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Abstract

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Keywords

Chinese resource demand, SVAR, multivariate historical decomposition, commodity demand shock, commodity supply shock.

JEL Classification

C51, E32, F43, F62

Transmission of a Resource Boom: The Case of Australia[*]

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Abstract

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1 Introduction

Stabilising the macroeconomy for policy-makers of commodity resource-rich countries when commodity prices are high depends upon knowing what drives the upsurge in the resource
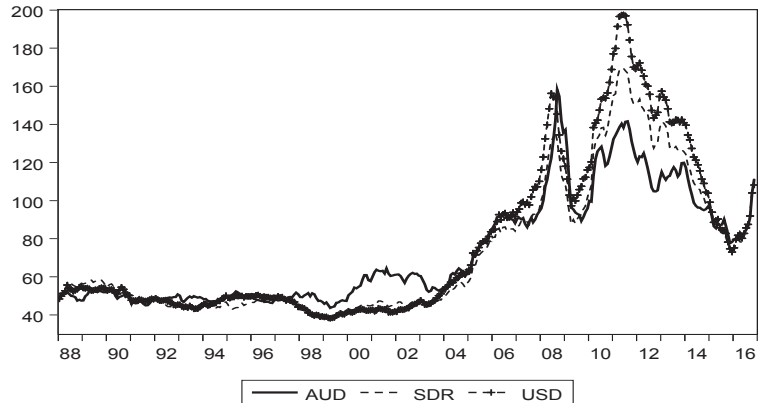
Figure 1: Reserve Bank of Australia commodity price indices, 1988Q1 to 2016Q1. The indices are expressed in Australian dollars (AUD), special drawing rights (SDR) and US dollars (USD). Source: Reserve Bank of Australia statistical table I2.

sector and how the upsurge transmits to the macroeconomy. Our research seeks evidence on resource boom transmission by modelling the effects of Chinese resource demand on the Australian macroeconomy. This application is a pertinent case study as Chinese demand for Australian iron ore used in steel-making for industrialisation was a central component of the commodities boom which began in the mid-2000s. Australia supplies 50% of global iron ore exports, while by 2010, two-thirds of world iron ore demand came from China.[1] Figure 1 shows the effects of the boom through the rapid growth of the Australian commodity price index between 2005 and 2012. To evaluate the transmission of a resource boom to the Australian macroeconomy, this paper uses a structural vector autoregression (SVAR) modelling framework with an international sector of Chinese steel production, world commodity prices, world output and iron ore exports, and a domestic sector that in addition to standard macroeconomic variables, includes mining investment.

Australia's success at having experienced no recession since the 1990s is readily attributable to the resource boom. However, the large literature on Dutch disease predicting low economic growth in these circumstances makes Australia's success worth investigating. van der Ploeg (2011) calls for detailed country studies to complement cross-country analyses to understand the effects of resource abundance on an economy.[2] Dutch disease predicts

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[1]Source: Australian Government Department of Industry, Innovation and Science fact sheets on Australia's major export commodities for 2015. See Holloway et al. (2018) for an overview of the steel industry in China.

[2]Bjørnland and Thorsrud (2016) also find a lack of empirical studies. For exceptions see Hutchison (1994), Bjørnland (1998), Ismail (2010) and Beine et al. (2012).

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that a sustained resource boom leads to a decline in other sectors of the economy, which can negatively impact growth (Corden, 1984, Corden and Neary, 1982, Gregory, 1976, Snape, 1977).

The Dutch disease theory separates the domestic economy into three sectors of the tradable commodity-producing sector, the tradable non-commodity sector, and the non-tradable sector. Strong external demand for a commodity leads to the flow of the factors of production from the tradable non-commodity sector and the non-tradable sector to the commodity-producing sector. The external demand for commodities appreciates the real value of the local currency. The currency appreciation reduces the ability of the tradable non-commodity sector to compete internationally. The price of non-tradable goods also rises for two reasons: i) the non-tradable sector shrinks because of the resources moving to the commodity-producing sector, reducing the supply of non-tradable goods; and ii) the boom creates an income effect, increasing the demand for goods. The shrinking of the sectors not directly associated with the boom, local currency appreciation and higher domestic prices can lead to low growth. An alternative explanation is that resource booms generate structural change with a period of short-term adjustment without the negative effects that Dutch disease implies (Larsen, 2006, van Wijnbergen, 1984). Bjørnland and Thorsrud (2016) explain the adjustment through positive productivity spillovers from the commodity sector to the non-commodity sector.

We use the information from our SVAR to highlight the transmission of the resource boom through the economy in three ways. First, the impulse response functions and variance decomposition of the SVAR trace the effects of commodity demand and supply shocks on the Australian macroeconomy. Second, we introduce the concept of a multivariate historical decomposition for the macroeconomy. The decomposition treats the macroeconomy as a network and combines aspects of the economy, such as GDP growth, inflation and the interest rate into a single measure. The method extends the network connectedness indices of Diebold and Yılmaz (2009, 2014) proposed by Dungey et al. (2017) where there is an allowance for changes in signs of the shocks in the measure, which subsequently move the macroeconomy away from the path projected by the model. We focus on the commodity sector shocks to illustrate the boom transmission. Finally, we present the univariate historical decompositions to establish how the resource boom transmits to specific macroeconomic variables.[3]

The results show the Chinese steel production shock is a commodity demand shock, while the commodity price shock is a commodity supply shock. Both negatively affect

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[3]Our model focuses on the short-term evolution of the boom and complements the analysis of Kulish and Rees (2017) who produce longer-term projections.

Australian output in the medium term. However, the effect is not substantial with production mostly determined by own shocks. The multivariate historical decomposition shows that the transmission of the boom divides into four phases corresponding to (i) the commencement of the resource boom from 2005Q1 to 2008Q1; (ii) the financial crisis from 2008Q2 to 2010Q1; (iii) the resumption of the resource boom from 2010Q2 to 2012Q1; and (iv) the unwinding of the resource boom from 2012Q2 to 2015Q3.

The first phase of the transmission of the boom shows supply-side features where the commodity price shocks lead the economy to deviate below a long-run projection, providing some evidence of Dutch disease effects. The second phase corresponds to the global financial crisis during 2008-2010 and reflects weak demand. The supply-side influences reappear in phase three. However, their effects are completely different from the first phase. In the third phase, commodity price shocks have a positive impact by moving the economy above the projection of the model. The results of periods one and three corroborate with the comparative study of Australia and Norway of Bjørnland and Thorsrud (2016) where price shocks, as in phase one of our analysis, can lead to Dutch disease conditions. We add to this the observation that the economy can recover given time so that both price and demand shocks have the expected effects on domestic demand without crowding out domestic production in other sectors. Our results suggest a period of structural change rather than long-term Dutch disease. Structural adjustment occurred over five years, between 2005Q1 to 2010Q1. The boom began to unwind in 2012, as Chinese resource demand and iron ore exports fell. We mark the end of the resource boom as 2015Q3 corresponding to the dissipation of the positive effect of the international shocks on the Australian macroeconomy.

The paper proceeds as follows. Section 2 provides the details of the SVAR model, including an overview of the data and the identification assumptions. Section 3 introduces the multivariate historical decomposition framework. Section 4 illustrates the effects of the transmission of a resource boom to the macroeconomy via impulse response functions and the forecast error variance decomposition by focusing on the commodity sector shocks of Chinese resource demand and commodity prices. Section 5 examines the transmission of the resource boom to the macroeconomy using the multivariate historical decomposition. Section 6 then examines the historical decompositions of the individual macroeconomic variables. Section 7 concludes.

2 Empirical setup

This section describes the data set and identification strategy for the proposed SVAR model. The model specification and the choice and treatment of the variables are similar to Dungey et al. (2014) and build upon the open economy framework of Dungey and Pagan (2000). The SVAR contains $n = 9$ variables consisting of four international variables and five domestic variables collected in the set X_t with ordering as follows: Chinese resource demand (csp_t), real commodity prices (pc_t), real foreign output (yw_t), the real value of iron ore exports ($iron_t$), real mining investment ($mininv_t$), real domestic output (yd_t), the inflation rate (pd_t), the cash rate (rd_t), and the real exchange rate (q_t). All data are quarterly, and the sample period ranges from 1988Q1 to 2016Q1. The availability of the data on mining investment constrains the starting date. Previous literature for Australia supporting the adopted specification includes Brischetto and Voss (1999), Dungey and Pagan (2000), Dungey and Pagan (2009), Berkelmans (2005), Lawson and Rees (2008), Jääskelä and Smith (2011) and Dungey et al. (2014). Appendix A contains a full description of the data sources, descriptive statistics and plots of the data.

The external commodity sector of the model consists of Chinese resource demand, real commodity prices and real iron ore exports.[4] As we do not have a direct measure of Chinese resource demand, Chinese steel production serves as a proxy.[5] The Reserve Bank of Australia's (RBA) Index of Commodity Prices in US dollars is the commodity price variable. The domestic variables are standard for Australian SVAR models with the addition of real private new capital expenditure in the mining sector. The standard macroeconomic variables are a domestic output measure of non-farm GDP, inflation and the overnight cash rate, which are the target and instrument of monetary policy, and the exchange rate which is the real trade-weighted index.

The data for csp_t, pc_t, yw_t, $iron_t$, yd_t and q_t are expressed in log form and demeaned and detrended in the model. The use of detrended data in SVAR models of Australia is common (Dungey and Pagan, 2000). The models are conceptualised as describing the dynamics around a user-determined deterministic steady-state, where the steady-state is given by the trends extracted from the data set X_t with the exclusion of inflation and interest rates. We do not estimate a cross-variable consistent steady-state system but rather view the individual trends removed from each variable as some indication of how these steady-state conditions

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[4]To control for non-commodity sector international shocks we include foreign output (yw_t) in the model which is the export-weighted real GDP of Australia's major trading partners.

[5]Dungey et al. (2014) considered alternatives for this measure, including Chinese manufacturing exports and a Chinese industrial production index. See also Roberts and Rush (2010).

may evolve. The complexity of issues such as migration and productivity trends in Australia suggests a degree of endogeneity in population and productivity growth, providing some support for this approach. The SVAR model of the set of variables X_t is

$$B(L)X_t = v + \epsilon_t, \tag{1}$$

where B(L) is a pth order matrix polynomial in the lag operator L, $B(L) = B_0 - B_1L - B_2L^2 - ... - B_pL^p$; B_0 summarizes the relationships between the variables contemporaneously and is nonsingular and normalized to have ones on the diagonal, and v is an intercept. The $n \times 1$ vector ϵ_t contains structural shocks, where $E(\epsilon_t\epsilon_t') = D$ and $E(\epsilon_t\epsilon_{t+s}') = 0$, for all $s \neq 0$. The variances of the structural disturbances are contained in the diagonal matrix D. The reduced form representation of the model is

$$A(L)X_t = c + u_t, \tag{2}$$

where $A(L) = B_0^{-1}B(L) = I - A_1L - A_2L^2 - ... - A_pL^p$, and c is an intercept. The reduced form errors are related to the structural errors as $u_t = B_0\epsilon_t$ and $E(u_tu_t') = \Sigma$, and $E(u_tu_{t+s}') = 0$ for all $s \neq 0$.[6] The lag structure is set to $p = 2$ in the empirical application.

The contemporaneous identification of the model is

$$
B_0X_t = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
b_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
b_{31} & b_{32} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
b_{41} & b_{42} & b_{43} & 1 & 0 & 0 & 0 & 0 & 0 \\
b_{51} & b_{52} & b_{53} & b_{54} & 1 & 0 & 0 & 0 & 0 \\
b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & 1 & 0 & 0 & 0 \\
0 & b_{72} & 0 & 0 & b_{75} & b_{76} & 1 & 0 & 0 \\
0 & b_{82} & 0 & 0 & b_{85} & b_{86} & b_{87} & 1 & 0 \\
b_{91} & b_{92} & b_{93} & b_{94} & b_{95} & b_{96} & b_{97} & b_{98} & 1
\end{bmatrix}
\begin{bmatrix}
csp_t \\
pc_t \\
yw_t \\
iron_t \\
mininv_t \\
yd_t \\
pd_t \\
rd_t \\
q_t
\end{bmatrix}.
$$

The restrictions on the lower triangle of the parameter matrix B_0 reflect the structure of a small open economy where the international variables are ordered before the Australian variables. We assume that Australian inflation does not react contemporaneously to Chinese steel production, world demand or resource exports. Inflation only responds contemporaneously to internationally determined commodity prices, as they may have supply-side effects, as well as to pressures from the domestic output and investment conditions. World output affects Australian inflationary conditions with a lag. The monetary policy response function reacts contemporaneously to international commodity prices and domestic investment,

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[6]The model is estimated using the AB form of the SVAR of Amisano and Giannini (2012).

output and inflationary conditions, given by the parameters b_{8j}. Monetary policy does not react contemporaneously to world output or resource exports. This behaviour is consistent with the statements around monetary policy put forward by the Reserve Bank in its reports to the Australian government on the operation of monetary policy. In Dungey and Pagan (2000), the small open economy assumption is employed throughout so that Australia does not affect the international economy. In this paper, we allow Australia to have some degree of price-setting power in commodity markets via feedback from lagged domestic variables to the international variables.

3 The multivariate historical decomposition

This section presents the multivariate historical decomposition (MHD) by building on the SVAR model discussed in the previous section. An alternative means of organizing the estimated parameter matrices when the shocks are orthogonal is via a historical decomposition.[7] Equation (2) can be represented in companion form as

$$HD_t = Sc + \mathbb{A}HD_{t-1} + SB_0\epsilon_t, \tag{3}$$

where

$$HD_t = \begin{bmatrix} X_t \\ \vdots \\ X_{t-p+1} \end{bmatrix}, \mathbb{A} = \begin{bmatrix} A_1 & \cdots & A_p \\ I_{n(p-1)} & & 0_{n(p-1)\times n} \end{bmatrix}, S = \begin{bmatrix} I_n \\ 0_{n(p-1)\times n} \end{bmatrix},$$

and I_n is assigned as an n-variate unit matrix.

Recursively substituting in equation (3) and abstracting from initial values gives

$$HD_t = \Big(\sum_{j=0}^{t-p-1} \mathbb{A}^j \Big) Sc + \sum_{j=0}^{t-p-1} \mathbb{A}^j SB_0\epsilon_{t-j}. \tag{4}$$

The univariate historical decomposition HD_t, defined in equation (4), is a standard tool for decomposing an observed variable at any point in time into the model projection and the deviation from the projection because of shocks (see Dungey and Pagan (2000) for example). The historical decomposition HD_t contains two terms. The first term in equation (4) is the baseline projection. The second term in equation (4) shows the effects of shocks before

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[7]Our shocks are not technically orthogonal as we have some zero restrictions in our contemporaneous matrix. However, analysis of the estimated VAR residuals show that they empirically conform to the assumption of independent shocks. The largest empirical correlation between the shocks is 0.21, and all correlations are not statistically significant at the 1% level.

period t. This term is the deviation between a time series and its projection calculated as the sum of the weighted contributions of the shocks to the series. The weights are from the impulse response functions.[8] The impact of the initial values of the data on the estimate of HD_t will vanish as time progresses if the data are stationary. This means that the analysis should focus on the latter sample period so that the initial effects cannot dominate.

The historical decomposition of HD_t can also be expressed as a multivariate decomposition. The multivariate decomposition aggregates the elements of the model into a single measure similar to the network interconnectedness measure proposed by Diebold and Yılmaz (2009, 2014). Their network interconnectedness measure summarises the off-diagonal elements of a forecast error variance decomposition matrix for specifications where the elements of HD_t are of the same unit, for example, international stock returns. Our extension allows for the elements of HD_t to come from different aspects of the economy where the variables are not measuring the same concept (for example, GDP, inflation and an interest rate). We interpret this as a measure of the macroeconomy considered as a network. The multivariate historical decomposition is the aggregation of the elements of the variable-specific decompositions. The multivariate representation of (4) is defined as

$$MHD_t \equiv \sum_{j=0}^{t-p-1} IRF_j \circ \Upsilon'_{t-j}, \tag{5}$$

where MHD_t is an $n \times n$ historical decomposition matrix that sums up to X_t at time t, IRF_j are orthogonalized impulse response matrices, $\circ$ is a Hadamard product, and $\Upsilon_t = [\epsilon_t, ..., \epsilon_t]$ is the $n \times n$ matrix containing structural errors in the columns. The indices constructed from the MHD_t matrices take into account the innovation in Dungey et al. (2017) of using the information of the signs of the shocks (positive or negative), whereas the spillover indices constructed from the forecast error variance decompositions of Diebold and Yılmaz (2009) are positive by construction.

We use the multivariate historical decomposition to develop the concept of how the macroeconomy deviates from a multivariate projection due to shocks. In constructing indices from the decomposition, we separate the component related to own shocks, and the component related to shocks between the variables (the off-diagonal shocks). The corresponding Diebold and Yılmaz (2009) spillover indices are net of own shocks. The deviation of the economy from the multivariate projection of the economy due to own shocks is

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[8]The impulse response functions represent the effects of a one standard deviation shock to the SVAR system occurring only at $t = 0$, which must be positive. The historical decompositions map the evolution of the variables over time by the contribution of all of the shocks in the model at all points in time. They also take into account the signs of the shocks.

$$SSG_t^{own} \equiv \sum_{i=1}^{n} MHD_{t,ii}, \tag{6}$$

and shocks from other variables is

$$SSG_t^{others} \equiv \sum_{i=1}^{n} \sum_{j=1}^{n} MHD_{t,ij} - SSG_t^{own}. \tag{7}$$

The SSG^{others} measure from equation (7) is used to examine how the resource boom transmits through the Australian macroeconomy. This equation allows us to identify the components causing the economy to deviate from the multivariate projection of our model, and to examine which subsets of shocks are more influential in the model over time. In Section 5, we examine how commodity sector shocks lead the economy to deviate from the multivariate projection relative to the other international and domestic shocks to give us a sense of how the resource boom transmits through the macroeconomy over time.

4 The effect of commodity sector shocks

This section provides the impulse responses functions to one standard deviation shocks to Chinese resource demand (csp_t) and commodity prices (pc_t) as well as the variance decomposition of the model. The impulse responses and their one standard deviation confidence intervals are plotted over 48 quarters. The impulse response functions identify the different effects of commodity demand and supply shocks on the Australian macroeconomy, while the variance decomposition shows that after own shocks, Chinese resource demand, commodity prices, the exchange rate and iron ore exports contribute most to the domestic macroeconomic variables after six years.

4.1 Shock to Chinese resource demand

The one standard deviation shock to Chinese resource demand (csp_t) proxied by the shock to Chinese steel production, shown in Figure 2, resembles a commodity demand shock. In addition to the sustained rise in resource demand, both real commodity prices (pc_t) received by Australian commodity exporters and foreign output (yw_t) respond positively. Chinese resource demand and commodity prices take some time to dissipate following the shock. Foreign output also responds positively and with longevity (Dungey et al., 2014, Humphreys, 2010).

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Chinese resource demand acts as a stimulus to iron ore exports and mining investment peaks after a lag of two years. Their joint effects lead to a two-peak exchange rate response. The exchange rate first appreciates in response to the increase in iron ore exports and commodity prices. The second peak of the exchange rate occurs after eleven quarters, coinciding precisely with the peak in mining investment. Mining investments tend to be large, lumpy and implemented with a substantial delay, and funding of the capital-intensive mining sector in Australia is through international capital inflows.[9] The exchange rate reflects the foreign inflows with demand for the Australian dollar rising. The international inflows are enough to offset the demand for foreign currency that occurs because of the stronger global economy reflected in the response of foreign output. The short-run dynamics of the exchange rate are precise, with the effects of the Chinese resource demand shock on the exchange rate statistically significant.

The rise in output in response to the Chinese resource demand shock shown in Figure 2 is offset after the first three years of the shock. The response of output shows some evidence of Dutch disease, as shown by the significant negative deviation of output from the baseline at the three-year time horizon. This result suggests that the non-resource-based sectors are shrinking through the reallocation of the resources of the economy to the mining and commodity sectors. The result also suggests that the appreciation of the exchange rate makes it difficult for the non-commodity tradable sector to export.[10]

The boom creates inflationary pressure in the smaller non-tradable sector as demand for non-tradable goods rises through the income effect. The high price of non-tradable goods worsens inflation and places further pressure on the exchange rate. Connolly and Orsmond (2011) find that on commencement of the mining boom inflation in the non-tradable sector is 4%, which is 1% higher in comparison to previous years. They also find that the interest rate mirrors the rise in inflation and mining income offsets the fall in output in response to monetary policy. Vespignani (2013) shows that monetary policy is ineffective for aggregate demand and inflation during resource booms for Australia, although we find that inflation returns to the baseline after the demand shock.

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[9]In 2001, the share of mining investment in total business investment in Australia was less than 20%, rose to 30% by 2011 when commodity prices peaked and continued to rise to almost 60% of total investment several years after this peak. Source: Australian Bureau of Statistics, catalogue 5625.0.

[10]We also ran the model on data that were not detrended. The impulse response of output to the Chinese resource demand shocks was slightly positive but was not significant. The model generated similar signed impulse responses for the remaining variables.
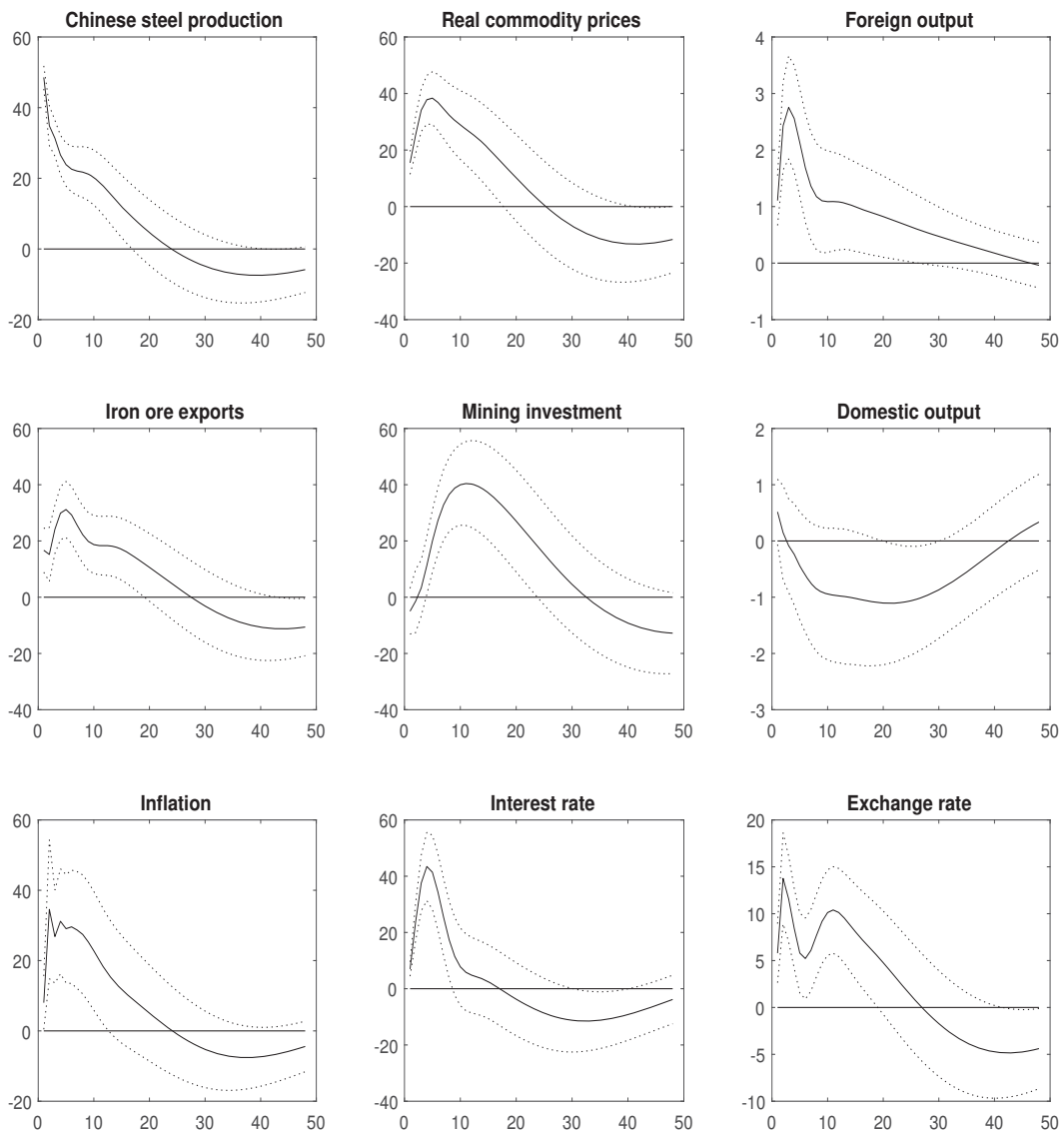
Figure 2: Impulse response functions of shocks to Chinese steel production (solid line). The dotted lines are the one standard deviation analytical confidence intervals. The impulses and confidence bands are scaled by 1000.
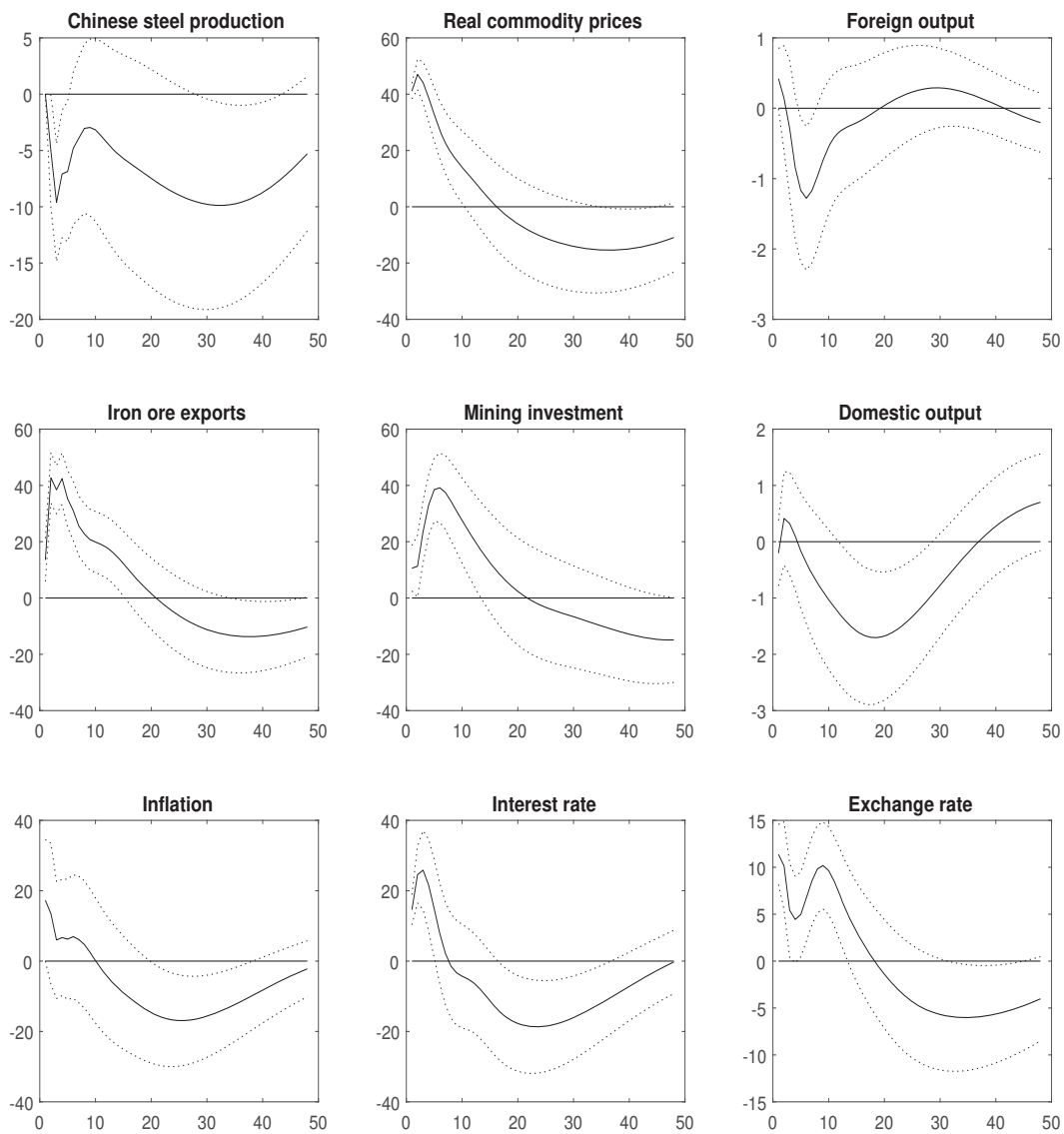
Figure 3: Impulse response functions of shocks to commodity prices (solid line). The dotted lines are the one standard deviation analytical confidence intervals. The impulses and confidence bands are scaled by 1000.

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4.2   Shock to commodity prices

Figure 3 contains the impulse response functions to the commodity price shock. As in Dungey et al. (2014) and Jääskelä and Smith (2011), the commodity price shock has a supply shock interpretation. Both Chinese steel production and foreign output fall below baseline in line with the expected consequence of higher commodity input prices. These effects are significant for short periods over the horizon of the impulses.

Both iron ore exports and mining investment respond strongly to commodity prices. The mining investment sector recognises that the rise in commodity prices is short-term compared to the rise in commodity prices resulting from the resource demand shock shown in Section 4.1. The response of mining investment to the commodity price shock peaks earlier than it does in response to the Chinese resource demand shock. The exchange rate has a two-peak response. However, the second peak does not coincide with that of mining investment as it did for the Chinese resource demand shock. Although mining investment rises in response to the commodity supply shock, both foreign and domestic output decline.

The Australian economy shows some evidence of Dutch disease in response to the commodity price shock. Output contracts after five quarters and stays below the baseline for nine years. The inflation response is not significant, consistent with the supply-side interpretation. The rise in the interest rate results from the misclassification of the shock as a demand shock rather than a supply shock. The effects of the resource demand shock on output compared to the commodity price shock on output align with Corden (1984) and Bjørnland and Thorsrud (2016) who find that if demand rather than price is the cause of a resource boom, then there is less likely to be long-term Dutch disease.

4.3   Variance decomposition

Table 1 presents the variance decomposition of the variables in the model in terms of the percentage contribution of each shock to the variance of each variable over forecast horizons of 1, 4, 12 and 24 quarters. The first column has the decomposition for the international variables, and the second has the decomposition for the domestic variables.

The variance decomposition of the international sector variables shows that the main contributors at the six-year horizon are world output, Chinese steel production and own shocks. The influence of commodity price shocks peaks at three years, capturing the short propagation of this shock. Iron ore exports, Australian output and inflation contribute in all cases reflecting Australian market power in the iron ore market.

Own shocks usually dominate the variance of the variables in the domestic sector, followed

TABLE 1

Forecast error variance decomposition of the variables in percentage terms at 1, 4, 12 and 24 quarter horizons.

		International variables						Domestic variables			
Variable	Shock	1	4	12	24	Variable	Shock	1	4	12	24
csp_t	csp_t	100.00	80.11	59.63	40.89	$mininv_t$	csp_t	0.34	0.79	17.54	21.10
	pc_t	0.00	2.56	2.12	3.81		pc_t	1.53	9.11	17.80	11.08
	yw_t	0.00	6.46	23.66	31.84		yw_t	1.15	2.82	5.55	20.31
	$iron_t$	0.00	8.11	9.32	7.11		$iron_t$	0.00	2.44	11.79	9.96
	$mininv_t$	0.00	1.01	1.03	0.83		$mininv_t$	96.98	83.35	31.73	20.44
	yd_t	0.00	0.08	1.02	12.07		yd_t	0.00	0.43	3.56	3.95
	pd_t	0.00	1.11	2.62	2.22		pd_t	0.00	0.90	10.00	11.64
	rd_t	0.00	0.40	0.42	0.78		rd_t	0.00	0.07	1.91	1.27
	q_t	0.00	0.16	0.16	0.46		q_t	0.00	0.10	0.11	0.26
pc_t	csp_t	12.42	27.72	32.93	22.44	yd_t	csp_t	0.72	0.25	1.87	4.95
	pc_t	87.58	58.61	30.19	17.44		pc_t	0.11	0.23	2.01	9.32
	yw_t	0.00	3.97	14.41	32.49		yw_t	3.18	1.12	1.87	1.92
	$iron_t$	0.00	3.78	8.47	6.98		$iron_t$	0.08	0.18	1.54	1.66
	$mininv_t$	0.00	1.33	1.87	1.87		$mininv_t$	0.02	2.10	3.70	3.48
	yd_t	0.00	0.27	0.55	7.92		yd_t	95.88	93.81	77.67	64.06
	pd_t	0.00	2.12	10.10	9.44		pd_t	0.00	0.56	1.92	2.23
	rd_t	0.00	1.12	0.99	1.10		rd_t	0.00	0.62	3.00	3.31
	q_t	0.00	1.09	0.49	0.33		q_t	0.00	1.13	6.42	9.05
yw_t	csp_t	5.53	13.93	15.97	17.55	pd_t	csp_t	0.17	4.73	9.02	8.67
	pc_t	0.80	0.65	3.23	2.95		pc_t	0.79	0.90	0.82	2.66
	yw_t	93.67	76.97	58.47	51.48		yw_t	0.00	0.38	0.92	2.48
	$iron_t$	0.00	2.88	3.69	3.27		$iron_t$	0.00	0.48	0.77	1.53
	$mininv_t$	0.00	0.48	1.08	1.58		$mininv_t$	1.98	1.53	1.24	1.26
	yd_t	0.00	0.20	7.98	13.82		yd_t	0.53	2.15	13.98	17.17
	pd_t	0.00	0.31	0.33	0.32		pd_t	96.52	88.30	70.42	61.36
	rd_t	0.00	4.39	8.03	7.51		rd_t	0.00	1.32	1.24	1.48
	q_t	0.00	0.19	1.22	1.53		q_t	0.00	0.20	1.60	3.40
$iron_t$	csp_t	4.02	11.36	19.60	16.16	rd_t	csp_t	2.00	15.81	15.84	12.14
	pc_t	2.65	30.20	31.24	21.14		pc_t	8.70	7.87	4.61	7.70
	yw_t	0.02	4.25	8.84	21.49		yw_t	0.29	10.51	13.21	15.61
	$iron_t$	93.31	46.66	26.72	19.20		$iron_t$	0.01	1.33	2.19	2.74
	$mininv_t$	0.00	1.15	1.26	1.10		$mininv_t$	0.07	1.02	1.11	0.94
	yd_t	0.00	0.96	3.32	10.79		yd_t	7.93	16.75	34.13	34.25
	pd_t	0.00	1.23	3.03	5.80		pd_t	0.03	0.00	0.47	1.61
	rd_t	0.00	0.18	0.26	0.60		rd_t	80.97	45.43	25.33	20.28
	q_t	0.00	4.01	5.74	3.73		q_t	0.00	1.29	3.11	4.73
						q_t	csp_t	2.67	11.00	15.41	14.06
							pc_t	10.31	7.22	13.17	9.20
							yw_t	1.12	5.15	8.68	22.08
							$iron_t$	14.92	23.60	19.91	15.45
							$mininv_t$	0.25	2.27	3.88	2.74
							yd_t	1.14	1.58	4.17	9.45
							pd_t	0.10	0.88	2.39	5.97
							rd_t	12.67	6.76	6.56	4.60
							q_t	56.82	41.54	25.84	16.45

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by international shocks and domestic output shocks. Most of the variance of Australian output (64%) comes from own shocks at the six-year horizon, followed by the international shocks of commodity prices (9.32%), the exchange rate (9.05%) and Chinese steel production (4.95%). In turn, domestic output shocks explain the variance of inflation (17.1%), the interest rate (34.25%) and the exchange rate (9.45%), but not mining investment (3.95%). More than 60% of the variance in mining investment comes from the international shocks at the six-year horizon consistent with the observation of the importance of internationally competitive capital flowing to this sector. The Reserve Bank responds to the international sector more than to the domestic sector. The contribution of domestic output shocks to the variance of the interest rate (34.25%) is slightly less than the sum of the contribution from shocks to Chinese steel production, commodity prices and world output (35.45%) at the six-year horizon. International shocks (45.34%) and iron ore (15.45%) explain the variance of the exchange rate.

5   Transmission of a resource boom

This section presents the empirical results obtained from the multivariate historical decomposition. Section 5.1 describes the decomposition in terms of the contribution of the international and domestic shocks to moving the macroeconomy away from the projection implied by the model as shown in equations (6) and (7). Note that in the discussion that follows, we are not including the effect of own variable shocks, as they do not spillover across the model variables. For completeness, Appendix B contains the contribution of own-shocks from the domestic variables. Section 5.2 presents a finer decomposition by separately examining the contribution of the resource sector shocks to the movement of the macroeconomy away from the multivariate projection given by our model. Analysis of this decomposition provides evidence on how the resource boom transmits to the aggregate Australian macroeconomy. The decomposition shows that the boom spanned from 2005Q1 to 2015Q3 and separates neatly into four phases.

5.1   International and domestic transmission

Figure 4 shows the multivariate historical decomposition of the Australian macroeconomy. The figure plots the international shocks in the model (dotted line) that lead the economy to deviate from the multivariate projection of the model. The international shocks consist of Chinese resource demand, commodity prices, world output and iron ore exports. Figure 4 also plots the contribution of the domestic shocks consisting of the remaining variables
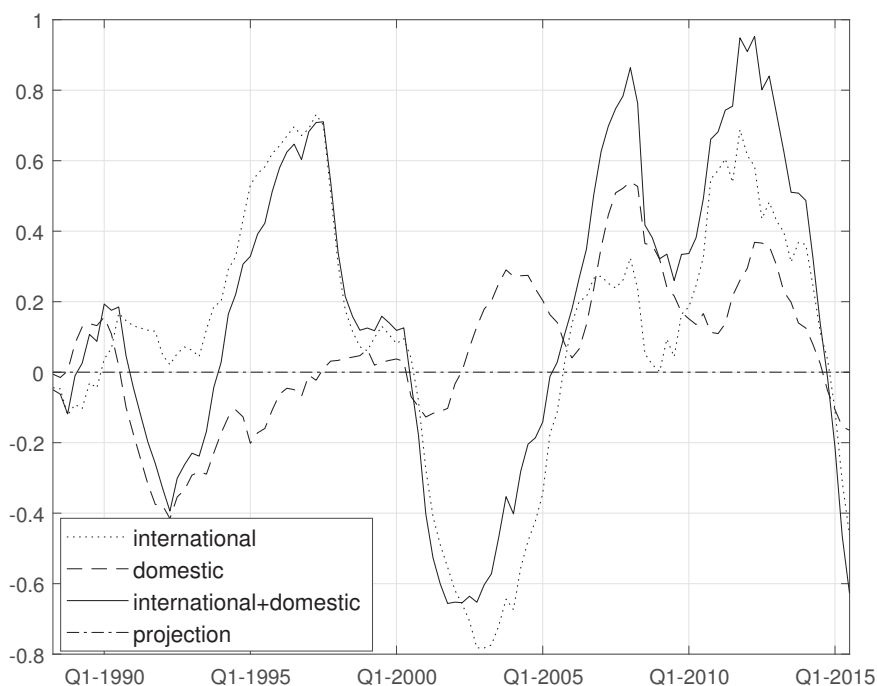
Figure 4: Multivariate historical decomposition of the Australian macroeconomy, 1998Q1 to 2016Q1. The figure shows how shocks to the international and domestic variables in the model lead the macroeconomy to deviate from the multivariate empirical projection of the model. See equation (7). The multivariate projection of the path of the economy is normalised to zero for ease of interpretation of the deviations.

(dashed line). The projection of the economy is normalised to zero for a more straightforward interpretation of the deviations. The zero axis corresponds to the normalised projection on the figure.

The interpretation of the deviation of the economy from the multivariate projection of our model differs from that of an output-gap analysis. The measure is not the deviation of the economy from equilibrium that a shock at time t produces. The deviation of the economy from the multivariate projection of our model at any point represents the effect of the cumulation of shocks over the immediate past considered jointly. At each point in time, previous shocks continue to influence the deviation of the economy from projection, but with decreasing weight. There is no constraint requiring the empirical deviation of the economy to balance out over the sample period.[11]

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[11]Recall that the weights are from the impulse response functions shown in (5). As the data are stationary,

The deviations of the macroeconomy from the multivariate projection show a non-synchronous cyclical pattern through time. During the resource boom period after 2005, the deviations caused by the transmission of the international and domestic shocks are both positive. The sum of the international and domestic shocks contribute to a period of sustained overall positive deviation from projection, as illustrated in Figure 4.

The macroeconomy deviates from the multivariate projection cyclically, but not synchronously, through time. During the resource boom period after 2005, the macroeconomy moves above the projection because of positive international and domestic shocks, as illustrated in Figure 4. A peak in a curve means that positive shocks no longer dominate the impact of the earlier shocks. The peaks in the curve for the sum of the international and domestic shocks in 2008 and 2012 align with the global financial crisis of 2008 and the peak of the resource boom in 2012. Figure 4 shows that despite the onset of the global financial crisis in 2008, the Australian economy does not fall below the projection. In 2012, as the resource boom begins to dissipate, the economy moves towards the projection faster because of the domestic shocks compared to the international shocks. At the end of the sample, the economy operates at the multivariate projection of the model.[12]

5.2 Resource sector transmission

The decomposition in Figure 4 of the previous section indicates that international and domestic shocks kept the Australian macroeconomy above projection. Figure 5 further decomposes the macroeconomy into movements away from the multivariate projection because of shocks to Chinese steel production, commodity prices, world output, iron ore exports and the exchange rate. The disaggregation of the international shocks into the components provides a more intricate understanding of the transmission of the resource boom and shows that focussing on the aggregate international shocks is misleading. The first four shocks all lead the economy to deviate from the projection, but commodity price shocks have the largest effect, both negative and positive at separate times. The exchange rate shocks have small effects. Figure 5 shows that the decomposition divides neatly into four phases over 2005 to 2015. The phases correspond to:

(i) the commencement of the resource boom from 2005Q1 to 2008Q1;

each shock converges to zero over time, with the weight on past shocks disappearing after approximately two years. The combination of the impulse response function weights and the sizes of the estimated shocks gives the path of the economy relative to the projection of the model.

[12]This is not a conditional statement. We fully recognise that the retrospective analysis of the development of past economic events depends on the unconditional estimate of the multivariate projection.
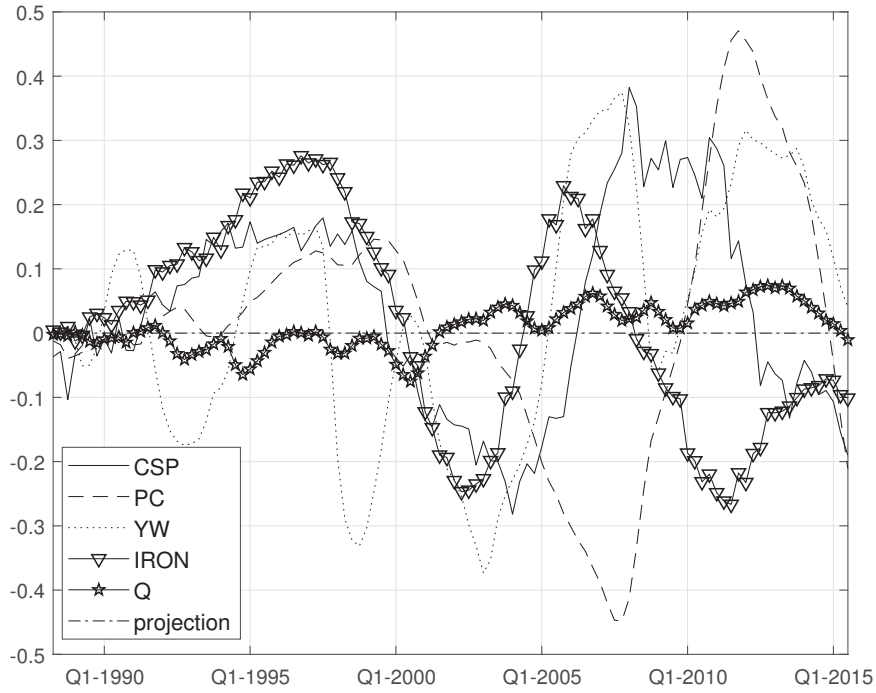
Figure 5: Multivariate historical decomposition of the Australian macroeconomy, 1998Q1 to 2016Q1. The figure shows how shocks to Chinese steel production, commodity prices, world output, iron ore exports and the exchange rate lead the macroeconomy to deviate from the multivariate empirical projection of the model. See equation (7). The multivariate projection of the path of the economy is normalised to zero for ease of interpretation of the deviations.

(ii) the financial crisis from 2008Q2 to 2010Q1;

(iii) the resumption of the resource boom from 2010Q2 to 2012Q1; and

(iv) the unwinding of the resource boom from 2012Q2 to 2015Q3.

The commencement of the resource boom begins in 2005Q1 at the point where the effect of iron ore shocks crosses the zero axis, where the economy moves above the multivariate projection. An inverse relationship between the movement of the economy due to shocks to commodity prices and iron ore exports lasts until the end of the first phase of the boom in 2008Q1, suggesting an economy experiencing supply-side constraints. Despite the period of rapid growth in commodity prices in 2005-2008 shown in Figure 1, the economy moves below the projection because of the commodity price shocks. The overall response of the economy

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to the resource sector shocks in the first phase of the boom suggests Dutch disease. Although the economy moves above the long-run projection of the SVAR because of the shocks to iron ore exports and Chinese resource demand, the movement is not enough to compensate for the negative effects of the commodity price shocks. The effect of the commodity price shocks reaches a trough in 2008Q2 in conjunction with the beginning of the global financial crisis.

During the financial crisis of phase two, the supply-side features disappear to become more demand-like. Innovations in both commodity prices and iron ore exports reflect low global demand and the Australian economy falls below the projection. Positive shocks from resource demand from China with a small impetus from the exchange rate keep the Australian economy above projection in the second phase of the decomposition.

By 2010Q2, the effects of commodity price and world output shocks on the macroeconomy are neutral, having neither positive nor negative effects. The resource boom is dated to resume in 2010Q2 as the financial crisis resolves itself for most of Australia's trading partners. From this point, the supply-side features evident in the first phase of the resource boom reappear. However, the nature of the economic effects across phases one and three differ completely. The economy moves above the multivariate projection because of commodity price shocks but moves below the projection because of shocks to iron ore exports. The effect of the commodity price shocks combined with the effect of positive Chinese resource demand shocks dominate the negative effects of the shocks to iron ore exports on the macroeconomy. The Dutch disease evident in phase one is short-lived. It takes five years, from 2005Q1 to 2010Q1 for structural adjustment of the economy to occur to accommodate the resource boom.

By the beginning of phase four in 2012Q2, the macroeconomy moves below the projection because of shocks to Chinese resource demand and iron ore exports. Around this time, the deviation of the macroeconomy because of commodity prices and world output begins to wane. This turn-around occurs one year after the macroeconomy begins to respond negatively to Chinese resource demand, and just after the first report of single-digit GDP growth rates of the Chinese economy compared to their usual double-digit rates. By 2015Q3, the economy approaches the multivariate projection, and the movement of the economy because of the commodity price shocks is neutral, marking the date of the end of the resource boom.
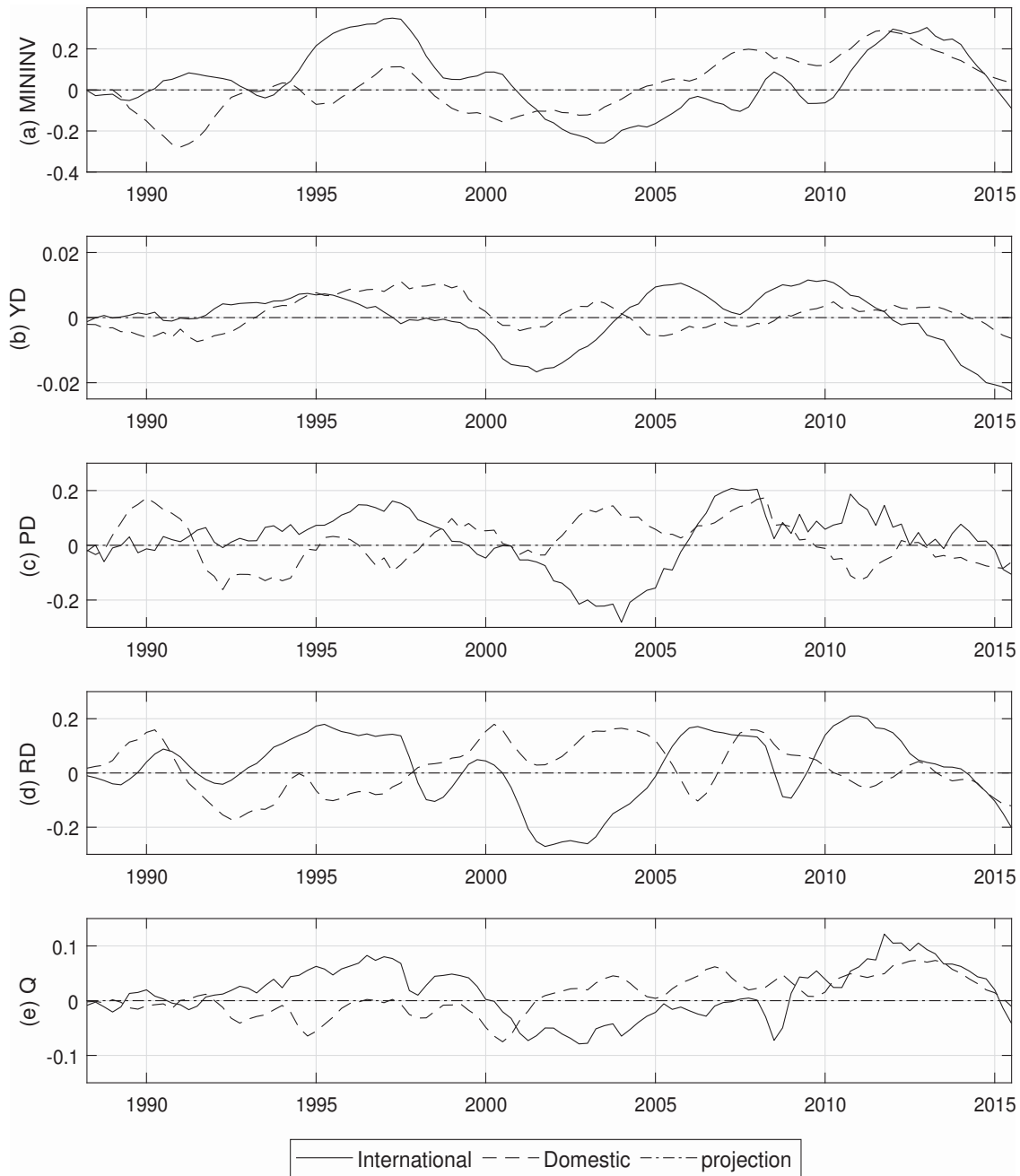
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Figure 6: Historical decomposition of the Australian macroeconomic variables, 1998Q1 to 2016Q1. The figure shows how shocks to the international and domestic variables lead each variable to deviate from its empirical projection given by the model. See equation (4). The projection of the path of each variable is normalised to zero for ease of interpretation of the deviations.
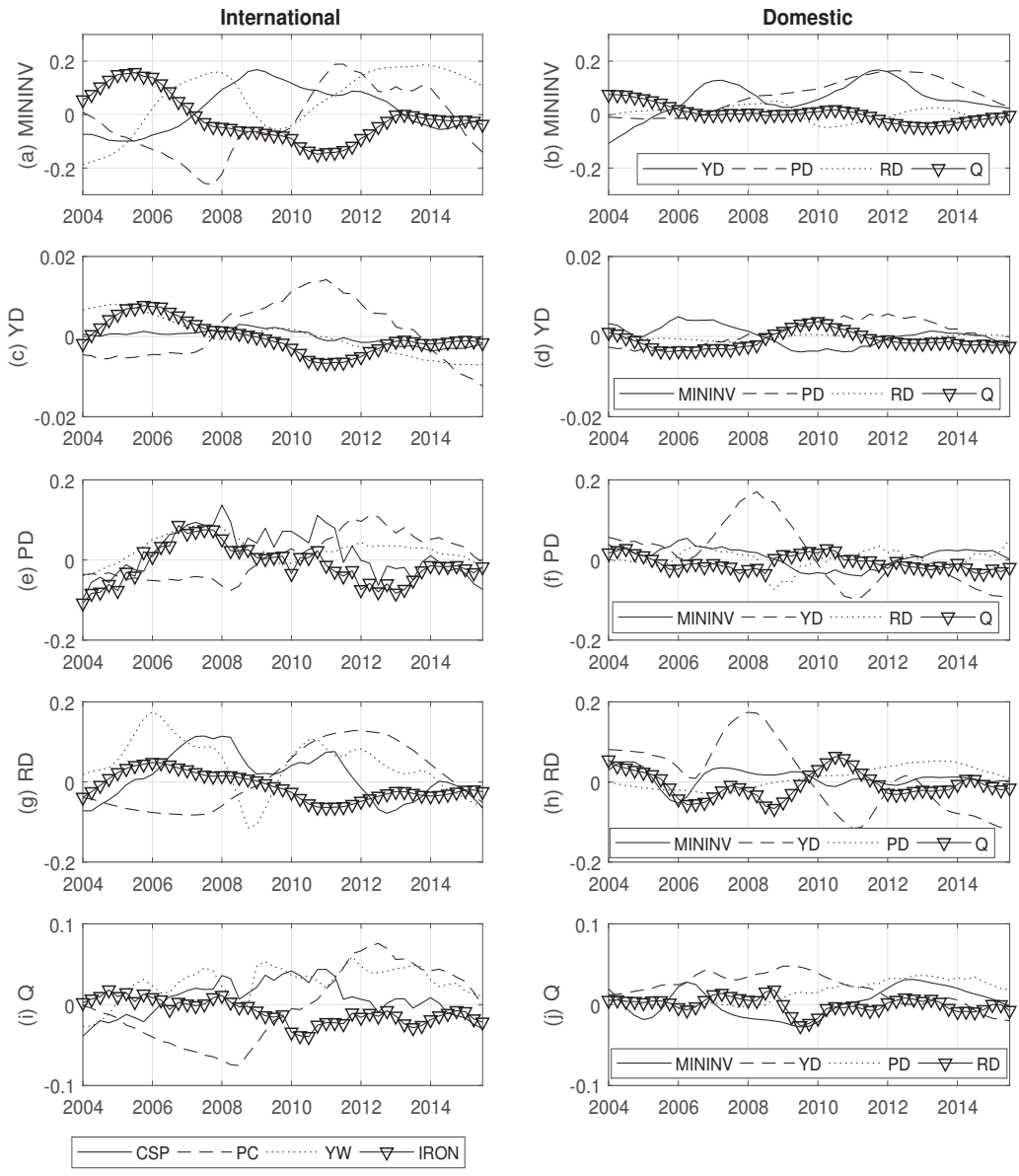
Figure 7: Historical decomposition of the Australian macroeconomic variables, 2004Q1 to 2016Q1. Column 1 shows how the resource sector shocks lead each variable to deviate from its empirical projection given by the model. Column 2 shows how the domestic sector shocks lead each variable to deviate from its empirical projection given by the model. See equation (4). The projection of the path of the economy is normalised to zero for ease of interpretation of the deviations.

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6 Macroeconomic variable decomposition

This section performs a similar exercise to that of Section 5 for the macroeconomic variables individually as given in equation (5), by first examining the evolution of each variable in the macroeconomy away from the model projection because of the international and domestic shocks, and then by further decomposing these shocks into the resource sector contributions. The results show that the effect of the resource sector and the Australian macroeconomic shocks on each variable differs from the interpretation of the multivariate historical decomposition. They also show the importance of international influences for Australia, through the commodity price channel for most variables, and from Chinese resource demand for mining investment.

Figure 6 shows how the international and domestic shocks lead the Australian macroeconomic variables to deviate from the projection given by the model. The effect of the international and domestic shocks often offset each other until the beginning of the unwinding of the resource boom for all variables except for output. The offsetting effects of the international and domestic shocks differ from the results for the aggregate economy shown in Figure 4, where both keep the economy well above the projection of the model for the duration of the resource boom period, including the unwinding phase.

Output generally deviates away from the projection by small magnitudes in response to the international and domestic shocks, reinforcing the finding of the forecast error variance decomposition. The Australian macroeconomic shocks do not lead output away from the projection through the first three phases of the resource boom, while the international shocks play a larger role. Output is above the model projection for stages one to three of the boom because of international shocks, but then falls below the projection at the date proposed as the beginning of the unwinding of the boom in 2012.

Figure 7 presents the decomposition for each variable into the contribution of all of the shocks in the model to the deviation from the model projections. Column 1 contains those from international shocks, and column 2 includes those from the domestic shocks. The figure supports several broad conclusions. Overall, the variables deviate from the model projections because of domestic shocks by less in magnitude than because of the international shocks during the resource boom. This result is consistent with others in the literature that find that international shocks are influential for Australia (Liu, 2010). Commodity price shocks dominate the macroeconomic variables during the resource boom for mining investment shown in panel (a), output (c), inflation (e) and the exchange rate (i). Commodity price shocks are crucial for output despite the earlier result that the effects of the aggregated

international shocks are not large. Output deviates negatively from projection because of commodity price shocks in the first phase of the resource boom (2005Q1-2008Q1) confirming the earlier interpretation of short-lived Dutch disease before structural change occurs by 2010. The inverse relationship capturing the supply-side nature of commodity prices and iron ore exports exists for all domestic variables and tends to change direction around the onset of the financial crisis.

Chinese resource demand shocks lead mining investment (in panel a), inflation (e), the interest rate (g) and the exchange rate (i) to deviate positively from their projection. The positive deviations of the variables begins in 2006 and last until the beginning of the un- winding of the resource boom in 2012, except for mining investment, which starts and ends a year later, reflecting the lags in mining investment. Domestic output shocks affect the Australian macroeconomic variables most, as shown in the second column of Figure 7.

7   Conclusion

This paper presents evidence on how a resource boom transmits through the macroeconomy of a resource-rich country using the example of the effects of Chinese industrialisation on the Australian economy. Australia accounts for 50% of global iron ore exports, and at the peak of the boom, China imported two-thirds of global iron ore, making the China-Australia relationship a critical case to explore. Policymakers of resource-rich counties need to know what types of shocks drive the upsurge in the resource sector, and they need to know how these shocks transmit through the macroeconomy.

A structural VAR model consisting of Chinese resource demand and commodity prices and a domestic sector that includes iron ore exports and mining is estimated to evaluate the transmission of a resource boom to the Australian economy. The information from the estimation of the model is used to trace out the effects of both commodity demand and supply shocks through the macroeconomy. We also introduce the concept of a multivariate historical decomposition which rearranges the information of the VAR to combine aspects of the macroeconomy, such as GDP growth, inflation and the interest rate into a single measure representing a multivariate long-run projection of the macroeconomy. The decomposition reveals how the aggregate macroeconomy and the individual macroeconomic variables in the model deviate from their long-run projected path because of the shocks in the model.

The structural VAR model shows that commodity demand and supply shocks are both identified for the Australian case. Both shocks reduce Australian output below baseline in the medium term. However, the effect is not substantial. Evidence from the multivariate

historical decomposition shows that the transmission of the boom divides into four phases corresponding to (i) the commencement of the resource boom from 2005Q1 to 2008Q1; (ii) the financial crisis from 2008Q2 to 2010Q1; (iii) the resumption of the resource boom from 2010Q2 to 2012Q1; and (iv) the unwinding of the resource boom from 2012Q2 to 2015Q3.

The results show that structural change occurred over five years after the resource boom began in 2005. The first three years of the boom showed that the Australian economy could not accommodate the rapid increase in commodity prices as supply-side constraints moved the economy below the multivariate projection. Afterwards, the supply-side constraints were alleviated, with the effects of the resource sector shocks reflecting the weak global demand of the global financial crisis. However, on the resumption of the resource boom in 2010, the economy responded positively to the commodity shocks as the economy had adjusted to the demands of the external resource sector. By 2012 the resource boom began to unwind as Chinese resource demand, and iron ore exports, both fell. The end of the resource boom is dated to be 2015Q3. At this time, the resource sector shocks were neither contributing positively nor negatively to the economy. The results confirm other work, such as Bjørnland and Thorsrud (2016), that commodity price shocks can lead to Dutch disease. However, our results show that the economy can adjust over time so that both price and demand shocks are positive for domestic demand without crowding out production in other sectors.

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Appendix A: Data details

This section contains the data descriptions and sources (Table A1), descriptive statistics (Table A2) and plots of the data (Figure A1).

TABLE A1

Data descriptions and sources

Variable	Code	Description and source
Chinese steel production	csp	s.a., Datastream (CHVALSTLH)
Commodity prices	pc	index of commodity prices in US dollars (RBA) deflated by the US CPI (Bureau of Labor Statistics)
Foreign output	yw	export-weighted real GDP of Australia's major trading partners, s.a. (RBA)
Aust iron ore exports	$iron$	sum of metalliferous ores and metal scrap (ABS Cat 5368.0) deflated by the consumer price index (RBA), s.a. using Census X-13 in Eviews
Mining investment	$mininv$	mining private new capital expenditure, s.a. cvm, 2009-10 prices (ABS Cat 5625.0)
Domestic output	yd	s.a. cvm non-farm GDP (ABS Cat 5206.0)
Inflation	pd	trimmed-mean CPI, 1989/90 = 100, excl. interest charges. GST dummy for 1999–2000 (RBA)
Cash rate	rd	quarterly average of target cash rate (RBA)
Exchange rate	q	real trade-weighted index (RBA)

TABLE A2

Descriptive statistics for all variables from 1988Q1 to 2016Q1. The data are demeaned and detrended.

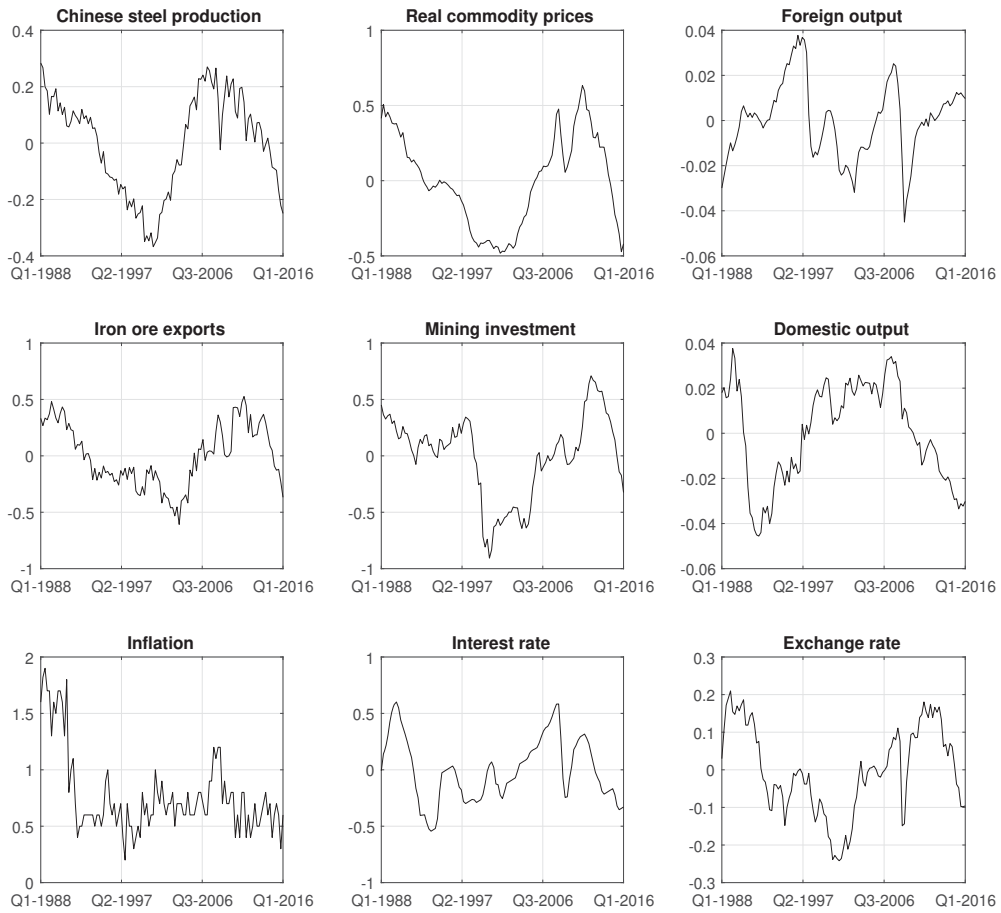|	Obs.	St. dev.	Skewness	Kurtosis
csp	113	0.1744	-0.3680	2.0586
pc	113	0.3080	0.0375	1.9436
yw	113	0.0167	0.0525	2.9518
$iron$	113	0.2736	0.0470	2.0370
$mininv$	113	0.3704	-0.5318	2.6504
yd	113	0.0222	-0.3307	1.9441
pd	113	0.3654	1.5332	4.7357
rd	113	0.2828	0.2592	2.3358
q	113	0.1171	-0.1732	2.1889

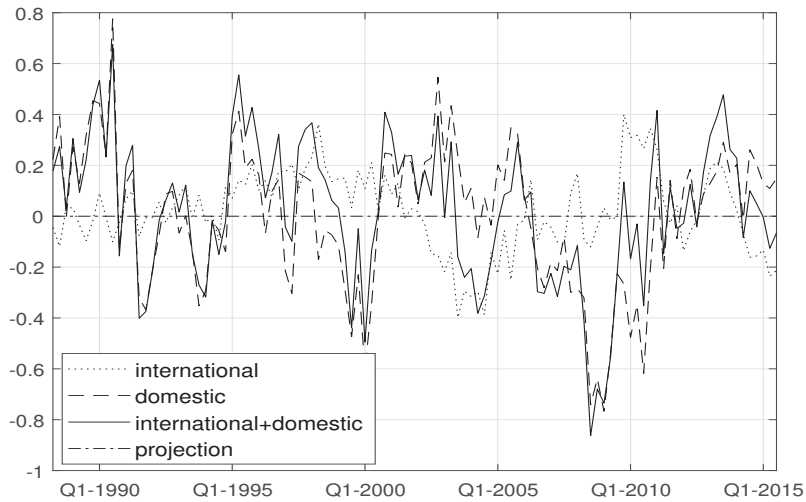Figure A1: Plots of the data, 1988Q1 to 2016Q1.

Figure B1: Deviation of the macroeconomy from the multivariate empirical projection of the Australian economy because of shocks to own-variables, 1998Q1 to 2016Q1. The figure aggregates the shocks to be own-international shocks (csp, pc, yw, $iron$) and own domestic ($mininv$, yd, pd, rd, q) shocks. The multivariate projection of the path of the economy is normalised to zero for ease of interpretation of the deviations.

Appendix B: Own shock contributions

Figure B1 illustrates how own-variable shocks in the model SSG_t^{own} lead the macroeconomy to deviate from the multivariate empirical projection of the model described by equation (6) for the international, $i = 1, ..., 4$, and domestic variables, $i = 5, ..., 9$. The effects of own shocks are more volatile than those from other shocks shown in Figure 4, although the magnitudes are similar. Domestic own shocks are negative and large from 2008 to 2011 during the global financial crisis and the second phase of the resource boom.