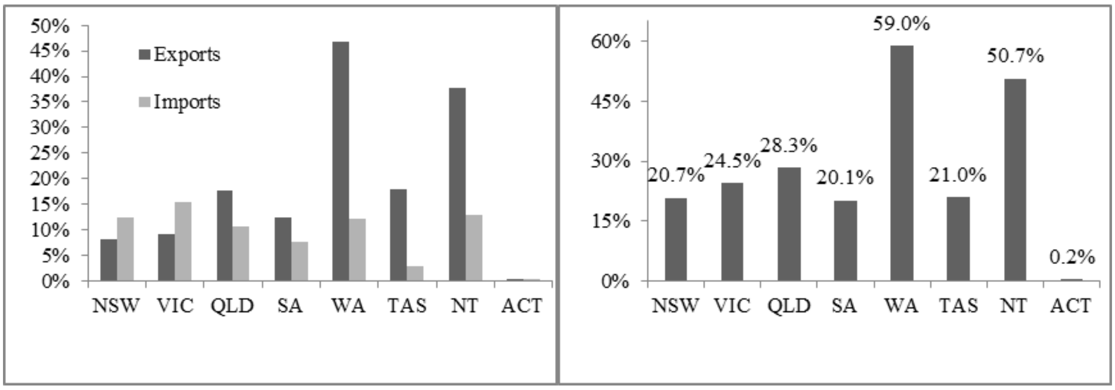
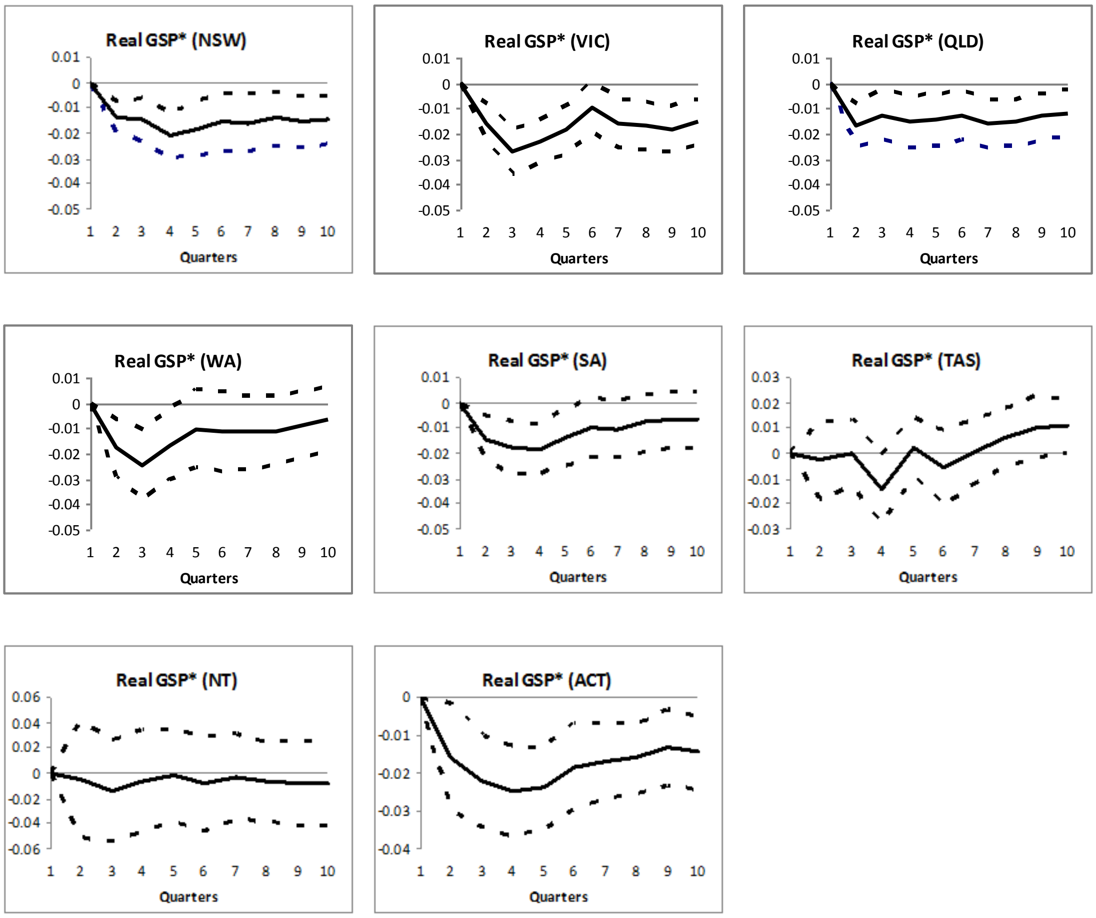


Figure 2. Mortgage Repayments as a Percentage of Disposable Income by State (2003-2004)



a) Imports and Exports by State/Territory b) Imports plus Exports by State/Territory

Figure 3. Exports and Imports by State/Territory as a Percentage of GSP (average of period 1990-2009)



*For each impulse response figure, the horizontal axis shows the number of periods. Each period represents a quarter. The vertical axis is expressed in percentage change. The dash lines represent a one standard deviation band around the estimates of the coefficients of the IRF. The confidence bands are obtained using Monte Carlo integration as described by Sims (Macroeconomics, pp. 1-48), where 500 draws were used from the asymptotic distribution of the VEC coefficient.

Figure 4. IRF of Real GSP* to an Official Cash Rate Shock (SVEC model), 100 bps