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How different is mining from mineral processing? A general equilibrium analysis of new resources projects in Western Australia†

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Western Australia has experienced an investment surge in the minerals sector of the economy in recent years. Unlike previous surges, this one involves a large proportion of mineral-processing projects. In this study, the differential effects on the WA economy of 25 mining and 10 mineral-processing projects are analysed using an economy-wide model of WA. The results indicate that: (i) both the mining and mineral-processing projects will have substantial flow-on benefits to the WA economy as a whole; (ii) on an A$1-million-invested basis, mineral processing has larger flow-on effects on employment and generates more export revenue than does mining once the projects are operational.

1. Introduction

The WA economy is heavily dependent on the mining and mineral-processing sector — in the early 1990s, this sector accounted for more than a fifth of gross state product, about 70 per cent of the state's international exports, and more than half of the total private investment undertaken in WA. In recent years, Western Australia has experienced a surge in investment in resources projects. In 1994–95, the mining and mineral-processing sector of WA invested A$4 billion, or about 60 per cent of the state's total private investment. In the same year, 16 resource development projects valued at A$3.5 billion were commissioned, 38 projects worth A$5.8

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billion were under construction, 22 projects worth A$4.3 billion were committed, and another 51 projects worth A$12.2 billion were under consideration (WA Department of Resources Development 1995, p. 14).

Similar investment surges were experienced in the 1890s, the 1960s and again in the 1980s. These earlier periods of strong mineral industry growth in WA have been generally prompted by new discoveries and/or favourable changes in world commodity markets. With the exceptions of liquefied natural gas (LNG) production and some processing of nickel, mineral sands and alumina, these episodes of surges in resource development have involved minimal levels of processing. By contrast, the current resource development projects stem mainly from new opportunities for downstream processing provided by the deregulation of the state's energy markets and technological innovation, as well as East Asia's increasing demands for minerals and mineral products. Institutional reform has promoted competition among the alternative suppliers of energy and caused substantial reductions in gas prices. Cheaper gas in WA, together with rapid growth in the use of electric-arc furnaces for steel making in East Asia, which use scrap and direct-reduced iron as feedstock, have already led to the establishment of BHP's Direct-Reduced Iron plant in the Pilbara. Furthermore, several other companies are considering the possibility of iron-ore processing plants in the Pilbara. As mining and mineral processing are energy-intensive activities, cheaper energy leads to a significant improvement in the potential profitability of these industries. Consequently, many new mineral- and chemical-processing projects are now being investigated.

The recent investment surge seems to provide an opportunity for WA to develop and strengthen its mineral processing industry. For a long time, the state government adopted favourable policies towards processing activities. Although government policies have long favoured processing over mining, the popular justification of such policies seems to come solely from the fact that mineral processing can produce more value added. On the other hand, there are some sceptics concerning such policies. For example, Fitzgibbons (1978) writes that 'the actual significance of mineral processing for economic growth has been insignificant' (p. 37). These views indicate some of the controversy surrounding developments in the minerals industry.

In this article, I analyse the effects of these new resource projects on the WA economy, paying particular attention to the important distinction between mining and mineral processing. This distinction involves a number of fundamental questions. Processing is usually considered to be more capital-intensive and involves more high-technology than mining. Is this true? Although mineral processing entails more value added, does it deliver more value to shareholders? Once the flow-on effects are taken into account, do processing activities generate more employment per dollar invested in the projects? What about exports — do mineral-processing projects generate more export earnings than do traditional mining projects?

I analyse some of the above issues by quantifying the effects of 35 new resources projects using a newly-developed computable general equilibrium (CGE) model of the WA economy. The article is organised as follows: in section 2, the main features of the mining and mineral-processing projects are identified. Section 3 deals with the Gregory Thesis and the absorption approach, which form the basis for much of the subsequent analysis. Section 4 gives details of how the simulations are carried out. Section 5 presents the macroeconomic effects. Later sections deal with the output and employment effects by industry, and concluding comments.

2. The projects

In this section I present data on a substantial number of mining and mineral-processing projects in WA which were either under construction or committed to proceed as at December 1995. Table 1 contains information on 25 mining projects and ten mineral-processing projects ranked in terms of decreasing cost. The classification is based on a project's function or its link with either mining or mineral processing. Where it is not obvious, more detailed reasons for the classification are given in the notes to the table. It can be seen from column 3 that the largest mining project is the North-West Shelf Participants' Wanaea/Cossack oil and gas project, which will cost A$760 million, while the largest mineral-processing project is BHP's DRI project, which will cost A$1.5 billion.[1] On average, the size of the mineral-processing projects is much larger than that of the mining projects. The total value of the 25 mining projects is A$3.3 billion, or A$133 million per project on average. By contrast, the corresponding figures for the ten mineral-processing projects are A$2.5 billion and A$246 million, respectively.

Columns 4 and 5 of table 1 contain estimates of direct employment in the construction period of each project. Total jobs created directly by the 25 mining projects is 6100, or 240 per project on average; the mineral-processing projects involve a total of 3300 jobs, or on average 330 per project. In terms of employment per dollar invested, column 5 of table 1 shows that each A$1 million invested in mining generates 2.7 direct jobs on average. As this figure is larger than that in mineral-processing projects, 2.0, mining projects are on average more labour-intensive in the construction phase than mineral processing projects.

[1] After this research was completed, press reports appeared stating that the cost of this project had increased by about A$1 billion; see, e.g., *The Australian Financial Review* (20–21 September 1997, p. 1).

Table 1 New mining and mineral-processing projects in WA

Project (1)	Company (2)	Cost of project ($ million) (3)	Employment in construction phase: Number of jobs (4)	Employment in construction phase: Number per $m invested (4)/(3) (5)	Construction period (years) (6)	Cost of project per year ($ million) (3)/(6) (7)
I. *Mining*						
1. Wanaea/Cossack, Oil and Gas	North-West Shelf Participants	760	1100	1.45	2	380
2. Wandoo, Oil	Ampolex & Partners (Wandoo Alliance)	610	1000	1.64	3	203
3. Goldfields Gas Pipeline	Goldfields Gas Transmission Joint Venture (GGTJV)	400	750	1.88	1	400
4. East Spar, Gas & Condensate	Western Mining Corporation & Partners	250	558	2.23	1	250
5. Beenup Mineral Sands Mine Development	BHP Titanium Minerals	175	200	1.14	2	88
6. Fimiston Gold Mine Upgrade	Kalgoorlie Consolidated Gold Mines	165	200	1.21	1	165
7. Kambalda Nickel Mine Expansion	Western Mining Corporation	105	180	1.71	1	105
8. Premier Mine, Collie, Coal	Western Collieries	100	174	1.74	1	100
9. Concrete Gravity Structure, Casting Basin Facility, Bunbury[1]	Ampolex & Partners (Wandoo Alliance)	89	162	1.82	1	89
10. Port Hedland Tunnel, Port Hedland[2]	BHP Iron Ore	85	45	0.53	1	85
11. Telfer Underground Gold Mine Extensions	Newcrest	76	75	0.99	3	25
12. Kanowna Belle Underground Gold Mine (Stage 3A)	Delta Gold & North Gold	74	50	0.68	5	15
13. Bronzewing Underground Gold Mine	Great Central Mines	64	300	4.69	1	64
14. Bounty Underground Gold Mine Expansion	Posgold & Forrestania	62	100	1.61	2	31
15. Ewington II Coal Mine, Collie	Griffith Coal Mining Company	55	123	2.23	1	55
16. Marillana Creek Iron Ore Expansion (Yandi 2)	BHP Iron Ore	50	300	6.00	1	50
17. Orebody 18, Iron Ore, Newman	BHP Iron Ore	50	200	4.00	1	50
18. Paddington Plant Expansion, Gold	Pancontinental Mining	36	101	2.80	1	36
19. Robe Iron Ore Project Augmentation	Robe River Iron Associates	33	97	2.95	1	33
20. Chalice Open Cut Gold Mine	Resolute Samantha & Partners	27	104	3.85	1	27
21. Gypsum	Dampier Salt-Lake Macleod Gypsum	25	50	2.00	1	25
22. Bullabulling Gold Open Cut	Resolute Samantha	16	88	5.50	1	16
23. Carr Boyd, Nickel	Defiance Mining	12	73	6.09	1	12
24. Kemerton Silica Sands[3]	Gwalia Consolidated & Partners	10	50	5.00	1	10
25. TT Sands, Mindijup, Mineral Sands	Tomen Australia & Tochu	4	12	3.00	1	4
Total		3333	6092	–	–	2318
Mean		133	244	2.67	1.4	93

II. *Mineral processing*						
26. Direct Reduced Iron Project, Port Hedland	BHP Minerals	1500	1400	0.93	2	750
27. Burrup Peninsula, Oil and Gas	Woodwide Petroleum and Partners	316	600	1.90	2	158
28. Oil Refinery Expansion, Kwinana	BP Refinery	200	400	2.00	4	50
29. Synthetic Rutile Plant Expansion, Capel	Westralian Sands	134	150	1.12	2	67
30. South Coogee Lime Kiln[4]	Cockburn Cement	76	250	3.29	2	38
31. Iron Ore Fines Processing Plant, Paraburdoo[5]	Hamersley Iron	68	150	2.21	1	68
32. Ammonium Nitrate/Nitric Acid, Kwinana[6]	Wesfarmers CSBP	60	150	2.50	1	60
33. Clinker Grinding and Lime Manufacturing Plant, Kwinana[7]	Swan Portland Cement	60	100	1.67	1	60
34. Pigment Plant De-Bottlenecking, Kwinana	Tiwest Joint Ventures	30	50	1.67	1	30
35. Sodium Cyanide Plant Expansion, Kwinana[8]	Wesfarmers CSBP & Partners	15	42	2.80	1	15
Total		2459	3292	–	–	1296
Mean		246	329	2.01	1.7	130
III. *Mining and Mineral processing*						
Grand total		5792	9384	–	–	3614
Grand mean		165	268	2.48	1.5	103

Sources: WA Department of Resources Development, *Prospect*, December 1995–February 1996, pp. 32–34 and the Economic Research Centre, the University of Western Australia.

Notes: 1. The Concrete Gravity Structure, Casting Basin Facility is to be used for the manufacturing of structuring components for the oil and gas sector which is included in Division B — Mining under the *Australian and New Zealand Standard Industrial Classification* (ANZSIC). Accordingly, this project is classified as mining.
2. The Port Hedland Tunnel is to be used for both shipping iron ore and HBI. To keep things simple, it is classified as mining.
3. The mining of silica sands is included in Division B — Mining under ANZSIC.
4. Lime manufacturing is included under Division C — Manufacturing, Subdivision 26 — Non-Metallic Mineral Product Manufacturing. The project ‘South Coogee Lime Kiln’ has therefore been included as a mineral-processing activity.
5. The Iron Ore Fines Processing Plant at Paraburdoo is classified as mineral processing as its function is to remove minus 10 micron material from the fine ore stream. Source: Mr A.J. Finucane, Hamersley Iron, personal communication, 1996.
6. Ammonium nitrate and nitric acid manufacture are included under Division C — Manufacturing Subdivision 25 — Petroleum, Coal, Chemical and Associated Product Manufacturing. The project ‘Ammonium Nitrate/Nitric Acid, Kwinana’ has therefore been classified as a mineral-processing activity.
7. For the same reason given above in Note 4, the project ‘Clinker Grinding and Lime Manufacturing Plant, Kwinana’ is classified as a mineral-processing activity.
8. As the raw materials for the project ‘Sodium Cyanide Plant Expansion, Kwinana’ are natural gas and salt, it is a mineral-processing activity

Column 6 of table 1 gives the estimated construction period of each project. The average for the mining projects is 1.4 years, while that for mineral processing is 1.7 years. Finally, note from column 7 of the table that, on an annual basis, the total value of mining projects is A$2.3 billion per annum, or on average A$93 million per project per annum. The corresponding figures for mineral processing are A$1.3 billion and A$130 million, respectively.

3. The economics of expanding sectors

This section sets out two ways of thinking about the general equilibrium effects of an expanding industry — the Gregory Thesis and the absorption approach. These form the basis for the subsequent analysis.

3.1 The Gregory Thesis

Clements, Ahammad and Ye (1996) point out that, as most of the output of the projects considered in the previous section will be exported, the export expansion is likely to put upward pressures on the exchange rate. An appreciation of the exchange rate would squeeze other exporters (i.e., exporters who are not part of the expanding sector), as well as firms in the import-competing sector. Thus, a large surge in new exports does not lead to an increase in total exports of the same amount. A similar effect could also occur during the period in which the projects are under construction; the additional economic activity puts upward pressures on costs in general. As the higher costs would have to be paid by all sectors, the profitability of other exporters and import-competing industries would be squeezed. These effects can be described as *an appreciation of the real exchange rate*, whereby the nominal exchange rate appreciates relative to costs. These effects are known as the 'Gregory Thesis' in Australia (Gregory 1976) and the 'Dutch disease' in Europe and elsewhere (*The Economist*, 26 November 1977, pp. 82–83).[2]

Before proceeding, it is worthwhile briefly noting that the experience of the Australian gold rushes in the 1850s seems to be consistent with the above theory. After gold was first discovered in New South Wales and Victoria in 1851, labour was attracted by the higher wages paid in the gold mining

[2] For the literature pertaining to Australia, see Corden (1982), Dornbusch and Fischer (1984), Gregory (1976), Helliwell (1984), Long (1983), Norman (1977), Snape (1977) and Stoeckel (1979). Dixon *et al.* (1978) provide an early CGE analysis of the effects of a mining boom in Australia. See also Choi (1988), Corden (1984), Corden and Neary (1982), Gelb *et al.* (1988) and Neary and Wijnbergen (1986).

sector: ‘people of all trades, callings and pursuits were quickly transformed into miners’ (The *Bathurst Free Press*, 1851, quoted by Doran 1984). In order to retain employees, wages in other industries had to rise and in 1859 average nominal wages were double those which had prevailed in 1850 (Cairnes 1859). The prices of other inputs also increased due to the enhanced level of economic activity. Given that the output prices of the non-expanding export industries and import-competing sectors were determined in the world markets, these cost pressures reduced their competitiveness and squeezed profitability. As a result, as observed by Maddock and McLean (1984), during the decade of the gold rushes, exports of wool (the dominant export industry since mid-century) grew at much reduced rates. Accompanying the gold rushes, imports increased substantially. Facing such a massive increase in imports and the associated cost pressures, the import-competing manufacturing sector was also adversely affected by the gold boom. By contrast, the nontradables or service industries generally benefited from expanded demand created by the gold rushes for their products since such demand cannot be satisfied by imports.

3.2 The absorption approach — a demand side perspective

The Gregory Thesis emphasises the role of relative prices in explaining the effects of an expanding sector, i.e., the upward cost pressures and/or appreciation of the nominal exchange rate caused by the expansion. These relative price effects squeeze other exporters and firms in the import-competing sector. While these effects could well occur at the national level, it is unlikely that they carry over with full force for an individual state such as WA. The reasons are (i) the exchange rate is determined by national, rather than state, economic conditions; and (ii) the most important component of costs, wages, is largely determined nationally, rather than at the state level. Accordingly, there is limited scope for the relative price effects to work at the state level. But the additional spending associated with an expanding sector will still have important general equilibrium effects at the state level. The underlying mechanism can be understood from the perspective of the ‘absorption approach’.

The absorption approach, initiated by Alexander (1952), is a theory of the balance of trade that emphasises the relationship between domestic spending and output. The balance of trade is viewed as the difference between what the economy produces and what it takes, or absorbs, for domestic use. According to the identity that total output is equal to total expenditure, we have

$$Y = C + I + G + (X - M), \tag{1}$$

where:

Y = total output
C = consumption
I = investment
G = government expenditure
X = exports
M = imports.

If we define absorption A as being equal to $C + I + G$ and net exports as $X - M$, equation 1 then can be written as $X - M = Y - A$, or

$$\text{trade balance} = Y - A. \quad (2)$$

Thus if domestic production exceeds absorption, then the economy will export the excess and run a balance-of-trade surplus. On the other hand, if absorption exceeds domestic production, then the excess of domestic demand over domestic production will be met through imports. For a given level of domestic production, there is a negative relationship between the trade balance and absorption — an increase in absorption will lead to a decrease in exports or an increase in imports, or any combination thereof. In the case of a substantial investment surge associated with an expanding sector, the perspective provided by the absorption approach indicates that exports would fall relative to imports.

In the previous literature on the effects of large investment projects in the resources sector, most of the focus is on the role of relative prices. Exchange-rate movements usually lead to crowding-out of the trade-exposed industries, i.e., the Gregory effects are highlighted. Though this is a very useful framework to study the effects of expanding sectors, as discussed before, it does not adequately capture the full story where there is only limited scope for changes in relative prices, such as a state in a federal system. In contrast to the Gregory Thesis, the absorption approach focuses on the relationship between net exports and domestic demand conditions and emphasises the spending effects from a demand perspective. Therefore, in a certain sense, the two approaches are complementary. Dixon, Horridge and Johnson (1992) and Dixon and Peter (1996) are leading examples where the two perspectives are combined.

Dixon *et al.* (1992) use the ORANI model to analyse the effects of establishing a Multifunction Polis (MFP) in Australia. Dixon and Peter (1996) apply the MMRF model[3] to simulate the effects of various packages

[3] The MMRF model is the MONASH Multi-Regional Forecasting model; see Naqvi and Peter (1996).

consisting of (i) an increase in South Australian (SA) manufacturing exports; (ii) an increase in SA professional service exports; and (iii) an increase in SA manufacturing productivity. In these two studies, movements in the exchange-rate and domestic absorption are both shown to be important channels in accounting for the changes in exports and imports and the gains and losses in sectoral/regional output and employment.

4. Application of WAM

In order to explore the impacts of the new projects on the WA economy, we use a regional CGE model, the Western Australian model (WAM for short). WAM captures the intersectoral linkages in some detail by identifying 42 broad sectors. All sectors are linked through production, employment, trade and consumption. At the core of WAM, there are (i) input demands and commodity supplies by industries; (ii) commodity demands and primary factor supplies by households; (iii) commodity demands by government; (iv) investment demand by industry; and (v) the external sector comprising imports into and exports from WA. WAM incorporates decisions made by producers and consumers, embodies government policies and recognises the constraints facing the economy. Like most CGE models, WAM assumes competitive markets and constant-returns-to-scale technology. The production structure in WAM is based on the assumption that the intermediate inputs are separable from each other, as well as from primary inputs. Household consumption demand is based on the assumption of preference independence. In WAM, there are two sources of supply, WA and non-WA which includes the rest of Australia and foreign countries. All goods are distinguished according to their origin of supply, WA and non-WA. Substitution takes place between imported (non-WA) and local inputs, as well as between labour and capital. The WAM database refers to the year 1989–90. For full details of WAM, see Clements *et al.* (1996) and Ye (1998). The WAM model described here was implemented and solved using GEMPACK (Harrison and Pearson, 1996).

Unlike the multi-regional CGE models such as the MMRF model (Naqvi and Peter, 1996) and FEDERAL (Madden 1995), WAM is a single-regional model. In WAM, the state of Western Australia is, in effect, viewed as being like a separate 'country', i.e., economically, it is separated from other states, as well as from the rest of the world. The combination of other states with the rest of world is perhaps a weakness of the current version of WAM. For example, as the same currency circulates in WA and the other Australian states, in effect the exchange rate is fixed among the states at a value of 1:1. By contrast, there are different currencies in other countries. However, since the WA investment boom is quite small in relation to Australia-wide investment or Australian GDP,[4] the variations in mining activity being analysed in this article are unlikely to have substantial impact on either the nominal exchange rate for Australia or real wages in WA. Accordingly, given the nature of the questions put to WAM, the lack of wage and exchange rate effects in the current version of WAM is not likely to substantially bias our simulation results in terms of being able to offer insights into the structural adjustments that the WA economy is likely to undergo as a consequence of the new investment in the minerals sector.

The WAM simulation is carried out under the assumption that the nominal exchange rate and nominal wages are both fixed. This amounts to assuming that the wage rate and exchange rate for WA are set by the rest of Australia, independently of developments in WA, which agrees with the way in which the Australian federal system works. Following Higgs and Powell (1992), we simulate the effects of new projects by distinguishing the *construction phase* from the *production phase* in a *typical year*.[5] In the construction phase each industry undertakes the appropriate amount of investment with its capital stock so created assumed not yet 'switched on' in the sense that the productive capacity of the industry is not yet enhanced. In the production phase the enhanced capital stock is assumed to be switched on so that the output of the industry in question expands. Although in reality these two phases overlap to a certain degree, for reasons of analytical simplicity in the simulations we shall keep the phases distinct. In the simulation, it is also assumed that, no matter what the ownership structure is, the new projects attract finance from non-WA sources. As a consequence, the trade balance will reflect the inflows of capital in the construction phase and subsequent outflows of interest, loan repayments and dividends in the production phase.

5. The macroeconomic effects

This section focuses on the macroeconomic effects, while the industry output and employment effects will be discussed in the next section. Table 2 gives the results for the main macro variables. Consider first the effects of the construction phase given in columns 3 and 4 of table 2. We see that in a typical year of the construction phase, the mining projects increase aggregate

[4] For example, in 1995–96, mining investment in WA was A$3,610 million, about 9.3 per cent of national investment (A$38,705 million) and 0.8 per cent of the national GDP (A$437,264 million) (Australian Bureau of Statistics 1998a and b).

[5] It should be noted that Clements *et al.* (1996) carry out a similar analysis of the effects of these projects, but without drawing the distinction between mining and mineral processing.

Table 2 Macroeconomic effects of new resource projects

Variable (1)	Base-year data (2)	Construction phase: Mining (3)	Construction phase: Mineral processing (4)	Construction phase: Total (5)	Production phase: Mining (6)	Production phase: Mineral processing (7)	Production phase: Total (8)
Per cent changes							
1. Employment	–	3.5	1.9	5.3	1.7	1.3	3.0
2. Gross state product	–	1.9	1.0	2.9	1.7	1.2	2.9
3. Private consumption	–	2.4	1.2	3.7	1.6	1.2	2.8
4. Consumer price index	–	1.3	0.6	1.9	0.4	0.1	0.5
5. Total exports	–	−9.4	−4.0	−13.4	2.9	2.0	4.9
6. Total imports	–	6.2	3.8	10.0	1.5	1.2	2.7
Changes in levels							
7. Employment (jobs)	666 000	22 700	12 300	35 000	11 900	9000	20 900
8. Gross state product ($ million)	39 000	730	410	1 140	670	470	1 140
9. Private consumption ($ million)	23 000	570	290	860	380	270	650
10. Consumer price index	100	1.3	0.6	1.9	0.4	0.1	0.5
11. Total exports ($ million)	15 000	−1 370	−580	−1 950	420	290	710
12. Total imports ($ million)	14 000	870	530	1 400	210	160	370

Source: Base-year data are from the WAM database, ERC, the University of Western Australia.

Note: Due to rounding, the results in terms of changes in levels may not agree with the products of corresponding percentage changes and base-year data.

employment by 3.5 per cent (or 22 700 new jobs), while mineral-processing projects increase aggregate employment by 1.9 per cent (12 300 new jobs). Due to the mining projects, gross state product expands by 1.9 per cent (or A$700 million) and private consumption by 2.4 per cent (A$600 million). The corresponding expansions caused by mineral-processing projects are 1.0 per cent (A$400 million) and 1.2 per cent (A$300 million), respectively. The mining projects increase the price level by 1.3 per cent, while mineral processing projects cause the price level to rise by 0.6 per cent. Mining projects reduce exports by 9.4 per cent (A$1400 million) and stimulate imports by 6.2 per cent (A$870 million). These effects are stronger than the corresponding effects of mineral-processing projects, which reduce exports by 4.0 per cent (A$580 million) and increase imports by 3.8 per cent (A$500 million). Comparing column 3 with column 4 of table 2, we see that the effects of mining projects are, roughly speaking, consistently twice as large as those of mineral-processing projects. The reason for this is that investment in mining is A$2.2 billion per year, while that for mineral processing is only A$1.2 billion — roughly half as large. We will come back to this issue shortly.

Looking at column 5 of table 2, which gives the total effects of the mining and mineral-processing projects as a whole, the cost pressures of the investment surge result in a rise in the price level of 1.9 per cent. Following the assumption of a fixed nominal exchange rate, this 1.9 per cent rise of the price level amounts to a real appreciation of the exchange rate. Given that the real appreciation is quite moderate, the substantial fall in exports (13 per cent) may seem puzzling. But in view of the large size of the investment surge (A$3.4 billion in a typical year), this can be understood in terms of the absorption approach discussed in section 3. Table 3 presents the combined results in terms of changes in values and confirms that equation 2, the key identity of the absorption approach, is satisfied. As can be seen, as a result of the new projects, output (GSP) increases by A$1100 million, while absorption increases by A$4500 million. Nearly 80 per cent of this increase in absorption is accounted for by the new investment in the projects (A$3400 million). The excess domestic demand of A$3400 million is met by a reduction in exports of A$2000 million, plus an increase in imports of A$1400 million. It should be noted that these exports include both international and interstate exports. In summary, the apparently large effects on exports and imports in the construction phase reflect the large increase in absorption, especially investment. Columns 2 and 3 of table 4 show the disaggregated effects on exports in the construction phase. As can be seen, exports of Construction services fall substantially. As a major component of the investment in the projects is devoted to spending on Construction, sales of this industry are diverted from non-WA markets to satisfy local demand. By contrast, exports by the international export industries such as Agriculture reduce very little; this is consistent with the above analysis that, when both the nominal exchange rate and nominal wages are fixed, the absorption effect outweighs the real exchange-rate-effect (the Gregory effect).

Now consider the effects of the production phase given in columns 6 and 7 of table 2. When the projects commence operations, the most obvious

Table 3 Changes in output, absorption, exports and imports in the construction phase

Changes in output and absorption			Changes in exports and imports	
Gross state product		1140	Exports	−1950
Private consumption	860		Imports	1400
Government consumption	230			
Investment	3400			
Absorption		4490		
GSP-absorption		−3350	Exports-imports	−3350

Note: Values are in 1989–90 A$ million.

Table 4 Disaggregated effects on exports of new resources projects

Industry (1)	Construction phase Per cent (2)	Construction phase $ million (3)	Production phase Per cent (4)	Production phase $ million (5)
1. Agriculture	−0.3	−6	−0.3	−5
2. Services to agriculture				
3. Forestry and logging	−3.9	−1	−8.2	−2
4. Fishing and hunting	−2.5	−2	−1.3	−1
5. Metallic minerals	−0.8	−51	2.8	179
6. Coal, oil and gas	−26.7	−107	82.9	334
7. Minerals n.e.c.	−1.6	−5	9.4	30
8. Services to mining n.e.c.	−2.9	−9	−9.8	−30
9. Food, beverages, tobacco	−6.1	−44	−3.7	−27
10. Textiles	−7.4	−7	−3.5	−3
11. Clothing and footwear				
12. Wood, wood products, furniture	−11.2	−20	−3.4	−6
13. Paper, printing, publishing	−16.5	−12	−9.7	−7
14. Chemical, petroleum, coal products	−13.1	−22	74.1	126
15. Non-metallic mineral products	−15.0	−15	22.2	22
16. Basic metal products	−3.4	−36	33.2	359
17. Fabricated metal products	−29.9	−45	−1.6	−2
18. Transport equipment				
19. Other machinery and equipment				
20. Miscellaneous manufacturing	−15.4	−7	−6.6	−3
21. Electricity, gas	−21.2	−22	−30.7	−31
22. Water, sewerage, drainage	−12.4	−12	−4.9	−5
23. Construction	−93.6	−1033	−7.6	−57
24. Wholesale trade	−49.1	−264	−8.8	−47
25. Retail trade				
26. Road transport				
27. Railway, transport n.e.c.	−26.7	−17	−3.6	−2
28. Water transport				
29. Air transport	−14.4	−21	−6.0	−9
30. Services to transport	−5.5	−19	−3.8	−13
31. Communication	−28.6	−16	−18.5	−10
32. Finance, investment	−17.5	−24	−10.4	−14
33. Insurance etc.				
34. Business services n.e.c.	−42.6	−85	−19.9	−40
35. Public administration	−14.4	−15	−8.9	−9
36. Defence				
37. Health				
38. Education, library etc.				
39. Welfare etc.				
40. Entertainment etc.	−20.6	−28	−12.2	−16
41. Restaurants, hotels, clubs				
42. Personal services				
Total	−13.4	−1946	4.9	708

Note: Values are in 1989–90 dollars.

Table 5 Scaled macroeconomic effects of new resource projects

Variable (1)	Construction phase: Mining (2)	Construction phase: Mineral processing (3)	Production phase: Mining (4)	Production phase: Mineral processing (5)
1. Employment (jobs)	10.4	10.1	5.4	7.4
2. Gross state product ($ million)	0.34	0.34	0.31	0.38
3. Private consumption ($ million)	0.26	0.24	0.17	0.22
4. Consumer price index (1989–90 = 100)	0.061	0.050	0.016	0.010
5. Total exports ($ million)	−0.63	−0.48	0.19	0.24
6. Total imports ($ million)	0.40	0.43	0.10	0.13

Source: Calculated from table 2. See text for details.

Note: Figures refer to the effects per A$1 million invested except for the CPI results which refer to the effects of $100 million invested.

change is that exports expand rather than contract. The increase in exports is 2.9 per cent for mining and 2.0 per cent for mineral processing. There is still a tendency for the effects of the mining projects to be larger than those of mineral processing, but now the differences are much smaller.

A further comparison of the results requires that they be put on a common basis by eliminating the 'size effect'. Recall from column 7 of table 1 that the annualised total value of mining investment is A$2.3 billion and the corresponding figure for mineral-processing investment is A$1.3 billion. When converted from current prices to 1989–90 prices so as to be consistent with the WAM database, these figures become A$2184 million and A$1213 million. As these values are used as the increases in investment expenditure in the construction phase, as well as the increases in capital stocks in the production phase, we therefore scale the results by dividing the relevant variables in terms of changes in levels (given in the lower panel of table 2) by 2184 and 1213, respectively. Table 5 presents the results. As can be seen, on a A$1 million-invested basis, the effects of the mining projects are similar to those of the mineral-processing projects in the construction phase. For instance, A$1 million invested in mining creates 10.4 jobs, while the same amount invested in mineral processing leads to 10.1 new jobs, more or less the same. However, in the operational phase, A$1 million invested in mineral processing creates 7.4 jobs which is significantly larger than 5.4 jobs generated by the same amount invested in mining.[6] Note also that in the production phase the effects

[6] From row 1 of table 5, note that the scaled employment effects in the construction phase (for both types of projects) are larger than those in the production phase. It must be remembered, however, that the additional jobs generated when the projects are operational occur over the whole lives of the projects; by contrast, employment in the construction phase occurs over a much shorter period of time.

of mineral-processing on GSP, consumption, exports and imports are also larger than the corresponding effects of mining. Accordingly, our major conclusion from this analysis is that investment in mineral-processing projects has a significantly larger effect on most macroeconomic variables, and on employment in particular, than does investment in mining once the projects are operational. This conclusion emerges when the size of the two types of investment is held constant.[7] The reasons why the mineral-processing projects have larger effects will be discussed in section 7.

Note from table 2 that there is a balance of trade deficit (of −A\$1950m −A\$1400m = −A\$3350m) in the construction phase and a surplus (A\$710m − A\$370m = A\$340m) in the production phase. This is consistent with our earlier assumption that the new projects attract 'foreign' finance from both overseas and interstate sources. From the viewpoint of the economy as a whole, do the projects pay for themselves? The answer depends on the discount rate and project life. Recall from table 1 that the average construction period for the new projects is 1.5 years. We assume that the real discount rate is 4 per cent per year[8] and the average operational period is 25 years. Then the present value of the trade deficit is $V_{deficit} = A\$3350m/(1+0.04) + A\$1675m/(1+0.04)^{1.5} \approx A\$4800m$, while the corresponding present value of the trade surplus is $V_{surplus} = [\Sigma_{i=1}^{25} A\$340m/(1+.04)^{i}]/(1+.04)^{1.5} \approx A\$5008m$. As the future surpluses exceed the deficits, in present value terms, the projects pay for themselves in a balance-of-payments sense.[9]

6. Output and employment by industry

In this section, we present the corresponding industry composition effects on output and employment. Table 6 gives the output effects by industry.

[7] This conclusion is unlikely to change substantially even after excluding the very large projects such as BHP's DRI project which accounts for 57 per cent of mineral-processing investment in a typical year. For example, a simulation of the effects of the DRI project alone reveals that (i) this project accounts for about 50 to 60 per cent of total effects of mineral processing in both the construction and production phases; and (ii) the scaled effects are more or less the same as those of the ten mineral-processing projects (including the DRI project), i.e., in the production phase mineral processing still has consistently larger effects than does mining, holding constant the size of investment. Details of the DRI simulation are given in a separate Appendix available on request.

[8] Dixon *et al.* (1992) indicate that discount rates of about 4 per cent per year are often used in cost-benefit studies.

[9] Note that as $V_{surplus} \approx V_{deficit}$, the internal rate of return of the projects is about 4 per cent per year.

Table 6 Effects of new resource projects on sectoral output

	Construction phase				Production phase			
	Mining		Mineral processing		Mining		Mineral processing	
Industry (1)	Per cent (2)	$ million (3)	Per cent (4)	$ million (5)	Per cent (6)	$ million (7)	Per cent (8)	$ million (9)
1. Agriculture	−0.0	−1	−0.0	−1	−0.0	−0	0.0	1
2. Services to agriculture	−0.0	−0	−0.0	−0	0.0	0	0.0	0
3. Forestry and logging	−0.0	−0	−0.0	−0	0.2	0	0.2	0
4. Fishing and hunting	−0.1	−0	−0.1	−0	−0.0	−0	0.1	0
5. Metallic minerals	−0.2	−12	−0.1	−8	4.0	253	0.1	4
6. Coal, oil and gas	0.4	2	−0.0	−0	53.1	351	0.1	1
7. Minerals n.e.c.	−0.1	−1	−0.1	−0	7.9	42	0.0	0
8. Services to mining n.e.c.	−0.9	−7	−0.5	−4	0.4	3	−0.2	−1
9. Food, beverages, tobacco	−0.1	−3	−0.1	−3	0.0	1	0.1	3
10. Textiles	−0.2	−1	−0.2	−1	0.1	0	0.3	1
11. Clothing and footwear	1.7	3	0.8	1	1.1	2	0.8	1
12. Wood, wood products, furniture	0.1	1	−0.1	−1	0.0	0	0.4	3
13. Paper, printing, publishing	0.6	6	0.3	4	0.4	5	0.5	5
14. Chemical, petroleum, coal products	0.1	3	0.1	3	1.2	24	14.2	293
15. Non-metallic mineral products	0.2	2	0.0	0	0.0	0	4.8	45
16. Basic metal products	−0.2	−4	−0.1	−1	0.1	1	22.1	498
17. Fabricated metal products	0.4	5	2.9	40	0.3	4	0.9	12
18. Transport equipment	4.1	37	1.7	16	0.9	8	0.8	7
19. Other machinery and equipment	7.1	166	6.5	152	1.3	31	0.7	16
20. Miscellaneous manufacturing	0.6	5	0.4	3	0.7	5	1.2	9
21. Electricity, gas	0.3	4	0.2	3	0.6	9	0.6	9
22. Water, sewerage, drainage	0.2	1	0.1	0	0.0	0	0.1	1
23. Construction	2.6	251	0.8	80	0.1	9	0.1	11
24. Wholesale trade	3.2	114	2.8	102	0.3	10	0.5	18
25. Retail trade	2.8	137	1.4	70	1.6	76	1.1	52
26. Road transport	4.1	54	2.1	27	1.6	21	1.2	16
27. Railway, transport n.e.c.	7.8	29	3.9	14	0.7	3	1.5	5
28. Water transport	5.1	14	3.6	10	1.5	4	3.9	11
29. Air transport	0.4	3	0.1	1	0.3	2	0.6	5
30. Services to transport	−0.2	−1	−0.0	−0.0	0.0	0	0.1	1
31. Communication	0.7	8	0.4	4	0.5	5	0.4	4
32. Finance, investment	0.9	15	0.5	7	0.7	11	0.6	9
33. Insurance etc.	4.0	24	1.6	10	1.6	9	0.9	5
34. Business services n.e.c.	1.6	80	0.8	38	0.6	31	0.5	26
35. Public administration	1.3	30	0.7	17	1.3	29	1.0	22
36. Defence	1.9	8	1.0	4	1.7	7	1.2	5
37. Health	2.5	70	1.3	36	1.7	47	1.2	33
38. Education, library etc.	2.3	51	1.2	27	1.7	38	1.2	26
39. Welfare etc.	2.2	34	1.2	18	1.6	25	1.2	19
40. Entertainment etc.	0.5	6	0.2	3	0.5	6	0.4	5
41. Restaurants, hotels, clubs	2.4	37	1.2	19	1.5	24	1.0	16
42. Personal services	2.4	11	1.2	5	1.4	6	1.1	5
Total		1180		697		1102		1202

Note: Values are in 1989–90 dollars.

Columns 2 and 3 of table 6 show that in the construction phase, as a result of the A$2.2 billion investment in mining for a typical year, 11 industries experience an output contraction and 31 industries an output expansion. The percentage changes of output range from −0.9 (Services to mining n.e.c.) to 7.8 (Railway, transport n.e.c.). Columns 4 and 5 of the table show the corresponding effects of the A$1.2 billion investment in mineral processing. The number of industries experiencing an output contraction is 13, while 29 record expansions, almost the same as that for mining investment. The percentage changes in industry outputs range from −0.5 (Services to mining n.e.c.) to 6.5 (Other machinery and equipment).

Comparing column 2 with column 4 of table 6, in terms of the direction of change we see that the industry output effects generated by mining and mineral-processing projects in the construction phase are very similar. For example, the 11 industries whose outputs decrease due to mining investment are the same industries which contract as a result of mineral-processing investment. Examples of these industries are Agriculture; Fishing and hunting; Metallic minerals; Minerals n.e.c.; Services to mining; Food, beverages, tobacco; Textiles and Services to transport. Many of these contracting industries are exporters, closely related to export or import-competing activities. These industries contract due to the appreciation of the real exchange rate, which occurs in the construction phase as the additional economic activity puts upward pressures on costs in general. But with the wage rate and nominal exchange rate fixed, the room for real appreciation is relatively limited. This explains why the international export industries such as agriculture contract very little. The output of Railway transport, Other machinery and equipment, Construction, Wholesale/retail trade and Business services increases substantially in the construction phase as a result of both mining and mineral-processing projects. These industries expand because they are directly (or closely) linked with the investment activities.

Columns 6 and 7 of table 6 present the results in the production phase of the mining projects. As can be seen from column 6, the output changes range from −0.02 per cent (Fishing and hunting) to 53.1 per cent (Coal, oil and gas). Now only two industries (Agriculture and Fishing and hunting) contract. The substantial percentage increase in the output of Coal, oil and gas (53 per cent) may in part be attributable to our database which refers to 1989–90 and thus underestimates the current size of the sector. Columns 8 and 9 of the table give the corresponding output effects of the mineral-processing projects in the production phase. Two broad results for the effects in the production phase emerge from table 6: (i) by comparing column 6 with column 8 of table 6, it can be seen that investment in mining has a larger impact on the output of mining sectors, while investment in mineral processing has a larger impact on the mineral-processing sectors. Clearly this is due to the 'direct effects' dominating. (ii) A result common to both the construction and production phases is that service sectors such as Retail trade, Transport, Health and Education, library etc. are always substantially stimulated by the new projects. The reason for this is that, as we mentioned earlier, the demand for most services cannot be satisfied by imports.

In the previous section we made the results for the two types of projects more comparable by adjusting for the differing scale of investment. We now use the same approach for industry outputs, i.e., dividing the change in the value of output for each industry by the corresponding total investment value. Table 7 presents the scaled results. These results answer the question, what are the differential output effects of A$1 million invested in mining rather than mineral processing? Columns 4 and 7 of the table give the answers for the two phases, respectively. The last row of table 7 is revealing. It shows that in the aggregate with total investment held constant, mining and mineral processing have roughly the same effects in the construction phase (see last entries in columns 2 and 3). By contrast, in the production phase, mineral-processing investment causes total output to increase by almost twice as much as does mining investment. According to the last entries in columns 5 and 6 of table 7, A$1 million invested in mining stimulates total output by A$505 000, while the same amount invested in mineral processing increases output by A$991 000.

By and large, the effects on sectoral employment mirror the output effects. Table 8 presents the scaled employment effects. (These are computed in exactly the same way as the calculations of the scaled output effects.) As before, a positive (negative) value indicates that a given amount invested in mining creates more (fewer) jobs in the industry in question than does the same amount invested in mineral processing. It can be seen from table 8 that in the construction phase, the effects of mining and mineral processing are quite similar in most cases. In the production phase, the differential effects are negative in 35 of the 42 sectors; in this sense, the effects of mineral processing are stronger than those of mining.

7. Why are the mineral processing effects larger?

The previous analysis shows that, when the amount invested is held constant, in the production phase the effects in terms of output and employment of mineral-processing projects are larger than those of mining projects. Why is this the case?

An analysis of the structure of costs for the two types of projects will provide an answer. Table 9 presents the cost shares for mining and mineral processing industries. As can be seen from column 8 of table 9, the mining industry is considerably more capital-intensive than is mineral processing as

Table 7 Scaled effects of new resource projects on sectoral output

Industry (1)	Construction phase: Mining (2)	Construction phase: Mineral processing (3)	Construction phase: Difference (2)–(3) (4)	Production phase: Mining (5)	Production phase: Mineral processing (6)	Production phase: Difference (5)–(6) (7)
1. Agriculture	–0	–0	0	–0	1	–1
2. Services to agriculture	–0	–0	0	0	0	–0
3. Forestry and logging	–0	–0	0	0	0	–0
4. Fishing and hunting	–0	–0	0	–0	0	–0
5. Metallic minerals	–5	–6	1	116	3	113
6. Coal, oil and gas	1	–0	1	161	1	160
7. Minerals n.e.c.	–0	–0	0	19	0	19
8. Services to mining n.e.c.	–3	–3	–0	1	–1	2
9. Food, beverages, tobacco	–1	–3	1	1	2	–2
10. Textiles	–0	–1	0	0	1	–1
11. Clothing and footwear	1	1	0	1	1	–0
12. Wood, wood products, furniture	1	–1	1	0	3	–3
13. Paper, printing, publishing	3	3	–0	2	4	–2
14. Chemical, petroleum, coal products	1	2	–1	11	242	–231
15. Non-metallic mineral products	1	0	1	0	37	–37
16. Basic metal products	–2	–1	–1	1	411	–410
17. Fabricated metal products	2	33	–31	2	10	–8
18. Transport equipment	17	13	4	4	6	–2
19. Other machinery and equipment	76	125	–49	14	13	1
20. Miscellaneous manufacturing	2	2	–0	2	7	–5
21. Electricity, gas	2	2	–0	4	7	–3
22. Water, sewerage, drainage	0	0	0	0	0	–0
23. Construction	115	66	48	4	9	–5
24. Wholesale trade	52	84	–32	5	15	–10
25. Retail trade	63	58	5	35	43	–8
26. Road transport	25	22	2	9	13	–4
27. Railway, transport n.e.c.	13	12	1	1	4	–3
28. Water transport	6	8	–2	2	9	–7
29. Air transport	1	1	0	1	4	–3
30. Services to transport	–1	–0	–0	0	0	–0
31. Communication	4	3	0	2	4	–1
32. Finance, investment	7	6	1	5	8	–3
33. Insurance etc.	11	8	3	4	4	0
34. Business services n.e.c.	37	32	5	14	21	–7
35. Public administration	14	14	0	13	18	–5
36. Defence	4	4	–0	3	4	–1
37. Health	32	30	3	21	27	–5
38. Education, library etc.	23	22	1	17	21	–4
39. Welfare etc.	16	15	0	11	16	–4
40. Entertainment etc.	3	2	0	3	4	–1
41. Restaurants, hotels, clubs	17	16	1	11	13	–2
42. Personal services	5	5	0	3	4	–1
Total	540	573	–33	505	991	–486

Source: Calculated from table 6. See text for details.

Note: Units are thousands of dollars per A$1 million invested. Values are in 1989–90 dollars.

Table 8 Scaled effects of new resource projects on sectoral employment

	Construction phase			Production phase		
Industry (1)	Mining (2)	Mineral processing (3)	Difference (2)–(3) (4)	Mining (5)	Mineral processing (6)	Difference (5)–(6) (7)
1. Agriculture	−0.3	−0.3	0.0	−0.1	0.5	−0.6
2. Services to agriculture	−0.0	−0.0	0.0	0.0	0.0	−0.0
3. Forestry and logging	−0.0	−0.0	0.0	0.0	0.0	−0.0
4. Fishing and hunting	−0.0	−0.0	0.0	−0.0	0.0	−0.1
5. Metallic minerals	−0.6	−0.7	0.1	3.2	0.4	2.8
6. Coal, oil and gas	0.1	−0.0	0.2	4.1	0.1	4.0
7. Minerals n.e.c.	−0.1	−0.1	0.0	0.7	0.0	0.7
8. Services to mining n.e.c.	−0.7	−0.7	−0.0	0.3	−0.2	0.5
9. Food, beverages, tobacco	−0.1	−0.3	0.1	0.1	0.2	−0.2
10. Textiles	−0.0	−0.0	0.0	0.0	0.1	−0.1
11. Clothing and footwear	0.2	0.1	0.0	0.1	0.2	−0.0
12. Wood, wood products, furniture	0.1	−0.1	0.2	0.0	0.4	−0.4
13. Paper, printing, publishing	0.4	0.4	−0.0	0.3	0.6	−0.3
14. Chemical, petroleum, coal products	0.1	0.1	−0.1	0.6	−0.3	0.9
15. Non-metallic mineral products	0.1	0.0	0.1	0.0	1.0	−1.0
16. Basic metal products	−0.1	−0.1	−0.1	0.0	8.8	−8.8
17. Fabricated metal products	0.2	3.6	−3.3	0.2	1.1	−0.9
18. Transport equipment	1.7	1.4	0.4	0.4	0.6	−0.2
19. Other machinery and equipment	4.6	7.8	−3.2	0.9	0.9	0.1
20. Miscellaneous manufacturing	0.2	0.2	−0.0	0.2	0.8	−0.5
21. Electricity, gas	0.3	0.3	−0.0	0.6	1.1	−0.4
22. Water, sewerage, drainage	0.1	0.1	0.0	0.0	0.1	−0.1
23. Construction	22.2	13.0	9.1	0.8	1.9	−1.1
24. Wholesale trade	9.1	14.9	−5.8	0.9	2.8	−1.9
25. Retail trade	21.3	19.9	1.4	12.9	15.7	−2.8
26. Road transport	6.3	5.7	0.5	2.6	3.5	−0.9
27. Railway, transport n.e.c.	1.8	1.6	0.2	0.2	0.7	−0.5
28. Water transport	0.4	0.5	−0.1	0.1	0.5	−0.4
29. Air transport	0.1	0.1	0.0	0.1	0.3	−0.2
30. Services to transport	−0.1	−0.0	−0.1	0.0	0.1	−0.1
31. Communication	0.7	0.7	0.0	0.5	0.8	−0.3
32. Finance, investment	1.1	1.0	0.1	0.8	1.3	−0.4
33. Insurance etc.	2.3	1.7	0.6	1.0	1.0	0.0
34. Business services n.e.c.	6.9	6.1	0.8	2.9	4.3	−1.4
35. Public administration	2.0	2.0	−0.0	2.1	2.8	−0.7
36. Defence	0.6	0.7	−0.0	0.6	0.8	−0.1
37. Health	7.2	6.7	0.5	5.2	6.4	−1.2
38. Education, library etc.	5.8	5.6	0.2	4.7	5.7	−1.0
39. Welfare etc.	3.1	3.1	0.0	2.5	3.3	−0.8
40. Entertainment etc.	0.5	0.4	0.1	0.5	0.7	−0.2
41. Restaurants, hotels, clubs	4.6	4.2	0.3	3.1	3.7	−0.6
42. Personal services	1.9	1.8	0.1	1.2	1.7	−0.4
Total	104.0	101.5	2.5	54.7	74.3	−19.6

Note: Units are jobs created per A$1 million invested. All entries are to be divided by 10.

Table 9 Cost shares for mining and mineral processing industries (%)

Industry (1)	Share in total costs: Intermediate inputs (2)	Imports (3)	Taxes (4)	Capital (5)	Labour (6)	Total (7)	Share in value added: Capital (8)	Labour (9)	Capital-labour ratio [(8)/(9) × 100] (10)
Mining									
1. Metallic minerals	34.4	12.8	2.5	36.8	13.4	100.0	73.2	26.8	273.8
2. Coal, oil and gas	19.4	7.2	1.2	56.7	15.5	100.0	78.5	21.5	366.1
3. Minerals n.e.c.	28.7	10.8	2.7	44.1	13.6	100.0	76.4	23.6	323.5
4. Average	27.5	10.3	2.2	45.9	14.2	100.0	76.1	23.9	321.1
Mineral processing									
5. Chemical, petroleum, coal products	38.9	31.0	7.1	14.2	8.8	100.0	61.8	38.2	162.1
6. Non-metallic mineral products	44.1	12.1	2.3	24.0	17.5	100.0	57.8	42.2	137.0
7. Basic metal products	51.7	12.7	1.4	21.8	12.4	100.0	63.6	36.4	175.0
8. Average	44.9	18.6	3.6	20.0	12.9	100.0	61.1	38.9	158.0

Source: Columns 2–6 are from Ye (1998).

Notes: 1. Column 8 is column 5 divided by the sum of columns 5 and 6; and column 9 is column 6 divided by the same sum.
2. 'Intermediate inputs' are sourced from WA and 'Imports' are both international and from the rest of Australia.

the average share of capital in value-added for mining is 76 per cent (row 4), which is substantially above that for mineral processing of 61 per cent (row 8). Accordingly, mining is capital-intensive relative to mineral processing, or, in other words, mineral processing is relatively labour-intensive. With a lower capital/labour ratio, a given output increase in mineral processing requires relatively more labour input than does mining, which also helps to explain the larger employment effects of the mineral-processing projects. It is interesting to note that the finding that mineral processing is relatively labour-intensive in the production phase contradicts the conventional belief that processing activities are usually more capital-intensive than mining activities.

It should also be noted that intermediate inputs play a more prominent role in mineral processing relative to mining. From rows 4 and 8 of column 2 of table 9, we see that these inputs absorb on average about 45 per cent of total costs in mineral processing, whereas the corresponding figure for mining is 28 per cent. As intermediate inputs are sourced from WA, a larger share of intermediate inputs means that mineral processing is more integrated with other WA industries. Accordingly, it is able to generate relatively larger increases in economic activity following expansion in mineral processing.

8. Conclusion

This article deals with the impact on the WA economy of mining and mineral-processing investments using a computable general equilibrium (CGE) modelling approach. Compared with other forms of economy-wide modelling, the CGE approach, which is based on solid microeconomic foundations and emphasises the role of prices, has obvious advantages for the current study. The essence of the CGE approach is the interdependence of economic variables and the mutuality of such interdependence (Kuenne 1992). Because CGE models recognise that the economy is subject to overall constraints such as those imposed by factor supplies, indirect linkages between the performance of industries resulting from these constraints are automatically in place (Vincent 1990). As Powell and Lawson (1990) observe: 'the economy had to be seen as a system — obviously decisions taken in one area . . . could make nonsense of those taken in another . . . if the interconnectedness of the economy was ignored.' Thus the big advantage of this approach is that it allows the economist to analyse the effects of policy actions and other exogenous events in the context of a consistent, interrelated global system (Ethier 1988). Given the importance of the minerals sector in the overall WA economy, the CGE approach is a more suitable tool for analysing the economy-wide effects on the WA economy of the activities undertaken in the minerals sector.

The major findings can be summarised as follows. First, both mining and mineral processing projects provide a strong stimulus to the WA economy. Second, most of the jobs generated by the new projects in both the construction and production phases are located outside the mining and mineral-processing sector. This indicates strong links between mining, mineral processing and the rest of the economy. Finally, holding constant the amount invested, in the production phase, the effects of mineral-processing projects are consistently larger than their mining counterparts. That is, on a A$1-million-invested basis mineral-processing projects will generate more employment, larger export revenue and higher GSP growth than will mining projects.

The findings of this article have some policy implications and seem to provide some justification for government policies favouring mineral processing activities. Given that mineral processing has larger impacts on the state's economy than mining, an economic growth-oriented government can logically provide greater support to processing activities over mining activities. To establish a strong mineral processing industry, the government needs to maintain and strengthen consistent policies in terms of royalties, infrastructure provision and native title. This should create a more favourable environment for the development of mineral processing activities. For example, reductions in the royalty rate imposed on ore which is subject to mineral processing, providing infrastructure for mineral processing and providing research support, will assist processing activities. It has to be recognised, however, that there exists a range of other factors influencing the decision to undertake value adding to minerals. As Stewardson (1991) points out, the factors that determine whether mineral processing is (privately) profitable can be divided into two groups: first, those applicable to all mining countries, such as location and the market structure; and second, those applying to Australia (and, presumably, Western Australia as well), such as high operating costs and the lack of a body of high-technology knowledge. As a result, support for mineral processing should be seen as only one factor that impacts on private company decisions on whether and where to locate mineral processing operations.[10]

[10] For more on the economics of value adding in the Australian context, see Glance (1992), McKern and Waltho (1988), O'Leary (1991), Prime Minister's Science Council (1990), Stewardson (1992), Wall (1988), White (1992) and Woodbridge (1988).

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