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# SOME GENERAL EQUILIBRIUM EFFECTS OF MINING GROWTH ON THE ECONOMY

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**The effects of mining sector growth are analysed with a five-sector general equilibrium model. The effect of the mineral discoveries is to cause the agricultural sector to contract, but to cause the import-competing sector to expand by a small amount—a result which differs from Gregory's (1976) analysis. However, a mining boom caused by increases in external demand, rather than by new discoveries, leads to a different set of results. Some likely effects of the boom on the growth rates of the different sectors in the economy are reported. Finally, the effects of an export tax on minerals are considered.**

## *Introduction*

Many commentators have discussed the effects of the rapid mining sector growth of the late sixties and early seventies on the Australian economy. Gregory (1976) was the first to point out the intersectoral aspects of the rapid growth of the mining sector, and used this phenomenon to illustrate the effects of tariff changes on the other traded goods sectors. In a now widely-quoted result, Gregory argued that the effect of the mineral discoveries (an exogenous increase in the supply of minerals) was equivalent, in terms of its effects on the output of the import-competing sector, to a complete removal of the Australian tariff plus the introduction of a small import subsidy.

While Gregory recognised that there would be terms of trade effects and income effects[1], these were suppressed in his analysis. Snape (1977) extended Gregory's partial analysis to cover the general equilibrium effects of mining sector growth. However, Snape still assumed terms of trade effects away and also treated the mining boom as a supply effect, that is, an outward shift of the production possibility frontier. Furthermore, his analysis was qualitative only. The effects of a mining

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[1] See Gregory (1976) footnotes 5 and 6 on pages 75 and 76. Actually, in my model there are two types of 'terms of trade effects'. One is the effect of the changing terms of trade on real income. The other is the effect of the changing terms of trade on relative input prices since in my model the output of each sector can be used as an input into each other sector.

boom have been examined quantitatively under general equilibrium by Dixon, Parmenter and Sutton (1977), but they treated the mining boom as a 'gift' to the economy of a large amount of export income. Hence only indirect effects of the boom were shown, that is, a mining 'boom' was shown to cause mining output to decline. Also, there was no delineation between quantity effects and price effects.

In this paper, the economic effects of the growth of the mining sector are analysed with a five-sector general equilibrium model of the Australian economy. It is shown, by explicitly allowing for terms of trade effects, interindustry flows and income effects, that it is possible to alter one of Gregory's findings substantially. Furthermore, it is also shown that the repercussions from a mining boom which is generated by an exogenous domestic supply shift (such as through the mineral discoveries) are very different from exogenous demand increases brought on by, say, world income growth or world stockpiling of resources.

An appreciation of the differences between a mining boom brought on by demand effects as opposed to supply effects is an important aspect of this paper. The reason is that the results presented below can be used to interpret other events, such as a mineral slump most likely resulting from depressed levels of export demand rather than a contraction of domestic supply; that is, to examine the economic effects of a mineral slump it is necessary to examine external demand effects and not shift a production possibility frontier inwards.

The remainder of the paper falls into four sections. In the first section, the mining boom of the late sixties and early seventies is attributed to both supply and demand increases. A non-technical description of the model and assumptions, and a description of the simulation experiments are given in the second part of the paper. In the third section, three sets of results are presented. The final section of the paper contains the main conclusions of the study.

In the first set of results, the effects of a mining boom caused by external demand factors are compared and contrasted with a boom caused by a domestic supply shift. The major finding reported in this section is that the effect of a mining boom brought on by a domestic supply shift is to cause the output of the import-competing sector to expand by a very small amount, rather than the large contraction implied in Gregory's results.

In the second set of results, the model is used in a 'dynamic' or growth sense to postulate the effect of mining growth on the other sectors of the economy. It is seen that the growth rate of the import-competing sector would have been approximately 25 per cent higher in the absence of mining growth, and the growth rate of the agricultural sector would have been over 60 per cent higher.

In the third set of results, the model is used to simulate the effects of an export tax on the mining sector. This simulation is instructive in itself and, in this model, is also formally equivalent to an equal *ad valorem* rate of protection being applied to the other traded goods sectors.[2]

[2] By Lerner's Symmetry Theorem—the only difference being, of course, that if other traded goods sectors were protected by an equal *ad valorem* rate of assistance, the exchange rate would be higher by the amount of the assistance.

### *Minerals Growth*

There was a large increase in the growth of value of mining output in the late sixties and early seventies. During these years the growth in value was due to both output increases and price rises. This is an important point, since the results show that the economic repercussions from a mining sector expansion are different, depending on whether the growth of the mining sector is viewed as an outward shift in the supply curve, an outward shift in the demand curve, or both.

From Figure 1, which shows the index of volume of output of three large mineral export groups, it can be seen that the output of each group has risen substantially since 1967. However, this expansion of output could be due to either outward shifts in the supply schedule for minerals or an upward movement along a supply curve, which would be due to external demand increases. In the case of a movement along the supply curve, one would expect to observe the real price of minerals rising over time. In Figure 2 the indexes of prices received for the same three large mineral export groups are shown along with the Consumer Price Index. From these graphs it may be concluded that for coal and bauxite, both volume and real price increases would account for an increased value of mineral exports while, for iron ore, output increases would account for the rise in real value of output.

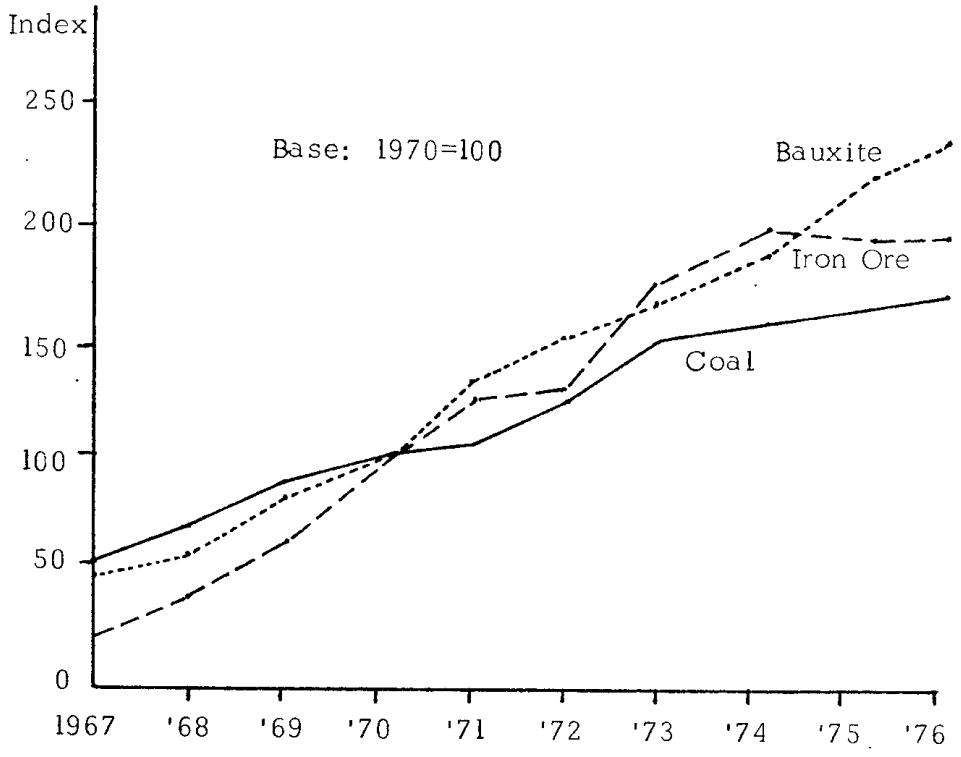


FIGURE 1—Indexes of volume of exports of selected minerals, Australia, 1967-76.
Source: IMF, *International Financial Statistics*, May 1977.

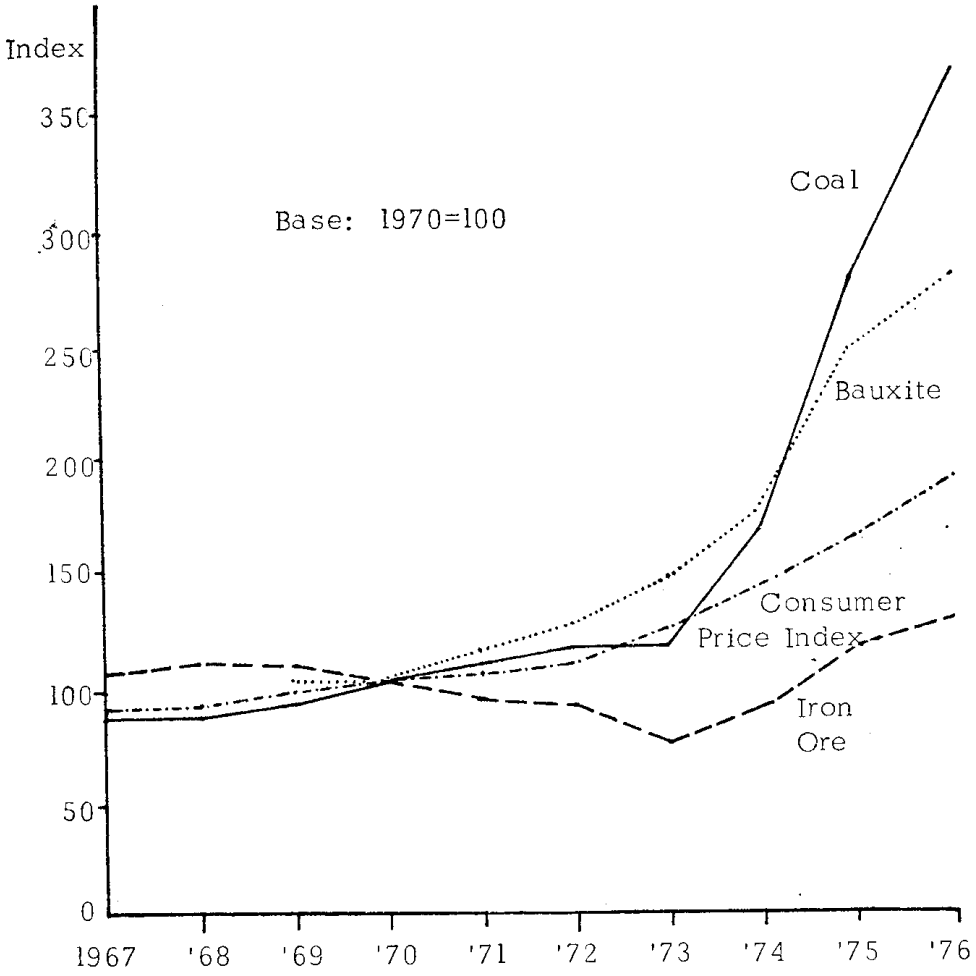


FIGURE 2—Indexes of prices received for exports of selected minerals, and the Consumer Price Index, Australia, 1967-76.
Source: IMF, *International Financial Statistics*, May 1977.

Identifying changes in the value of mining production into supply and demand shifts is a difficult task without a detailed econometric analysis or further information on the nature of the supply and demand curves. Gregory (1976) and Snape (1977) assumed that the mining sector expansion was due to the discovery of minerals, that is, an outward shift of the supply curve which in general equilibrium is represented by an outward shift of the production possibility frontier. In this paper, however, the mining boom is treated as being due to both supply and demand shifts. These effects are first considered separately to demonstrate some important differences in their repercussions, and then they are considered jointly to gauge the impact of the mining boom on the economy.

## *The Model and Assumptions*

### *The model*

Details of the model used to analyse the effects of mining sector growth on the other sectors are contained in Stoeckel (1978) but a non-technical description of its features and assumptions follows.

The model is a five-sector Walrasian general equilibrium trade model in which wages and prices are determined endogenously by competitive market behaviour. The model is non-linear but is solved by approximating to a linear solution through logarithmic differentiation.[3] It is similar to other general equilibrium models used in empirical analysis. Johansen (1964) and Taylor and Black (1976) report examples of the application of such multisector models in which prices are endogenous. Another detailed and more recent application of this type of model is that by the IMPACT team, who have developed the 'ORANI' model for Australia (Dixon, Ryland, Parmenter and Sutton 1977).

It is assumed that the Australian economy can be represented by five sectors, of which three are export-oriented, one is import-competing and the fifth is a non-traded goods sector. The three export-oriented sectors, which also supply the domestic market, are those of agriculture, mining and manufacturing exports. The import-competing sector is the balance of total manufacturing less the manufacturing export group, while services industries comprise the services or non-traded goods sector. Details of the classification by ASIC code are contained in the original study (Stoeckel 1978).

Each sector produces a single output with a linear homogeneous Cobb-Douglas production technology under competitive conditions.[4] Inputs consist of both primary and intermediate inputs. Intermediate goods can be used both for inputs into production and for final consumption. The distinction between primary and intermediate inputs in this system is that primary factors cannot be produced or reproduced by a production function. Hence there are no investment goods.

The primary factors are: capital; two types of labour, skilled and unskilled; land, which is used only in the agricultural sector; and fixed mining capital which is specific to the mining sector. The effects of changing the numbers and mobility of these primary factors have been investigated for this model elsewhere (Stoeckel 1979). Apart from

[3] In a comparison of a linear and non-linear solution to a general equilibrium model, Hawley (1978) found differences only at the fourth decimal point for small changes in exogenous variables.

[4] While Cobb-Douglas may sound simplistic, some evidence by Caddy (1977) indicates that 1·0 may be a reasonable estimate of the 'long-run' elasticity of substitution between capital and labour in Australian manufacturing. Also, in a study by Boadway and Treddenick (1975) in which a similar general equilibrium model was employed for Canada, it was found that for trade elasticities around 10, the results were not sensitive to the production technology. The two technologies compared were Cobb-Douglas between all inputs as used here and a mixed CES beween primary inputs and Leontief for intermediate inputs. When rounding to integers, a complete removal of the tariff (solved non-linearly) meant that output was different in only two industries out of sixteen as between the two technologies. Even then, the difference was only one percentage point. For elasticities around 25, however, there were some differences. Also, as Bigman (1978) has shown, the Cobb-Douglas production function is neither a necessary nor sufficient condition for the constancy of the aggregate income shares in a multisector, multifactor model.

differences in factor rewards, changing the specification of primary factors led to only small differences in other variables such as output and the exchange rate. Labour and capital are treated as being freely mobile between sectors but not internationally.[5] Competitive conditions are assumed to exist in the markets for factors which are therefore paid their marginal products and are fully employed. Stocks of primary factors are fixed and are exogenous. Simulations are performed in which the endowments of these factors change exogenously. Hence investment is only exogenous and there is no depreciation of the capital stock.[6]

On the demand side it is assumed that there exists an aggregate community utility function. The community indifference curves are assumed to have all of the usual properties of individual preference mappings. Assuming the existence of such a function necessarily implies that some quite strong assumptions are being made about the underlying individual utility functions and the distribution of income.[7] The assumption of the existence of an aggregate utility function permits an aggregate demand function to be derived from maximisation, subject to the aggregate budget constraint. The net result is that an aggregate demand curve is derived for domestic goods in which the income elasticity of demand for different goods can be a number other than one. The model was not found to be sensitive to the domestic demand elasticities in the original study. The results reported in this paper are for a Hicks-Allen elasticity of substitution of 0·8 between all goods.

The foreign export demand for Australia's goods and the foreign supply of imports to Australia are taken as given and the respective elasticities are less than infinite. Hence, the small country assumption does not apply in this model, although very large elasticities, especially the supply elasticity of world imports to Australia, are experimented with. A discussion of the sensitivity of the results to the terms of trade effects is contained in the Appendix. Australia is, however, assumed to be small enough in world trade for there to be no foreign repercussions from any change in domestic policies or incomes. Exogenous shift variables are specified on the demand functions so experiments such as a 10 per cent exogenous increase in the world demand for minerals can be performed. Exogenous tariff and export subsidy variables are also included so that changes in commercial policy

[5] The validity of this assumption was tested in the original study (Stoeckel 1978) by permitting endogenous capital inflows into the mining sector. This made the model much more complex and, because such endogenous capital flows were found to be of minor consequence for the results, they are not reported here. Actually, the model, as it stands, does allow for some *indirect* foreign capital inflows (and international labour flows). Substitution is permitted between intermediate inputs and capital and labour. Many of the intermediates are importables; therefore, to the extent that intermediate inputs substitute for primary factors, and to the extent that they are imported, the labour and capital embodied in these goods is imported.

[6] However, the endogenous capital flows into the mining sector mentioned in footnote 5 did mean that endogenous investment in the mining sector (the 'boom' sector) did occur for a set of simulations described in Stoeckel (1978). Because little effect was observed, particularly for the economy, it was decided not to experiment further with endogenous investment, at this stage.

[7] See Tower (1978) and Chipman (1974) as a very small sample of the literature on this subject.

can be simulated. The exchange rate is assumed to be perfectly flexible and to adjust to maintain balance of payments equilibrium.

*Simulation of the mineral discoveries and mining boom*

To model the mineral discoveries, there are two separate approaches that can be used. The first is to view the discoveries as an exogenous increase in the stock of some primary factor. The second is to view them as factor-specific technical changes in which, in a sense, 'some more' of the factor is 'found'. In both cases, the production possibility frontier shifts outwards, but the implications for the rewards to factors are different. In the first case, the specific factor rewards would be expected to decline, and in the second, to rise. However, for the specification of the production side of this model, changes for all other variables will be exactly the same.

Strictly speaking, the discovery of minerals is not a wholly exogenous occurrence. Resources are consumed in the process of discovery and developing the resources. The rate of discovery and development of resources depends a great deal on the cost of search, the cost of development, the rate of interest, the price of the final product, and the rate at which that price is expected to rise over time. However, for purposes of this paper, it is not necessary to model the amount of search. All that is required is that an exogenous expansion of the mining sector takes place.

In this model, the mineral discoveries are represented by exogenous technical change. Therefore, it was assumed that there is virtually an infinite amount of reserves of minerals available—the problem being to locate concentrations of these ores which are high enough to permit economic extraction. Finding a high concentration of ore in effect lowers the cost of production, as does technical change. In the same way, resource depletion, in which mines have to be dug deeper for lower grade ores, increases the cost of production and can be modelled by negative technical change.

As stated before, modelling the mineral discoveries as an outward shift of the production possibility frontier results in an outward shift of the supply curve for mineral production. To represent the mining boom by a demand shift, all that was required was to move the export demand schedule for minerals outwards by the exogenous shift parameter specified on that function. Therefore, under the demand shift, the expansion of mineral production was by a movement around a fixed production possibility frontier.

The first set of results was obtained by simulating a once-only percentage change in the technical change parameter for mineral production and a once-only shift in the demand parameter for mineral exports, holding all other exogenous variables constant. In this form, the model was used in a comparative static sense, that is, it was used to examine the changes in endogenous variables between two equilibrium positions in response to some exogenous shock.

The second set of results was obtained by specifying both supply and demand shifts for minerals, plus appropriate changes for other exogenous variables described later, using the model in growth rate form. Because the model is linear in percentage changes, it was possible to

differentiate throughout with respect to time and express all variables in growth rate form. An increase in an exogenous variable, therefore, represents a continuous growth in that variable.

The third set of results of an export tax on minerals was obtained in a similar way to the first set, that is, a once-only change was made in the tax parameter in the mineral export equation.

### *Data and solution*

Since the model is expressed in percentage change or elasticity form, the data required are the various weights or shares for the different variables in the economy, and the various elasticities such as the price elasticity of export demand. Real data for the base year 1973/74 were used for the various parameters of the model. Because input-output data relate to 1968/69, the condensed input-output table had to be updated to the base year 1973/74. This was done by using the RAS, or Richard Stone method as described in Bacharach (1970). The updating made little change to the input-output coefficients (at the level of aggregation used) and the results were not sensitive to small changes in these coefficients (Stoeckel 1978).

Elasticities, where required, were taken from various econometric studies and other sources. The elasticities used in this study are shown in Appendix Table A.1. Although both high and low values were used for the complete study, only those results using 'best' estimates are reported here.

Once the various elasticities and parameter values have been specified, the model is in a form in which simulations can be performed of exogenous shifts in technology, factor endowments, minerals discovery, export demand, import supply, tariffs, and export subsidies. The system is then solved for all the endogenous variables, viz. prices, wages, outputs, factor demands, the exchange rate, incomes, exports, imports, and the terms of trade. The model is designed not to reproduce the Australian economy, but rather to provide approximate estimates of the sectoral effects of phenomena such as mineral discoveries. Naturally all the results described below are dependent on the simplifying assumptions made. Relaxing some of these assumptions is the subject of further research.

## *Simulation Results*

### *Supply and demand induced mining boom*

The results for all endogenous variables from simulating the above model under an exogenous increase of 10 per cent in export demand, technical change (the mining discoveries), and a 10 per cent increase in mining export taxes (starting from the distortion-free situation) are shown in Appendix Table A.2. To place the results of an export demand increase and of a domestic supply increase on an equal footing, the exogenous increases in both supply and demand were adjusted so that the value added by the mining sector increased by 10 per cent. The choice of value added as the basis for the comparison was arbitrary and the change in output could equally have been selected. However, value added shows the contribution of the mining sector to GNP and

was felt to be more relevant. A summary list of the results of key variables is given in Table 1.

*Mining growth due to domestic supply increases.* Table 1 shows that a 10 per cent increase in value added by the mining sector which is due to an increase in domestic supply, causes the value added by the manufacturing import-competing sector to increase by 0·7 per cent, and output to expand by 1·5 per cent. That is, this model shows that the effect of mining growth brought on by exogenous supply increases, such as mineral discoveries, is to cause the import-competing sector to expand by a small amount. By explicitly allowing for terms of trade effects, interindustry flows and income effects in a general equilibrium model, it is possible to alter substantially Gregory's earlier finding.

There are several factors which together explain the difference between the two sets of results. First, in this model, the manufacturing import-competing sector is the largest user of mining output as an

TABLE 1

*Comparison of Effects of Mining Sector Growth Due to Demand or Supply Changes*

| | Effects of a 10 per cent increase in value added by the mining sector due to | |
|---|---|---|
| | Exogenous increase in domestic supply | Exogenous increase in export demand |
| | % | % |
| Value added | | |
| Agriculture | −2·2 | −1·3 |
| Mining | 10·0 | 10·0 |
| Manufacturing export | −1·3 | −1·3 |
| Manufacturing import-competing | 0·7 | −2·3 |
| Services | 1·4 | −0·2 |
| Gross output | | |
| Agriculture | −2·0 | −0·9 |
| Mining | 22·0 | 8·4 |
| Manufacturing export | −1·6 | −0·8 |
| Manufacturing import-competing | 1·5 | −2·1 |
| Services | 0·8 | −0·1 |
| Factor prices | | |
| Unskilled labour | 1·4 | −0·2 |
| Skilled labour | 1·5 | −0·1 |
| Capital | 1·3 | 0·1 |
| Land | −2·2 | −1·2 |
| Mining capital | 10·0 | 10·0 |
| Income[a] | 1·1 | +0·0 |
| Terms of trade effects[b] | −0·3 | +0·0 |
| Terms of trade[c] | −3·0 | 0·1 |
| Exchange rate[d] | 1·4 | 0·8 |

[a] Income is in real terms.
[b] The effect on real income of the change in terms of trade.
[c] The ratio of external export prices to import prices.
[d] Exchange rate is defined as the reciprocal of the price of foreign exchange, hence an increase represents an appreciation of the Australian dollar.

input into its own production process.[8] Also, given a relaxation of the small country assumption, the outward supply shift will tend to lower real mineral prices. Hence an input into domestic manufacturing has become slightly cheaper, which is a relative advantage over competing imports. Of course, the exchange-rate appreciation caused by the export boom offsets some of the advantage to domestic manufactured goods, but the net effect is a relative advantage over imports. A third factor is that the mining sector uses output of the manufacturing import-competing sector, so that the mining expansion means extra demand for manufactured goods. While the absolute amount of this extra demand is small, the relative amount compared to other users is important in the competition for the economy's resources. In this respect, it is the agricultural and manufacturing export sectors which are at a disadvantage. Finally, the discovery of minerals results in a rise in real income—barring an immiserising growth[9] situation wherein exogenous growth can actually make a country worse off. Therefore, because the income elasticity of demand for goods of the manufacturing import-competing sector was assumed to be 1·2 (which is relatively greater than that for the other sectors), the sector incurs a relative advantage from the mineral discoveries.

*Mining growth due to external demand increases.* By contrast with the previous results, Table 1 shows that a 10 per cent increase in mining value added which is due to an exogenous export demand increase through, say, world depletion of reserves or world economic growth, leads to a different set of results. For an equivalent increase in value added by the mining sector, the external demand increase results in a smaller output effect than under the supply increase. The reason is that the price and output effects under the former are compounding, but under the latter case a much larger output is required to offset the price decline to give the same increase in value added.

The income effect under the demand increase is much smaller than under the supply increase. It is now constrained to the terms of trade improvement since the production point has simply moved around the original production possibility frontier. There are four reasons why the effect of the improving terms of trade on income is very small. First, the improvement in mineral prices is partially offset by declines in the real prices of agricultural and manufacturing export goods. These two groups experience price declines because the revaluation of the dollar shifts the foreign export demand curve downwards, as measured in units of Australian currency. Second, the change in the terms of trade is also small because, although the small country assumption (in which case there are no terms of trade effects) is relaxed, the elasticities assumed are still high and price changes throughout the model are not great. Third, even where the small country assumption is relaxed, there can be no terms of trade effect on real income if the country does not trade. That is, to gauge the effect on income, the terms of trade change has

[8] There are, of course, second, third and fourth round effects as well. That is, the services sector uses minerals too (e.g. coal in electricity generation) and incurs a relative advantage, and the manufacturing import-competing sector is also a relatively large user of such services, and so forth. In other words, there are multiplier effects from discovering more of a mineral such as coal.

[9] See Bhagwati (1958) for a discussion of immiserising growth.

to be weighted by the trade weights. Even though Australia is thought of as a 'trading nation', nearly 70 per cent of our goods are non-traded. Fourth, only small changes are being considered. As discussed later, under the imposition of an export tax on minerals, the terms of trade are directly altered and change by a greater amount.

The increased cost of minerals imposes additional costs on the import-competing sector (and the other users of minerals). Therefore, the absence of any significant income effects, the extra costs of minerals, and the appreciation of the exchange rate all mean a contraction for the three traditionally traded goods sectors. The difference now is that the import-competing sector contracts by 2·3 per cent in value-added terms and by 2·1 per cent in output terms.

It can also be seen from Table 1 that the agricultural sector would much rather see a mining boom generated from increases in export demand than one generated by a supply shift. The fall in value added under the demand shift is 1·3 per cent, while for the supply shift it is 2·2 per cent.

Other differences are apparent too. For example, the value added of the services sector expands under the simulated mineral discoveries. The value added by this sector expands by 1·4 per cent and output by 0·8 per cent. Differences in other variables, such as the exchange rate, are also evident from the table. Under the supply increase, the exchange rate appreciates by 1·4 per cent, while under the 10 per cent increase in mining value added caused by demand factors, the appreciation is 0·8 per cent. The latter effect is smaller since, under the demand shift, the cost of minerals rises. Because mining is also an input into manufacturing, the cost of domestic manufactured goods also rises relative to imported goods. Hence, imports tend to increase quite apart from any exchange rate effect, offsetting some of the increased export earnings from minerals. The exchange appreciation, of course, serves to increase imports further and reduces export earnings from the exporting sectors, bringing about balance of payments equilibrium.

*Mining growth and factor prices.* As could be expected, the effects of mining growth on factor prices differ, depending on whether the growth had its origins in demand or supply increases. Growth through supply increases improves the real wage, while growth through demand effects lowers the real wage. The reason why mining growth through an outward shift of the production possibility frontier increases real wages is that the marginal product of labour becomes greater in the mining sector. Consequently, labour is attracted to the mining sector, bidding up real wages. At the same time, the reduction of labour from other sectors causes the marginal product of labour in those sectors to rise until the values of marginal products and real wages are equalised over the economy. This mechanism also holds for the other factors apart from land, which is, of course, specific to agriculture.

The basic reason why mining growth induced by demand effects lowers real wages is that the factor intensities differ between sectors. However, under the demand-induced growth, there is not the same initial change in marginal products. Because mining is relatively capital intensive, and because of the assumptions of no new investment and full employment of capital, then the extra capital required to produce

the increased mining output must come from elsewhere in the economy, in this case from all the other sectors. Since they are relatively more labour intensive, a proportionately greater amount of labour is released that is not absorbed by the mining industry. The marginal product of labour falls since relatively more labour and less capital is used in other production and so the real wage falls.

The prospect that demand increases will not cause real wages to rise is interesting because it implies that, even if export demand for minerals were to increase, there would not be any new employment effect for the economy as a whole. Although a completely inelastic supply curve for labour was assumed for the model, an upward sloping supply curve could have been assumed. Alternatively, a rigid wages and unemployment model could have been specified. Under the assumption of either initial unemployment or an upward sloping supply curve, given that capital was fully employed in the economy and that there was no new investment, the demand increase in mining would mean aggregate employment would fall (or unemployment increase)—albeit by a very small amount.

As stated earlier, the above effects are conditional on there being no new investment. If there were new investments, the extra capital required need not come from other sectors. Allowing for new endogenous investment from overseas capital inflow into the mining sector, as described by Stoeckel (1978), does mean that the skilled real wage rises marginally while the unskilled wage still falls.

*Some likely effects of mining growth on the economy*

Having argued that both mining demand and supply increases were instrumental in the overall growth of the mining sector, it now remains to see what the model suggests were the 'most likely' effects of this growth on the economy. Data are not readily available on most exogenous variable changes which actually occurred in the Australian economy and which gave the pattern of growth rates for the period 1962/63 to 1973/74. Therefore, for reasons justified below, a set of exogenous changes was specified to serve as a base from which the potential contribution of mining growth could be assessed. While there is necessarily some arbitrariness in this approach, it was considered important enough to make an attempt at such a measurement. The fact is that mining growth, holding everything else constant, is very different from growth against a backdrop of other changes.

The overriding criterion used in selecting the set of exogenous changes to be considered was to specify a set of changes that may have been reasonably expected to occur, such that they reproduced the historical pattern of growth rates shown in Table 2 reasonably well. In addition to this criterion, however, some knowledge of changes which did occur permits some constraints to be placed on the size of the exogenous changes specified. For example, the annual growth rate of population in Australia was 2·8 per cent; since the period referred to was one of relatively stable employment levels, it may be supposed that the labour endowment was growing at an annual rate close to 2·8 per cent. The annual growth rate of the capital endowment was assumed to be 4·0 per cent. The land endowment may be con-

sidered as 'effective' land, so that pasture improvement and land clearing will increase the initial endowment. It was assumed that the land endowment was growing at an annual rate of 2·0 per cent.

To have the mining sector growing at a rate of 16·0 per cent per annum, which is consistent with the real price changes for minerals, a set of exogenous increases in both export demand and domestic supply was postulated. It was supposed that the supply schedule of mining products was shifting outwards through technical change of 4·5 per cent per annum and the export demand schedule was shifting upwards by 7·5 per cent. It has been well documented (BAE 1977) how output of the agricultural sector has been expanding despite falling relative prices, and therefore it was postulated that technical change must have been occurring, so an annual rate of 4·5 per cent was assumed.

Finally, given the set of changes described so far, and given the fact that the economy was growing at an overall rate of 5·6 per cent per annum, it was necessary to assume that technical progress was also occurring in the manufacturing and services sectors. To reproduce the historical pattern closely, these rates had to be set at the values of 3·0 per cent per annum and 2·0 per cent per annum for the manufacturing and services sectors respectively. All other exogenous variables were specified to have no change.

While the set of selected exogenous changes may not correspond exactly to those that actually occurred, the object of this exercise is not so much to reproduce the Australian economy exactly as to gauge the likely influence of the mining sector growth on the other sectors. This goal is accomplished by postulating a set of exogenous changes which reasonably may have occurred, so that the model simulates the historical pattern of growth. It is then possible to answer questions about what would have been the growth rates of outputs, prices, and so on, of the sectors of the economy had the mining sector not grown exogenously.[10] Therefore, using 'best' elasticities described earlier, the results in Table 2 were simulated with the set of exogenous changes described above.

It can be seen from Table 2 that, with the exogenous changes mentioned above, the model can simulate the important changes reasonably well. There are still another seven exogenous variables in the model which have been assumed constant in this simulation, and there are also fourteen elasticity parameters which could be varied. Adding more exogenous changes permits more degrees of freedom, and it would be possible to simulate the economy even more closely. In fact, it would be possible to derive a unique set of seventeen exogenous changes for a subset of seventeen endogenous variables. This could be achieved by specifying the actual changes for the seventeen endogenous variables of interest and labelling them as 'exogenous', then solving the model by relabelling the previously exogenous variables as 'endogenous'. To ascertain the effect of the mining sector expansion, the model was simulated

[10] Even when the exogenous shifts in export demand and domestic supply for minerals are assumed away, there is still an amount of endogenous growth of the mining sector if the rest of the economy is growing because mining is an input into other sectors. Also, there are increases in endowments which are used by all sectors.

TABLE 2

*Growth Rates of Selected Endogenous Variables*

| | Actual 1963/64 to 1973/74 | Simulated base: 1973/74[a] | Simulated rates in absence of autonomous mining growth[b] |
|---|---|---|---|
| | % | % | % |
| Gross product | | | |
| Agriculture | 2·6 | 2·4 | 3·9 |
| Mining[c] | 16·0 | 14·0 | 3·4 |
| Manufacturing[c] | 5·3 | 4·4 | 5·5 |
| Services | 5·7 | 5·6 | 5·9 |
| All sectors | 5·6 | 5·9 | 5·6 |
| Employment[d] | | | |
| Agriculture | −1·0 | −1·1 | 0·8 |
| Mining[c] | 5·4 | 9·4 | 0·3 |
| Manufacturing[c] | 1·9 | 1·0 | 2·4 |
| Services | 3·6 | 2·6 | 2·7 |
| All sectors | 2·8 | 2·8 | 2·8 |
| Agricultural real prices[e] | −1·9 | −2·0 | −1·7 |
| Terms of trade | −0·5 | −1·5 | −0·7 |
| Exchange rate[f] | 1·3 | 1·1 | 0·1 |

[a] See text for details of the exogenous changes which gave these results.
[b] Autonomous mining sector growth relates to the two exogenous shifts of the export demand and domestic supply schedules referred to in the text.
[c] The classification of mining and manufacturing sectors as between the actual results and the simulated results from the model are slightly different. See Stoeckel (1978) for details. 'Manufacturing' for the simulated results refers to a weighted average of the manufacturing export and manufacturing import-competing sectors.
[d] Weighted average of skilled and unskilled labour for the simulated results.
[e] In comparing agricultural real prices (ratio of agricultural prices received to agricultural prices paid) it is necessary to assume that the index of agricultural prices paid is similar to the index of economy-wide prices paid.
[f] The comparison between exchange rates is not strictly applicable since the exchange rate was 'fixed' over most of the period in question. However, other currencies did change and Australia's effective exchange did increase over the period in question. Also, the Australian dollar appreciated by 20 per cent in 1973. The trend growth rate is obtained from the trend rate of change of the effective exchange rate for the period 1962/63 to 1973/74, from IMF statistics using Rhomberg (1976) as the source for trade weights.

assuming the two mining sector exogenous changes were zero but using all other exogenous changes as above. The results from this simulation are shown in the third column of Table 2.

If it is assumed that the events which gave the results recorded in the second column of Table 2 actually occurred, then, by comparing these results to those assuming there was no autonomous mining sector growth, several important conclusions can be drawn. First, the annual growth rate of value added by the agricultural sector would have been 3·9 per cent in the absence of the autonomous mining sector growth. That is, the growth rate of the agricultural sector would have been 63 per cent higher. Whether or not this is a large effect is a debatable question, but the model also showed that, to offset the above

effect of mining sector growth in output terms, a 1·6 per cent annual increase in an export subsidy to agriculture would be required (Stoeckel 1978).

The effect on the agricultural sector is relatively large compared to the influence on the manufacturing sector. It is estimated that the growth rate of the manufacturing sector would have been 25 per cent higher in the absence of autonomous mining growth. Note that the growth of the manufacturing sector is smaller under mining growth, since both demand and supply factors have been considered. To offset this smaller effect, a larger amount of intervention would be required than that required to protect the agricultural sector from the effects of growth. The reason is that the manufacturing sector consists of an export-oriented sector and an import-competing sector. An export subsidy is required to protect the manufacturing export group, and an import tariff is required to protect the import-competing group. Since the tariff acts as an export tax, the two policy measures are offsetting and so a greater combination of tariff and export subsidy has to be prescribed to shift the burden on to the other sectors of the economy.

It is estimated that, to offset the depressing effect of mining growth on the growth rate of the manufacturing sector, an annual increase of 2·5 per cent in the tariff factor and of 1·8 per cent in the subsidy factor on manufacturing exports would be required. If the growth of the mining sector were assumed to be entirely due to a supply shift then, due to the earlier result of a small boost to the import-competing sector, a very small import subsidy would be required to hold the growth rate of the import-competing sector at a rate equal to that without the mining sector growth. In passing, however, it is worth pointing out that it was not possible to simulate the actual growth pattern in Table 2 nearly as closely by assuming that all the mining sector growth occurred as a result of a supply shift.

By comparing the second and third columns of Table 2 it can also be seen that the mining sector growth has a significant effect on the growth rates of employment of the agricultural and manufacturing sectors. The employment effects of the mining growth are an overstatement of what would have occurred in reality because the definition of 'mining', as described in the original study (Stoeckel 1978), includes processed minerals, which are not included in the definition of 'mining' for the figures in the first column of Table 2. However, the definition is consistent between the simulations with and without mining growth, so the comparison is still instructive. It may therefore be concluded that, had the mining sector not grown autonomously, the rate of growth of employment in agriculture would have been of the opposite sign, and equal to an annual rate of 0·8 per cent. The rate of growth of employment in the manufacturing sector would also have been very different. In the absence of autonomous mining growth, the employment of the manufacturing sector would have grown at an annual rate of 2·4 per cent, instead of 1·0 per cent as simulated in the presence of minerals growth.

The overall conclusion which can be drawn from this exercise is that the growth of the mining sector has reduced the growth rates of the agricultural and manufacturing sectors, and the effect on the

agricultural growth rate is greater than the effect on the growth rate of the manufacturing sector. However, the growth rate of the agricultural sector is still the lowest in the economy, even in the absence of autonomous mining sector growth. Agricultural prices would still have fallen had the mining sector not grown and the sector would have declined relative to the other sectors. This relative decline is despite the fact that a rate of technical progress in the agricultural sector greater than that of the other sectors has been assumed. This point is made clear from other simulations of the model described elsewhere (Stoeckel 1978): the agricultural sector does not do well relative to the other sectors under general economic growth.

The above conclusions have also been possible without resorting to changing exogenous trade variables such as a reduction in the exogenous demand for Australian agricultural products, brought on by, say, a greater rate of development in third world countries or a greater rate of technical progress by developed countries. Furthermore, the sensitivity results described in the original study show that the relative decline of agriculture is not due to a low income elasticity of demand for agricultural products. Even if identical income elasticities (necessarily all unity) had been assumed, a similar conclusion could have been reached. The relatively low growth rate of agriculture, and hence a relative decline of agriculture in the economy in this simulation, is due to the nature of the factor intensities in the economy, the pattern of domestic demands, and the fact that the large quantity of agricultural output exported has not been growing exogenously in this simulation.

Finally, the effect of mining growth on the services sector appear small. The reasons for this are: the services sector is very large compared to the mining sector; and, the exchange rate effects ensure that a large proportion of the adjustment occurs in the traded goods sectors.

*Export taxes on the mining sector*

Imposing an export tax on the mining sector (in effect imposing a tariff on imports and an export subsidy on the other two export sectors of an equal *ad valorem* rate) is an interesting policy option. Naturally, the tax on exports causes some of the mining output to be diverted onto the domestic market. This tendency for excess supplies to this market causes the domestic price to fall. As intended, the export tax has created a 'wedge' between export and domestic prices. These extra supplies being diverted onto the domestic market of course represent an advantage to those sectors using a large proportion of mineral output, both directly and indirectly, in their own production processes. The output of the import-competing sector expands by 1·7 per cent under the imposition of the export tax on minerals. As could be expected, there is a large contraction of mineral exports under the tax and the exchange rate depreciates. This depreciation is not very large because the advantage afforded to the import-competing sector discussed above causes imports to contract, quite apart from any exchange rate change. Imports contract by 8·3 per cent, which, because of the large weighting factor, represents a very significant reduction in the import bill.

As a consequence of the magnitudes of the elasticities assumed, the simulation of a 10 per cent *ad valorem* export tax, as measured from an undistorted free trade situation, would lead to an improvement in the terms of trade and, as shown in Appendix Table A.2 lead to a 0·3 per cent rise in real income. It then appears that imposing a tax on mining exports in the presence of mining sector growth would have some beneficial effects at the expense of the mining sector; it would improve real incomes and, from the point of view of the agricultural, the manufacturing export, and the import-competing sectors, it would remove pressure for readjustment. Also, the model predicts that the imposition of an export tax on minerals would lead to an increase in the real wage of both skilled and unskilled labour and, given an upward sloping supply curve for both groups of labour, would cause aggregate employment to rise.

The above benefits and costs from an export tax on minerals have been obtained without any reference to externalities. For example, Pindyck (1977) has estimated that, although proven reserves of most cartel members of the International Bauxite Association would last about 200 years at current production levels, reserves would last only 55 years if production grew by 4 per cent per annum. If the expected rate of increase in prices were greater than the social rate of time preference, then Australians would be quite justified in leaving their resources in the ground. For such a divergence to justify a tax, however, it must be supposed further that the market rate of interest is greater than the social rate of time preference.[11] If this is the case, the market will tend to consume exhaustible resources too fast and public intervention with a tax on mining output will improve social welfare. Whether or not there is a divergence between the private and social rate of time preference in Australia is an issue beyond the scope of this paper. The possibility of such an externality is raised here to draw attention to the fact that there are other potentially important reasons why Australians may wish or wish not to tax mining exports.

In regard to the potential gains or losses from taxing mining exports, two other points should be re-emphasised here. First, the gains from the tax represent the optimal tariff argument as measured from the free trade situation. As noted before, Australia already maintains a tariff on imports which is relatively high by world standards.[12] It could be that this tariff is equal to or greater than the optimal position already and any further change in Australia's protection levels could be a move away from an optimal position. Second, the simulations reported in Appendix Table A.2 are percentage changes in endogenous variables required to restore long-run equilibrium from a once-only exogenous shock to the system. So, if the mining sector growth is continuous, and some policy instrument was desired to offset the repercussions of this growth, then a continuous change in that policy instrument would be required. Over several years this could represent a large change and would become a significant distortion. It would not be possible to shield the traded goods sectors permanently from the consequences of mining growth.

[11] See Solow (1974, p. 8) for a discussion of the reasons why the market rate of interest and the social rate of time preference may diverge.

[12] See Industries Assistance Commission (1976, p. 78).

## *Conclusions*

The aim in this study has been to examine the effects of the recent rapid expansion of the mining sector in Australia on the rest of the economy with particular reference to the agricultural sector. Specifically, it has been argued by other authors that the rapid growth of the mining sector has placed large pressures for the readjustment of resources on the traditional export and import-competing sectors. This study has sought to quantify the economy-wide effects of this rapid growth of the mining sector through the specification of a five-sector neoclassical general equilibrium model.

There are two principal findings of this study which are highly related. First, it was demonstrated how the effects of mining sector growth on the other sectors of the Australian economy were very different depending on the source of the growth; that is, whether the expansion of mining was caused by an exogenous increase in the demand for exports or an exogenous increase in the domestic supply. Second, and related to the first, is that, if the mining sector growth were caused by a domestic supply shift (such as by mineral discoveries), then the effect on the import-competing sector was to cause gross output and value added to increase by a very small extent. In other words, a small increase in the tariff would have been required to hold the output of the import-competing sector constant. This result is very different from Gregory's finding that the effect of the mining sector growth through mineral discoveries on the import-competing sector was equivalent to a very large reduction in the tariff. The reason for the difference is that this model explicitly accounts for terms of trade effects, income effects, and interindustry flows in a general equilibrium framework.

By comparison, under the simulations of mining sector growth caused by an exogenous increase in export demand, it was observed that the import-competing sector did contract. Therefore, the effect of mineral growth on the import-competing sector is very different depending on the source of the growth. Because this study is a general equilibrium analysis, if the different origins of mineral growth have different effects on the import-competing sector, then they must also have different effects on the agricultural and other sectors of the economy. It was observed that the effect on the agricultural sector of the growth in mining is roughly double under the exogenous increase in domestic supply than under the exogenous increase in export demand.

Having argued that the effects of mining growth were different, depending on the source of the growth, and having argued that both price and quantity effects were apparent in the 'boom', a set of exogenous changes in both mining export demand and domestic supply was simulated, along with the other exogenous changes in the economy which could have been reasonably expected to occur. The choice of exogenous shifts was such that they were consistent with both the historical growth pattern of the Australian economy and the various export price and volume changes observed over the period. This exercise permitted the partial effects of the exogenous growth of the mining sector to be separated out.

Several important conclusions were then possible. First, had the mining sector not grown autonomously, the gross product of the agricul-

tural sector would have grown at an annual rate of approximately 3.9 per cent instead of the simulated historical rate of 2·4 per cent. That is, the growth rate of the agricultural sector would have been over 60 per cent higher in the absence of autonomous mining sector growth. The rate of decline of agricultural prices, however, would not have been much different, but would have been less at —1·7 per cent per annum than the simulated historical rate of —2·0 per cent per annum.

Because the actual mining growth was considered to be due to both demand and supply shifts, it was also concluded that the rate of growth of value added by the manufacturing sector would have been approximately 25 per cent higher had the mining sector not grown autonomously. The employment effects of the mining sector growth were also seen to be relatively important. Without the exogenous increase in export demand or domestic supply of minerals, employment in the agricultural sector would have increased by 0·8 per cent per annum instead of falling by a simulated 1·1 per cent per annum, which is an appreciable change. Also, employment in the manufacturing sector would have increased by 2·4 per cent per annum instead of increasing at the 1·0 per cent rate simulated with mining sector growth.

Another interesting conclusion from the results on the possible impact of mining growth was that, if the simulated exogenous changes had actually occurred, and had the exchange rate been flexible in real life, the Australian dollar would have been appreciating at an annual rate of 1·1 per cent. The contribution of the mining sector growth to this appreciation (using 1973/74 as the base) was over 90 per cent and the dollar would have appreciated by only 0·1 per cent per annum if the mining sector had not grown. Finally, it was shown how an export tax on minerals would reduce pressure for readjustment in the other sectors of the economy but only at the expense of a large reduction in output of the mining sector.

## APPENDIX

### *Terms of Trade Effects*

It was mentioned above that there were several reasons for the difference between Gregory's result and the present result, one of which was attributed to the changing terms of trade. It is worthwhile discussing these terms of trade effects since the small country assumption is frequently applied to Australia.

The elasticities used for this study were mentioned earlier and the justification for their selection was given in the original study (Stoeckel 1978). Rather than document this evidence again here, it is sufficient to note that there are studies which show that the demand for Australian exports is not infinitely elastic. In fact, some studies[13] have shown that the elasticity of demand for Australian exports is less than unity, which seems unbelievably low. That Australia can influence her terms of trade is not so much the issue, as by how much, and how sensitive the results are to the terms of trade effects.

[13] For example, the 'best' estimate of the elasticity of demand for exports given in R. M. Stern's bibliography of trade elasticities (Stern 1976) is, for the long run, —0·74.

The first point to note about these elasticities is that the model is not overly sensitive to the terms of trade effects. For example, a simulation was performed in which all trade elasticities were doubled, that is, they were changed in the direction of the small country assumption. The elasticities of export demand for agriculture, mining and manufacturing exports were then —8·0, —8·0 and —15·0 respectively, while the import supply elasticity was assumed to be 40·0. The result of assuming these elasticities was that a 10 per cent increase in mining value added brought on by a domestic supply shift caused the gross output of the import-competing sector to fall by 0·1 per cent. That is, instead of there being a small increase in output, there was a small decrease. To place this terms of trade effect into perspective, had an income elasticity of demand of 2·0 been assumed instead of 1·2 for import-competing goods, then under the high trade elasticities, the change in gross output would have been small positive again.

## APPENDIX TABLE A.1

*'Best' Elasticity Estimates*

| Sector | Price elasticity of export demand | Price elasticity of import supply | Income elasticity of final domestic demand |
|---|---|---|---|
| Agriculture | —4 | — | 0·3 |
| Mining | —4 | — | 0·5 |
| Manufacturing exports | —7 | — | 0·3 |
| Manufacturing imports | — | 20 | 1·2 |
| Services | — | — | 1·02 |

## APPENDIX TABLE A.2

*Percentage Changes in Endogenous Variables Due to a 10 Per Cent Increase in Selected Mining Exogenous Variables*

| Endogenous variable | 10 per cent exogenous increase of mining: Export demand | Technical change (supply) | Export tax |
|---|---|---|---|
| | % | % | % |
| *Gross output* | | | |
| Agriculture | −0·2 | −0·9 | −0·6 |
| Mining | 1·9 | 10·0 | −7·7 |
| Manufacturing export | −0·2 | −0·7 | 0·6 |
| Manufacturing import | −0·5 | 0·7 | 1·7 |
| Services | −0·0 | 0·3 | 0·3 |
| *Real prices*[a] | | | |
| Agriculture | −0·1 | −0·1 | 0·3 |
| Mining | 0·4 | −5·5 | −1·5 |
| Manufacturing export | −0·1 | 0·1 | 0·1 |
| Manufacturing import | +0·0 | −0·4 | −0·1 |
| Services | −0·0 | −0·3 | +0·0 |
| *Factor prices* | | | |
| Unskilled labour | −0·1 | 0·6 | 0·3 |
| Skilled labour | −0·0 | 0·7 | 0·1 |
| Capital | +0·0 | 0·6 | −0·1 |
| Land | −0·3 | −1·0 | 0·8 |
| Mining capital | 2·2 | 4·5 | −9·2 |
| *Traded goods* | | | |
| Agricultural export | −0·4 | −2·2 | 1·7 |
| Mining exports | 7·9 | 19·4 | −31·3 |
| Manufacturing export | −0·9 | −5·0 | 3·9 |
| Manufacturing import | 2·1 | 2·6 | −8·3 |
| *Unskilled labour use* | | | |
| Agriculture | −0·2 | −1·6 | 0·5 |
| Mining | 2·3 | 3·9 | −9·5 |
| Manufacturing export | −0·2 | −1·3 | 0·4 |
| Manufacturing import | −0·4 | −0·3 | 1·3 |
| Services | +0·0 | +0·0 | +0·0 |
| *Skilled labour use* | | | |
| Agriculture | −0·3 | −1·7 | 0·7 |
| Mining | 2·2 | 3·8 | −9·3 |
| Manufacturing export | −0·2 | −1·3 | 0·6 |
| Manufacturing import | −0·4 | −0·4 | 1·5 |
| Services | −0·0 | −0·1 | 0·2 |
| *Capital use*[b] | | | |
| Agriculture | −0·3 | −1·6 | 0·9 |
| Mining | 2·2 | 3·9 | −9·1 |
| Manufacturing export | −0·2 | −1·2 | 0·8 |
| Manufacturing import | −0·5 | −0·3 | 1·7 |
| Services | −0·1 | +0·0 | 0·4 |
| Income[c] | +0·0 | 0·5 | 0·3 |
| Terms of trade effect[d] | +0·0 | −0·1 | 3·0 |
| Terms of trade[e] | +0·0 | −1·3 | 3·0 |
| Exchange rate[f] | 0·2 | 0·6 | −0·7 |

[a] Prices are relative to a production weighted index, which is held constant.
[b] Capital use refers to general capital use and not land and 'fixed' mining capital, which are held constant.
[c] Income is in real terms.
[d] The effect on real income of the change in terms of trade.
[e] The ratio of external export prices to import prices.
[f] Exchange rate is defined as the reciprocal of the price of foreign exchange; hence an increase represents an appreciation of the Australian dollar.

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