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ABSTRACT

In this paper, an input-output framework is used for measuring the significance of domestic levels of mineral and energy sectors for various economies at different stages of economic development. The aim is to determine the significance of industry interconnectedness between each mineral and energy sector and the rest of the economy. The rationale is that development planners prefer sectors with extensive inter-industry ties to enclave sectors or sectors with a few industry connections. It has been argued that the mineral sector is nothing but an enclave sector. Following a brief evaluation of the literature concerning the importance of mining and energy-related activities for economic development, an empirical analysis was performed employing a static input-output framework to measure mineral and energy sector impacts. The focus is on quantifiable linkages between the mineral and energy sectors and the rest of the economy. Direct, indirect and induced impacts are felt through macro-economic measures such as gross national income and output. Both multipliers and linkages which capture these effects are derived. The results presented here emphasise the significant role of the mineral and energy sectors in economic development. Mineral and energy sectors are able to generate great industry inter-linkages and high output. Nonetheless, the opportunities for generating growth prospects seem to vary with the type of mineral and energy activity undertaken as well as with the level of economic development achieved by the country.

RESUME

Cette étude utilise un modèle TES pour évaluer l'impact des ressources minières et énergétiques sur le tissu économique de plusieurs pays à différente phase de développement. Plusieurs controverses existent à propos de la nature de l'impact des deux secteurs sur le développement économique. L'étude débute par un parcours en revue de la littérature disponible sur l'impact du secteur minier et énergétique sur les PVD. L'objectif essentiel de l'étude est de mesurer quantitativement le lien économique entre ces deux secteurs et les autres secteurs de l'économie. Pour atteindre cet objectif, la méthodologie utilisée repose sur l'analyse du tableau entrée-sortie. Ainsi, le secteur des matières premières est décomposé en des lignes distinctes de produits miniers et énergétiques afin de déterminer l'effet multiplicateur de chaque industrie séparément. Les résultats obtenus suggèrent que des gains importants peuvent être obtenus de l'exploitation et la transformation de produits miniers et énergétiques si on améliore le niveau ainsi que la technologie du processus opérationnel. De même, l'analyse des multiplicateurs permet de confirmer le fait que le développement efficient des activités minières et énergétiques permet des changements structurels positifs de s'opérer dans une économie donnée. Néanmoins, le succès d'une stratégie de développement basée sur ce type d'activité économique dépend réellement du support direct apporté à ces industries, des choix technologiques, de la capacité technologique à long terme, des choix des politiques économiques gouvernementales surtout en matière de développement du secteur privé, ainsi que du choix du minerai ou produit énergétique à exploiter et à transformer.

The Mineral and Energy Sectors and Stages of Economic Development: A Comparative Input-Output Analysis

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Brigitte Bocoum*

1. Introduction

The purpose of this paper is to highlight the nature of the linkages between the mineral and energy sectors and the rest of the economy at various stages of national development. It also aims at identifying viable investment alternatives among several mineral activities. The analysis is based upon the concept of intersectoral "linkages" which emphasizes the importance of stimulating key sectors which have strong technological linkages with other sectors in order to stimulate economic growth. It relies upon the use of input-output (I-O) tables for three countries at various stages of economic development, namely the United States, Australia and Chile. The results are later compared with the author's previous research work performed on Zambia and Morocco as well as similar work by another author on Brazil. This gives rise to the following specific objectives: (1) to present a quantitative framework capable of analyzing the potential impact of mineral and energy related activities on industry linkages and growth prospects, (2) to apply the methodology to three mineral producing countries, (3) to identify viable mineral and energy activities for investment, and (4) to provide policy suggestions which can be employed in the mining sector to increase domestic value-added and foreign export revenues through such investments. Finally, the implications are drawn for the potential of the proposed approach for evaluating resource-based activities other than minerals in similar situations in other countries.

2. Minerals and Economic Development

Most studies evaluating the economic impacts of the mineral sector highlight the complex nature of the link between that sector and economic development. The view has been advanced that the development performance of mineral-exporting countries has fallen behind countries with similar initial income levels but with different composition of production and trade. A large body of literature shows that many developing countries with large mining sectors have had great difficulty in converting mineral wealth to economic development despite high investment rates (Tilton, 1992; Stern, 1994 a,b). In Africa, mineral exports from lower-income countries so often seem to be associated with a retardation of growth and development.

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More optimistic viewpoints emphasize the importance of the mineral sector to a region or a nation's economic development. This stems from the structural advantage that the mineral exporters are said to have over other developing nations. This is largely because they are in possession of a resource that is readily converted into a large financial flow, much of it in the form of foreign exchange. Furthermore, the mineral economies are characterized by an overwhelming dominance of the fiscal linkage over production and consumption linkages; structural features underline the importance of maximizing the fiscal linkage and of the state's role in transforming the economy. By the same token, these same structural differences, and the typical policy responses to them, tend to render the mineral economies more prone to a number of economic problems as compared to non-mineral economies. Historically, export-led development has relied more effectively on backward and forward linkages between the export industry and other economic sectors. While the success of the fiscal linkage depends on the ability of the governments to generate maximum income and redistribute it effectively, backward and forward linkages are found to work themselves out through the market more easily. This lack of automaticity has been recognised as the major weakness of the fiscal linkage, and hence a major problem in mineral and energy exporting economies.

Additional structural impediments generally comprise wage and technological dualism, stagnation in agricultural production resulting in food price inflation, and large scale food imports (all of which cause the persistent increase in prices to spread throughout the economy, increasing overall inflation). Financial problems which can arise include (i) Dutch disease, whose negative effects on mineral and oil economies were identified as early as in the mid-1980s by Corden (1984), and (ii) currency revaluation (Lewis, 1990); i.e. an increase in export revenues will tend to appreciate the exchange rate, leading to a loss of competitiveness and hence to a fall in output in the other tradable goods sectors. Similarly, while attempting to analyse the potential impact of the mineral and energy sectors from a sustainable economic development standpoint, one could further enrich the argument by also linking the discussion with the Construction Boom Theory, an extension of the Dutch Disease theory which analyses the macro as well as micro economic effects of a temporary positive external trade shocks in small open economies (Bevan et al., 1990; Brownbridge and Harrigan, 1996). Other negative factors include the inefficiency of management, the small size of domestic markets, the low ratios of capacity utilisation, the inadequacy and/or misuse of technical skills, the high costs of most traditional mining operations, the environmental impacts from mining, oil extraction, mineral processing and metal product manufacturing and the continuing general lack of financing for such projects, at least in Africa.

Indeed, the lack of financing has been identified by several researchers in the field as being one the most important deterrent to the development of mineral and energy resources on the continent. A recent study by UNECA (1999) has advanced that Latin America, which has the same quality of mineral endowment as Africa, is currently the darling of the global mining industry. The region attracted 28.7% of the 1998 global exploration and development (E&D) budget with an estimated 66 advanced stage exploration/development projects. Comparing this with Africa's 17.5% and 35 respectively, it is clear that there is a tremendous gap to be closed by Africa. Most have argued that this situation stems from the fact that exploration and mine development in Africa carry considerably greater risks. Table 1 offers a comparison of indicators for political stability, investment ratings, and investment levels for major E&D regions. Although for both political stability and investment rating indicators, Africa scores lower that the other regions, global investment expenditures were low and comparable to those of a single country like Australia.

Table 1: Comparison of global E&D regions

	1998 Global exploration budget	Political stability ranking	Direct investment ranking
Pacific/SE Asia	US$265,7 m	76	B+
Canada	US$308,0 m	91	A
Africa	US$494,3 m	65 (lowest)	B (lowest)
Australia	US$494,6 m	93	A+
Latin America	US$814,1 m	75	B+

Source: Metals Economics Group (1998).

The next table outlines the current risk perception by mining companies in African countries and the percentage of 1998 E&D funds each category attracted (in percent). From Table 2 it is clear which African the mining industry views as reliable long-term partners at present. African countries should be particularly sensitive to these perceptions.

Table 2: Perceived Political risk of African countries as related to mining activities

	Medium risk (33%)	Acceptable trend (45%)	High risk (22%)
Traditional E&D countries	Ghana, Mali, Burkina Faso, South Africa, Côte d'Ivoire, Botswana	Tanzania, Zambia, Guinea, Namibia	Sierra Leone, Zimbabwe, DRC, Angola
85%	33%	33%	19%
New E&D countries		Madagascar, Mozambique, Swaziland, Mauritania, Senegal, Tunisia, Kenya, Niger	Uganda, Ethiopia, Lesotho, Eritrea, Sudan
15%		12%	3%

Source: United Nations Economic Commission for Africa (1999).

Ultimately, it is up to each African countries to attract mining investment by improving its risk/ reward perception relative to other competing countries.

In terms of overall performance, there is, however, a considerable difficulty in arguing the thesis that mineral-and oil-exporting countries share a common record of overall performance. What is striking, though, is the widespread absence of a strong mineral and energy sector in African countries[1] , except perhaps for a few. Furthermore, mineral processing and manufacturing are also virtually absent in African countries. This confirms the accepted need for improvement of the functioning of this sector on the continent.

Earlier research work by Lewis (1990) and Daniel (1989) explore the forces at work in the mineral economies that lead away from progress toward sustainable growth. Lewis identifies an investment disequilibrium that he terms the "automatic adjustment mechanism" which brings external payments and government budgets back into balance at higher levels of (more unequal) consumption, with some associated problems of social and political tensions, and an inefficient set of prices facing investors. He also suggests that a better spread of the investment of an increased share of mineral rents through time would produce a pattern of growth more consistent with the aims of development policy in most mineral economies. Three important categories of policy choices in mineral economies are introduced by Daniel: (i) an effective taxation policy, (ii) a policy that encourages a change in consumption patterns and inter-sectoral shifts, and (iii) a policy that emphasizes adjustment in the spending pattern over time.

Mining generate effects that arise from the linkages that mining has to offer to other industries. Hirschman (1958) was one of the first researchers to advocate the stimulation of economic growth by promoting a limited number of key sectors which have a strong technological linkage with other sectors. The promotion of these key sectors would induce the growth of sectors which supply their inputs as well as induce the expansion of sectors which utilize the products additionally produced as inputs. The identification of key sectors of the economy thus becomes crucial for attaining the most efficient utilization of resources with regard to sectoral allocation. The identification of these strategic sectors constitutes a useful foundation for the setting of sectoral priorities commensurate with the objectives of national development plans.

Mineral development can, undoubtedly, contribute to the development of many developing economies both because its benefits exceed its costs and because of its potential linkage effects. Impacts of mining and energy-related activities can be felt throughout a nation's economy in terms of employment generation and the production of new materials for use in the manufacture of semi-finished and finished products. It is clear, however, that much will depend on an improved performance on the part of African countries that are traditional mineral exporters in keeping down inflation, increasing agricultural growth rates and saving performance. Hill suggests in the 1990s that the appropriate response to a temporary increase in revenues is to avoid the macroeconomic effects and structural changes that would only be appropriate for a permanent increase. When a country's income increases temporarily, the importance of savings and investment path that are consistent with long-term development objectives needs not be over-emphasised. Hill encourages a pattern of saving for a large percentage of the windfall, spreading the increased consumption allowed by the boom overtime that would be consistent with the life cycle-permanent hypothesis.

Mineral and energy product revenues offer the opportunity to close a significant proportion of the development gaps between regions. The potential economic gains must, however, be estimated under controlled assumptions. These include the additional constraints imposed by the choice of the "appropriate" technology, given the country's resource endowment; the consideration of environmental constraints at both national and global scales; macro-economic issues, such as the effect of foreign capital inflow on the price of foreign exchange; and sectoral or microeconomic issues such as the need to protect infant-industry and a strong commitment to encouraging learning-by-doing.

These issues are complex enough that any strong ideological position is insufficient to inform and guide policy. Some dealing with entities outside African countries for financing, managing, marketing and trading will be required if mineral activities assume the proportion most would expect. That being the case, the issues then become operational: how to best allocate activities to promote sustainable development of the mineral and energy sectors of African countries.

3. The Model

A static input-output model is utilized in this paper to describe the interactions between the various mineral and energy sectors and the rest of the economy. More particularly, the derivation of both linkages and multipliers is performed through the use of input-output analysis. These quantitative measures represent direct economic impacts (measured in terms of value-added, net foreign exchange earnings and direct employment), indirect impacts (on associated industries plus the final demand spending) and positive externalities (such as gains in labour skills, technological capability, marketing skills and process know-how). Demand for outputs, such as those made by consumers, private investors, foreign traders, and governments, are included in final demand. Value-added also include, in addition to inputs of capital and labour, profits and business. The sum of final demand is equal to the sum of value-added, and the gross inputs for an industry are equal to the gross output of that industry. Final demand and value-added also represent total GDP expenditures. A schematic representation of the mineral and energy sector input-output model is offered in Figure 1.

Quantifying the economic impact of the mineral and energy sector is made possible by determining the magnitude of inputs to the mineral and energy sector from other productive sectors per monetary unit of sectoral output. According to I-O theory, output is related to final demand, as given by the usual input-output equation:

$$X = (I-A)^{-1} Y \qquad (1)$$

where Y is the vector of final demand, X is a vector of total output, I is the nXn identity matrix in an economy identified as having n productive sectors including the mineral and energy sectors, A is the technology matrix of input-output coefficients and $(I-A)^{-1}$ is the inverse matrix (termed the Leontief inverse matrix). Let the elements of the Leontief inverse matrix be denoted α_{ij}'s. These indicate the direct plus indirect plus induced input requirements per unit of output in a model closed for households.

Output and income multipliers

In input-output modelling, the effect of exogenous changes in a given sector resulting from a unit change in final demand on output of other sectors is represented by the output multiplier (O_j). The income multiplier, which allows for an assessment of income earned by households per monetary unit's worth of sectoral output is given by (Y_j), in a model closed for households[2] , h.

FIGURE 1:
SCHEMATIC REPRESENTATION OF THE MINERAL AND ENERGY SECTOR INPUT-OUTPUT MODEL

Pro- ducers Sales	Producers Purchases					TOTAL			TOTAL	TOTAL
Other Sectors	Other Sectors	Mineral Sector	n -..	Energy Sector	Sector n		EXPORTS	Other Final Demand		
. . . Mineral Sector, n -... Energy Sector, n -... .	Intra-Sector/Stage Sales and Purchases a_{ij}'s					Total Sectoral Purchases	Export Demand by Sector	Other Final Demand by Sector	Total Demand by Sector F_j	Gross Output by Sector X_j
Total Intermediate Inputs, D_j	Total Sectoral Inputs d_{ij}s									
Wages & Salaries Imports, M_j	Sectoral Value-Added Transactions					Total Value-Added by Type	GROSS DOMESTIC PRODUCT			
Total V_j	Total Value-Added Sector									
Total VI_j	Gross Input by Economic Sector									
EMPLOYMENT BY SKILL TYPE	Sectoral Employment in Physical Units									

$$O_j = \sum_{i=1}^{n,h} \alpha_{ij} \quad (2)$$

The output multiplier is merely the column sum of the Leontief inverse. Output multipliers indicate the origin of increments in business activity generated per dollar of delivery to final demand.

$$Yj = \sum_{i=1}^{n,h} a_{h,i}\ \alpha_{ij} / a_{h,j} \quad (3)$$

The $a_{h,i}$'s represent household incomes received per monetary unit of sectoral output. Income multipliers give the expected income increase generated by additional consumer spending, i.e. by an additional dollar (or peso in the case of Chile) of income paid directly to households.

Linkages

Input-Output analysis also often allows for the quantification of direct and indirect effects in terms of linkages. Linkages tell us how closely linked sectors are with each other. Three types of linkages are commonly measured through the use of input-output models: (1) backward linkages; (2) forward linkages; and (3) total linkages. Key sectors according to Hirschman are those sectors with both backward and forward indices greater than unity. Linkages may ranked as either strong, intermediate or weak.

Strong	Linkage index ≥ 1
Intermediate	$0.9 \leq$ linkage index < 1
Weak	Linkage index < 0.9

A sector with strong forward and backward linkages, that is a sector whose total linkage value exceeds 2.0 and has both backward and forward linkages greater than 1.0 qualifies as a "key sector." As a common rule, sectors with high forward linkages in relative terms should be expected to induce opportunities in these sectors that utilize their products as inputs. On the other hand, sectors that constitute strong overall backward linkages should be expected to induce investment opportunities to those sectors that supply their inputs through expanded production. The backward (U_j) and forward (U_i) linkages (later labeled BL and FL respectively) are defined as given

$$U_j = \frac{A_j}{1/n \sum_{j=1}^{n} A_j} \quad (4)$$

$$U_i = \frac{A_i}{1/n \sum_{i=1}^{n} A_i} \qquad (5)$$

where $A_i = \sum_{j=1}^{n} \alpha_{ij}$ denotes the sum of the row elements and $A_j = \sum_{i=1}^{n} \alpha_{ij}$ denotes the column elements. The α_{ij}'s are same as described previously. Total linkages (TL) can merely be obtained from the addition of both backward and forward linkages which appear above. Also, it is common practice with input-output analysis to define the ranking of economic sectors based on their linkage value.

4. Estimating Mineral and Energy Impacts

Empirical framework

Three stages of national economic development are identified prior to the analysis. The information thus obtained on stages of development is matched against the availability of input output tables and data for those countries. The choice of a specific country is further based on the importance of the sectors for the given economy. The United States is selected for the present study as its mineral and energy sectors have in most cases reached a development stage which is higher than those of Australia and Chile. These two countries were selected for this study because of the importance of the mineral sector in each economy, and because of the importance of the minerals involved in international trade, i.e. a strong export sector. For each country, the economic impact of the mineral and energy sector is evaluated. As stated previously, these results are later compared with those obtained in earlier studies for Zambia and Morocco, two important African mineral economies, and Brazil. Again, these countries were selected for this study because of they are all developing countries whose mineral production and export levels are significant on a global scale. The author realizes that the present methodology could have been applied to several other African countries (Zimbabwe, Gabon, Namibia, Togo, etc...) which are also producers and exporters of minerals and oil. However, it is important to acknowledge that the reliability of input-output data represents a limiting factor.

The present modelling exercise involves several important steps. For all countries investigated, most recent available national I-O tables are first obtained. In all cases, the empirical application requires modifying through aggregation underlying input-output data obtained from available base tables. From a "large" input-output table, a "smaller" one is derived by aggregation, with the aim to "standardise" the impacts of the mineral and energy sectors of interest across all I-O tables utilised.

The aggregation of the I-O base tables is performed next using a mechanical adjustment technique where the I-O matrix is modified so that it will sum to given row and column totals by the successive prorating of its rows and columns. This procedure has been successfully used in various I-O studies to isolate sectors of interest from others which are grouped together in smaller I-O tables. The linkage and multiplier measures derived subsequently estimate the direct and indirect impacts of the mineral and energy sectors on supplier and user sectors, as well as on gross income and output.

Input-Output procedure

I-O Sector Label. Because the original I-O table for each country differs according to the total number of economic sectors in each table, as well as the labeling of those sectors, this affects the nature of linkages for the mineral and other industries. Hence, it is first found necessary to level the grounds for the analysis. Similarities and differences in the information provided in the tables were identified by comparing the available tables for Australia, Chile and the United States. This inspired the denominations and classification presented in Table 3. As stated previously, and in order to simplify the present illustrative analysis and to make results as comparable as possible between the three countries, the tables were aggregated into 40 sectors (including the twelve mineral and energy resources sectors) using the same sector classification for each country. The mineral and energy-related activities of interest are grouped into twelve main sectors described in Table 4 and both their sectoral and aggregate impacts later assessed.

Table 3:
Aggregated I-O Table (n = 40)
Allocation of Sector Number and Designation

1. Agriculture & livestock production	21. Lumber & wood products
2. Forestry & Fishing production	22. Furniture & Fixtures
3. Ag., forest., fishing services	23. Paper, printing & publishing
4. Metallic mineral mining, non-ferrous	24. Rubber & misc. plastics
5. Metallic mineral mining, ferrous	25. Glass & glass products
6. Coal, oil and gas extraction	26. Machinery, except electrical
7. Industrial mineral mining	27. Transport Equipment
8. Other mining	28. Other manufacturing
9. Mining Services	29. Utilities, except energy
10. Chemicals, including agricultural	30. Construction
11. Petroleum & coal transformation	31. Repair services
12. Non-metallic mineral processing	32. Wholesale & retail trade
13. Metallic mineral processing, non-ferrous	33. Transport services
14. Metallic mineral processing, ferrous	34. Communications
15. Metal products	35. Financial inst., insurance & other business services
16. Energy	36. Education & health services
17. Food and Tobacco	37. Recreational services
18. Textiles & wearing apparel	38. Restaurants & hotels
19. Leather products	39. Other services
20. Footwear manufacturing	40. Public administration & defense

Table 4:
Mineral and energy sector classification

Stage of processing	Name of mineral & energy sector/Code		Sector Number in Aggregated I-O Table
Mining	Metallic mineral mining, non-ferrous	(M1)	4
	Metallic mineral mining, ferrous	(M2)	5
	Oil, coal and gas	(M3)	6
	Industrial mineral mining	(M4)	7
	Other mining[a/]	(M5)	8
	Mining services	(M6)	9
Mineral Processing	Metallic mineral processing, ferrous	(MP3)	14
	Metallic mineral processing, non-ferrous	(MP2)	13
	Non-metallic & industrial mineral processing	(MP1)	12
Mineral & Energy Product Manufacturing	Petroleum & coal transformation	(MM2)	11
	Chemicals, including agricultural[b/]	(MM1)	10
	Fabricated metal products	(MM3)	15
Energy	Energy	(E1)	16

a/ Minerals which belong to categories other than those mentioned above.
b/ Includes the mineral-based agricultural chemicals used principally as fertilizers such as those derived from phosphate, nitrogen, sulfur and potash.

I-O Table Aggregation. A 500 intermediate sector US national table is the most detailed for this exercise and the latest available that contained the mineral industries of interest. This I-O table is obtained from Implan/Q[3] . For Australia and Chile, the aggregation technique applied to group the economic sectors which appear in their base I-O tables is identical. It consists in adding up row and column transactions and balancing the table using the I-O software package called Grimp[4] .

Results

Empirical estimates of total linkages (TL), backward linkages (BL), and forward linkages (FL) are derived for the aggregated 40 sectors of the Australian, Chilean, United States economies. In summary, among key mineral and energy sectors which were found common to all three countries is that of petroleum and coal transformation. In terms of strong backward linkages common to all three regions, two were identified, namely, the non-metallic processing and the ferrous metallic mineral processing sectors. With regards highest rankings for forward linkages, the petroleum and coal transformation sector was positioned among the top five economic sectors. Further details concerning the ranking of mineral and energy-related activities are discussed below, and summarized in Table 5. These are depicted by stage of processing and associated activities in Figures 2 through 5.

Ranking of mining activities. In terms of their dependence on other activities for their inputs represented by backward linkages, mining activities alone ranked comparatively low, with the exception of non-ferrous metallic mineral mining and industrial mineral mining activities in the United States and Chile. This does not totally come as a surprise in the case of Chile since copper mining is the major mineral activity in that country. Ferrous metallic mineral activities (iron ore) ranked low in all three countries as the industry's major inputs are provided mainly by imports. Mining services had a relatively high ranking deriving the majority of its inputs locally in Australia. Regarding the ability of the mining sectors to serve as inputs to other non-mining economic activities (forward linkages), it was found that they ranked very low with the exception of the other mining category which comprises gemstones and diamond mining in the United States. Of greater significance was the industrial minerals sector which recorded slightly higher marks. Overall, the mining of gemstones and diamonds (other mining category) and the mining services were found to be the most significant sectors among all mining (primary) activities.

Mineral processing. A comparison of the rankings offered by various mineral processing activities in all three countries showed that mineral processing activities ranked higher than mining activities with the exception of iron and steel (ferrous metallic mineral processing category) when dealing with backward linkages. However, ferrous metallic mineral processing activities were significant in Australia, a major exporter of iron and steel. Of even greater significance are the indices recorded in the non-metallic mineral processing activity which concerns activities such as the processing of industrial chemicals and mineral-based fertilizers. This is particularly true of a developed nation such as the United States. Forward linkage analysis led to the conclusion that mineral processing ranked higher than mining in their ability to provide inputs to other sectors. In terms of total linkage, the processing of iron and steel was significant in Australia and the United States. However, it is worth noting that these activities are much stronger than those of mining in their capability to create backward and forward linkages with other industrial sectors and thereby establish a quasi-automatic process of industrialization. These findings confirm earlier research findings by the author (see Bocoum-Kaberuka, 1999 a,b).

Mineral and energy product manufacturing. This concerns three sectors in our analysis: that of industrial chemicals (sector 10) that include mineral-based products such as phosphatic and potassic fertilizers; the manufacturing of metal products (sector 15); and petroleum and coal transformation (sector 11). While the metal product manufacturing sector had strong backward linkages in both Australia and Chile, it had weak forward linkages in the same two countries. This stems from the fact that this mineral activity derives most of its inputs locally in both countries. It also emphasizes the importance of final demand absorption for the outputs by this sector. This is related to the importance of export activities for metal products from these two countries relative to other economic activities. Similar results were obtained for the chemicals sector in Chile. Petroleum and coal transformation activities were also important for the three economies.

Energy-related activities. These sectors show interesting mixed results. The impact of the energy related activities varies depending on the country. In the economies of Australia and the United States, energy activities ranked from average to high in terms of total linkages. However, in Chile, coal, gas and oil extraction had the second highest rankings among all economic activities. Petroleum and coal transformation had strong forward linkages in all three economies. The impact of energy utilities was most significant in Australia. This is not totally surprising as this country is a major exporter of energy worldwide.

Multiplier analysis of sectoral effects

Related to the question of the role that each mineral and energy related sector plays in aggregate increase in output and income is the question concerning the magnitude of the impact experienced by each sector. Multipliers showing the relative output effects which can be expected in each sector of the economy as a response to a stimulus in mineral and energy related activities were computed.

When considering output, it was found that the ferrous metal ore sector had the greatest impact on the ferrous metallic mineral mining sector, the finance institutions and insurance sector, the repair services sector, the transport and machinery sectors. The non-ferrous metal ores sector had the greatest impact on the non-ferrous metallic mining sector, followed by the financial institutions and insurance sectors, the repair services sector, the transport and machinery sectors. The non-ferrous metal ores sector had the greatest impact on the non-ferrous metallic mining sector, followed by the financial institutions and insurance sector, the repair services and transport and machinery sectors. In fact, all mining related activities would follow the sequence outlined above. Least influenced by mining activities in Australia are the manufacturing sectors of leather and footwear, rubber and plastics, paper making and printing industries, and traditional activities such as agriculture, forestry and fishing.

The mineral processing and energy transformation activities had similar output effects on the economy, although their recorded effect on the coal, oil and gas and energy sector was in general greater than that of mining activities. This is consistent with the energy intensiveness of mineral processing activities such as iron and steel and coal transformation. The chemicals and non-metallic mineral processing seem to impact output by the machinery sector less significantly than other mineral activities. The figures also show that there is a high degree of interdependence between all mineral and energy processing activities.

Mineral product manufacturing shows similar features. First, the strong link between product manufacturing, processing and mining industries is noticeable. Second, the even greater importance of the energy sector in metal fabricating industries is underlined.

The sectoral results of mineral and energy activities in Chile were also analyzed. Generally speaking, all mineral activities would impact the most their own output. Output effects on the energy sector and petroleum and coal transformation sectors were relatively large.

When considering various stages of production, the following remarks can be made. As regards mining activities, both copper mining and iron ore mining had a great impact on output by other mining activities. Also, mining activities influenced machinery sector output significantly. Metal product manufacturing shows strong links with output by the mining sector. Concerning mineral processing and petroleum and coal transformation activities, strongest links appear with the coal, gas and oil sector, other transformation sectors such as petroleum and coal transformation and industrial mineral manufacturing, repair services, financial institutions, and transport services. Similar results are obtained with mineral product manufacturing activities, and output by the energy sector.

Comparison with previous findings on Zambia, Morocco and Brazil[5]

A comparison of the above findings with those found at other locations is offered in this section. The impact of mineral activities is assessed in three other developing countries which are also at different stages of development. While in Zambia mining ranked the highest of all economic groupings, it ranked the lowest in Morocco, and in Brazil. Metal products combined with basic

Table 5:
Comparative ranking of mineral and energy related sectors (total =40)

Type of mineral and energy activity	BL			FL			TL		
	Australia	Chile	US	Australia	Chile	US	Australia	Chile	US
Metallic mineral mining, non-ferrous[a/]	24	18	4	35	37	38	36	37	22
Metallic mineral mining, ferrous	31	29	32	37	34	23	39	35	33
Industrial mineral mining	33	12	12	25	24	12	31	21	12
Other mining[b/]	33	30	31	25	35	3	31	38	4
Mining services[c/]	2	c/	6	21	c/	18	7	c/	13
Non-metallic mineral processing	13	15	2	32	26	15	29	24	10
Metallic mineral processing, non-ferrous[a/]	7	14	20	34	14	22	30	13	24
Metallic mineral processing, ferrous[a/]	4	14	30	18	14	16	4	13	19
Chemicals, including agricultural[d/]	27	5	14	4	23	17	9	7	17
Metal products	5	6	33	27	22	27	20	14	17
Coal, oil & gas extraction	38	29	34	28	1	32	34	2	35
Petroleum & coal transformation	38	29	34	28	1	32	34	2	35
Energy	19	8	36	3	4	25	2	3	38

a/ Consists of copper mining alone in the case of Chile.
b/ Mining activities other than those listed above. Also, the original Australian I-O base table does not differentiate among these sectors.
c/ Services to mining activities are not described separately in the Chilean I-O base table.
d/ Includes the manufacturing of the following mineral-based products: phosphatic, nitrogenous and potassic fertilizers, as well as sulfur.
BL Backward linkage.
FL Forward linkage.
TL Total linkage.

Source: Based on the author's estimates.

metal industries ranked high in both Morocco and Brazil, two countries which have fairly developed mineral processing activities. It ranked low in Zambia. Activities related to nonmetallic minerals had an average ranking in all three economies, except in Morocco where the phosphatic fertilizer industry is better developed. Existing mineral manufacturing industries ranked low in all three countries.

Also a ranking of both output and income multipliers (Table 6) is offered for Zambia and Morocco, two major African mineral exporters, major world producers of copper and phosphates.

Table 4 shows that despite the well-known importance of the phosphate industry in the Moroccan industry (Morocco's export is highly diversified), the sector ranked last in terms of its ability to generate output in the economy, but ranked among the top ten in its ability to generate income. In Zambia, the key sector of copper mining ranked first in terms of output, showing a strong reliance of the economy on copper mining activity.

Table 6:
Ranking of multipliers for mineral and energy related sectors in Zambia, Morocco and Brazil

	Rank[a/]	
SECTOR DESCRIPTION	OUTPUT	INCOME
Zambia		
Metal mining	1	11
Other mining	25	4
Chemicals & Chemical products	10	13
Non-metallic mineral products	21	18
Basic metal industries	28	16
Fabricated metal products	26	22
Electricity[b/]	17	19
Morocco		
Phosphates	33	9
Other non-metallic minerals	8	8
Metallic minerals	31	23
Crude, petroleum solvents	26	15
Petroleum refineries	13	13
Electricity[c/]	16	14
Quarrying	28	7
Basic metal industries	3	19
Metal products	29	21
Chemicals & similar products	32	18
Brazil[d/]		
Mining	25	
Nonmetallic minerals	19	
Metal products	1	
Chemicals	22	

a/ Up to a total of 29 sectors for Zambia; 33 for Morocco; and 27 sectors for Brazil.
b/ Including water and gas.
c/ And water.
d/ Based on backward linkage measures which approximate output multipliers in ranking. Income multipliers are not available.
Source: Bocoum and Labys (1995) for Morocco and Zambia; Sonis et al. (1995) for Brazil.

Macro-Economic Effects

In order to make this study more complete, an attempt is made at analyzing the impacts of each sector on gross output and income in this section based on the computation of output and income multipliers.

Looking at mineral and energy sectors alone, the non-ferrous metallic mineral mining sector's overall contribution to both gross income and output was generally low, except in the case of Chile, an economy which is highly dependent on copper mining activities. The strength of this sector relies in the generation of strong linkages with domestic industries such as energy and other mineral related activities, including mining and processing. However, relative contribution of that sector to national output and income in a balanced economy is marginal as is evidenced by the low rankings recorded by this sector.

Impacts by the ferrous metallic mineral mining sector (iron ore, etc.) seemed of lesser importance to the generation of income in Chile than in Australia. In the later, this sector ranks highest among all mining activities, with the exception of the services to mining sector. This is understandable as the latter country's economy is ore dependent on this type of mineral activities. However, a look at this sector's impacts in the economies of the United States shows ferrous metallic mineral mining activities have stronger technological linkages than either non-ferrous metal activities or other mining activities.

Coal, oil and gas extraction activities show a relatively small contribution to national income and output. However, the results show its importance in terms of total linkages and a greater dependence of the less developed economy of Chile on output by that sector.

Industrial mineral mining ranked higher than metallic mineral mining activity such as copper in all economies in terms of income. The strength of this sector relies in the diversity of its output, and hence on its potential for generating strong linkages in a producing economy.

The other mining category includes all others but the ones mentioned above. Limitations in individual country classification does not make a comparison across countries possible here. The economic impact of these can be best assessed once the composition of that sector in each region is known.

Mining services, wherever this activity exists, ranks very high in terms of backward linkages, i.e. in its ability to purchase inputs from other sectors as well as in its overall contribution to output and income. In an economy where they are fully developed (as in Australia), services to mining activities rank among the top three overall economic activities in income and output generation and its ability to create strong intersectoral linkages with the rest of the economy.

The results derived for the agricultural and industrial chemicals sector are rather interesting. Firstly, its potential impact is acknowledged as being important in terms of income and output generation as well as total linkages. This is evidenced by the strong both backward and total linkages experienced by this sector in nearly all regions. This is not totally surprising as this sector is involved in the making of mineral-based fertilizers which are used in agriculture.

The petroleum refineries and coal transformation sector assumes great importance in terms of generating strong forward linkages with the rest of the economy. In advanced industrialized economies like the United States, output by the petroleum refineries and coal transformation sector is shown to be the most important in determining output from other economic activities. The usually integrated nature of the industry is evidenced by the strong links between that sector and other energy related sectors of the economy. Other links of importance, are those created with the agricultural, chemical, food and a number of service related activities.

Of great interest are the strong links that exist between the non-metallic mineral processing sector and output by other manufacturing industries such as paper, rubber and petroleum transformation, as well as with oil extraction. This is not totally surprising as this sector is involved in the making of products derived from industrial minerals used principally in the making of paper pulp, rubber and various plastics as well as during oil exploration.

Results recorded by metallic mineral processing activities show stronger linkages with the rest of the economy than with metal mining. Economic impacts in terms of backward, forward and total linkages are significant. However, no comparison can be effectively drawn here between these two types of economic activity in their ability to generate output and income in the economy. It is evident based on the results obtained for Australia and Chile that it will depend on resource endowment.

Metal product manufacturing activities rank high in all economic regions in terms of both income and output. Their ability to effectively impact these macro-economic variables seem directly linked to the extent of metallic mineral processing taking place at a given location. This type of mineral activities is found to generate greater backward than forward linkages. Most of this sector's output is purchased outside of the economy, making it very attractive for exports.

There is no doubt that the energy sector is the most attractive of all mineral and energy related activities in terms of its ability to create total linkages. Results have evidenced that both backward and forward linkages are strong in the related economy. However, because of greater domestic absorption capability that with other sectors, income and output effects of the energy sector are relatively small.

5. Conclusions and policy guidelines

The concept of intersectoral linkages has proven a useful analytical tool in this modeling exercise where the aim is to assess the role of specific mineral and energy related activities in various economies at different stages of development.

The Hirschman indices were used to see how each mineral and energy related activity behaved, regardless of the level of economic development achieved. Interconnectedness among sectors was measured through linkages, whether backward, forward or total, as well as through output and income multipliers. More particularly, the derived measurements allow a detailed identification of the nature of the links between the mineral and energy sectors and the rest of the economy, as well as between the mineral and energy sectors themselves. The variables also permitted an assessment of the magnitude of the aggregate impact, measured in terms of gross output and income, of specific mineral activities on the other economic sectors.

The results highlight the central role of the petroleum and coal transformation sector, as well as the mineral-based agricultural[6] and industrial chemical sector play in a given economy regardless of its stage of development. Equally important is the primordial role played by the mineral and energy-based manufacturing sector (as compared to primary mining and processing activities); and that of the mining services sector wherever it exists as in the Australian economy. Among different types of primary mining activities, the non-ferrous metallic sector ranked highest in terms of its ability to purchase inputs locally, especially in more developed economies. This is not surprising since the non-fuel mineral sector is mainly distributed as value added, the stimulus for other sectors when final demand for non-fuel minerals increase is quite small. In terms of processing activities, non-metallic mineral processing had a less significant impact at lower stages of development than activities such as ferrous metallic mineral processing sectors. At intermediate stages of development, activities such as metal products scored high. However, the production of energy gave even better results with the strongest multipliers being recorded in that category. The non-ferrous metallic mineral processing sector also ranked high.

Policy guidelines

Comparing the results for the five case studies, the following policy guidelines are now outlined. Efficiency of mineral and energy operations presupposes the identification of clear national development goals, and the development of national competence in the form of knowledgeable individuals and appropriate institutions. African countries have to develop a set of measures to bring about improved economic management on mineral and petroleum resources and a policy environment conducive to healthy economic growth and diversification through the mineral and energy sector. One important step would be to establish where applicable a program that monitors national and international mineral issues and provides a training ground in order to increase interest and foster the development of skills in the area. Similar action by governments of African countries could be taken and greater involvement by the private sector would be welcomed in the case where mineral and energy-product development requires additional infrastructure. In addition, a variety of legislative instruments can be used by African countries to further the development of their mineral resources. A straightforward tax policy is advisable to attract international financing. Other tax measures that can be used by African countries to boost domestic mineral processing activity including tax rate reductions on profits earned from processing, accelerated depreciation on processing capital, and other preferential accounting methods to encourage processing investments and increased transformation of mineral resources prior to export.

Considering the issue of investment, available research work indicates that each successful target supports, on the average, US$35-40 million in exploration costs alone. Mine development costs approximately amount to US$60 million for a medium scale mine while the large base metal mines may require well in excess of US$300 million. In addition, studies in capital/labor ratios have shown that there is usually an increase in capital intensity as one moves from mining to the final stage of metal products. Downstream processing aimed at capturing a decisive share of the international market requires a greater scale of operation and capacity than that of meeting import substitution needs. By the same token, a large-scale operation is necessary for a project intended to make a real impact on the balance of payments. Large projects are capital-intensive and usually incorporate highly sophisticated technology. Directly related to the capital-intensity problem is the issue of financing. The risks often associated with mining investment, at least at the exploration stage, coupled with the large financial requirements, have led many African governments to refocus their energies into attracting high risk mining capital on a global basis. Africa still attracts small-scale investment compared to its mineral endowment. However, key challenges therefore remain as to what Africa needs to do to further improve its share of investment from global sources of exploration and mine development. The possibility of mobilizing new sources of capital is currently being studied through the establishment of (i) a Mining Development Seed Capital Fund to fund a portion of bankable feasibility studies or project specific R&D; and (ii) a Mining Investment fund that ideally could be listed on the London Stock Exchange, with secondary listings in other parts of the world in order to invest in major mining companies and small-scale mining enterprises.

It is fairly clear from the evidence on economic development that mineral and energy development must be accompanied by total factor productivity growth in all sectors. The additions to resources from investment financing enable a country or enterprise to grow faster than would otherwise be possible only for some period of time. The underlying development constraint remains at the operational level one of (1) increasing productivity, (2) doing so in a wide range of mineral and energy sectors, which in turn means (3) providing stimuli for the acquisition of skills for the purchase of physical capital assets and for the development of new technologies through the mastering of transferred technologies. In fact, African countries should take greater advantage of available technological advances to increase the efficiency of their operations and their product competitiveness.

Other crucial underlying challenges remain those of (1) building at the country level a credible political track record as well as creating a competitive fiscal regime, (2) improving means of mobilizing funds by establishing greater links with world capital markets and also harmonizing Africa's capital markets, and (3) encouraging more productive collaboration with some of the key exploration and mining companies worldwide in the development of solutions in order to facilitate strategic partnership building. However, such venture could be beneficial as long as foreign partner's participation is perceived and integrated into a broader policy that makes prudent use of foreign goods and factors of production to fill gaps in domestic capacity.

A conclusion thus emerges that the success of mining and energy operations are really matters of efficient direct institutional support to an industry, its technological choice, long-term technological capability, locational policy, as well as product choice. A strategy based on the development of these resources for either domestic consumption or export may improve the balance of payments, but it may well, by the same token, increase dependence on export earnings to finance producer goods, especially imports of capital equipment. The only way that a strategy based on the development of mineral and energy resources might lead to structural transformation is if it incorporates indirect effects to stimulate a domestic producer goods industry, such as a capital-goods supplying sector, starting with simple technologies, so that a steady demand is generated over a long period of time for domestically manufactured equipment.

Finally, it is important to emphasize that the past experience – from African mineral and oil exporters - have been sufficiently disappointing and their potential is so great that alternative approaches need to be considered. Developing countries outside Africa that have fully integrated mining and petroleum operations seem to have greater expectations of survival than those of Africa which have not.

Implication for future research

The practical value of the model described here depends on the stability of the coefficients overtime. Also, with regard to evaluating the economic impact of mineral and energy activities, further refinement should be added to the measurements of the macro-variables presented in this study. One suggestion would be the use of dynamic input-output analysis as opposed to the static input-output approach. Dynamic input-output would incorporate dynamic capital investment effects upon macro-economic variables which are explicitly ignored in this study. Unfortunately, the data necessary for such input-output modeling are often very difficult to obtain for many countries, let alone African countries. Nonetheless, the methodology derived in this study has been instrumental to the determination of key mineral and energy sectors. Although the model is static, it has proven capable of depicting the relationship between production levels and national benefits from mineral and energy related activities.

There are a number of extensions of the present study. Various applications could be derived from the model. The quantitative approach utilized in this study could be applied to other countries, i.e. oil industry in Nigeria, gold mining in Ghana, gemstones and diamond mining in South Africa, etc. More particularly, the general order of magnitude of impacts for the mineral and energy sectors may indicate the likely nature of these impacts for alternative resources and/or countries with similar inter-sectoral technical relationships.

Given the modest goals of this study, it is the author's hope that it will serve as a motivation for continued meaningful research in the area of mineral and energy resources development on the continent.

Figure 2
Total Linkages: Mining Activities

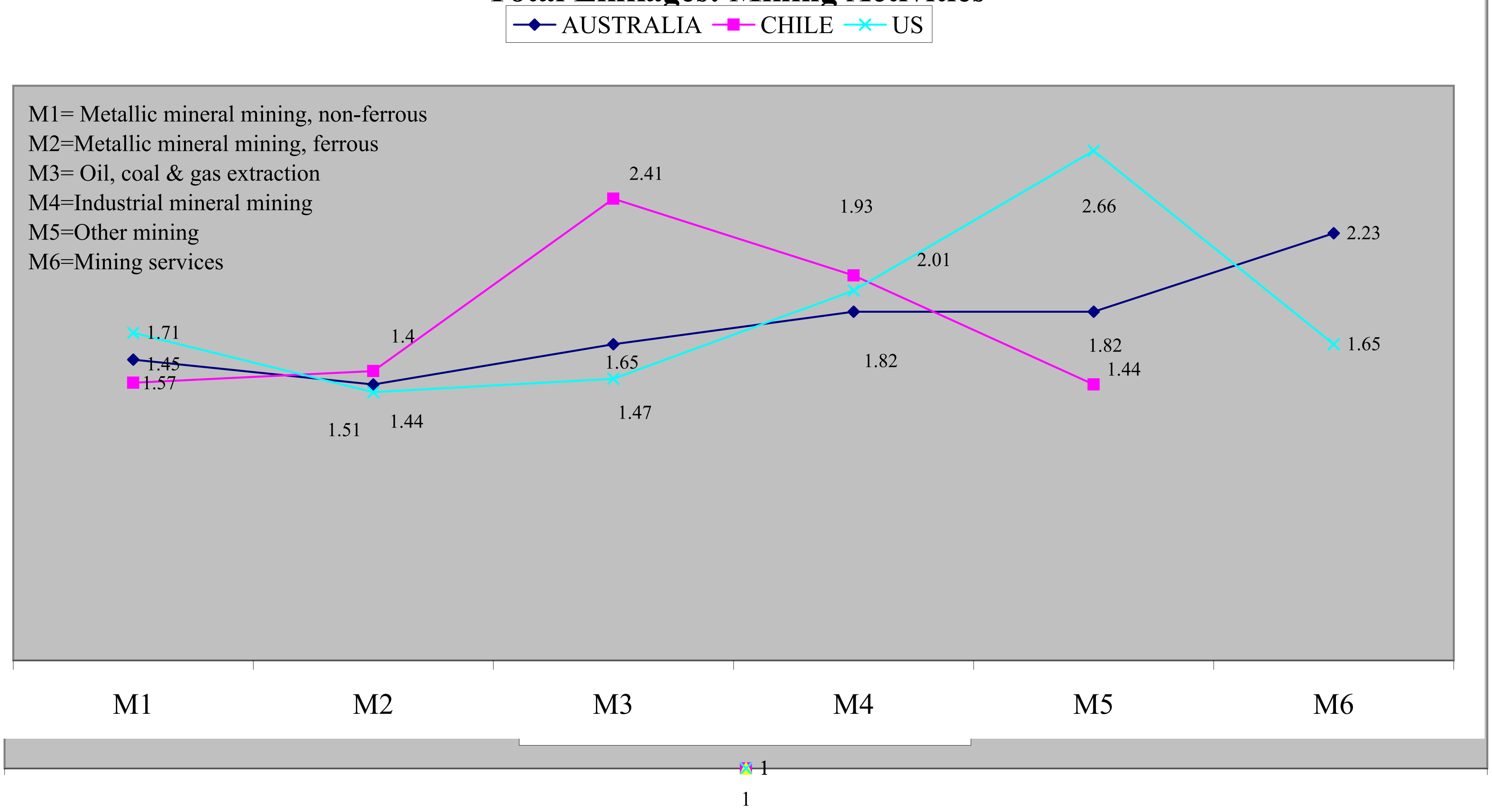


Figure 3
Total Linkages: Intermediate Mineral Processing

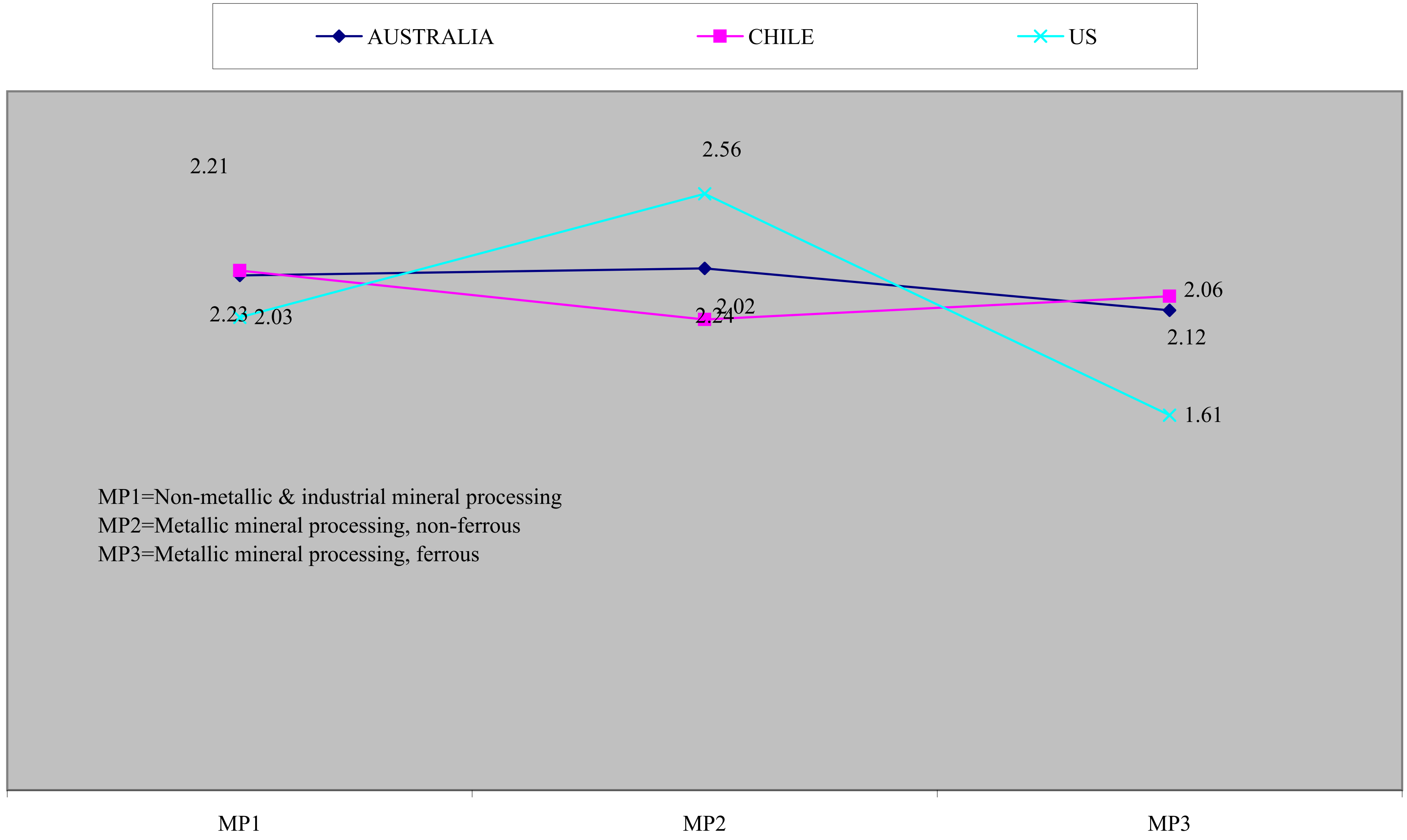
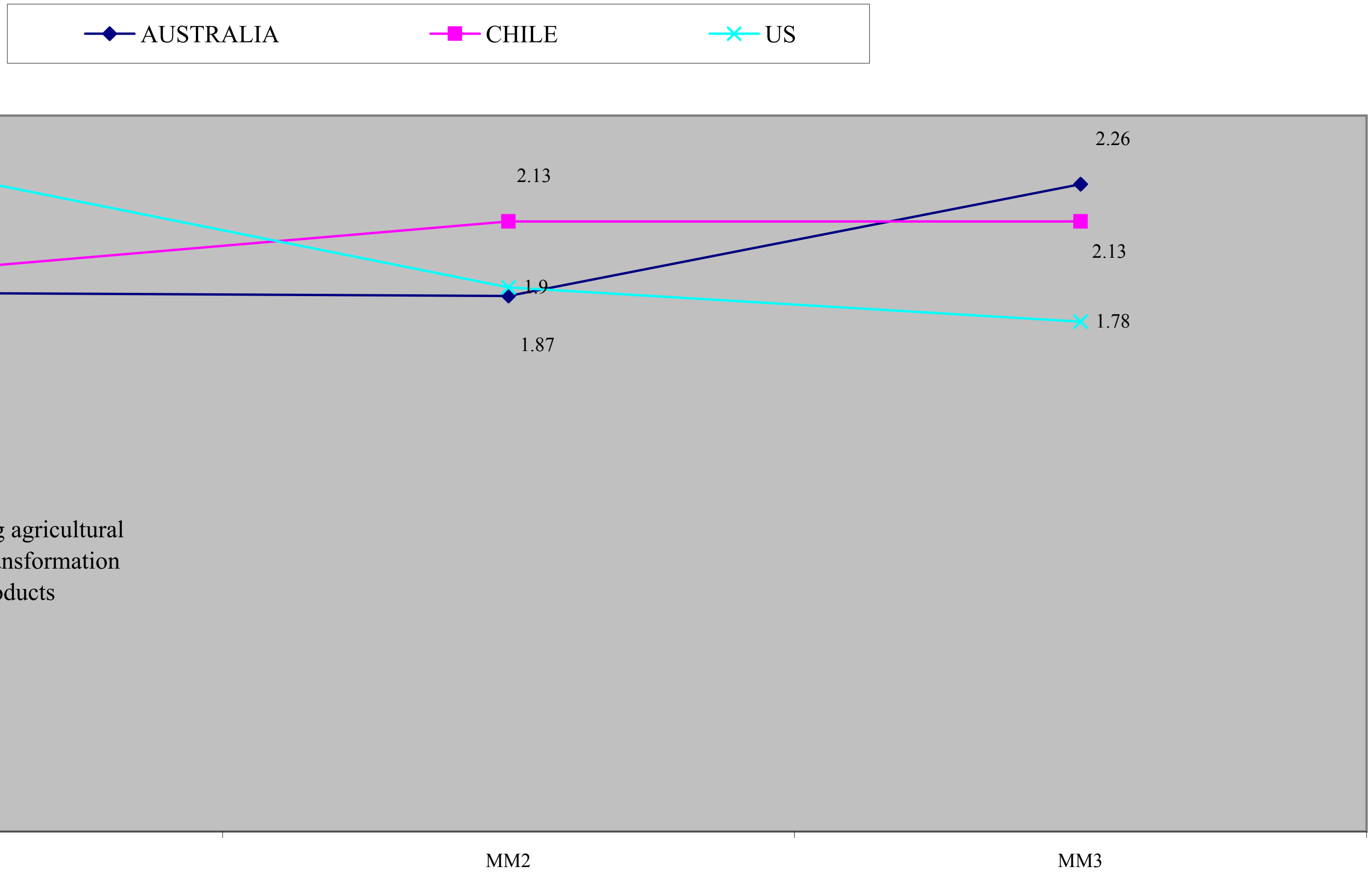


Figure 4
Total Lingakes: Mineral & Energy Product Manufacturing



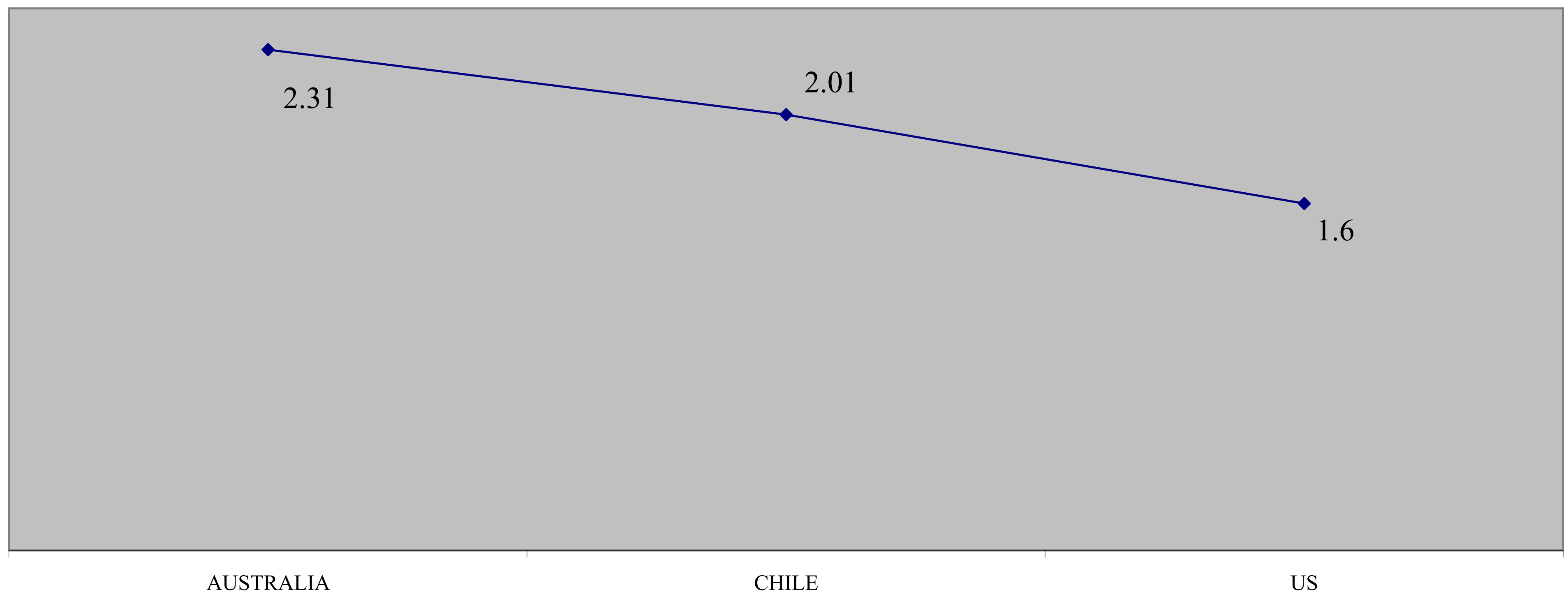


Figure 5
Total Linkages: Energy Sector

Notes and References

1. The mineral and energy sectors dominate the country's export sector with more than 50% in 17 African countries. These include Algeria, Congo, Libya, Nigeria, Gabon (crude petroleum); Guinea (Bauxite); Mauritania (iron ore); Niger (uranium); Togo (crude phosphates); and Zambia (copper).
2. This type of multipliers are calculated for a model closed for households, i.e. for a model where households are endogenous. These multipliers tend to be larger, and contain information on direct plus indirect plus induced effects (payments for labor services and the associated consumer expenditures on goods produced by various sectors).
3. IMPLAN/QTM is a computer program developed in the United States that constructs regional input/output (I-O) accounts and models.
4. GRIMP is an interactive input-output software package developed at the Department of Economics at the University of Queensland, Australia.
5. Brazil is used here as a middle-income country.
6. Includes the mineral-based agricultural chemicals used principally as fertilizers such as those derived from phosphate, nitrogen, sulfur and potash.

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