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The sectorial impact of commodity price shocks in Australia

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Abstract

It is found that commodity price shocks largely affect the mining, construction and manufacturing industries in Australia. However, the financial and insurance sector is found to be relatively unaffected. Mining industry profits and nominal output substantially increase in response to commodity price shocks. Construction output is also found to increase significantly, especially in response to a bulk commodities shock, as a result of increased demand for resource related construction. Increased demand for construction has a positive spillover effect to parts of the manufacturing industry that supply the construction sector with intermediate inputs, such as the non-metallic mineral sub industry. In contrast, other manufacturing sub industries with only tenuous links to the resources sector such as textiles, clothing and other manufacturing, are relatively unresponsive to commodity price shocks.

Keywords: Commodity prices, Commodity Shocks, Australian economy

JEL Codes: E00, E30, F20

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1. Introduction

Rapid growth in Asia over the past decade, particularly in China, has had a substantial impact on the Australian economy. This is well documented in a number of papers.[1] Increased demand for Australia's natural resources has led to sustained increases in commodity prices and the terms of trade since 2002. Garton (2008) explains that these changes in relative prices induce reallocation of resources between sectors and have boosted real incomes in Australia, stimulating aggregate demand.

However, the benefits of the increase in commodity prices have not been borne equally by all sectors of the Australian economy. A relatively strong Australian dollar has resulted in a negative impact on parts of the export sector that have not directly benefited from the resources boom, such as parts of the manufacturing sector. This phenomenon is often referred to as 'Dutch Disease', and has been discussed at length in the Australian context.[2]

This paper develops a methodology to quantify the impact of commodity prices on different industries by examining; i) the impact of commodity price shocks in terms of real and nominal gross value added (GVA) and profits; ii) and examining whether all commodity price shocks are alike, by disaggregating commodity price indices into bulk commodities, base metals and rural commodities.[3]

To find answers to these questions a structural vector autoregressive (SVAR) model is developed, for the period January 1993 until March 2013.[4]This paper builds on existing Australian models that examine shocks to international relative prices such as

[1] For example; Dwyer, Gardner and Williams (2011), Kearns and Lowe (2011), Bishop et al. (2013) and Plumb, Kent and Bishop (2013).
[2] For recent examples referring to Dutch Disease and the Australian economy see; Mitchell and Bill (2006), Corden (2012) and Lim, Chua and Nguyen (2013).
[3] Gross value added is defined as gross output less the intermediate inputs used to produce that output.
[4] The start date coincides with the start of inflation targeting by the Reserve Bank of Australia.

Dungey and Pagan (2000), Jääskelä and Smith (2011) and Dungey, Fry-Mckibbin and Linehan (2014), while also integrating the methodology of analysing specific industries, as in Lawson and Rees (2008) and Vespignani (2013).

The major finding of this study is that commodity price shocks have a significant positive impact on mining sector profits and nominal GVA. Conversely, real GVA in the mining sector declines (in the short run) in response to commodity price shocks. Mines are often run at close to full capacity, and a sudden increase in commodity prices encourages increased extraction of minerals. In the short term this requires the use of more intermediate inputs such as labour, resulting in higher cost production. This can have a negative impact on real GVA in the mining industry in the short-run. Results also indicate that commodity price shocks increase output in the construction sector, due to increased demand for resource related construction. However, manufacturing profits decline significantly in response to commodity price shocks.

The paper proceeds as follows. Section 2 details the importance of commodity prices to the Australian economy. Section 3 provides a review of the existing literature. Section 4 outlines the SVAR methodology and modelling identification assumptions. Section 5 presents an extended model. Section 6 presents the results of commodity price shocks on industry variables in terms of impulse responses and variance decomposition. Section 7 provides a brief robustness analysis. Section 8 concludes.

2. Commodity prices and the Australian economy

Connolly and Orsmond (2011) explain that the floating exchange rate has had a stabilising effect during the current mining boom, by allowing an appreciation of the

Australian dollar. Subsequently, increased inflationary pressures have not accompanied the surge in mining related investment and activity as they did during previous booms.

Commodity prices have also been affected by the substantial change in the composition of global growth. In particular, the increased importance of China has resulted in a global demand shift towards commodities.[5] Connolly and Orsmond (2011) outline that the increase in global commodity prices during the 2000s has made mining more profitable and encouraged a shift in labour, investment and materials into the mining industry. While the increase in global commodity prices has been broad, Connolly and Orsmond (2011) highlight that there has been particularly large increases in the price of steelmaking commodities such as coking coal and iron ore. Over the past decade, commodity exports have, on average, contributed 55 per cent of total export values and 11 per cent of Australian GDP.

Figure 1 shows the evolution of the RBA index of commodity prices disaggregated into rural, base metals and bulk commodities in US dollars from January 1993 to March 2013.

Rural commodities include food products such as lamb, wheat, beef and veal. Iron ore and coal are both bulk commodities, while base metals refer to metals such as aluminium, lead and copper. Clearly evident in Figure 1 is the increase in the prices of bulk commodities and base metals after the onset of the mining boom and their rapid decline during the GFC. Rural commodity price fluctuations have not been as extreme over the same time period, though they have still been relatively volatile.

[5] See Dwyer, Gardner and Williams (2011).

3. Literature review

The sectoral impact of commodity prices on the Australian economy is analysed in a non-SVAR framework by Rayner and Bishop (2013), who use input-output tables to quantify the links between domestic industries. They conclude that the mining boom has had a positive impact on sectors that supply inputs to the resources sector, such as resource related construction and manufacturing. However, the output of industries not directly related to the resources sector has declined due to a stronger currency and increased competition for factors of production.

In terms of SVAR studies that analyse industry level data, internationally there are a number of papers that have examined the impact of commodity prices on specific industries, with a many of these focusing on oil price shocks. However to date, sectoral responses to commodity price shocks have not been examined in an Australian SVAR.

Lee and Ni (2002) examine the effects of oil price shocks across 14 different industries in the United States using an identified VAR model. Their results indicate that for the majority of industries, oil shocks significantly decrease output.

Many studies focus on the impact of commodity prices on the manufacturing sector. Jiménez-Rodríguez (2008) find that an oil price shock decreases the level of manufacturing output across all countries examined. However, results suggest oil price shocks produce different reactions across sub industries within the manufacturing industry.

Guidi (2010) analyses the impact of oil price shocks on the performance of both the manufacturing and service sectors in the United Kingdom. His analysis indicates that output in the manufacturing sector contracts significantly, and the service sector is relatively unaffected following a positive oil price shock. Finally, Fukunaga, Hirakata and Sudo (2010) find that oil price shocks have a positive impact, in terms of output, on oil-intensive industries in Japan.

4. Methodology

A SVAR model is constructed using quarterly data from March 1993 until March 2013, spanning 81 observations, our sample period coincides with the Reserve Bank of Australian moves to inflation targeting in 1993.

When estimating a SVAR model for a small open economy it is common to incorporate two sets of variables; foreign variables representing world economic conditions and domestic variables that attempt to model the domestic economy. Following Australian studies such as Dungey and Pagan (2000), Lawson and Rees (2008), Jääskelä and Smith (2011), Vespignani (2013), a small open economy assumption is present in the SVAR model. The domestic variables are affected by the world economy, but by specifying the foreign variables as exogenous, there is no feedback within a quarter.

4.1 Foreign variables

The purpose of the foreign variables is to model world economic conditions. While for the majority of the 20th century the United States boasted the world's largest economy, in the 21st century, emerging countries such as China have increased their share of world real GDP significantly. China's prominence to the Australian economy is especially important, as they purchase a substantial amount of Australian exports, particularly commodities. For this reason when modelling international economic conditions, it is important to take into consideration the changing structure of the global economy.

Figure 2 shows Australia's largest trading partners in terms of total trade value from January 1993 until March 2013. China's increasing importance to the Australian economy is clear, as is the declining role of the United States.

As a result of the diminishing importance of the United States economy in contributing to Australian economic outcomes, this study incorporates a weighted bundle of economies when representing global economic conditions.

There are three exogenous foreign variables; world real gross domestic product in U.S dollars ($WGDP_t$), a world inflation rate ($WINF_t$) and a world interest rate (WIR_t).

For this study, proxies of world output, inflation and a world interest rate are derived from GDP, consumer price index (CPI) and interest rate data from Australia's five largest trading partners; China, Japan, the United States, the United Kingdom and the Euro area.

$WGDP_t$ is an aggregation of quarterly real GDP of Australia's five largest trading partners, seasonally adjusted, all measured in United States Dollars. WIR_t is constructed by aggregating government policy rates and weighting by their share of Australian trade. $WINF_t$ is constructed by aggregating consumer price indices for each of the five countries, rebasing to a common base year, and weighting by their share of *Australian trade.*

4.2 Domestic variables

The second group of variables represents the Australian economy and builds on the models of Dungey and Pagan (2000), Lawson and Rees (2008), Vespignani (2013) and Dungey, Fry-Mckibbin and Linehan (2014).

Consistent with existing Australian SVAR literature (Brischetto and Voss, 1999; Berkelmans, 2005; Lawson and Rees, 2008; Vespignani, 2013), real Australian GDP ($AGDP_{-it}$) is used as a measure of domestic output. Following Jääskelä and Smith (2011) and Dungey, Fry-Mckibbin and Linehan (2014), non-farm GDP is used, as farm GDP can suffer from extreme short-term volatility due to weather effects. In order to analyse industry specific responses, the variable $AGDP_{-it}$ is defined as Australian GDP minus the GVA of industry i. This method follows Lawson and Rees (2008) and Vespignani (2013) and ensures that $AGDP_{-it}$ and IND_{it} sum to total Australian non-farm GDP when analysing each individual industry. IND_{it} is the real GVA of industry *i*.

In order to analyse the impact of commodity prices on individual industries more thoroughly, two subsidiary measures of industrial output are also considered; industry profits before income tax ($PROF_t$) and nominal GVA ($NIND_{it}$). Each variable is included in the SVAR model one at a time in place of real GVA (IND_{it}).

INF_t is a measure of relative prices in Australia. The CPI excluding interest and tax changes of 1999-2000 is used in line with most Australian papers.[6]The target cash rate ($CASH_t$) is included as a measure of the policy reaction function of the central bank. The trade-weighted index (TWI_t) is included as a measure of the real exchange rate following the majority of Australian SVAR studies.

The SVAR can be expressed by the following structural form (ignoring for simplicity any constant terms in the model):

$$B_0 X_t = B_1 X_{t-p} + C Y_{t-p} + \varepsilon_t \tag{1}$$

where $= 1{,}2$, X_t is a vector of endogenous variables:

$$X_t = [COM_t, AGDP_{-it}, IND_{it}, INF_t, CASH_t, TWI_t] \tag{2}$$

[6] See for example, Dungey and Pagan (2000), Berkelmans (2005), Lawson and Rees (2008), Claus, Dungey and Fry (2008), Jääskelä and Smith (2011) and Vespignani (2013). The inflation rate has been the target of the RBA's monetary policy for the entirety of our sample period.

and Y_t is a vector of exogenous variables:

$$Y_t = [WGDP_t, WINF_t, WIR_t] \tag{3}$$

The vector ε_t contains the orthogonal structural disturbances, which are identified by placing restrictions on the B_0 matrix, which are proposed in the following section.

4.3 Identification Restrictions

In line with these international and domestic studies, we impose restrictions only on the contemporaneous relationships between the variables.

$WGDP_t$, $WINF_t$ and WIR_t are our measures of international economic conditions. These foreign variables are specified as strictly exogenous, which follows Jacobs and Rayner (2012) and Vespignani (2013).

Commodity prices are the most exogenous of the domestic variables. It is assumed that none of the Australian variables can contemporaneously influence world commodity prices due to the small size of the Australian economy. Australian domestic variables can influence commodity prices in lags, in line with Dungey, Fry-Mckibbin and Linehan (2014). $AGDP_{-it}$ is affected contemporaneously by commodity prices, which is standard across the existing literature. The cash rate does not contemporaneously affect GDP as monetary policy takes time to influence consumption and investment decisions.

IND_{it} is contemporaneously affected by commodity prices and Australian GDP. Fluctuations in commodity prices are likely to influence production decisions in industries such as mining and manufacturing and consequently impact on industry GVA in the same quarter. IND_{it} is ordered after $AGDP_{-it}$ as in Lawson and Rees (2008) and Vespignani (2013). Reasoning for this is that each industry comprises only a small fraction of the total economy and as such, the rest of the economy will have flow on effects on individual industries in the same quarter. Due to the interrelated nature of nominal GVA ($NIND_{it}$), industry profits ($PROF_t$) and real GVA (IND_{it}), we utilise the same contemporaneous restrictions when each variable is considered.

INF_t responds immediately to commodity prices and Australian domestic output, which is consistent with Brischetto and Voss (1999), Dungey and Pagan (2000), Berkelmans (2005), and Lawson and Rees (2008). Shocks to commodity prices, such as the price of oil, would be expected to influence the inflation rate in the same quarter as firms change their prices quickly in response to the change in price of an important input. Inflation does not respond to the cash rate contemporaneously as changes in the cash rate take time to influence consumption and investment decisions, and hence flow through to prices. Jacobs and Rayner (2012) explain that inflation does not respond immediately to changes in the trade-weighted index as these changes occur gradually.

There are two common methods of specifying the contemporaneous restrictions in the domestic cash rate equation. The first method allows contemporaneous interaction between the cash rate and variables that are deemed to be observable by the RBA at the time of the policy decision.[7] The second involves specifying a Taylor type monetary policy rule whereby the domestic cash rate responds contemporaneously to inflation and domestic output.[8] In our specification we have chosen the latter approach, and have allowed the cash rate to respond contemporaneously to commodity prices, inflation and Australian GDP.[9]

TWI_t responds contemporaneously to all variables and is the most endogenous variable in our system. This is standard in the majority of domestic and international

[7] For example, Brischetto and Voss (1999), Berkelmans (2005), Lawson and Rees (2008), Jacobs and Rayner (2012) and Vespignani (2013).
[8] For example, Dungey and Pagan (2000, 2009), Claus, Dungey and Fry (2008), Dungey, Fry-Mckibbin and Linehan (2014).
[9] The first method is also considered in our robustness analysis in Section 7, and our results remain relatively unchanged.

literature, as the exchange rate is a variable that trades daily and responds quickly to all available information. A summary of these identification restrictions is shown in Equation (4).

$$B_0X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & 1 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & 1 & 0 & 0 \\ b_{51} & b_{52} & 0 & b_{54} & 1 & 0 \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & 1 \end{bmatrix} \begin{bmatrix} \Delta\log(COM_t) \\ \Delta\log(AGDP_{-it}) \\ \Delta\log(IND_{it})^{10} \\ INF_t \\ CASH_t \\ \Delta\log(TWI_t) \end{bmatrix} \tag{4}$$

Given these restrictions the model is over-identified; there is one more zero restriction than necessary to just identify the model. The likelihood ratio test for over identification is calculated for each of the permutations of the SVAR considered (profit and real and nominal GVA of each industry). In all but one case the null hypothesis of valid over-identification restrictions cannot be rejected at the 10 per cent level, indicating that the restrictions placed on the model are reasonable.[11]

Two lags of the exogenous foreign variables affect all domestic variables, and world GDP also affects the domestic variables contemporaneously. Allowing contemporaneous interaction between world GDP and the domestic variables is consistent with Dungey and Pagan (2000), Berkelmans (2005), Lawson and Rees (2008) and Dungey, Fry-Mckibbin and Linehan (2014) and is supported by the model.[12]

[10] Nominal GVA and industry profits are also considered in place of real GVA, with the same contemporaneous restrictions. However when nominal GVA is considered, real GDP is replaced with nominal GDP. When industry profits are considered, non-farm real GDP remains as an unadjusted variable, rather than subtracting the industry of interest.
[11] Statistics are available in Appendix B, Table 4.
[12] The contemporaneous world GDP term is statistically significant in the majority of domestic variable equations.

4.4 Choice of lag length

To select the lag length, the Schwartz Bayesian, Hannan-Quinn and Akaike information criteria are considered for each industry. For each industry, the Schwartz and Hannan-Quinn criterion suggest one lag and the Akaike criterion suggests eight lags with the exception of the construction industry where it indicates seven lags. Including too many lags risks over parameterising the model, however selecting too few may result in omitted variable bias. Consequently, a lag length of $p = 2$ is selected in line with Jacobs and Rayner (2012) and Dungey Fry-Mckibbin and Linehan (2014) .

4.5 Tests for stationarity

The Augmented Dicky Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests are conducted to determine whether the variables are stationary. The null hypothesis of the ADF test is that the variable is non-stationary; the KPSS test has the opposite null hypothesis, that the variable is stationary. Test statistics are shown in Table 5, located in Appendix B.

For the majority of the variables, the ADF and KPSS tests suggest that the variables are non-stationary in levels. Both tests support that the domestic inflation rate and industry profits are stationary in levels at the 10 per cent level. The statistics for the ADF and KPSS tests are -6.041 and 0.115 for inflation and -4.624 and 0.072 for industry profits, respectively.[13]. Table 5 also shows the results of unit root testing using the first difference of the variables that are non-stationary in levels. Both ADF and KPSS tests indicate that these variables are all first difference stationary at the 10 per cent level of significance.

[13] Industry profit test statistics quoted are for mining, other industries exhibit similar stationary results.

5. Extended model

In this section we consider an extended model, by disaggregating commodity prices into individual components. Three separate commodity price indices are reported by the RBA: rural commodities, base metals and bulk commodities.

We specify bulk commodities as the most exogenous variable. Justification for this is that the majority of the bulk commodities index is made up of coal, which is used in generating a substantial amount of the world's supply of electricity. An increase in bulk commodity prices, and hence in the cost of generating electricity, is likely to have flow on effects to rural commodity and base metals prices. Base metals are ordered as the second variable, followed by rural commodities. Rural commodities are ordered after base metals as metals are used as inputs in a large number of industries.

Different contemporaneous relationships between the commodity price indices are considered, and the restrictions which are most supported by the model are selected. To determine the most appropriate restrictions, the criteria of the highest p-value when testing for valid over-identifying restrictions is employed. The resulting restrictions (b_{21}, b_{31} and b_{32}) are shown in Equation (5). Similarly to the baseline model introduced in Section 4, two lags of the exogenous foreign variables enter the model, and world GDP is allowed to affect the domestic variables contemporaneously. [14]

$$B_0 X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & 1 & 0 & 0 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & 1 & 0 & 0 & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 & 0 & 0 & 0 \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & 1 & 0 & 0 \\ b_{71} & b_{72} & b_{73} & b_{74} & 0 & b_{76} & 1 & 0 \\ b_{81} & b_{82} & b_{83} & b_{84} & b_{85} & b_{86} & b_{87} & 1 \end{bmatrix} \begin{bmatrix} \Delta\log(COMBC_t) \\ \Delta\log(COMBM_t) \\ \Delta\log(COMR_t) \\ \Delta\log(AGDP_{-it}) \\ \Delta\log(IND_{it}) \\ INF_t \\ CASH_t \\ \Delta\log(TWI_t) \end{bmatrix} \qquad (5)$$

[14] Different over-identification restrictions are considered in the robustness analysis, Section 7.

Given these restrictions the model is over-identified; there is one more zero restriction than necessary to just identify the model. The likelihood ratio test for over identification is calculated for each of the permutations of the SVAR considered (profit and real and nominal GVA of each industry). In the majority of these tests, the null hypothesis of valid over-identification restrictions cannot be rejected at the 10 per cent level, indicating that the restrictions placed on the model are reasonable. [15]

6. Results

This section analyses the cumulative impulse responses of industry variables to commodity price shocks and the variance decomposition of the estimated SVAR.

One per cent shocks are applied to the SVAR model. For the impulse responses presented in this section, asymptotic standard errors of one standard deviation are used. Since we are focusing on the industrial impact of commodity price shocks, most of the analysis within this section centres on the responses of the industry variables to innovations to commodity price indices. However, in Section 6.5 we also consider shocks to our domestic variables in order to check the adequacy of the model. Sensitivity checks are also performed on each of our SVAR models. The presence of residual heteroskedasticity is rejected in all models at the 10 per cent level, and for the majority of the models first order serial correlation is not present.[16]

6.1 Commodity price shocks: All items

Figure 3 indicates that in general, the impulse responses of real and nominal GVA and profits respond in a similar fashion. However, two notable exceptions are the mining and construction industries.

[15] Statistics are available in Appendix B, Table 4.
[16] See Appendix B, Sensitivity Analysis.

A one per cent shock to commodity prices results in a negative response of mining real GVA that reaches its minimum at 0.2 per cent below the baseline in the fifth quarter and remains significantly negative from the fourth quarter over the impulse horizon.

The response of mining profits and nominal GVA provide a stark contrast; both are significantly positive over the entire impulse horizon, mining profits increase by 2.1 per cent contemporaneously, before peaking at 3.9 per cent in the fourth quarter. These contrasting results are due to the different way in which real and nominal GVA are constructed.

Real GVA is a volume measure of production of a particular industry. Topp et al. (2008) explain that the surge in commodity prices during the past decade considerably increased the value of output produced by the mining sector, but had little impact on the volume of output in the short run (measured by real GVA). Furthermore, increasing commodity prices encourages extraction of 'more-marginal' deposits, which require more intermediate input per unit of output, resulting in higher cost production. In addition, mines are also usually run at, or close to, full capacity. Consequently output can only be increased in the short term by using more intermediate inputs such as labour. Topp et al. (2008) also highlight that there is a significant lead-time associated in investing in new production capacity (such as new mine sites) and the corresponding increase in output. Accordingly, an increase in commodity prices does not lead to a significant increase of real mining GVA in the short term, due to the cost of intermediate inputs increasing by more than the gross volume of output.

Turning to the construction sector, the response of real and nominal GVA for the industry is positive. Real GVA peaks at 0.35 per cent in the fourth quarter, and remains significantly positive over the impulse horizon. Dungey, Fry-Mckibbin and Linehan

(2014) find that a commodity price shock results in an increase in mining investment, such as the building of new mine sites. As the construction industry will be involved in the creation of these new mines, the real GVA of the construction industry is likely to increase.

In response to a one per cent commodity price shock, manufacturing real GVA responds positively in the second quarter before declining to baseline in subsequent periods. Profits increase at first before declining sharply. Commodities are intermediate inputs in a range of manufacturing sub industries, and a commodity price shock may be expected to result in a decline in real output in the industry by increasing the costs of production in certain sub sectors. However, certain manufacturing industries provide a large amount of inputs for the construction industry, and will face increased demand following commodity price shocks as the construction sector increases output.

6.2 Commodity price shocks: Bulk commodities

In figure 4, the responses the responses of industry variables to a bulk commodity shock are shown, these responses remain similar to the responses to an all items price shock. Industry profits continue to closely follow real GVA with the exception of the mining and construction industries.

Mining real GVA responds negatively to a one per cent increase in bulk commodity prices, stabilising at negative 0.08 per cent, and is significantly negative from period three onwards. As found previously, mining profits and nominal GVA respond significantly positively over the impulse horizon.

Construction real GVA responds positively to a bulk commodity shock for the entire impulse horizon, peaking at 0.23 per cent in the third quarter. Increases in the price of iron ore and coal stimulate mining related investment, for which the construction industry is required to build new mine sites. Construction profits increase by 0.38 per cent contemporaneously before declining. This mixed response is due to the conflicting impact of a bulk commodity price shock on construction industry profits; increased demand for resource related construction has a positive impact on industry profits, while the price of inputs such as steel increases, decreasing profits.

The response of manufacturing real GVA and profits increase initially before declining, likely due to the contrasting responses within sub sectors. The response of manufacturing sub industries real GVA to a bulk commodities shock is analysed in the following section. Similarly to the all items commodity price shock, financial services' GVA and profits remain unresponsive to a bulk commodity price shock.

6.2.1 The response of manufacturing sub industries

Since manufacturing is a broad sector, the ABS disaggregates real manufacturing GVA into eight sub sectors. Six of these sectors are examined.[17]

In figure 5, the results of these subsectors within the manufacturing industry provide a better understanding of the response of the entire industry to a bulk commodity price shock. Some sectors suffer from rising input costs, others benefit from resource related demand spillovers from other industries such as construction.

Sub industries such as metal products and Food, beverage and tobacco product manufacturing remain relatively unresponsive to a bulk commodity price shock. The petroleum, coal, chemical and rubber product sector experiences a reduction in output in response to a bulk commodity price shock, likely due to increased cost pressures as the price of inputs such as coal rise.

[17] Two of the smaller sub sectors, wood and paper products, and printing and recorded media are omitted due to the small size of these sectors.

In contrast the non-metallic mineral products reacts positively to a bulk commodities shock, real GVA increases by 0.17 per cent contemporaneously, peaking at 0.23 per cent and remains significantly positive over the impulse horizon. This is due to the construction industry requiring products manufactured by this sub industry. [18]

6.3 Commodity price shocks: Base metals

Figure 6 shows the responses of industry variables to a one per cent base metals shock. A base metal shock has a relatively smaller effect than a bulk commodities shock, highlighting the increased importance of bulk commodities.

Mining real GVA is unresponsive to a one per cent increase in base metals, echoing the results in the previous sections; real output in the mining industry does not increase in the short term following increases in commodity prices, due in part to capacity constraints.

However, profits and nominal GVA respond positively which can be attributed to the increase in the value of the outputs of mining industry. This response is smaller in magnitude than the increase in profits associated with a bulk commodities shock, underlining the importance of iron ore and coal relative to base metals for the mining industry. [19] Manufacturing output is relatively unresponsive, while profits increase initially before declining.

Construction real GVA has a negative contemporaneous response of 0.08 per cent before increasing above the baseline, though not significantly. This is potentially attributed to the use of base metals as an input by the construction industry; increases in prices result in an immediate increase in cost pressures, influencing output. However,

[18] Over 63 per cent of the non-metallic mineral sectors output was used by the construction industry in 2008/09. See ABS Input-Output tables cat 5209.0 Table 2.
[19] Other mining includes copper, silver, lead and zinc ore mining, all of which are classified as base metals in the RBA commodity price index. Iron ore and coal mining made up over 56 per cent of mining GVA in March 2013, compared to only 18 per cent for other mining.

increases in base metal prices are also associated with an increase in mining investment, which increases construction output, so the net effect over the period is negligible.

6.4 Commodity price shocks: Rural commodities

This section (figure 7) shows the responses of industry variables to one percent rural commodity shock. A rural commodity shock has a positive impact on manufacturing, increasing real GVA by 0.16 per cent in the fourth quarter. A substantial amount of the intermediate inputs used in the agricultural sector are provided by the manufacturing industry.[20] An increase in rural commodity prices is likely to encourage increased agricultural production and the demand for intermediate inputs, stimulating output in the manufacturing industry.

In contrast, manufacturing industry profits increase initially, before falling below baseline in subsequent periods. This is due to the interrelated nature of the manufacturing and agricultural sectors; the biggest sub industry in manufacturing (food, beverage and tobacco product manufacturing) requires a substantial amount of rural commodities as inputs.[21] The manufacturing sector initially experiences increased demand for their products from the agricultural sector, which increases profits. However, in the longer term some sub industries' profits decline due to increased input costs.

The response of real mining GVA to a one per cent rural commodity shock peaks at negative 0.2 per cent in the seventh quarter, remaining significantly negative throughout the impulse horizon. In the model, commodity price shocks result in an

[20] In 2008-09 approximately 23 per cent of intermediate inputs in the agricultural industry were provided by the manufacturing industry. See ABS Input-Output tables cat 5209.0 Table 2.
[21] In 2008-09 approximately 40 per cent of intermediate inputs in the food, beverage and tobacco product industry were provided by the agricultural industry. See ABS Input-Output tables cat 5209.0 Table 2.

exchange rate appreciation.[22] Intuitively, this has a negative impact on demand in the mining industry as commodity exports become relatively more expensive to overseas buyers.

6.5 Shocks to the domestic variables

This section outlines the impulse responses of the baseline model domestic variables.[23] Non-cumulative impulse responses are discussed, in order to make direct comparisons with a number of Australian SVAR models.[24]

The responses of the domestic variables to a commodity price shock are consistent with those presented in Dungey, Fry-Mckibbin and Linehan (2014). Australian GDP falls in response to a commodity price shock, though the response is small and only significant in the initial period. Dungey, Fry-Mckibbin and Linehan (2014) attribute this fall in production to a decline in activity in the non-resources sector that is not fully compensated for by an increase in production in the resources sector. Inflation increases contemporaneously in response to rising commodity prices, but declines in subsequent periods. The decline in the inflation rate is due to an appreciation of the real exchange rate making imported goods cheaper, and an associated contraction of the domestic cash rate that reduces inflationary pressures. The cash rate initially increases before declining as commodity prices and inflation fall.

The real exchange rate originally appreciates in response to commodity price shocks. In cumulative terms (not shown in this figure) the impact of commodity prices remains positive even after 2 years. Results are consistent in terms of sign, magnitude and significance to those observed in Dungey, Fry-Mckibbin and Linehan (2014). The impact of commodity prices on the exchange rate helps to explain the negative impact

[22] See Appendix B, Figure 9 for impulse responses of a commodity price shock on the exchange rate.
[23] The model is identical to the baseline model in Section 4, but without an industry variable present.
[24] Impulse responses are located in Appendix B, Figure A.1, in order to conserve space.

of commodity prices in the mining real GVA observed in figure 3. Following the standard Mundell and Fleming model with a floating exchange rate and perfect capital mobility, an appreciation in the domestic currency leads to a reduction in net exports, as exports became more expensive for foreign economies while imports for the domestic economy became cheaper.

Figure 9 also shows that the appreciation of the exchange rate as a consequence of commodity price shocks, occur immediately in the first quarter, while the transmission from the exchange rate to real output, inflation and monetary reaction occur after the first quarter. Variance decomposition results show that up to 13% of the Australian exchange rate variation can be explained by commodity price shocks.

An inflation shock results in a sustained increase in the cash rate that peaks in the third quarter before slowly returning to the baseline. The exchange rate initially increases before falling below baseline in the third period. GDP is unresponsive to an inflation shock.

As expected, GDP decreases in response to a shock to the cash rate. However, the response of inflation highlights the presence of a ‘price puzzle’, whereby a domestic cash rate contraction leads to an increase in inflation. The increase in inflation is short-lived, as the response decreases after the first two periods, moving below the baseline in period six. The response of inflation to a cash rate shock is comparable to Lawson and Rees (2008) and Jacobs and Rayner (2012) who find a similar ‘price puzzle’ in their results. In response to an unanticipated increase in the cash rate, the exchange rate appreciates initially, before depreciating, consistent with uncovered interest rate parity.

In response to an exchange rate shock the cash rate decreases, as monetary policy moves to offset the price level effects following the initial appreciation.

6.6 Variance decomposition

Variance decomposition provides information on the proportion of the variation in each of the variables that can be explained by shocks to the other variables within the model. The variation decomposition for the baseline model is shown below, focusing only on the results of industry variables to a commodity price shock innovation.

The results in Table 1 highlight the importance of commodities in the mining, manufacturing and construction industries. In the mining industry shocks to commodity prices explain only a small amount of variation in real GVA, compared to the large amount of variation explained in nominal GVA and profits. This result highlights the muted response of real output, relative to nominal output, in the mining industry to increases in commodity prices found in previous sections. Commodity prices explain more of the variation in profits in the mining, manufacturing and construction industries than in the financial services and insurance sector. This is unsurprising as commodities are direct inputs into the manufacturing and construction industries, and will likely have a more significant impact on industry wide profits.

Table 2 shows the results of the variance decomposition for the extended model. In a similar vein to the impulse response results, bulk commodities shocks explain only a relatively small amount of the variation in real mining GVA (3.91 per cent after four quarters), in contrast to the large amount of variation explained in nominal mining GVA and profits (35.64 and 13.03 per cent after four quarters, respectively). Bulk commodity shocks explain a larger amount of the variation in the mining, construction and manufacturing industries relative to financial services.

The results for the construction industry also reaffirm the impulse response results; rural commodity shocks explain little of the variation in real construction GVA (1.26 per cent in the fourth quarter) as the link between the rural sector and construction is tenuous. Base metals explain the most variation in terms of profits (3.98 per cent in the fourth quarter), due to the impact of base metals on input costs, and bulk commodities explain the most in terms of real GVA (8.56 per cent in the fourth quarter).

7. Robustness analysis

SVAR systems can be sensitive to the specification of the model. Accordingly, this section examines a number of alternate specifications to determine the robustness of our results. Using alternate variables in the baseline model. Figure 8 shows the effect of estimating the model with the 90-day bill rate, Australian GDP and trimmed mean inflation as alternative variables.

7.1 Variable specification

To consider the impact that including different variables in the model may have, the alternate variables in Table 3 are substituted into the baseline model one at a time. We consider using a different weighting scheme for our exogenous foreign variables, by weighting the world inflation and interest rate by GDP rather than by trade. The use of GDP weighting has little impact on our results. The use of Australian GDP instead of non-farm Australian GDP is also examined, with the results shown in Figure 8. We also consider using the 90-day bill rate, as this rate closely follows the domestic cash rate target and more directly reflects the costs that banks pay for short-term funds. Finally, we incorporate a measure of underlying inflation, as this is used in some previous studies (Lawson and Rees, 2008; Jacobs and Rayner, 2012; Dungey, Fry-Mckibbin and Linehan, 2014). There are no discernible changes to our results when substituting different measures of the real exchange rate.

8. Conclusions

The three industries that are most affected by commodity price shocks are the mining, construction and manufacturing industries. In comparison, the output and profits of the financial and insurance sector is found to be relatively unaffected.

The results indicate that the value of mining output and industry profits increase substantially in response to a commodity price shock. Conversely, impulse responses show that the volume of real mining output responds negatively to a commodity price shock. This is partly due to rising commodity prices encouraging extraction of more marginal deposits, which requires more intermediate input per unit of output. These results are reemphasised in the variance decomposition with commodity price shocks explaining a substantial amount of variation in the value of mining sector output (nominal GVA and profits) and little of the real volume of output (real GVA).

The construction and parts of the manufacturing industry are both found to benefit from demand spillovers from the resources sector. In response to commodity price shocks, construction output increases significantly as a result of increased demand for resource related construction. Variance decomposition also shows that commodity prices explain a significant amount of variation in the output and profits of the construction industry.

Manufacturing output also increases in response to a commodity price shock, however profits only increase initially before declining, highlighting increased cost pressures in manufacturing in the longer term. More generally, analysis of innovations to each of the three commodity price indices reveals that bulk commodity prices have a greater impact on industry variables relative to rural commodities and base metals, reflecting the increasing importance of bulk commodities to the Australian economy.

Our findings also suggest that the floating exchange rate policy in Australia has helped significantly to stabilise the economy in the presence of commodity price shocks. [25]A rise in commodity prices substantially increases the value of the Australian currency which reduces competitiveness of Australian exports. Mining real outputs are materially affected by the appreciation of the Australian dollar, as this sector exports most of its production.

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[25] Note that according to the Mundell and Fleming model with perfect capital mobility, a flexible exchange rate regime implies that monetary policy is effective while fiscal policy is ineffective in terms of stabilising the economy.

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Table 1. Variance decomposition of industries to a commodity price shock

	Proportion of forecast error variance for variable					
	Real GVA		**Nominal GVA**		**Profit**	
Quarter	4	8	4	8	4	8
Mining	1.73	1.95	27.78	32.16	13.83	13.79
Manufacturing	14.42	14.76	0.38	1.19	7.50	7.58
Construction	5.85	5.93	8.49	9.87	5.93	6.05
Financial Services	3.35	4.08	5.98	9.47	3.30	3.37

Table 2. Variance decomposition of industries to each commodity price shock

		Proportion of forecast error variance for variable					
	Innovation	**Real GVA**		**Nominal GVA**		**Profit**	
Quarter		4	8	4	8	4	8
Mining	*Bulk*	3.91	4.00	35.64	32.29	13.03	13.08
	Base Metals	2.65	2.69	5.63	8.13	2.60	3.04
	Rural	4.43	4.99	3.40	8.13	10.14	10.18
Manufacturing	*Bulk*	11.41	11.00	2.54	2.31	8.20	8.27
	Base Metals	0.94	1.12	3.01	2.79	3.28	3.23
	Rural	6.70	8.66	17.92	19.06	8.81	9.52
Construction	*Bulk*	8.56	8.78	1.90	2.51	3.07	3.08
	Base Metals	2.94	3.04	8.65	12.35	3.98	4.56
	Rural	1.26	1.96	0.82	3.36	3.20	3.21
Financial	*Bulk*	2.32	2.92	5.61	6.05	1.49	1.62
Services	*Base Metals*	8.35	10.68	4.40	6.69	8.10	7.90
	Rural	4.16	4.36	0.67	1.57	4.49	5.59

Table 3. Alternative variables used in the baseline model

Variable in baseline model	**Alternate variables considered**
Trade-weighted world inflation rate	GDP-weighted inflation rate[26]
Trade-weighted world interest rate	GDP-weighted interest rate
Australian non-farm GDP	Australian GDP
Headline inflation	Underlying inflation; trimmed mean
Cash rate	90-day bank accepted bill rate
Real trade-weighted index	Real export-weighted index, real G7 GDP-weighted index

[26] GDP weights for each of Australia's five largest trading partners are calculated by dividing each country's quarterly GDP in US dollars, by the sum of all five countries quarterly GDP in US dollars.

Table 4. Testing for valid over-identification restrictions

Real GVA	Variable	Chi-Square (1)	Chi-Square (1)
	Mining	2.116 (0.1457)	1.716 (0.1902)
	Construction	1.028 (0.3107)	0.482 (0.4875)
	Manufacturing	0.069 (0.7927)	0.051 (0.8217)
	Financial and Insurance Services	1.562 (0.2113)	4.478 (0.0343)
Manufacturing	Food, Beverage and Tobacco		0.314 (0.5751)
sub industries	Textiles, Clothing		8.602 (0.0034)
	Wood and Paper		1.017 (0.3132)
	Printing and Recorded Media		4.827 (0.0280)
	Petroleum, coal, chemical		0.004 (0.9492)
	Machinery and Equipment		0.769 (0.3806)
	Non-metallic Mineral Products		0.185 (0.6669)
	Metal Products		0.103 (0.7480)
Profits			
	Mining	0.042 (0.8373)	2.057 (0.1515)
	Construction	0.083 (0.7726)	0.005 (0.9435)
	Manufacturing	0.186 (0.6660)	0.040 (0.8417)
	Financial and Insurance Services	0.222 (0.6376)	0.645 (0.4221)
Nominal GVA			
	Mining	0.773 (0.3793)	0.983 (0.3214)
	Construction	7.746 (0.0054)	11.16 (0.0008)
	Manufacturing	0.966 (0.3258)	1.107 (0.2927)
	Financial and Insurance Services	2.006 (0.1567)	3.832 (0.0503)

The null hypothesis that the over identification restrictions are valid. Test statistics are reported, p-values are in parenthesis. Left column shows statistics for the baseline model, right shows the extended model.

Table 5.Testing for unit roots

Variable	ADF	KPSS	Variable	ADF	KPSS
$\mathbf{log}(\boldsymbol{WGDP_t})$	-1.523	2.744***	$\Delta\log(WGDP_t)$	-4.652***	0.356*
$\mathbf{log}(\boldsymbol{WINF_t})$	1.304	2.723***	$\Delta\log(WINF_t)$	-7.745***	0.269
$\mathbf{log}(\boldsymbol{COM_t})$	-0.184	1.977***	$\Delta\log(COM_t)$	-4.709***	0.273
$\mathbf{log}(\boldsymbol{AGDP_{-it}})$	-2.387	2.780***	$\Delta\log(AGDP_{-it})$	-4.185***	0.452*
$\mathbf{log}(\boldsymbol{AGDPNOM_{-it}})$	-1.398	2.661***	$\Delta\log(AGDPNOM_{-it})$	-7.188***	0.169
$\mathbf{log}(\boldsymbol{IND_{it}})$	-0.079	2.663***	$\Delta\log(IND_{it})$	-5.167***	0.067
$(\boldsymbol{PROF_t})$	-4.624***	0.072			
$\mathbf{log}(\boldsymbol{NIND_t})$	0.685	2.558***	$\Delta\log(NIND_t)$	-4.416***	0.404*
$\boldsymbol{INF_t}$	-6.041***	0.115			
$\mathbf{log}(\boldsymbol{TWI_t})$	-0.230	2.255***	$\Delta\log(TWI_t)$	-5.634***	0.116
$\mathbf{log}(\boldsymbol{COMBC_t})$	-0.475	1.951***	$\Delta\log(COMBC_t)$	-5.436***	0.195
$\mathbf{log}(\boldsymbol{COMR_t})$	-1.516	1.031***	$\Delta\log(COMR_t)$	-5.819***	0.133
$\mathbf{log}(\boldsymbol{COMBM_t})$	-1.904	1.373***	$\Delta\log(COMBM_t)$	-5.252***	0.057

The null hypothesis is that the variable has a unit root. ***, **, * denotes rejection of the null hypothesis at the 1%, 5% and 10% level. Δ denotes first difference. Lag length is 2. Only intercept included in the test equation.

Figure 1.Disaggregated RBA index of commodity prices in United States dollars

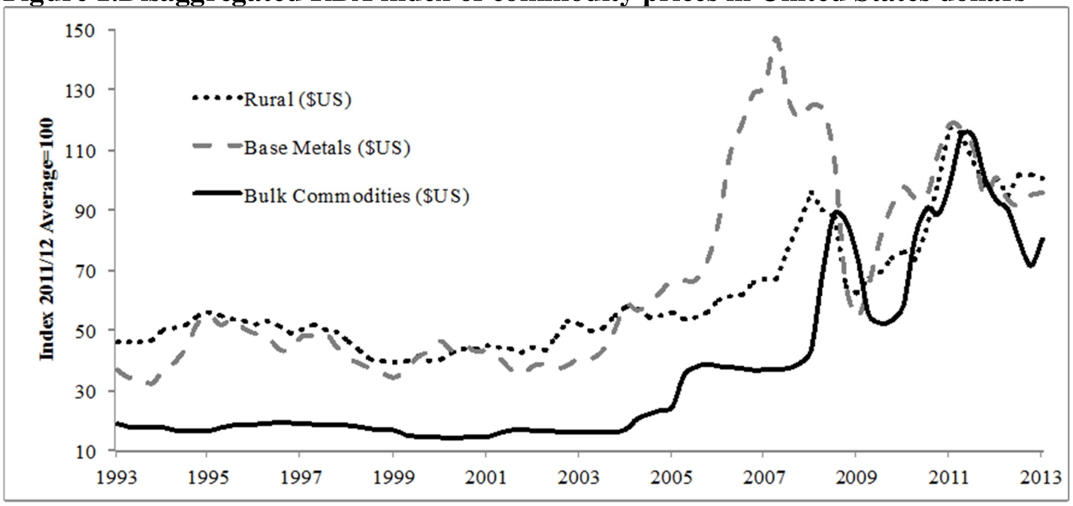


Figure 2. Largest trading partners of Australia in terms of total trade value

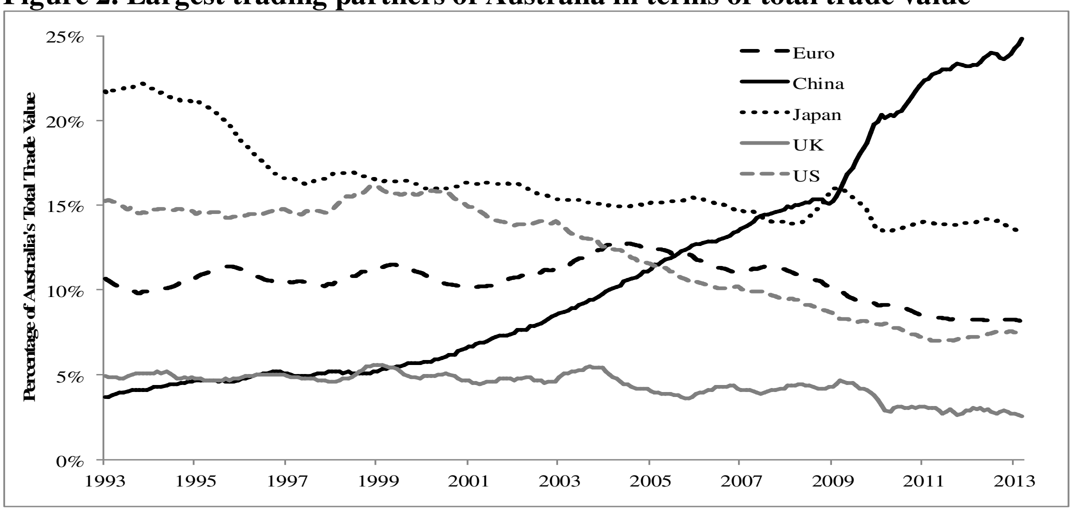


Figure 3. Response of industry variables to a 1% commodity price shock

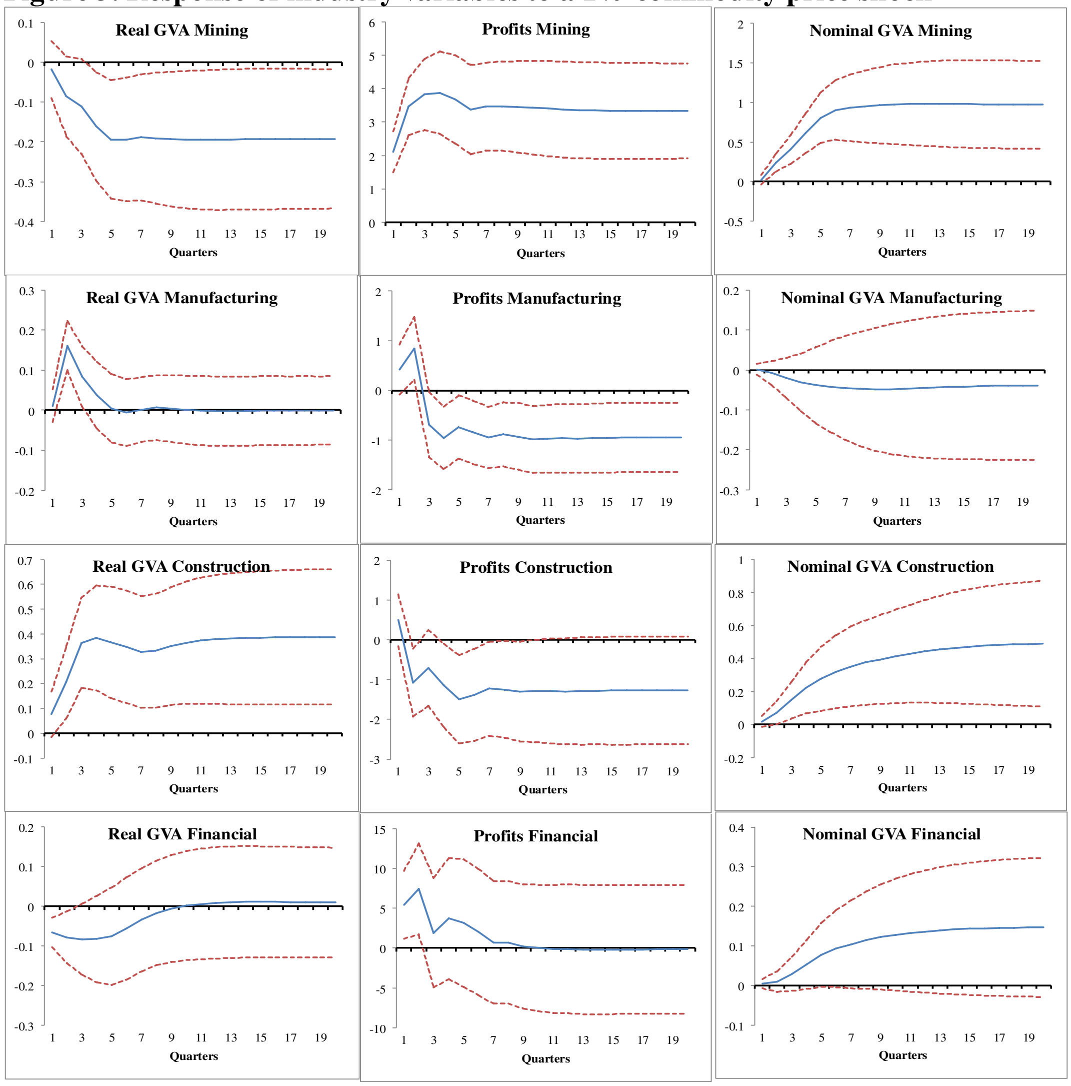


Figure 4. Response of industry variables to a 1% bulk commodity price shock

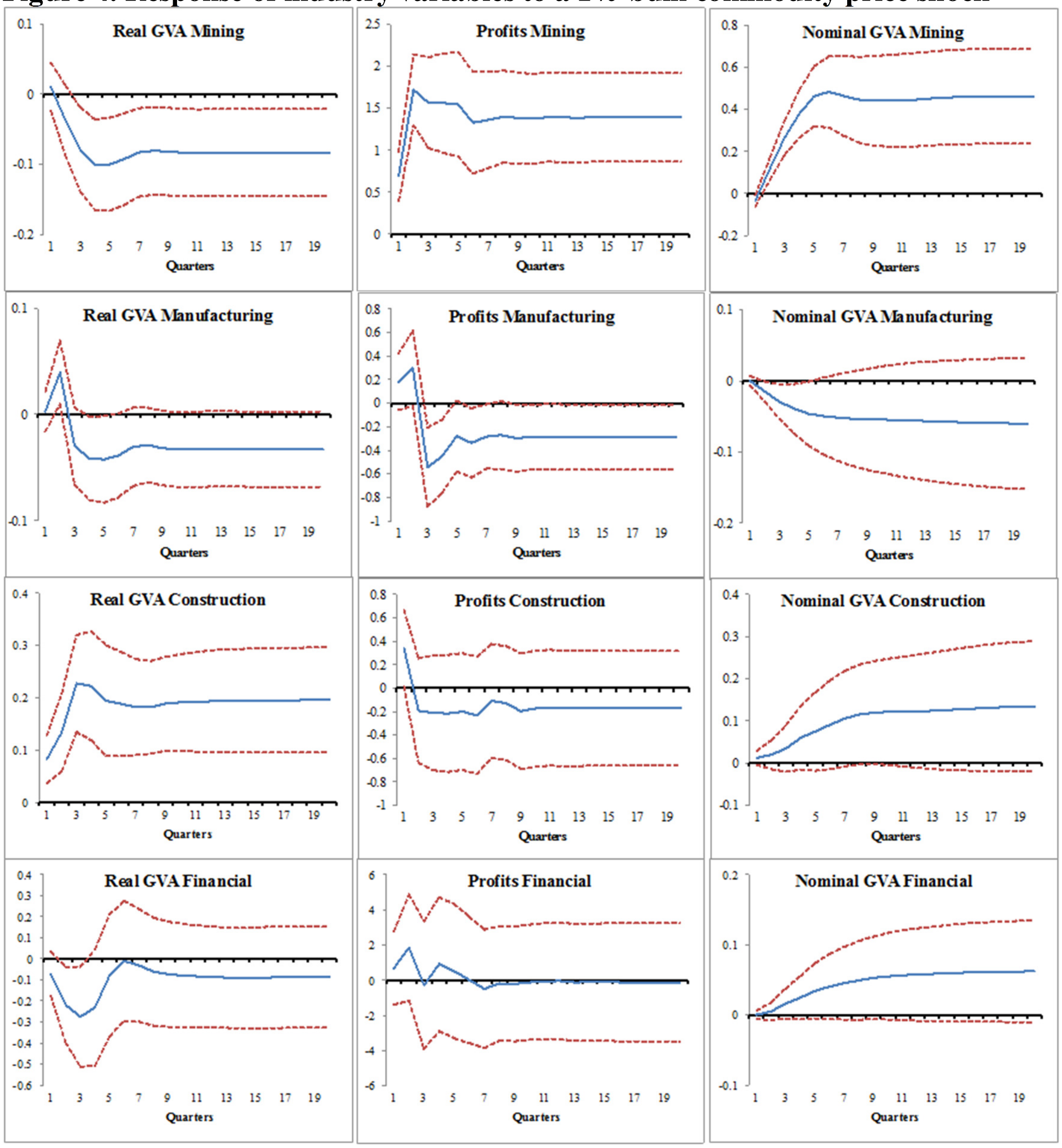


Figure 5. Responses of manufacturing sub industry real GVA to a 1% bulk commodity price shock

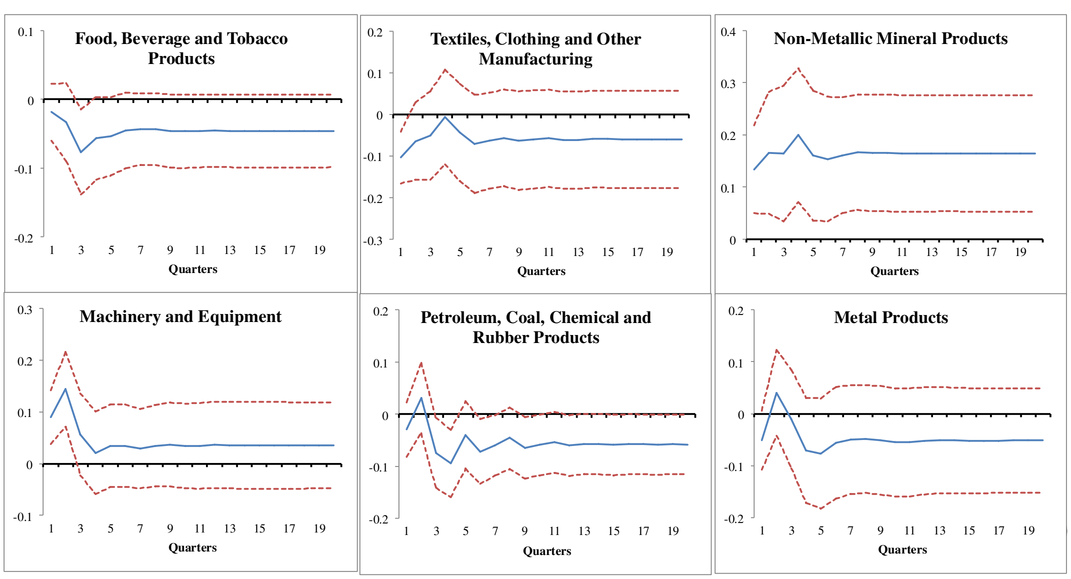


Figure 6. Response of industry variables to a 1% base metals shock

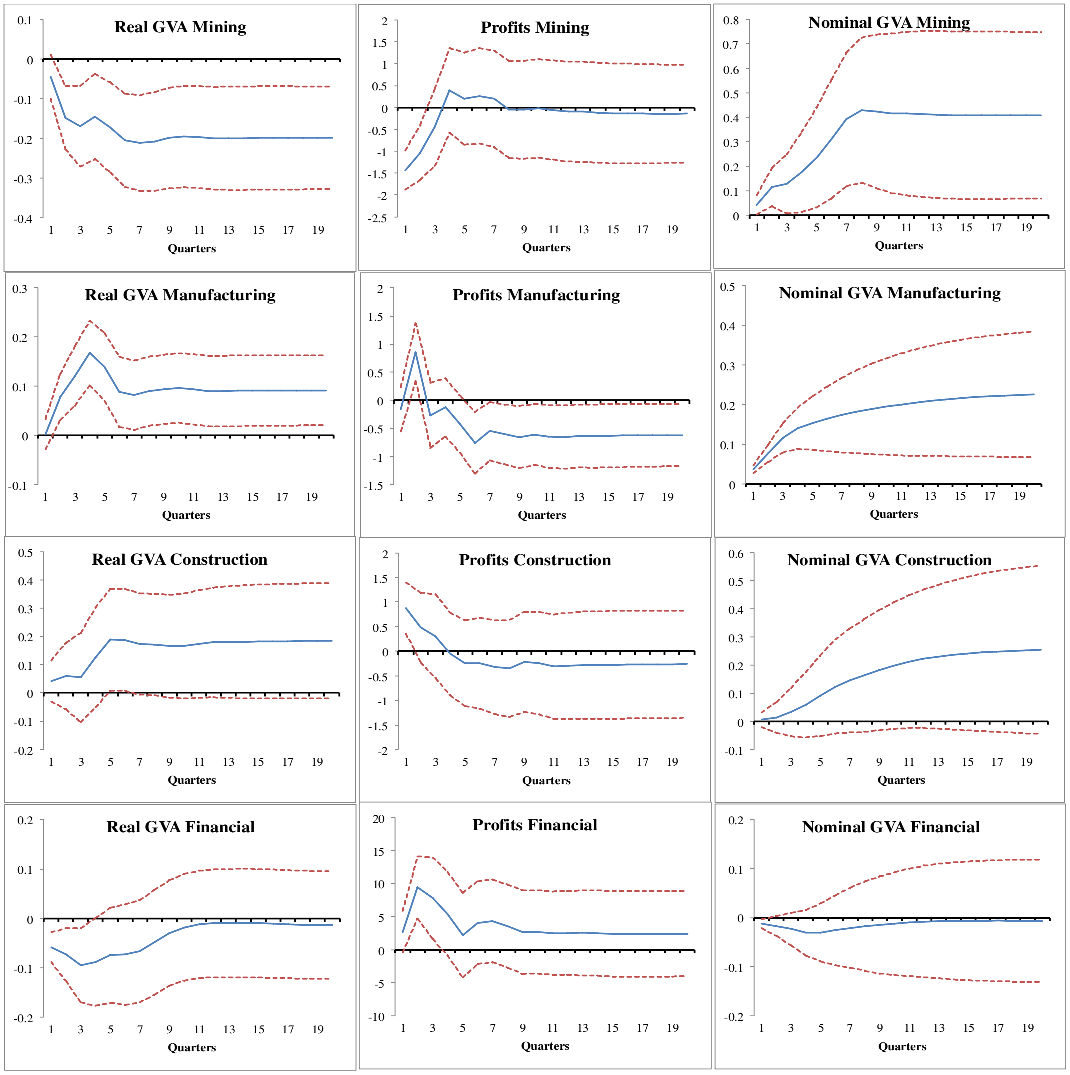


Figure 7. Response of industry variables to a 1% rural commodity price shock

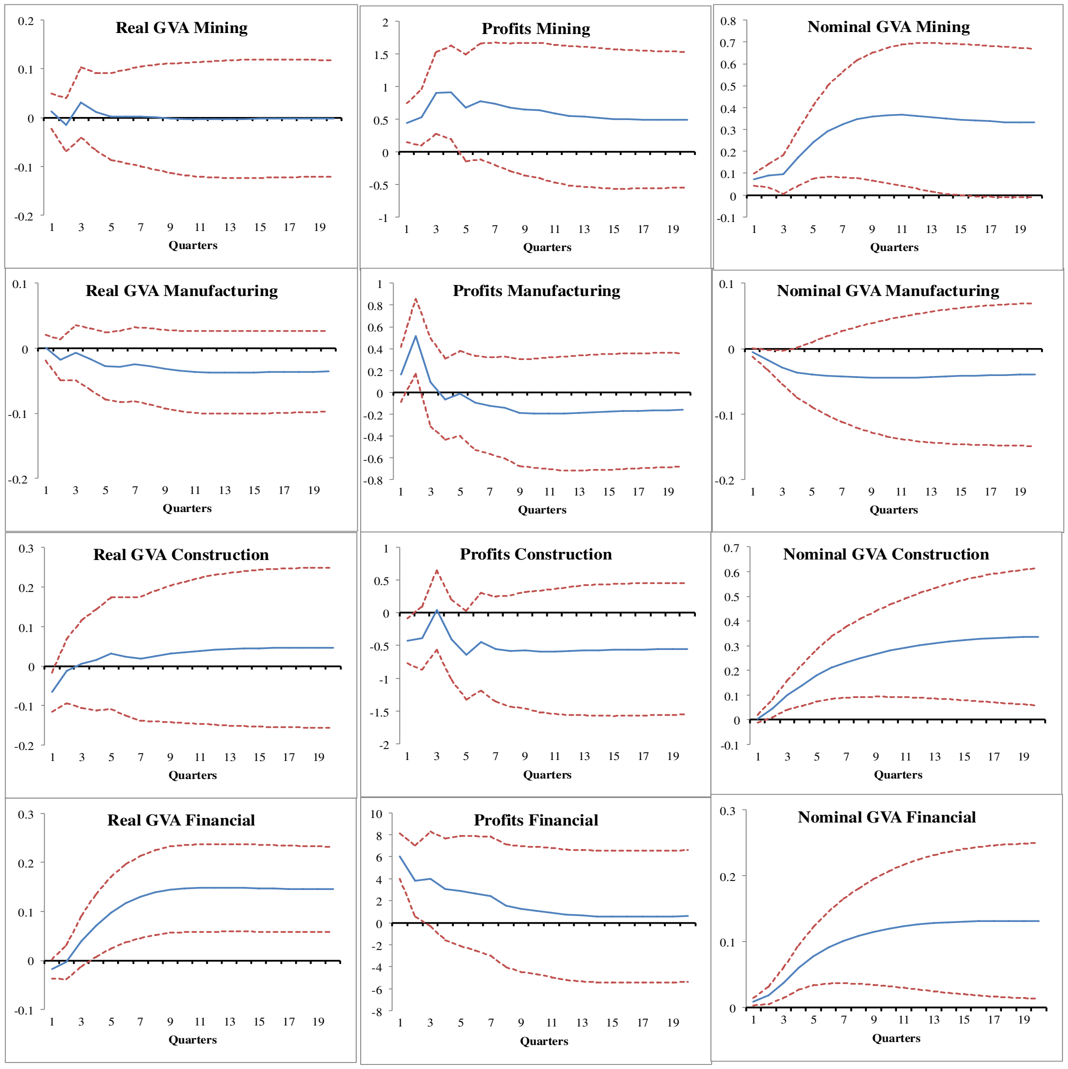


Figure 8. Robustness of accumulative impulse responses to a 1% commodity price shock

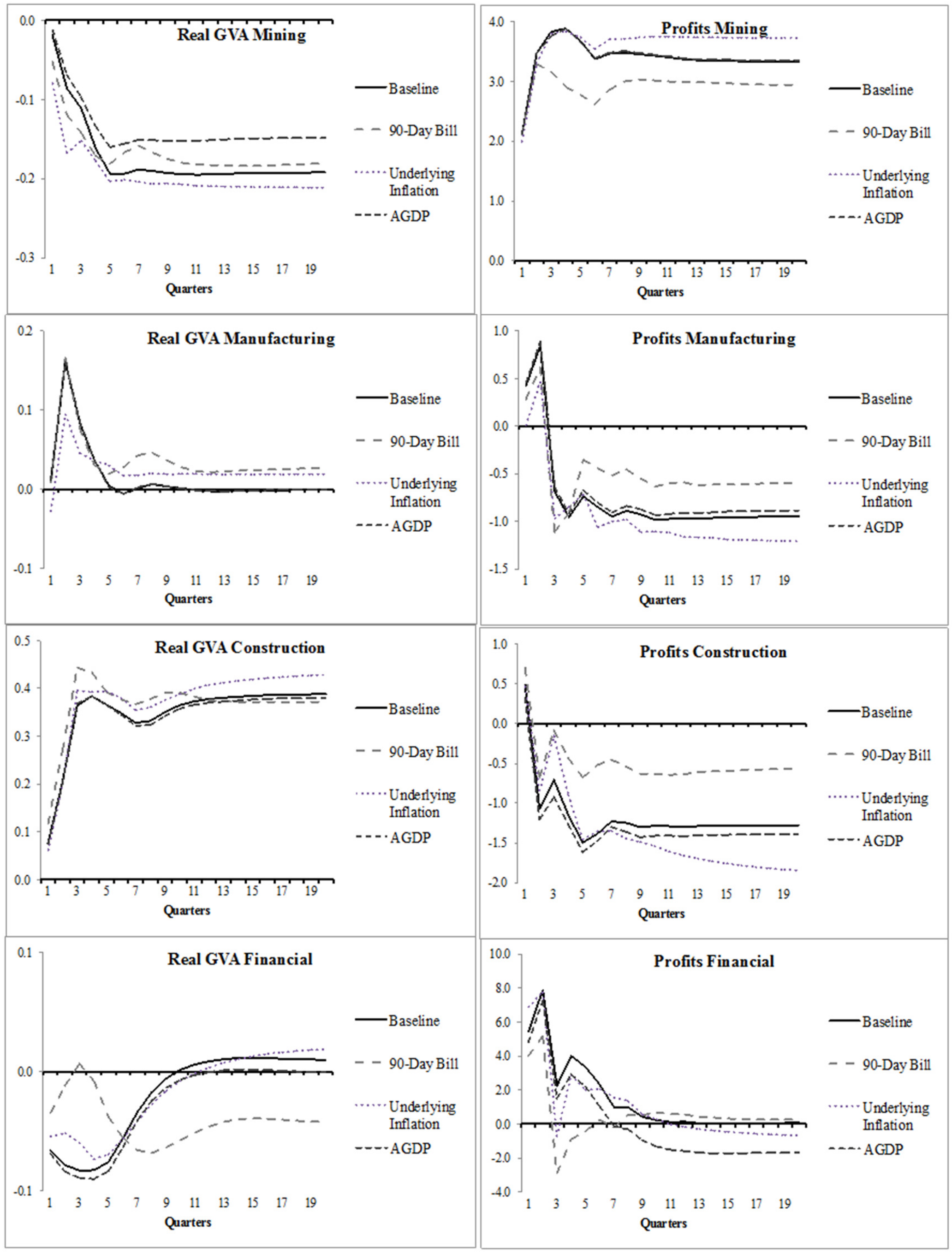
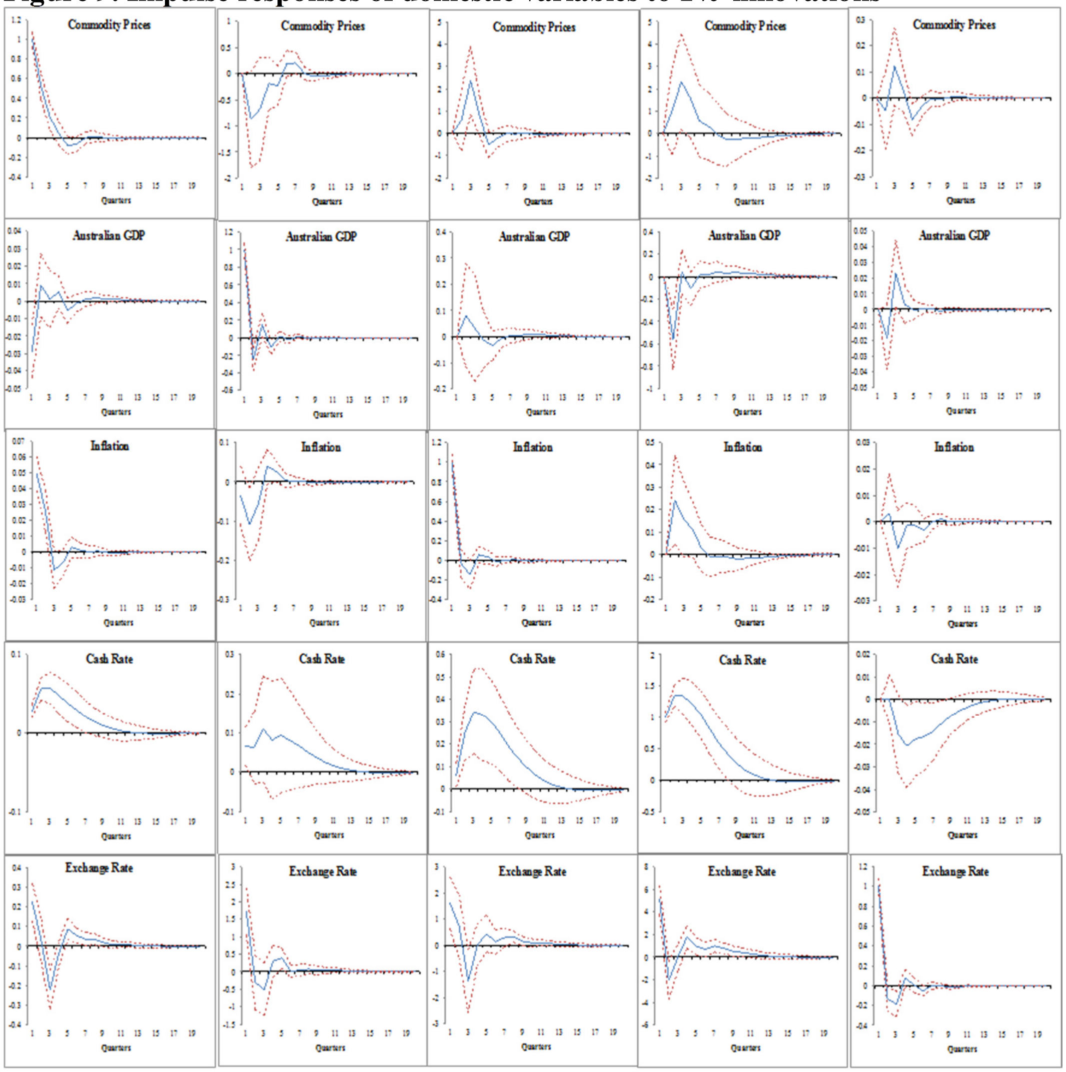


Figure 9. Impulse responses of domestic variables to 1% innovations



Appendix A: Data description and sources

Variable	Source	Transformation
$\boldsymbol{WGDP_t}$	Gross domestic product in real US dollars (Datastream codes: EXXGDP$.C, USXGDP$.C, JPXGDP$.C, CHXGDP$.C, UKXGDP$.D)	Each countries' series are seasonally adjusted using a moving average.
$\boldsymbol{WINF_t}$	Consumer price index: all items (Datastream codes: UKXCPI..F, USXCPI..E, CHXCPI..F, JPXCPI..F, EKXCPI..F)	Each countries' series are seasonally adjusted using a moving average.
$\boldsymbol{WIR_t}$	Interest rate: central bank policy rate (Datastream codes: EKXRCB..R, CHXRCB..R, JPXRCB..R, UKXRCB..R, USXRCB..R)	
$\boldsymbol{COM_t}$, $\boldsymbol{COMBC_t}$, $\boldsymbol{COMBM_t}$ $\boldsymbol{COMR_t}$	Index of commodity prices, all items, bulk commodities, base metals and rural commodities in US dollars (RBA, Statistical Table G5)	Deflated by the US CPI for all Urban Consumers (FRED)
$\boldsymbol{AGDP_{-it}}$	Seasonally adjusted chain volume measure of non-farm gross domestic product (ABS Cat No 5206.0, Table 6)	
$\boldsymbol{NAGDP_{-i}}$	Seasonally adjusted chain volume measure of gross domestic product (ABS Cat No 5206.0, Table 3)	

IND_{it}	Seasonally adjusted chain volume measure of industry gross value added, (ABS Cat. No. 5206.0, Table 6)	
$NIND_{it}$	Current price industry gross value added (ABS Cat. No. 5204.0, Table 5)	Data is converted from annual into quarterly data by using simple linear interpolation.
$PROF_t$	Seasonally adjusted, current price company profits before income tax in percentage change (ABS Cat. No. 5676.0, Table 10)	Outliers have been removed.
INF_t	All groups consumer price index, 1989/90 = 100, excluding interest and tax changes of 1999—2000 (RBA Statistical Table G1)	
$CASH_t$	Quarterly average of the target cash rate (RBA Statistical Table F1)	Converted from monthly to quarterly using a 3-month average.
TWI_t	Real trade-weighted index, March 1995=100 (RBA Statistical Table F15)	

Appendix B: Test for model suitability

Sensitivity Analysis (*Autocorrelation and heteroskedasticity tests)*

The residual serial correlation LM test is used to test for first order autocorrelation. Of the 38 models estimated, the null hypothesis of no first order serial correlation cannot be rejected at the 10 per cent level for 36 of the models (nominal GVA of both mining and professional services, in the baseline model exhibit first order serial correlation).

The residual heteroskedasticity LM test is also estimated for all 38 models, and in each case the null hypothesis of no heteroskedasticity of the join combinations of all error term products cannot be rejected at the 10 per cent level.

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