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Abstract

This paper quantifies the links from demand for Australia's natural resources to activity in other domestic industries by using structural relationships embedded in input-output tables. Extending the methodology of Kouparitsas (2011), we estimate the size, growth rate, and industry value-added content of a broad measure of the 'resource economy', which is defined to include all final demand related to resource extraction and investment. Under certain productivity assumptions, we also estimate the amount of labour that is required by each industry to service the demand for Australia's natural resources.

We estimate that the resource economy accounted for around 18 per cent of gross value added (GVA) in 2011/12, which is double its share of the economy in 2003/04. Of this, the resource extraction sector – which we define to include the mining industry and resource-specific manufacturing – directly accounted for 11½ per cent of GVA. The remaining 6½ per cent of GVA can be attributed to the value added of industries that provide inputs to resource extraction and investment, such as business services, construction, transport and manufacturing. This 'resource-related' activity is significantly more labour intensive than resource extraction, accounting for an estimated 6¾ per cent of total employment in 2011/12, compared with 3¼ per cent for the resource extraction sector.

JEL Classification Numbers: D57, E01, Q33

Keywords: resource boom, industry analysis, input-output tables

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1. Introduction

The Australian economy has been going through a period of structural adjustment in response to the boom in the terms of trade starting in the mid 2000s and the associated appreciation of the exchange rate (Figure 1). These significant changes in relative prices, and the associated boom in resource investment, have had very different implications for growth in the resource and non-resource parts of the economy.[1]

In order for Australia to take advantage of the rapid increase in demand for its natural resources, not only has the resource extraction sector been required to grow rapidly, but so too have industries that provide inputs to resource extraction and investment. This 'resource-related' activity tends to be more intensive in the use of labour than the resource extraction sector.

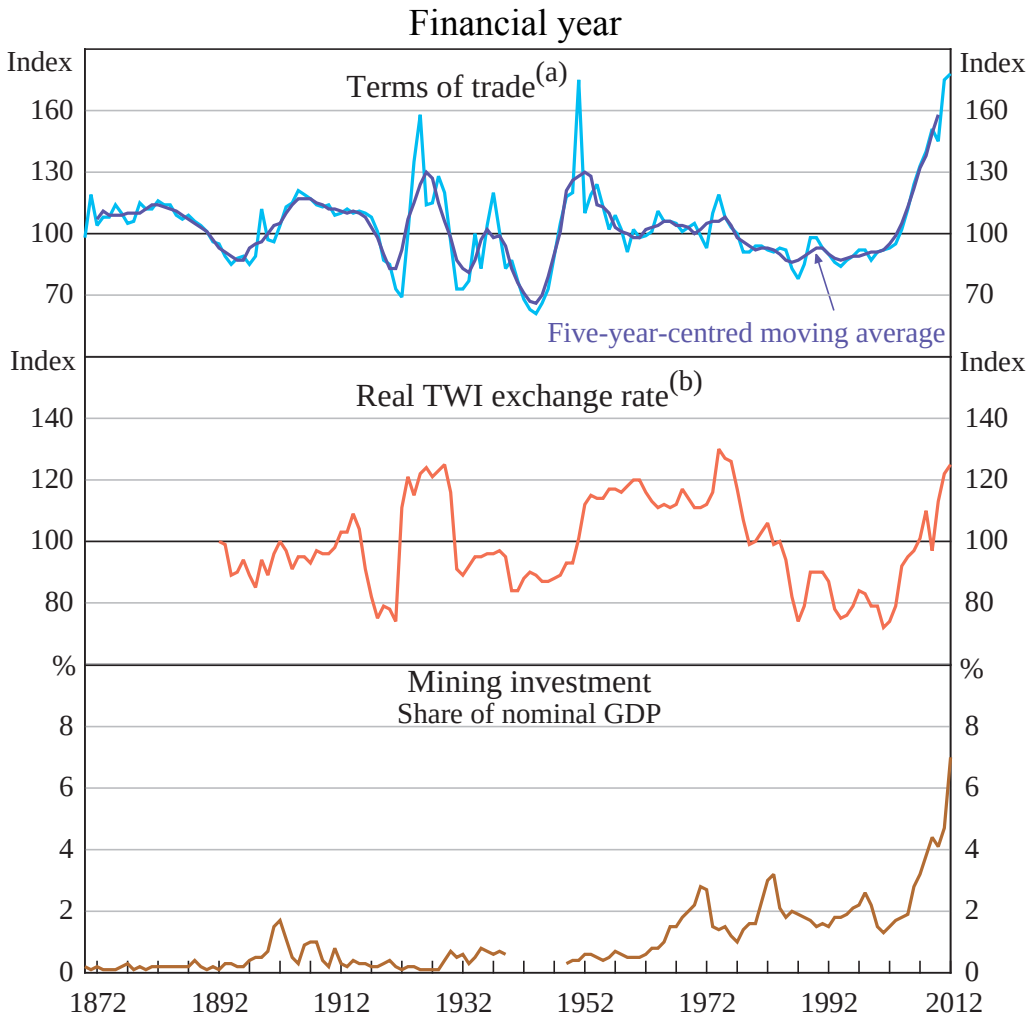
The purpose of this paper is to estimate the size, growth rate, and industry composition of a broader measure of the resource economy, which includes both resource extraction and resource-related activity. This broader measure has been discussed in recent Reserve Bank of Australia (RBA) analysis including Lowe (2012), Plumb *et al* (2012) and Kent (2013). The main contribution of our paper is to outline the methodology, assumptions and limitations of this measure.

There are a number of reasons why it is important to quantify the linkages from demand for Australia's natural resources to activity in other domestic industries. Most importantly, it can provide an insight into the nature of structural change that is taking place in the economy as a result of the resource boom. Specifically, our methodology allows us to assess which industries have benefitted the most from

1 There have been a number of speeches and papers published by the RBA in recent years on the causes of the resource boom and the implications for the Australian economy. For example, see Plumb, Kent and Bishop (2012), Lowe (2012), Connolly and Orsmond (2011), RBA (2011a, 2011b), Stevens (2011b), Battellino (2010) and Connolly and Orsmond (2009).

the resource boom and, as a corollary, which industries will be most affected by any decline in the terms of trade and resource investment. Related to this, under certain productivity assumptions, we can also estimate the amount of labour that is required by each industry to service the demand for Australia's natural resources.

Figure 1: Relative Prices and Mining Investment



Notes: (a) 1900–2000 average = 100

(b) 1900–2000 average = 100; calendar year prior to 1970

Sources: ABS; Butlin (1964, 1985); Gillitzer and Kearns (2005); McKenzie (1986); RBA; authors' calculations

As outlined in Plumb *et al* (2012), it is useful conceptually to divide economic activity into three parts: (i) resource extraction, (ii) resource-related activity, and (iii) non-resource activity. We define the 'resource economy' to be the sum of resource extraction and resource-related activity:

- **Resource extraction** includes mineral and gas extraction, and also resource-specific manufacturing (such as the production of metals and refined petroleum). This is very close to the Australian Bureau of Statistics' (ABS) definition of the mining industry, the only difference being that we include resource-specific manufacturing in our measure.

- **Resource-related activity** includes investment that supports the future production of resources as well as the provision of intermediate inputs that are used in the current production of resources. In other words, it captures activities that are directly connected to resource extraction, such as constructing mines and associated infrastructure, and transporting inputs to, and taking extracted resources away from, mines. It also captures some activities less obviously connected to resource extraction, such as engineering and other professional services (legal and accounting work, for example).

- **Non-resource activity** includes everything else in the economy that does not have a direct relationship to the current and future production of resources. That is not to say that these other parts of the economy are not affected by the resource boom. Among other things, there are income effects associated with dividend payments to households, the benefits of tax revenue from resource extraction and resource-related activities, and spending by those working in those industries. However, only production, not income linkages, are considered in this paper.

In previous work, the RBA (2011a) has presented a demand-side measure of the resource economy, summing together resource exports and resource investment, and subtracting the imported component of that investment. While this is a simple and transparent way to measure the resource economy, it does not capture the entire resource economy (it excludes domestic final demand for resource output and does not adjust for imports of resource commodities, such as oil and petroleum), and it cannot be used to quantify the linkages that the resource sector has with other industries.

To address these issues, we use input-output tables from the ABS to transform a more comprehensive demand-side, expenditure-based measure of the resource economy into a supply-side, value-added-based measure that can be decomposed

by industry. Input-Output tables allow us to identify the industries that provide intermediate inputs to resource extraction and investment, and to answer questions such as: to export $1 of iron ore, which industries would need to provide intermediate inputs for this $1 of iron ore to be produced, and how much gross value added (GVA) and employment would be generated by these industries as a result?

Our methodology builds on that in Kouparitsas (2011), which condenses input-output tables into three industries – agriculture, mining and 'non-agriculture, non-mining' – to examine the spillovers from mining production and investment to other industries.[2] The contributions of our research are four-fold. First, we extend the methodology in Kouparitsas by using a finer level of industry disaggregation: we disaggregate the mining sector into 9 sub-industries, and the rest of the economy into 13 industries that align closely with ABS industry definitions. This allows us to estimate more precisely which industries have benefitted the most from the resource boom. Second, we include *all* final demand for the output of the resource extraction sector in our measure of the resource economy, not only resource exports. Third, we decompose resource investment by *type* of investment and allocate this to the industries responsible for undertaking the investment, which again allows us to estimate more precisely the industries that have been particularly important in the recent resource boom. Finally, the additional level of industry disaggregation used in our paper allows us to derive an estimate of the labour required to service the demand for Australia's natural resources.

In summary, our approach requires us to:

- First, estimate all of the final demand in the economy that is related to resource extraction and investment, and then identify the industries that produce these *final* goods and services. The industry that produces a *final* good or service is the industry that is responsible for the final steps in the production chain for that product. For example, resource exports are produced by the resource extraction industry, and resource-related construction investment is assumed to be undertaken by the heavy & civil engineering construction industry.

2 The methodology in Kouparitsas (2011) is implemented in Gruen (2011) and also summarised in the appendix to Gruen.

- Second, using input-output tables, we calculate the value and industry composition of *intermediate* inputs required to meet this final demand. For example, we calculate the value and industry composition of intermediate inputs that are required by the resource extraction sector to produce each $1 of resource exports, and the value and industry composition of intermediate inputs that are required for each $1 of resource-related construction investment undertaken by the heavy & civil engineering construction industry.

- After making some simplifying assumptions, we can then use the information in the second step to transform the final demand that is related to resource extraction and investment into estimates of GVA by industry.

The structure of the rest of our paper is as follows. The next section outlines our methodology, including a brief overview of input-output tables and how they are applied to our research question. Section 3 outlines our baseline results, and those for a narrower definition of the resource economy. The assumptions that underpin our approach are discussed and tested in Section 4. Section 5 considers the implications of strong demand for Australia's natural resources on employment by industry, and Section 6 concludes.

2. Methodology

2.1 A Brief Overview of Input-Output Tables

Our methodology for estimating the size, growth and industry value-added content of the resource economy is based on structural economic relationships embedded in input-output (I-O) tables. I-O tables provide a detailed dissection of the supply and use of inputs and outputs in the economy.

The following discussion of I-O tables and multipliers draws on ABS (1995). Assume that the economy is divided into n industries. If we denote the total gross output of industry i (in dollars) as X_i, the final demand for industry i's product as Y_i^f, and the intermediate input sales from industry i to industry j as Z_{ij}, we can write an I-O system of equations for gross output as:

$$
\begin{aligned}
X_1 &= Z_{11} + Z_{12} + \cdots + Z_{1j} + \cdots + Z_{1n} + Y_1^f \\
X_2 &= Z_{21} + Z_{22} + \cdots + Z_{2j} + \cdots + Z_{2n} + Y_2^f \\
&\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
X_i &= Z_{i1} + Z_{i2} + \cdots + Z_{ij} + \cdots + Z_{in} + Y_i^f \\
&\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
X_n &= Z_{n1} + Z_{n2} + \cdots + Z_{nj} + \cdots + Z_{nn} + Y_n^f
\end{aligned}
\tag{1}
$$

The right hand side of row i represents the sales from industry i to all other industries (as intermediate inputs) and to final demand. In the representation above, final demand is defined as the sum of household consumption, private investment, public demand, changes in inventories, and net exports. Column j (from $j = 1, \ldots, n$) represents the sales of intermediate inputs to industry j. Thus, row i represents the distribution of industry i's *output* and column j represents the sources and magnitudes of industry j's *inputs*. The Z_{ij} terms – inter-industry flows of input and output – are central to I-O analysis.

To aid further analysis, we define $a_{ij} = \dfrac{Z_{ij}}{X_j}$

where a_{ij} (known as a *technical coefficient*) defines the value of intermediate inputs that are required by industry j from industry i to produce \$1 of gross output in industry j. Using these technical coefficients, we can re-write the I-O system of equations in matrix form:

$$\mathbf{X} = \mathbf{A}\mathbf{X} + \mathbf{Y}^f \tag{2}$$

where $\mathbf{X} = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix}$ and $\mathbf{Y}^f = \begin{bmatrix} Y_1^f \\ Y_2^f \\ \vdots \\ Y_n^f \end{bmatrix}$ are n x 1 vectors, and

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2j} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}$$ is the n x n matrix of technical coefficients.

Also note that $Y_i^f = C_i + I_i + G_i + \Delta Inv_i + EX_i - M_i^f$ where C denotes household consumption, I private investment, G government demand, ΔInv the change in inventories, EX exports, and M^f final imports.

The matrix **A** is known as the *direct requirements matrix.* In the representation above, the technical coefficients in the direct requirements matrix define the value of *domestic* intermediate inputs required by industry *j* from industry *i* to produce $1 of gross output (i.e. excluding imported intermediate inputs).[3]

2.2 Industry Definitions

The first step in our methodology involves organising and consolidating information in the I-O tables. The ABS has been publishing I-O tables on an annual basis over the past five years, but the data are published with a three year lag; for example, the 2008/09 tables (the latest available tables) were published in September 2012. Prior to 2004/05, the tables were published infrequently, usually every few years.[4] Recent I-O tables provide data for 111 sub-industries (i.e. $n = 111$).[5] There are six sub-industries classified by the ABS as being part of the mining industry:

3 Technical coefficients can also be calculated under a different representation of the economy where imports are included in intermediate and final sales.

4 With the release of tables for 2008/09, the ABS has completed 24 I-O tables for Australia. Previous tables were published for the following years: 1958/59, 1962/63, 1968/69, 1974/75, 1977/78 to 1983/84, 1986/87, 1989/90, 1992/93 to 1994/95, 1996/97, 1998/99, 2001/02, and 2004/05 to 2007/08.

5 There are 111 sub-industries in the 2006/07, 2007/08 and 2008/09 I-O tables, which use the 2006 Australian and New Zealand Classification (ANZSIC06) and 2008 System of National Accounts (SNA08) classification systems. Prior to this, the number of sub-industries varies.

- coal mining;
- oil & gas extraction;
- iron ore mining;
- non-ferrous metal ore mining;
- non-metallic mineral mining and quarrying; and
- exploration and other mining support services.

We include all six sub-industries in our measure of the resource extraction sector. We keep these sub-industries disaggregated in our I-O calculations because the intermediate inputs used in each type of mining can differ, and aggregation may have implications for our measure of the resource economy if the composition of resource extraction changes over time.

We also include resource-specific manufacturing in our measure of the resource extraction sector.[6] This is consistent with Gruen (2011) and the RBA's definition of resource exports, which includes some processed commodities that are classified as manufacturing in the I-O tables. These sub-industries include:

- iron & steel manufacturing;
- petroleum & coal product manufacturing; and
- basic non-ferrous metal manufacturing (e.g. refining bauxite to form alumina, and the smelting or refining of copper, lead and zinc).[7]

6 Section 3.2 of this paper considers a narrower definition of the resource extraction sector that excludes resource-specific manufacturing.

7 We do not include fabricated metal products in our definition of resource extraction, since these products contain a larger share of manufacturing value added than basic metal refining, smelting, casting and manufacturing. Also, fabricated metal products are not included in the RBA's definition of 'resource exports'.

For our purposes, we aggregate the remaining 102 sub-industries in the I-O tables into 13 industries. In most cases, our industry classifications align closely with those defined by the ABS, such as agriculture, forestry & fishing; retail trade; wholesale trade; transport, postal & warehousing; electricity, gas, water & waste services; and ownership of dwellings. However, for presentational purposes, we also make use of two broader industry definitions:[8]

- Business services: includes professional, scientific & technical services; information, media & telecommunications; financial & insurance services; rental, hiring & real estate services; and administrative & support services.

- Household and public services: includes accommodation & food services; health care & social assistance; education & training; arts & recreation; and public administration & safety.

As noted above, our definition of the resource economy also includes final demand related to resource investment (net of capital imports). The two main types of resource investment are non-residential construction investment and machinery & equipment investment.[9] I-O tables identify three construction sub-industries that would be responsible for undertaking construction investment: residential building, non-residential building and heavy & civil engineering. We assume that the domestic component of *resource-related construction investment* is undertaken by

8 The results presented in Section 3 would be the same if we were to leave the business services and household services industries disaggregated for the I-O calculations in Sections 2.3 and 2.4 and then aggregated these industries' resource-related GVA at a later stage.

9 We define 'resource investment' to be the sum of the ABS measures of 'mining investment' in machinery & equipment and non-residential construction (Cat No 5204.0). The remaining types of 'mining investment' (as defined by the ABS in the national accounts) comprise investment in various intangibles such as mineral & petroleum exploration, research & development and computer software (together, these expenditures accounted for a little more than 10 per cent of total mining investment in 2011/12). Following the treatment of these expenditures by the ABS in I-O tables, we assume that all mining investment in intangibles is undertaken by the resource extraction sector itself; that is, we include it as part of the final demand for the output of the resource extraction sector. See Appendix B for further details.

the heavy & civil engineering construction sector.[10] This is not to say that the heavy & civil engineering construction sector *only* undertakes resource-related construction investment; in addition to the construction of mine sites, the heavy & civil engineering construction sector is also responsible for the construction of railways, roads, dams, harbours and pipelines, and on-site assembly of heavy electrical machinery, which may or may not be resource-related. Regarding *resource-related machinery & equipment investment*, we assume that the domestic component of this investment is undertaken by the machinery & equipment manufacturing sub-industry. For this reason, we separate the machinery & equipment manufacturing sub-industry from the rest of manufacturing in the I-O tables. Table A1 provides more details on the industry definitions used in this paper.

2.3 Direct and Total Input Requirements

We calculate the direct requirements matrix based on the industry classifications outlined above. For presentational purposes, a condensed version of this matrix is shown in Table 1.[11]

The direct requirements matrix tells us the value of intermediate inputs required, on average, to produce $1 of industry output in a given year.[12] For example, reading down column 1 of Table 1, for the resource extraction sector to produce $1 of output in 2008/09, it used, on average, $0.41 of domestic intermediate inputs; of this, $0.22 of inputs were from its own industry and $0.19 of inputs were from other domestic industries (predominately business services, transport, construction

10 The more recent tables in 2006/07, 2007/08 and 2008/09 separately identified heavy & civil engineering construction. For years prior to this we allocate resource-related construction investment to the more broadly defined non-residential construction industry. We also assume that some part of resource-related construction investment is provided by the 'construction services' sub-industry, which performs activities such as concreting, erecting metal structures, electrical services and hire of construction machinery.

11 The full direct requirements matrix – with 22 rows and 22 columns – is available from the authors on request.

12 It is important to note that the direct requirements matrix tells us the average value of inputs required to produce every $1 of gross output in a given year, and not the *marginal* input requirements to produce an *additional* $1 of output. The value and composition of inputs used by firms in a given industry will vary depending on the technology available to the firm, whether they achieve economies of scale, and if there are any constraints on the availability of inputs.

and manufacturing). The reason that the resource extraction sector consumes intermediate inputs that are produced by its own industry largely reflects the use of resources for further processing or refinement (e.g. the use of iron ore and coal as intermediate inputs in the production of steel), as well as the use of exploration and other mining services.

Table 1 also shows the value of imported intermediate inputs used by each industry to produce $1 of output. For example, in 2008/09, the resource extraction sector used $0.13 of imported intermediate inputs for every $1 of output, which is quite high relative to the average of all industries ($0.07). This largely reflects the high imported content of inputs to petroleum and coal product manufacturing (such as crude oil).

Table 1: Direct Requirements Matrix

Value of intermediate inputs required for every $1 of industry output – 2008/09

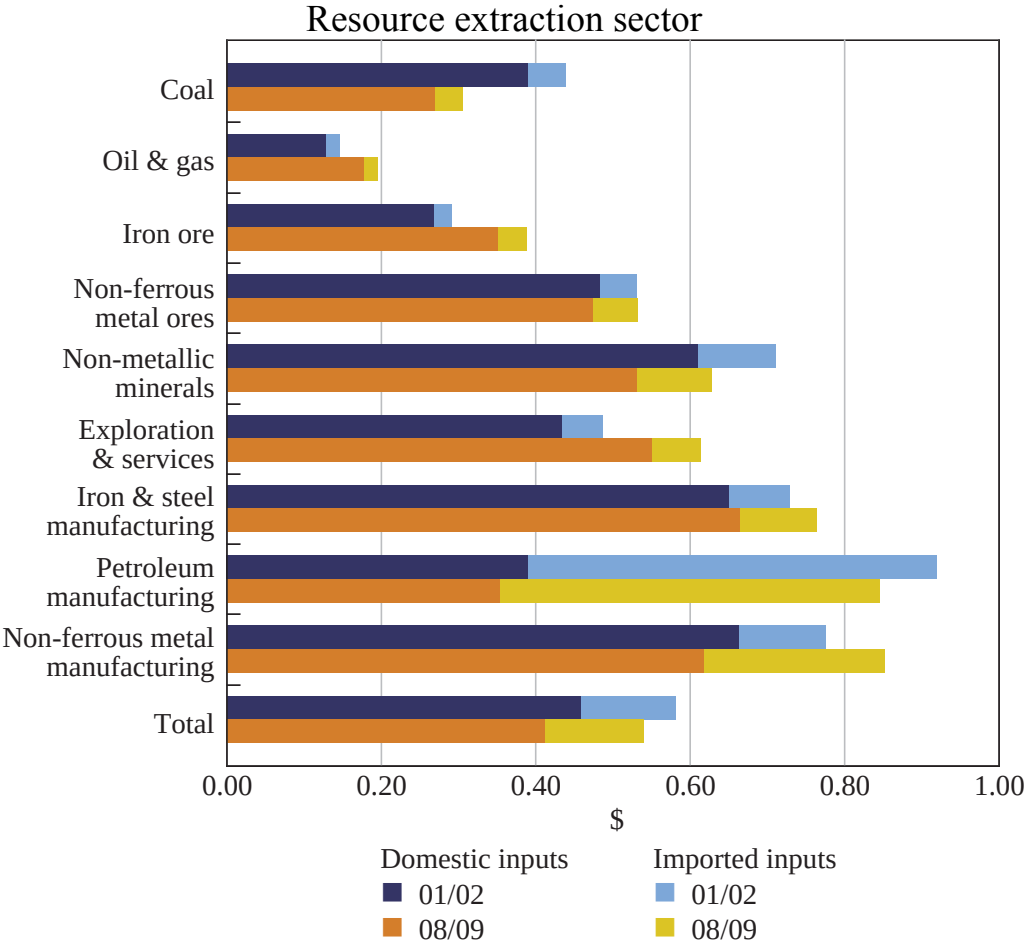
	Resource extraction	Construction	Manufacturing	Business services	Transport	Other industries
Resource extraction	0.22	0.03	0.07	0.00	0.04	0.01
Construction	0.03	0.26	0.01	0.02	0.02	0.03
Manufacturing	0.03	0.12	0.15	0.03	0.05	0.06
Business services	0.07	0.17	0.09	0.30	0.19	0.15
Transport	0.03	0.02	0.05	0.02	0.08	0.03
Other industries	0.04	0.05	0.18	0.06	0.09	0.10
Total (excl imports)	**0.41**	**0.65**	**0.56**	**0.43**	**0.47**	**0.38**
Imported inputs	0.13	0.05	0.12	0.04	0.07	0.04
Total (incl imports)	0.54	0.70	0.68	0.46	0.54	0.42

Notes: Resource extraction is the aggregation of the mining and resource-specific manufacturing sub-industries listed in Section 2.2; 'Construction' is the aggregation of residential building, non-residential building, heavy & civil engineering and construction services; 'Manufacturing' is the aggregation of all forms of manufacturing except for resource-specific manufacturing; and 'Other industries' is the aggregation of agriculture, forestry & fishing, wholesale trade, retail trade, household services and electricity, gas, water & waste services

Sources: ABS; authors' calculations

We have disaggregated the resource extraction sector in our I-O calculations because the composition and intensity of intermediate inputs used by each sub-industry can differ (Figure 2). For example, the total value of intermediate inputs that are used to extract $1 of oil & gas is typically much lower than other types of resource extraction. In fact, oil & gas extraction is one of the least intensive users of intermediate inputs in the economy, using only $0.18 of domestic intermediate inputs for every $1 of industry output in 2008/09.

Figure 2: Direct Intermediate Input Requirements



Notes: Value of intermediate inputs required for every $1 of sub-industry output

Sources: ABS; authors' calculations

The industries that supply inputs to resource extraction and investment also require inputs from other industries, which in turn require intermediate inputs from other industries and so on. To account for these second, third and additional rounds of production linkages, we can calculate a matrix of gross output multipliers (also

known as a total requirements matrix). To do this, we manipulate Equation (2) as follows:

$$\mathbf{X} = \left(\mathbf{I} - \mathbf{A}\right)^{-1} \mathbf{Y}^{f} \tag{3}$$

where **I** is the identity matrix and $(\mathbf{I} - \mathbf{A})^{-1}$ is the total requirements matrix. This matrix is shown in Table 2 for the same group of industries as in Table 1.

Table 2: Total Requirements Matrix

Value of intermediate inputs required for every $1 of final demand for industry output – 2008/09

	Resource extraction	Construction	Manufacturing	Business services	Transport	Other industries
Resource extraction	1.29	0.08	0.13	0.02	0.08	0.03
Construction	0.06	1.37	0.04	0.04	0.05	0.05
Manufacturing	0.06	0.22	1.22	0.06	0.10	0.10
Business services	0.19	0.42	0.27	1.49	0.37	0.30
Transport	0.05	0.06	0.09	0.04	1.11	0.05
Other industries	0.09	0.15	0.27	0.12	0.16	1.15
Total (excl imports)	**1.74**	**2.31**	**2.01**	**1.77**	**1.86**	**1.69**
Imported inputs	0.42	0.30	0.45	0.16	0.27	0.19
Total (incl imports)	2.16	2.61	2.46	1.94	2.13	1.88

Notes: See notes in Table 1 for industry details

Sources: ABS; authors' calculations

Reading down column 1 in Table 2: for every $1 of final demand for the output of the resource extraction sector in 2008/09 (e.g. $1 of resource exports), a total of $1.74 of gross output was generated by domestic industries; $1.29 from the resource extraction sector itself and $0.45 from other industries. This gross output multiplier of $1.74 can be decomposed into three components:

1) *The initial effect:* $1 of gross output from the resource extraction sector is required to meet the $1 of final demand;

2) *The first round effect:* the value of intermediate inputs required from all industries in order to produce the initial $1 of gross output ($0.41 from column 1, Table 2); and

3) *The industrial support effect:* the extra output induced as a result of all industries having to produce the first round of intermediate inputs (i.e. $1.74 – $1.00 – $0.41 = $0.33).

The reason why the gross output multipliers are greater than one is because intermediate inputs are counted multiple times – in the next section we adjust the gross output multipliers to take account of this.

2.4 GVA Requirements

Equation (3) allows us to link final demand for resource extraction and investment to the gross output that is generated by all other domestic industries as a result. However, this does not tell us about the *economic contribution* of each industry to the resource economy, because it generates estimates of gross output rather than GVA. The GVA of an industry is the gross output of that industry less the intermediate inputs that it uses to produce that output. As outlined in Kouparitsas (2011), two further transformations can be made to Equation (3) in order to link final demand to industry GVA:

1) To transform the gross output multipliers in the total requirements matrix into GVA coefficients, we need to multiply Equation (3) by each industry's ratio of GVA to gross output:[13]

$$\mathbf{GVA} = \mathbf{VX} = \mathbf{V}\left(\mathbf{I} - \mathbf{A}\right)^{-1}\mathbf{Y}^{f} \qquad (4)$$

13 GVA is published in the I-O tables for each of the 111 sub-industries.

where $\mathbf{V} = \begin{bmatrix} v_1 & 0 & 0 & 0 & \cdots & 0 \\ 0 & v_2 & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & v_i & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & v_n \end{bmatrix}$ and $v_i = \dfrac{GVA_i}{X_i}$.

2) Recall that we define final demand as $\mathbf{Y^f = C + I + G + \Delta Inv + EX - M^f}$ where $\mathbf{M^f}$ denotes final imports (i.e. it does not include imported intermediate inputs). However, the imports data that we receive from the ABS do not lend themselves to being easily disaggregated into final imports and intermediate imports, especially at the industry level, which is what we require for our analysis. Given this, the following adjustment is made to Equation (4) to take account of the fact that our imports by industry data will include both final and intermediate imports:

$$\mathbf{GVA = V\left(I - A - B\right)^{-1} Y} \tag{5}$$

where $\mathbf{Y = C + I + G + \Delta Inv + EX - M}$ and $\mathbf{M = M^{int} + M^f}$ (i.e. intermediate + final imports),

$\mathbf{B} = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1j} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2j} & \cdots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ b_{i1} & b_{i2} & \cdots & b_{ij} & \cdots & b_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nj} & \cdots & b_{nn} \end{bmatrix}$, $b_{ij} = \dfrac{m_{ij}^{int}}{X_j}$ and

m_{ij}^{int} is the value of imported intermediate sales from industry *i* to industry *j*.

The matrix **B** is the imported counterpart to matrix **A**; that is, **A** defines the value of *domestic* intermediate inputs that are required by industry *j* from industry *i* to produce $1 of gross output, whereas **B** defines the value of

imported intermediate inputs that are required by industry *j* from industry *i* to produce $1 of gross output.

Equation (5) is the key to estimating the industry value-added content of final demand for resource extraction and investment. From here on, we will refer to $\mathbf{V(I - A - B)^{-1}}$ as the *GVA requirements matrix*. The GVA requirements matrix reveals the distribution of industry GVA generated for every $1 of final demand for a particular industry's output (Table 3). For example, take column 1 in Table 3: the coefficients in this column can be thought of as the industry value-added content of resource exports. These coefficients will differ for each type of resource exports but, on average, for $1 of resource exports in 2008/09:

- The resource extraction sector contributed $0.70 of value added.
- The business services industry contributed $0.13 of value added.
- The manufacturing, transport and construction industries each contributed around $0.02–$0.04 of value added, while the remaining $0.07 was contributed by other industries, such as utilities and wholesale trade.

Table 3: GVA Requirements Matrix

Value of GVA generated for every $1 of final demand for industry output – 2008/09

	Resource extraction	Construction	Manufacturing	Business services	Transport	Other industries
Resource extraction	0.70	0.07	0.11	0.02	0.07	0.03
Construction	0.02	0.42	0.01	0.01	0.02	0.02
Manufacturing	0.04	0.11	0.45	0.04	0.06	0.06
Business services	0.13	0.25	0.18	0.82	0.22	0.18
Transport	0.03	0.03	0.05	0.02	0.51	0.03
Other industries	0.07	0.11	0.19	0.08	0.11	0.68
Total	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**

Notes: See notes in Table 1 for industry details; total does not equal $1.00 due to taxes less subsidies on intermediate goods and services

Sources: ABS; authors' calculations

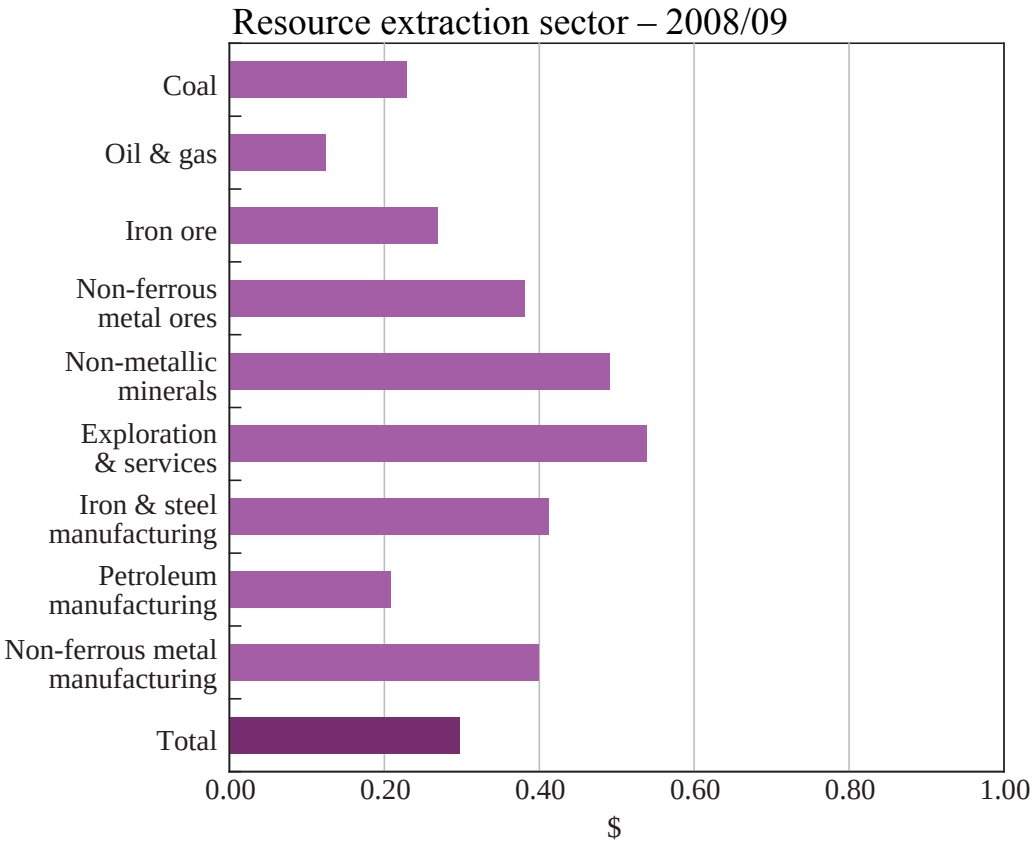
These estimates suggest that there are non-trivial spillover effects from demand for Australia's natural resources to activity in domestic industries, outside of the resource extraction sector itself.

The sum of each column in Table 3 is close to one, which is what you would expect: $1 of final demand (excluding any intermediate or final imports) creates $1 of gross value added. The reason why the multipliers are slightly less than one is because GDP equals GVA plus taxes less subsidies on products, and on average, there is 1 cent of taxes less subsidies on intermediate goods and services per $1 of final demand.[14]

Figure 3 shows the value of GVA generated in industries outside the resource extraction sector for every $1 of final demand for the output of the resource extraction sub-industries in 2008/09. On average, around one-quarter of the value of coal and iron ore exports in 2008/09 represented value added by industries outside of the resource extraction sector. On the other hand, oil & gas extraction, which uses fewer domestic intermediate inputs to extract every $1 of output than coal and iron ore, generated fewer spillovers to other domestic industries. Indeed, these estimates suggest that all other domestic industries benefited almost twice as much – in terms of GVA spillovers – from a given increase in iron ore or coal exports than from a similar increase in oil and gas exports in 2008/09.

14 In total, taxes less subsidies represented 6¾ per cent of GDP in 2008/09, though the majority of these taxes are levied on final demand rather than on intermediate goods and services.

Figure 3: GVA Spillovers to Non-Resource Extraction Industries



Notes: Value of GVA generated outside the resource extraction sector for every $1 of final demand for the output of the resource extraction sub-industries

Sources: ABS; authors' calculations

2.5 Allocating Final Demand to Industries

We are able to calculate the GVA requirements matrix at different points in time using different vintages of the I-O tables. To calculate the GVA of the resource economy, we first need to accurately allocate all the final demand related to resource extraction and investment to the industries that produce this final output. The precise details of this mapping exercise are described in Appendix B, but in summary we have included two broad types of final demand in our measure of the resource economy:

(i) The final demand for the *output* of the resource extraction sector. This source of final demand is dominated by resource exports, but it also includes domestic final demand for resource output and nets off imports of resource commodities (our measure is broader than that in Kouparitsas (2011) and Gruen (2011),

where only resource exports are included). We allocate this final demand to each of the nine sub-industries within the resource extraction sector.

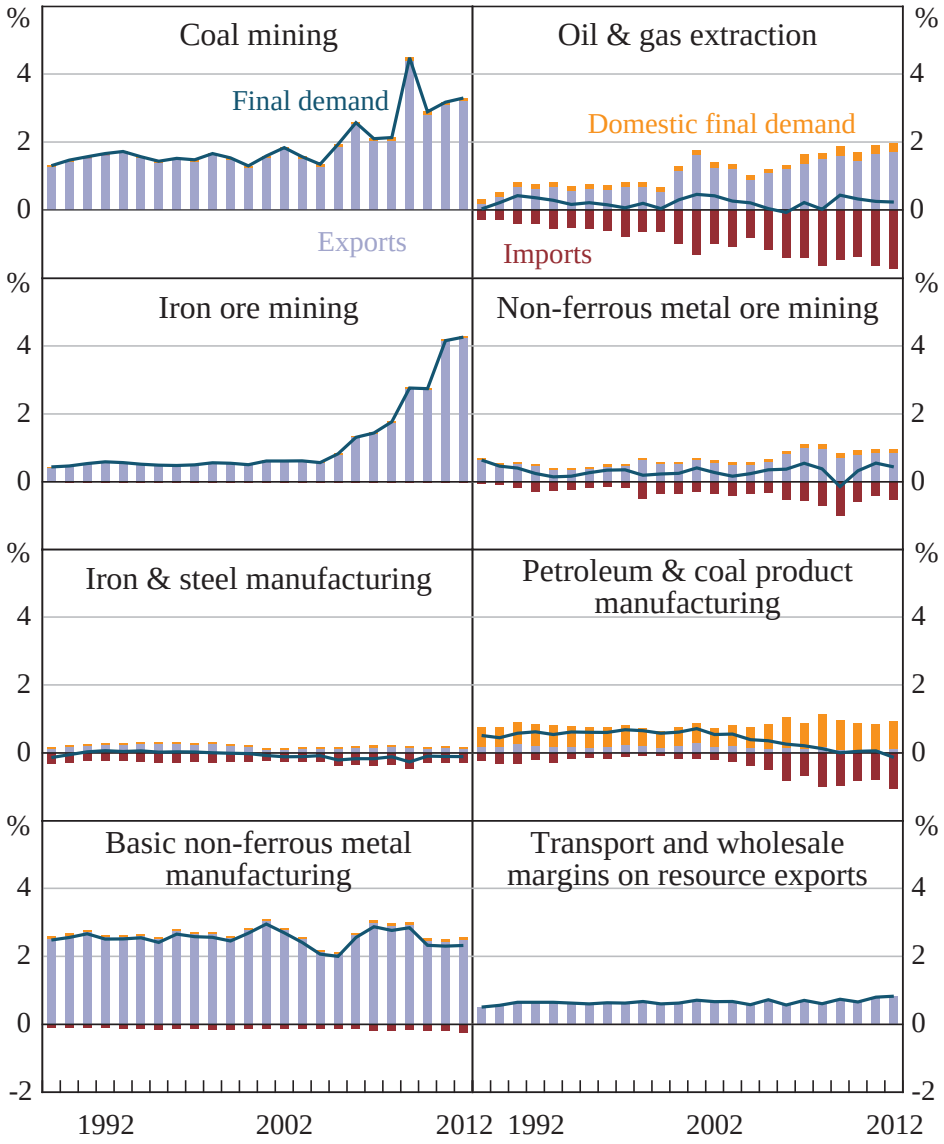
(ii) The final demand related to *investment* by the resource extraction sector to expand and update capacity (adjusted for capital imports). We allocate the majority of this investment to the heavy & civil engineering construction and the machinery & equipment manufacturing industries, depending on the type of investment.

Figure 4 illustrates how we have allocated final demand for the output of the resource extraction sector to its various sub-industries. Resource exports represent the majority of final demand, accounting for 12¾ per cent of nominal GDP in 2011/12, in basic prices.[15] Of this, Australia's largest resource exports by value were iron ore and coal, which have risen sharply as a share of GDP since the early to mid 2000s, following a rapid rise in prices and strong growth in iron ore export volumes. Exports of unrefined oil and gas have also increased relative to GDP over the past decade, though this mostly reflects higher energy prices rather than growth in volumes; while LNG export volumes have more than doubled since 2004 (and are expected to continue to grow rapidly), the production of crude oil peaked in 2000 and has since fallen by around 45 per cent as a result of the depletion of several of Australia's major oil basins. Australia also exports a wide range of non-ferrous metal ores (which include bauxite, copper ore, gold ore and nickel ore). These exports have grown broadly in line with nominal GDP over the past decade, reflecting a less pronounced run-up in prices (compared to coal and iron ore), and sluggish growth in volumes.

15 The flows in the I-O tables are valued in basic prices, and therefore the final demand data that we use also need to be valued in basic prices. The basic price is the price received by a producer from the sale or production of a unit of its output, excluding any trade and transport margins and taxes payable, and plus any subsidies received. The alternative way of valuing transactions in I-O tables is in purchasers' prices, which is the amount paid by the purchaser in order to take delivery of the good or service (including any taxes less subsidies on products and margins such as transport, wholesale and retail margins). The expenditure-side data in the national accounts are typically valued in purchasers' prices, so we use information from I-O tables to transform the national accounts data into basic prices (see Appendix B).

Figure 4: Final Demand – Resource Extraction

Share of nominal GDP, financial year



Notes: All data are measured in basic prices; final demand is domestic final demand plus exports less imports. Data for exploration & other mining support services and non-metallic mineral mining & quarrying are not shown.

Sources: ABS; authors' calculations

Resource exports also include exports of resource-specific manufactured goods. This includes firms engaged in the smelting, refining and production of metal products such as iron and steel and non-ferrous metals (e.g. aluminium, copper and gold). Exports of processed metals have benefited little from the terms of trade boom and have faced growing competition from Chinese smelters and refineries over the past decade (Connolly and Orsmond 2011). Hence, the volume of these

exports remains below its level in the early 2000s (though some strength in base metal prices has supported the nominal value of these exports).

Exporting resources also requires distribution activity. In 2008/09, around 6 per cent of the final value of resource exports represented the margins of transport and wholesale firms in the supply chain.

Imports of resources are far smaller than resource exports, equivalent to 3¾ per cent of GDP in 2011/12. Around half of these imports were oil and gas, which are mainly used as an intermediate input by the manufacturing sector in the production of petroleum. Australia also imports petroleum and petroleum products, iron and steel and some non-ferrous metals and ores.

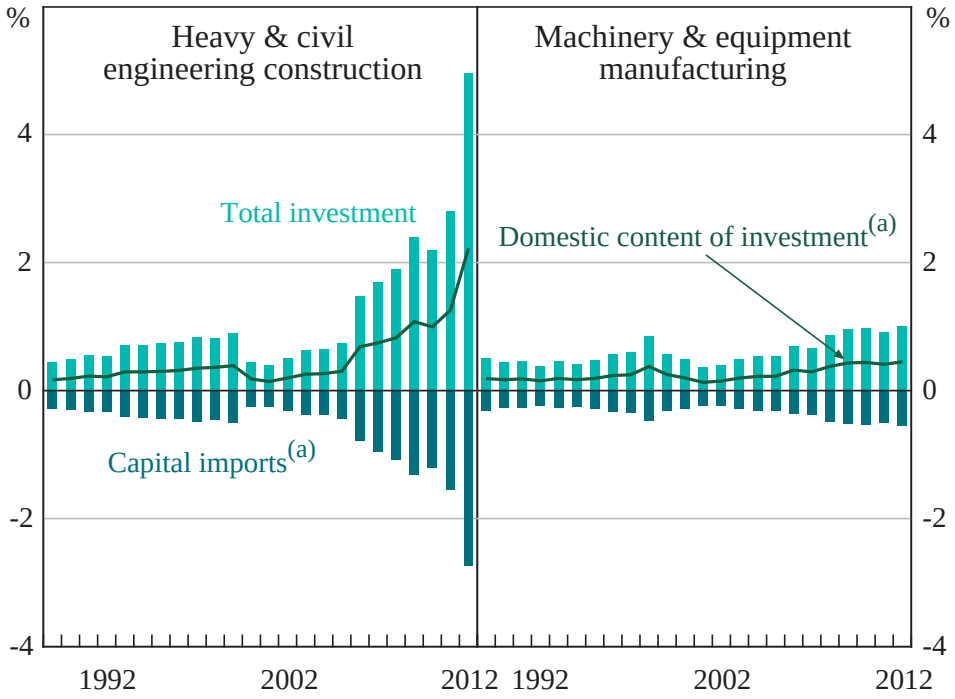
Domestic final demand for resource output by the household, business and government sectors accounted for around 2 per cent of GDP in 2011/12. This was mainly comprised of household spending on automotive fuels and gas, and spending by the resource extraction sector on research & development and mineral & petroleum exploration.

We also need to allocate the demand related to resource *investment* to the domestic industries that produce this output. It is important to note that given the high import content of this investment, we assume that around one-half is local content and one-half is imported (Figure 5).[16] Given the nature of resource-related construction projects – which are dominated by engineering works such as constructing new mines and railroads rather than new buildings – we allocate all resource-related construction investment to the heavy & civil engineering construction sector. We allocate around three-quarters of resource-related machinery & equipment investment to the machinery & equipment manufacturing industry. The remaining one-quarter is allocated to the wholesale, retail, and transport industries since machinery & equipment investment also incorporates a wholesale, retail and transport margin on manufactured products (these margins are not illustrated in Figure 5).

16 This is consistent with liaison the Bank has conducted. Of course, these shares vary with the nature and details of the specific resource project (Stevens 2011a).

Figure 5: Final Demand – Resource Investment

Share of nominal GDP, financial year



Notes: In basic prices

(a) Authors' calculations based on RBA estimates of the import content of total mining investment

Sources: ABS; RBA; authors' calculations

Once we have allocated final demand related to resource extraction (i.e. Figure 4) and investment (i.e. Figure 5) to the industries that produce this final demand, we can construct a time series of resource-related final demand by industry, Y_{it} (in nominal dollars):

$$Y_{it} = C_{it} + I_{it} + G_{it} + \Delta Inv_{it} + EX_{it} - M_{it} \qquad (6)$$

for industries $i = 1, \ldots, 22$ and $t = 1989/90, \ldots, 2011/12$. There are some industries that do not produce any *final* goods and services related to resource extraction and investment, namely: agriculture, forestry & fishing; electricity, gas, water & waste services; residential building; non-residential building; other manufacturing; business services; household services; and ownership of dwellings. However, this does not imply that these industries do not contribute anything to the final value of resource extraction and investment; as illustrated in Table 1, some of these industries are important suppliers of *intermediate* inputs used in resource extraction and investment. As such, industries including business services are still

important contributors to the total value added of the resource economy (see Section 3).

The next step is to take the final demand that we have allocated to the resource economy and transform it into gross value added by industry. To do this, we take the time-varying GVA requirements matrices and multiply them through by the matrix of final demand by industry, for each year in our sample period.[17] This gives us time-varying estimates of GVA generated by industry as a result of final demand for resource extraction and investment. However, to form a complete picture of the resource economy, we also need to add the GVA generated by the resource extraction sector through its sales to other domestic industries as intermediate inputs, which is discussed in the next section.

2.6 Intermediate Sales

The previous section outlined our methodology for calculating the GVA that is generated by the final demand for resource extraction and investment. However, the resource extraction sector also sells its output to other industries for use as intermediate inputs to production. For example, part of coal mining output is sold to the utilities industry, which is consumed as an input to generate electricity. The resource extraction sector generates GVA from these intermediate sales, and as

17 The GVA requirements matrix from the 2001/02 I-O tables is applied to expenditure data between 1991/92 and 2001/02; an average of the 2001/02 and 2004/05 GVA requirements matrices are applied to expenditure data between 2002/03 and 2003/04; and an average of the 2007/08 and 2008/09 GVA requirements matrices are applied to expenditure data beyond 2008/09. The I-O tables for the period 1992/93–1998/99 are not incorporated in our analysis because these tables did not treat coal mining and oil & gas extraction as separate industries. The ABS also introduced a number of methodological changes in the 2001/02 I-O tables that make the earlier tables less comparable (Gretton 2005).

such we need to incorporate this component of demand if we want to capture the entire GVA of the resource extraction sector.[18]

One approach to capture these intermediate sales is to repeat the earlier exercise and allocate all final demand for the output of the non-resource economy to the industries that produce this output and multiply through by the GVA requirements matrices. However, mapping all non-resource final demand to industries is a very difficult exercise that would require many assumptions. For example, household consumption includes many different types of goods and services that are produced by many different industries. While household consumption data is disaggregated by type of consumption (e.g. motor vehicles, food, electricity), it is not disaggregated by the industries that produce these final goods and services and therefore our methodology would require us to make assumptions about what industries produce these final goods and services. For example, a proportion of motor vehicles consumption would be produced by the domestic machinery & equipment manufacturing sector, a proportion would be imported, and a proportion would be accounted for by a wholesale and retail trade margin. Estimating these 'proportions' for every type of household consumption (and more broadly for every component of final demand) in each year would be beyond the scope of this paper and the potential for error would be large given the number of assumptions required.

To simplify this process, we construct a GVA requirements matrix that contains the nine resource extraction sub-industries along with a broadly defined 'non-resource' sector capturing the other 102 sub-industries in the I-O tables. We then allocate all remaining final demand not already attributed to our resource

18 Up until this point, if we had repeated our methodology for every industry in the economy and then aggregated across all industries, our estimate of total GVA would have been equal (or very close to) GVA published by the ABS. However, this will not be the case when we make an adjustment for the GVA generated by intermediate sales to other industries; in this case, total GVA would exceed that published by the ABS because the GVA generated from intermediate sales would be double counted. The reason why we include the GVA generated from intermediate sales is because we want to capture 100 per cent of resource extraction GVA and employment in our measure of the resource economy. In Section 3.2 we consider a measure of the resource economy that excludes intermediate sales from the resource extraction sector to other industries.

economy to this non-resource sector.[19] By multiplying this final demand by the 10x10 GVA requirements matrix we get an estimate of how much GVA is generated by the resource extraction sector as a result of domestic demand for intermediate resource inputs.[20]

The GVA generated from these intermediate sales is then added to the GVA generated from final demand for resource extraction and resource investment to derive our measure of the GVA of the resource economy. The GVA of the non-resource economy is then calculated as the residual from total industry GVA. Thus, the sum of the value added of the resource and non-resource economies is equal to the total value of all goods and services produced in the economy (i.e. GDP in basic prices).

3. Results

This section presents the key results. First, we document the extent to which the broader resource economy is larger than traditional estimates of the mining industry due to the inclusion of resource-related activity. Second, we examine the industry composition of resource-related activity. Third, we show that growth in the resource and non-resource parts of the economy has been very different over the course of the 2000s. And finally, we present a narrower definition of the resource economy that includes only those sub-industries of the resource extraction sector that have been most heavily exposed to external demand conditions and the associated boom in resource export prices and investment.

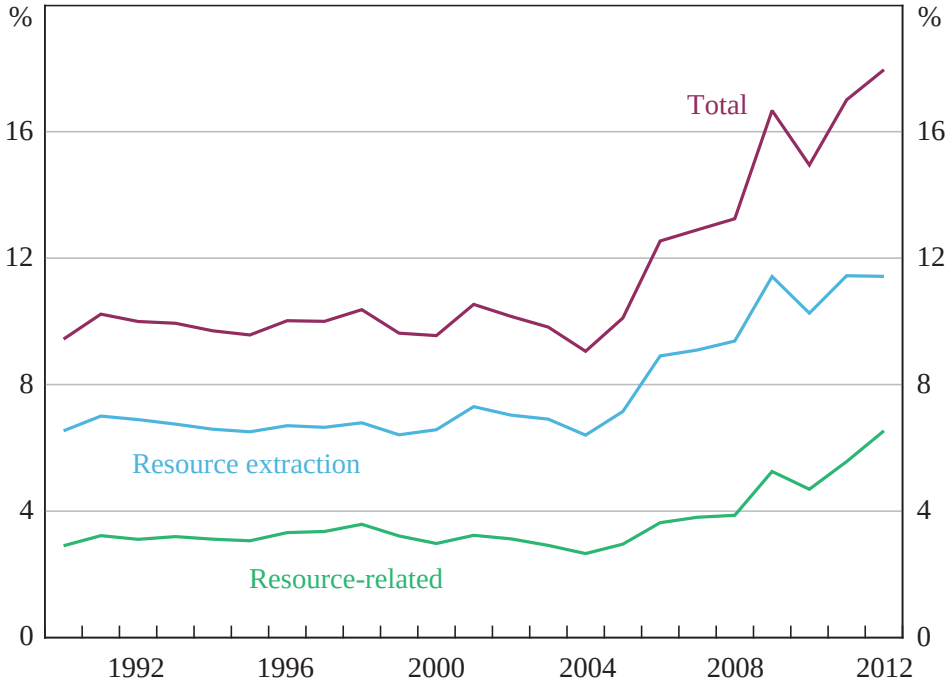
19 The final demand for the output of the non-resource economy is calculated by subtracting final demand for resource extraction and investment (in basic prices) from GDP in basic prices.

20 The limitation of having to aggregate non-resource final demand is that the GVA multipliers will be an average over all industries in the non-resource sector, which contains less information than separating out all industries and having a GVA multiplier for each. This would be a concern if, for example, particular industries in the non-resource economy started to use resource inputs more or less intensively over time relative to other industries in the non-resource economy. This does not appear to be a first order problem since our estimates of total mining GVA, using the method described in Section 2.6, are close to those published by the ABS (see Section 4).

3.1 Size and Composition of the Resource Economy

We estimate that the resource economy accounted for around 18 per cent of nominal GVA in 2011/12, around double its share of the economy in 2003/04 (Figure 6). This reflects an increase in both resource extraction and resource-related activity.

Figure 6: GVA – Resource Economy
Share of nominal GVA, financial year



Sources: ABS; authors' calculations

Our estimate of the size of the resource economy is larger than the measure presented in RBA (2011a). The difference between the two measures (which is around 1¾ per cent of GDP in 2011/12) can be attributed to our inclusion of intermediate sales (as described in Section 2.6) and domestic final demand for

resource output, although this is partly offset by subtracting resource imports and imported intermediate inputs used in resource extraction.[21]

Resource extraction is estimated to have accounted for around two-thirds of the value of the resource economy in 2011/12 (11½ per cent of GVA; Figure 6 and Table 4). This includes the extraction of the resources themselves (the 'mining' industry as it is referred to by the ABS) – 9¾ per cent of GVA – and also the processing and refinement of those resources – 1¾ per cent of GVA. The large rise in resource extraction as a share of nominal GVA largely reflects higher export prices for resource commodities over the past decade; as a share of *real* GVA, resource extraction has been broadly unchanged, with strong growth in iron ore production having been offset by a sharp fall in oil production and falls in the production of other ores (which include bauxite, copper, gold, lead, nickel and zinc), as discussed in Section 2.5.

21 Our estimate of the size of the resource economy is within the range of estimates published by the Australian Treasury (15–20 per cent over the forecast horizon) in the May 2012 Budget (Australian Government 2012) and in Gruen (2011). Our estimate is a little smaller than in Shann (2012); Shann estimates that the mining and mining-related sectors accounted for 19½ per cent of GDP in 2010/11, whereas our measure suggests these sectors accounted for 17 per cent of GDP in 2010/11. Shann makes adjustments to include mining services investment and exports in the scope of the 'mining-related sector'. We do not make this adjustment for investment, as we have already captured most of this activity in our measure of resource investment, and hence would be double-counting. Likewise, we do not make Shann's adjustment for exports of mining services as these exports are not separately identified in ABS data and estimates of their size vary widely.

Table 4: Industry Composition of the Resource Economy
Estimated share of nominal GVA, per cent – 2011/12

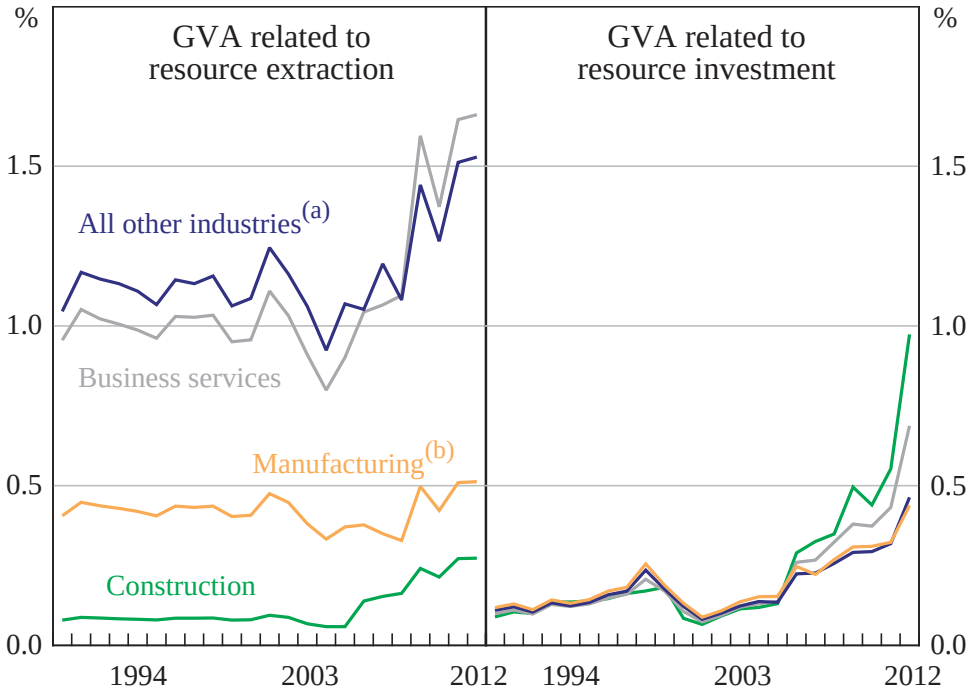
Resource economy	**18**
of which:	
Resource extraction	**11½**
Resource-related activity	**6½**
of which:	
Business services	2¼
Construction	1¼
Manufacturing	1
Transport, postal & warehousing	¾
Wholesale trade	½
Electricity, gas, water & waste services	¼
Other	½

Sources: ABS; authors' calculations

The most important contribution of our methodology is to estimate resource-related activity and to decompose this activity by industry. As the resource boom has gathered pace, resource-related activity has picked up sharply, rising from an estimated 3 per cent of GVA in the early 2000s to around 6½ per cent in 2011/12. The largest contributions to resource-related activity in 2011/12 came from the business services, construction, manufacturing, transport, and wholesale trade industries (Table 4 and Figure 7).[22] While construction and transport have obvious connections to the resource sector, business services (for example, engineering, legal and accounting services) account for a larger share of resource-related activity. As shown in Figure 7, business services are key inputs to both resource extraction and resource investment. In part, the relatively small share of construction reflects the fact that the construction industry itself draws on a relatively high share of intermediate inputs from other industries, and that a large share of resource-related construction investment is imported. However, consistent with the significant increase in resource investment since the mid 2000s, resource-related construction has increased sharply as a share of nominal GVA.

22 A finer disaggregation of the resource economy by industry can be found in Appendix C.

Figure 7: GVA – Resource-related
Share of nominal GVA, financial year



Notes: (a) Includes agriculture, forestry & fishing; electricity, gas, water & waste services; wholesale trade; retail trade; transport, postal & warehousing and household services

(b) Excludes resource-specific manufacturing

Sources: ABS; authors' calculations

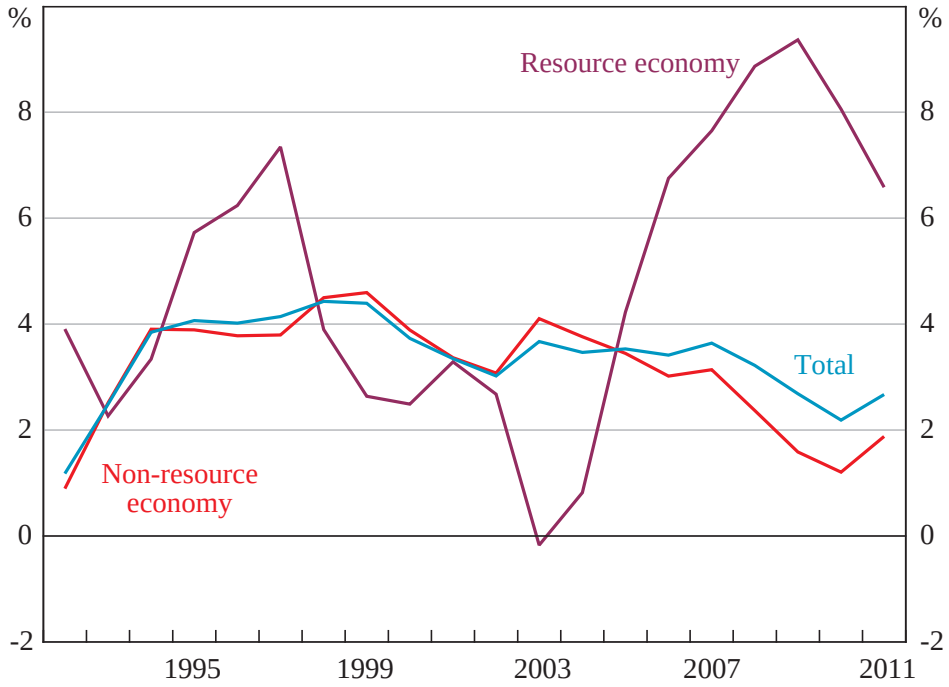
One key driver of the increase in the nominal share of the resource economy has been higher prices for resource exports (relative to other prices). To abstract from changes in relative prices, we construct a measure of real GVA of the resource economy by deflating nominal GVA by industry-specific implicit price deflators, and then aggregating across industries.[23] Over recent years, the resource economy has, in real terms, grown much faster than the non-resource economy (Figure 8).

23 Implicit price deflators (IPDs) for GVA are published annually in the *Australian System of National Accounts* (ABS Cat No 5204.0). The ABS publishes these IPDs at the broadest industry level (i.e. the industry 'division'). In instances where we have used a more disaggregated industry definition, such as with the manufacturing industry, we deflate all sub-divisions by the aggregate IPD for that industry. To account for compositional change in output over time, we sum the chain volumes using an appropriate chain-volume aggregation method. The 'implied' price deflator for the resource economy using this approach is not strongly correlated with the relevant final price deflator from the expenditure side of the national accounts (i.e. the weighted average of the IPDs for resource exports and investment). The reason for this difference is difficult to identify, and could reflect measurement errors in our approach or in the published expenditure IPDs, or both.

Since 2004/05, the resource economy has averaged 7½ per cent growth per year, while the non-resource economy has averaged 2¼ per cent growth. This difference largely reflects very strong growth of 16 per cent per year in resource-related activity, whereas to date, resource extraction has expanded only a little faster in real terms than the non-resource economy.

Figure 8: Growth in Real GVA

Three-year-centred moving average, financial year



Sources: ABS; authors' calculations

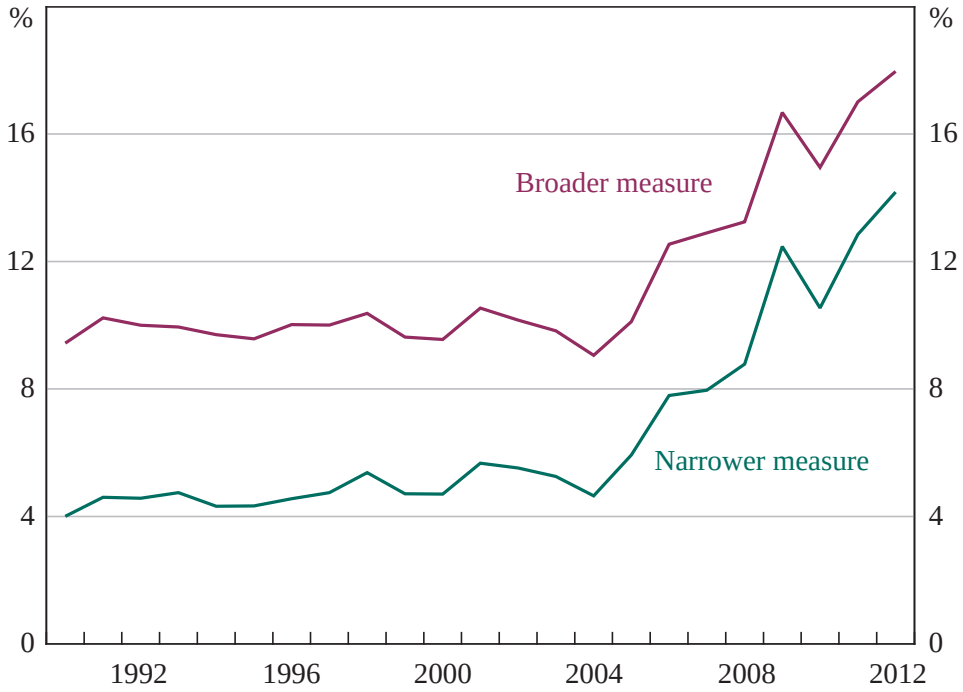
3.2 A Narrower Definition of the Resource Economy

Given that a strong rise in external demand, particularly from emerging Asia, has been the key driver of the recent resource boom, it is useful to consider a narrower definition of the resource economy that excludes the parts of the resource economy that have not directly benefited from this increase in external demand and the associated boom in resource export prices and investment.

In our narrower measure we exclude resource-specific manufacturing from our measure of final demand, as well as intermediate and final sales of any resources to the domestic economy. This leaves us with a measure of the resource economy that includes only resource exports (excluding resource-specific manufactured exports) and resource investment, less any intermediate and capital imports. We make the

simplifying assumption that all resource investment is undertaken to increase future resource exports, not domestic sales, so all resource investment is included in our narrower measure. Under this narrower definition, the size of the resource economy accounted for 14¼ per cent of GVA in 2011/12, compared to 18 per cent for the broader definition. The average rate of growth for the narrower definition has been faster than the broader measure, reflecting the divergence in growth patterns between external and domestic demand (Figure 9).

Figure 9: GVA – Resource Economy
Share of nominal GVA, financial year



Sources: ABS; authors' calculations

4. Key Assumptions

There are a number of important assumptions underlying our results in Section 3. In what follows, we examine the validity of some of these assumptions.

As noted in Section 2, the I-O tables are not available for all years in our sample. For the years in which I-O tables are not published, we assume that every $1 of industry output requires the same value and industry composition of inputs as that implied from I-O tables that are close to the year in question. For example, we use an average of 2001/02 and 2004/05 GVA requirements matrices to transform final

demand into industry GVA in 2002/03 and 2003/04 (when I-O tables were not published). For this assumption to be valid, we would need to observe very little change in relative prices in the years in which we do not have I-O tables, no changes in production technology, and no constraints on the availability of inputs.

The relative price that is of particular importance for our analysis is the price of resource output relative to the price of its inputs. Figure 10 shows a proxy for this relative price over our sample period, calculated as the ratio of a resource export price deflator to a weighted input price deflator for the resource extraction sector.[24]

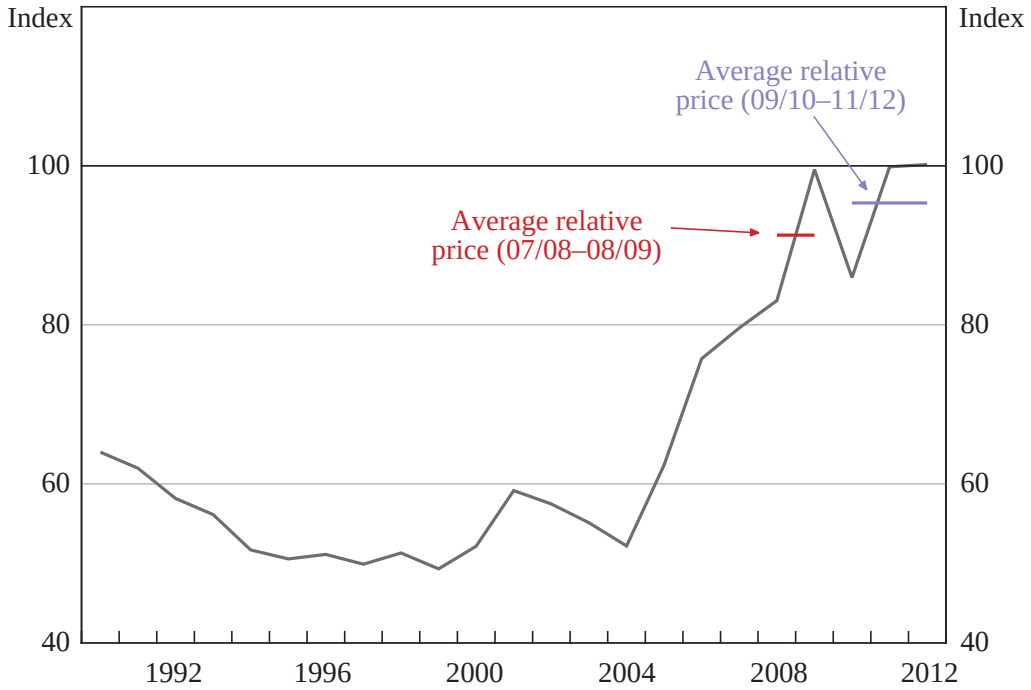
Fortunately, over the period where we observe a significant increase in the relative price of resource output to its inputs (from 2004/05 to 2008/09), we have annual I-O tables so we can take reasonable account of any changes in the structure of the economy in these years. In the 1990s (where we use the 2001/02 I-O tables to transform final demand into GVA), there is some variation in relative prices, but nothing like that experienced through the 2000s. Also reassuringly, beyond 2008/09 (where we use an average of the 2007/08 and 2008/09 I-O tables to transform final demand into GVA), the average relative price is reasonably close to

24 The resource export price deflator is calculated as the ratio of resource export values to resource export volumes, where resource exports are comprised of the following categories from the ABS' 'Balance of Payments and International Investment Position, Australia' release (ABS Cat No 5302.0): metal ores & minerals; coal, coke & briquettes; other mineral fuels; metals; and non-monetary gold. To calculate the weighted input price deflator, we follow the methodology used in D'Arcy, Norman and Shan (2012). First, IPDs – measured as the ratio of gross value added in current prices and chain volumes – are calculated for each industry. Second, these deflators are weighted according to each industry's contribution to total use of domestic intermediate inputs by the resource extraction sector. Third, this domestic input price index is combined with a goods import price deflator, with the two series weighted according to the relative share of domestic and imported inputs used by the resource extraction sector. One alternative method for calculating the weighted input price deflator is to use implied deflators from the ABS' 'Business Indicators, Australia' (ABS Cat No 5676.0). This release has data on income from sales by industry in both current prices and chain volumes. Using the IPDs from 'Business Indicators' gives a similar result to that presented in Figure 10.

the average of 2007/08 and 2008/09.[25] However, there is some volatility in the relative price from year to year (reflecting changes in resource export prices); as a result, we chose to smooth through some of the resulting volatility in our estimates by calculating the average growth rate over a run of years rather than focusing on the rate of growth in any single year. For example, in Figure 8 we presented the three-year-centred moving average of the annual growth in our estimates of the resource economy.

Figure 10: Relative Price of Resource Extraction Outputs to Inputs

2010/11 = 100, financial year



Sources: ABS; RBA

Another way of testing whether the I-O approach is providing estimates of GVA that are not biased by relative price changes, technology changes and/or capacity constraints is to compare our estimates to industry GVA data published by the

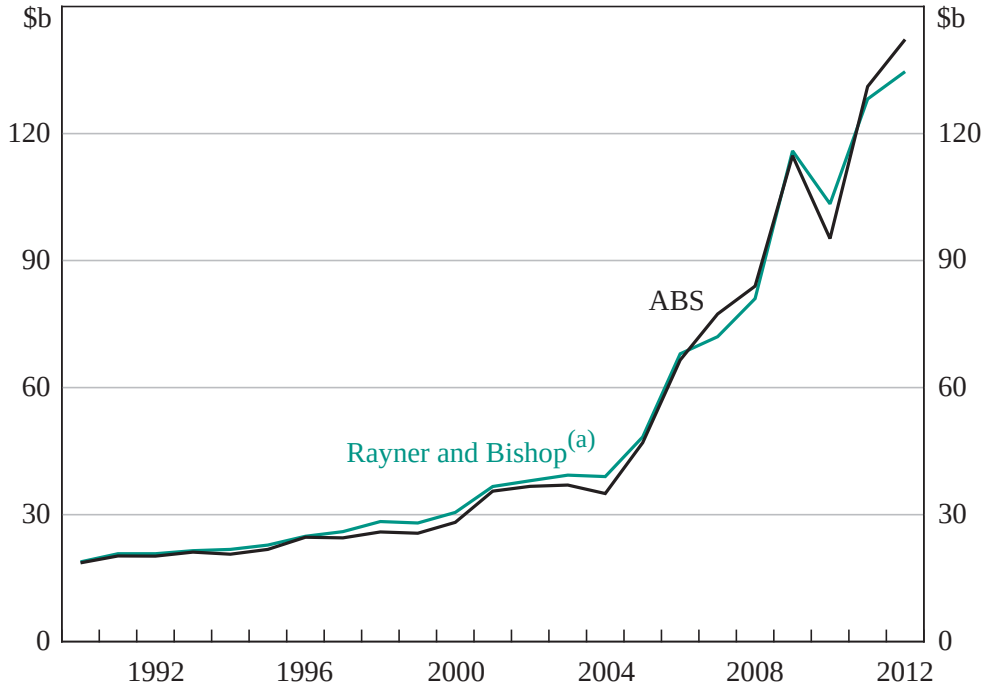
25 We average over the 2007/08 and 2008/09 tables because the structure of the economy in 2008/09 may not be representative of future years, given that Australia experienced a significant fall in its terms of trade and slowdown in GDP growth in 2008/09 as a result of the global financial crisis. As Figure 10 shows, the average of the I-O tables in 2007/08 and 2008/09 is likely to provide a better representation of the nominal input-output structure of the economy than if we use either of the individual tables. Our results are qualitatively unchanged if we only use GVA requirements from 2008/09 to transform final demand data from 2009/10 onwards.

ABS. For instance, if the model has correctly captured the relationships between industries in the economy, then we would expect to see only a small difference between mining GVA published by the ABS and our estimates.

We find that the mining industry GVA estimates implied by our model – in other words, resource extraction excluding resource-specific manufacturing – are generally close to those published by the ABS (Figure 11). The largest discrepancy occurs in 2009/10, where our estimate of mining GVA is $8 billion (or 0.7 per cent of total GVA) higher than that published by the ABS. More recently, our estimate of mining GVA in 2011/12 was around $7½ billion lower than that published by the ABS (or around 0.5 per cent of total GVA).

Figure 11: GVA – Mining Industry

Nominal, financial year



Note: (a) Resource extraction less resource-specific manufacturing

Sources: ABS; authors' calculations

There are several possible explanations for the discrepancies presented in Figure 11. First, the relationships embedded in the 2007/08 and 2008/09 I-O tables may not accurately capture the structure of the economy in the years beyond 2008/09. If this is the case, our estimates of mining GVA could be revised once we incorporate the I-O tables for these later years. Another potential source of error is the measurement and allocation of final demand to industries. It is difficult to

achieve a perfect concordance between final demand data and the ABS's Input-Output Industry Groups given the level of disaggregation available in the published data, and without detailed knowledge of the various adjustments made by the ABS (some of which are confidential).

5. Employment in the Resource Economy

One of the advantages of decomposing the resource economy by industry is that it gives us a framework for estimating the amount of labour that is involved, either directly or indirectly, in servicing demand for Australia's natural resources. While the resource extraction sector itself is a relatively small employer, industries involved in resource-related activity tend to use more labour.

To estimate employment in the resource economy, we calculate the share of each industry's GVA that is generated by final demand for resource extraction and investment in a particular year and then multiply it by the number of workers employed in that industry in that year. For example, in 2011/12, we estimate that 9 per cent of the business services industry's GVA was linked to the resource economy, so we allocate 9 per cent of business services employment in 2011/12 (or 210 000 workers) to resource-related employment.

The assumption underlying these calculations is that the productivity of a worker *who works in a particular industry* will be the same if they supply their labour to the resource or non-resource economies. In other words, a $1 million increase in business services GVA will require the same number of workers no matter whether this additional activity is the result of an increase in demand from the resource or non-resource parts of the economy. This assumption is difficult to verify with the data we have available, although it seems reasonable for most industries. One possible exception is the construction industry, where the labour productivity of a worker employed in resource-related construction may be higher than that for a worker employed in residential construction, given the relatively capital intensive nature of resource-related construction.

Based on this simple productivity assumption, Table 5 shows our estimates for employment in the resource economy in 2011/12. We estimate that 9¾ per cent of total employment in 2011/12 was engaged in servicing final demand for resource extraction and investment. Of this, resource extraction employment directly

accounted for around one-third (3¼ percentage points). Our measure of resource extraction employment is close to the ABS' definition of mining employment (which accounted for 2¼ per cent of total employment in 2011/12); the reason why our measure of resource extraction employment is higher than the ABS' definition is because we include resource-specific manufacturing in the resource extraction sector. The remaining 6¾ per cent of total employment in the resource economy comes from the various resource-related industries, such as business services, construction, and manufacturing, which are significantly more labour intensive than resource extraction.

Table 5: Industry Composition of Resource Economy Employment
2011/12, per cent

	Share of industry GVA linked to the resource economy (A)	Industry share of total employment (B)	Resource economy employment (share of total employment)[(a)] = (A) * (B) / 100
Resource extraction	**100**	**3¼**	**3¼**
Other industries	**7½**	**96¾**	**6¾**
Business services	9	20¾	1¾
Construction	16	9	1½
Manufacturing[(b)]	16	7½	1¼
Transport, postal & warehousing	15¼	5	¾
Household services	1½	36¼	½
Wholesale trade	9¼	3½	¼
Retail trade	2½	10¾	¼
Agriculture, forestry & fishing	5¾	3	¼
Electricity, gas, water & waste services	9	1¼	0
Resource economy	–	–	**9¾**

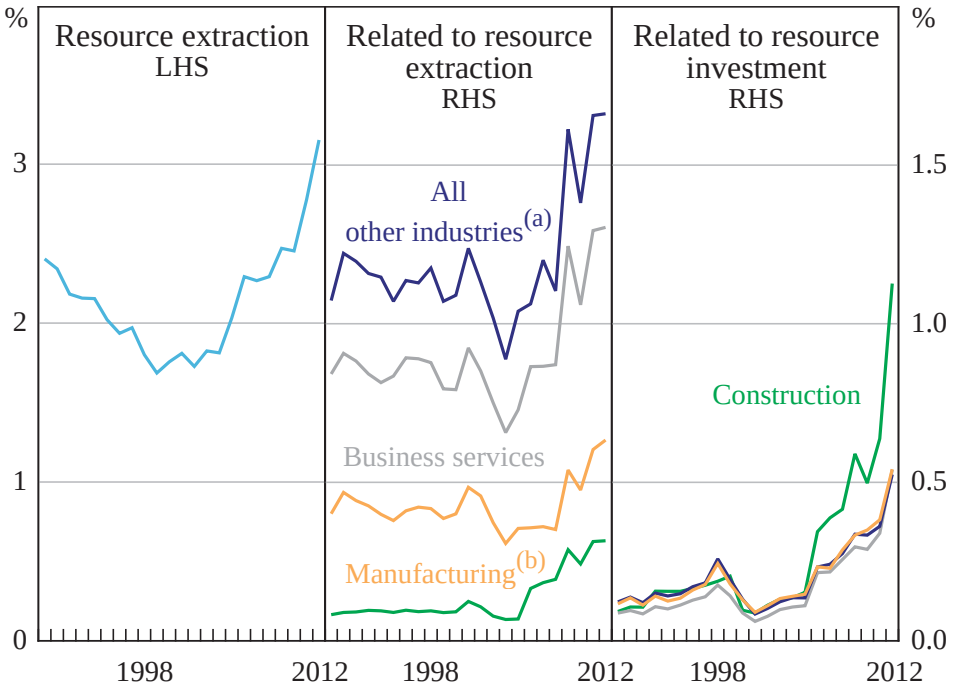
Notes: (a) The aggregate of 'Resource extraction' and 'Other industries' employment – as a share of total employment – does not equal the share of employment in the 'Resource economy' due to rounding
(b) Manufacturing industry excludes resource-specific manufacturing
Sources: ABS; authors' calculations

The share of total employment accounted for by the resource economy is estimated to have doubled since the mid 2000s. Around two-fifths of this growth reflects the expansion in resource investment, which has increased demand for labour in

resource-related construction and other industries that provide inputs to these investment projects (such as some types of machinery manufacturing and engineering services; right-hand panel of Figure 12). The share of workers employed in the resource extraction sector has accounted for only one-quarter of the overall increase in the resource economy's share of employment since 2004/05 (left-hand panel of Figure 12), while the remainder is due to an increase in employment in industries that service the operations of mines (such as transport of output from the mine site to ports, business services and power generation; middle panel of Figure 12). Once the peak in resource investment has passed and the resource boom enters its production phase, the share of labour employed in the more labour-intensive resource-related industries is likely to decline and the share employed in the less labour-intensive resource extraction sector is likely to rise further.

Figure 12: Resource Employment by Industry

Share of total employment, financial year



Notes: (a) Includes agriculture, forestry & fishing; electricity, gas, water & waste services; wholesale trade; retail trade; transport, postal & warehousing and household services

(b) Excludes resource-specific manufacturing

Sources: ABS; authors' calculations

6. Conclusion

The large and persistent rise in Australia's terms of trade and the associated boom in resource investment has had very different implications for growth in the resource and non-resource parts of the economy. However, it is not only the resource extraction sector that has benefited from the change in relative prices and surge in investment, but also industries that provide inputs to resource extraction and investment.

The contribution of this paper has been to estimate the size, growth rate and industry composition of a broad measure of the resource economy that includes both resource extraction and resource-related activity. Underpinning our approach are the input-output tables published by the ABS, which enable us to trace the effects of higher demand in the resource extraction sector through to the value added of the industries that provide the inputs necessary for this demand to be met. In this way, we can analyse the impact of this increase in extraction and investment not only on the resource extraction sector itself, but also on other sectors of the economy.

Under certain assumptions for relative prices, the spillovers from the resource sector to activity in other industries appear to be large. In terms of its contribution to aggregate economic activity, the resource economy – broadly defined – accounted for around 18 per cent of GVA in 2011/12. Of this, resource-related activity accounted for about one-third (6½ per cent of GVA), which includes activities as diverse as business services, construction, transport, and manufacturing. The remaining two-thirds of the resource economy was accounted for by the resource extraction sector itself (which also includes some processing of resources).

These estimates have implications for how we view employment in the resource economy. Under certain productivity assumptions, we find that the resource economy accounted for around 9¾ per cent of employment in 2011/12. This is around three times larger than the workforce employed in resource extraction, and reflects the employment generated by resource-related activities as a result of the extraction of the resources themselves and investment in new capacity. These

resource-related industries have also provided the largest contribution to growth in resource employment since the mid 2000s.

Appendix A: Industry Concordances

Table A1 provides a concordance between the ABS's Australian Input-Output Industry Groups and the industry definitions used in this paper.

Table A1: Industry Definitions

Industry	Australian Input-Output Industry Group (IOIG)[(a)]
Resource extraction	
Coal mining	0601
Oil & gas extraction	0701
Iron ore mining	0801
Non-ferrous metal ore mining	0802
Non-metallic mineral mining & quarrying	0901
Exploration & other mining support services	1001
Iron & steel manufacturing	2101
Petroleum & coal product manufacturing	1701
Basic non-ferrous metal manufacturing	2102
Other industries	
Agriculture, forestry & fishing	0101–0501
Residential building construction	3001, ⅓ of 3201
Non-residential building construction	3002, ⅓ of 3201
Heavy & civil engineering construction	3101, ⅓ of 3201
Machinery & equipment manufacturing	2301–2405
Other manufacturing	1101–1601, 1801–2005, 2201–2204, 2501–2502
Electricity, gas, waste & water services	2601–2901
Wholesale trade	3301
Retail trade	3901
Transport, postal & warehousing	4601–5201
Business services	5401–6601, 6702–7201, ½ of 9401–9502
Household services	4401–4501, 7501–9201, ½ of 9401–9502
Ownership of dwellings	6701

Notes: (a) IOIG codes are on an ANZSIC06 basis; IOIG codes for ANZSIC93 are available from the authors on request

Sources: ABS; authors' calculations

Appendix B: Final Demand Data

This Appendix describes how we construct the sub-industry level data for final demand related to the output of the resource extraction sector. The construction of the data related to the final demand for resource investment is described in Section 2.5. All data are valued in basic prices (i.e. excluding trade and transport margins, and taxes less subsidies on products).

Household consumption: Data on household demand for the output of the resource extraction sector are provided in I-O tables. Most of this represents demand for refined petroleum, including automotive fuels such as petrol, diesel and liquefied petroleum gas. To estimate the demand for refined petroleum in years for which an I-O table is not available, we interpolate and extrapolate the series using unpublished ABS data for motoring fuel consumption (ABS Cat No 5206.0).

Household final demand for oil and gas (e.g. mains gas at residential dwellings) is also measured using data from I-O tables and interpolated and extrapolated using ABS data on household consumption of electricity, gas and other fuels (ABS Cat No 5206.0). Other components of household consumption are calculated using the data from I-O tables, and are interpolated and extrapolated using total household consumption.

Private investment: Mining investment data (by type of asset) are published in the *Australian System of National Accounts* (ABS Cat No 5204.0). We allocate all the mining investment in mineral & petroleum exploration to the exploration & other mining support services sub-industry. The remaining components of mining investment (i.e. research & development and computer software investment) are allocated to each sub-industry of mining based on the shares given in I-O tables. Investment related to the output of the sub-industries of resource-specific manufacturing is taken from I-O tables, and extrapolated and interpolated using total private investment.

Note that investment related to the output of the resource extraction sector is different to the investment associated with expanding and updating capacity in the sector, such as resource-related construction and machinery & equipment investment (see footnote 9).

Public demand: Public demand for the output of the resource extraction sector is constructed by interpolating and extrapolating the data in I-O tables by growth in total public demand.

Changes in inventories: We assume there are no changes in resource extraction inventories from year-to-year. While data on mining inventories are published in the national accounts, these data are prone to substantial revision, so the current vintage of data bears little resemblance to the changes in mining inventories published in historical I-O tables.

Exports and imports: To provide a fine level of disaggregation of exports and imports we use detailed data from the 'International Trade in Goods and Services, Australia' (ITGS) release (ABS Cat No 5368.0). The ITGS release provides trade data at the 3-digit Standard International Trade Classification (SITC) level, which is the minimum level of disaggregation required to individually identify the exports and imports of the nine resource extraction sub-industries used in this paper.[26]

We map the Input-Output Industry Groups to the Australia and New Zealand Standard Industrial Classifications 2006 (ANZSIC06) using concordance tables published by the ABS. The 3-digit SITC codes are then mapped to the ANZSIC06 groups using a concordance table that was provided by the ABS on request. By doing this, we are allocating exports to the industry that performed the final activity required to complete the extraction or processing of the commodity in question. Imports are allocated to the industry that is most likely to have produced goods equivalent to those imported. These allocations are listed in Table B1.

We make further adjustments to the ITGS data to improve their consistency with I-O tables. First, since the exports data in the I-O tables are measured in basic prices, we need to adjust the ITGS exports data – which are valued in purchasers' prices – for trade and transport margins. This adjustment is based on the detailed data on margins provided in the I-O tables, or the average of nearby tables for years in which no tables are available. We then allocate these margins to the industry that provided the service, which is primarily the transportation industry, and to a lesser extent, the wholesale and retail trade industries.

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26 The ITGS release also provides trade data at the ANZSIC industry level, however in some cases these data are not provided at a disaggregated enough level for our purposes.

Second, we re-classify imports of non-monetary gold from the manufacturing sector to the mining sector. This reflects the role of the Perth Mint, which is accredited by the London Bullion Market Association in refining gold for global markets; gold is imported into Australia as gold ore, refined, and exported as a manufactured product.[27] Following the ABS, all exports of gold are treated as a manufactured export (allocated to the basic non-ferrous metal manufacturing industry).

Third, we subtract goods procured in ports by carriers (i.e. ship and aircraft stores) from exports and imports of refined petroleum products in ITGS. These data are sourced from the 'Balance of Payments and International Investment Position, Australia' release (ABS Cat No 5302.0).

Table B1: Assignment of SITC Codes to Industries

Industry	SITC codes (3-digit)
Coal mining	321, 322
Oil & gas extraction	333, 342, 343, 344, 345
Iron ore mining	281
Non-ferrous metal ore mining	Note (a)
Non-metallic mineral mining & quarrying	272, 273, 274, 277, 278
Exploration & other mining support services	na
Iron & steel manufacturing	282, 671, 672, 673, 674, 675, 676, 677, 678, 679
Petroleum & coal product manufacturing	325, 334, 335
Basic non-ferrous metal manufacturing	Note (b)

Notes: (a) Non-ferrous metal ore mining is calculated as the difference between total metal ore mining (provided on an ANSZIC basis in ITGS) and iron ore mining. Imports of non-ferrous metal ore mining also include non-monetary gold.
(b) Basic non-ferrous metal manufacturing is calculated by subtracting non-ferrous metal ore mining from the sum of the following SITC codes: 280, 283, 284, 285, 286, 287, 288, 289, 681, 682, 683, 684, 685, 686, 687, 689 (and non-monetary gold in the case of exports).

Sources: ABS; authors' calculations

27 We use the Balance of Payments and International Investment Position data for non-monetary gold exports and imports in place of the SITC codes 951 and 971 due to various confidential adjustments made to the former series by the ABS.

Appendix C: Industry Composition of the Resource Economy

Table C1: Industry Composition of Resource Economy
Nominal, per cent – 2011/12

Industry	Estimated share of GVA
Resource economy	**18**
Of which:	
Resource extraction	**11½**
Coal mining	2½
Oil & gas extraction	2½
Iron ore mining	2½
Non-ferrous metal ore mining	1½
Exploration & other mining support services	¾
Non-metallic mineral mining & quarrying	0
Basic non-ferrous metal manufacturing	¾
Iron & steel manufacturing	½
Petroleum & coal product manufacturing	½
Resource-related activity	**6½**
Business services	2¼
Construction[(a)]	1¼
Transport, postal & warehousing	¾
Wholesale trade	½
Machinery & equipment manufacturing	½
Other manufacturing	½
Electricity, gas, water & waste services	¼
Agriculture, forestry & fishing	¼
Household services	¼
Retail trade	0
Ownership of dwellings	0

Note: (a) The aggregate of residential building, non-residential building and heavy & civil engineering construction

Sources: ABS; authors' calculations

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