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Handbook On Measuring Employment from Extractive Industry Investments

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Key Definitions

Earnings multiplier: dollar increase in households' earnings in the economy for a \$1 increase in the final demand of an industry's goods.

Final demand: final consumers' demand.

Final demand output/Final demand earnings multipliers: equivalent to output or earnings multipliers.

Input-output table: matrix that describes all monetary flows among industries in an economy. Specifically, the table reports the dollar value of output that each industry sells to other industries as well as the dollar value of inputs purchased by each industry from the other industries.

Leontief matrix: portion of the table of technical coefficients that contains only input shares for the industries (equivalent of leaving out inputs from government, labor and import sectors).

Output multipliers: dollar increase in an industry's output when the final demand for goods produced by another (or the same) industry increases by \$1.

Social accounting matrix: matrix that compiles all the monetary flows among agents and sectors from a particular economy. It includes information from most transactions, such as the wages firms pay to households, household's consumption of goods, and taxes and transfers administered by the government.

Supply table: describes, for each industry, the dollar value of each category of goods and services produced by that industry.

Table of fixed input shares or technical coefficients: describes for each column-industry what is the share of total inputs purchased from each row-industry or sector (e.g. government, labor, import).

Total output multipliers: dollar increase in output of an economy when the final demand for goods produced by an industry increases by \$1. It is the sum of output multipliers across industries for a change in final demand of a given industry.

Type I earnings multiplier: describes how many additional dollars of household earnings in the economy are generated for each \$1 directly generated in a given industry.

Type I employment multiplier: describes, for a given dollar increase in final demand of a sector, how many additional people in the economy are employed per additional person employed in that sector.

Use table: describes, for each industry and for each final use (final consumption, capital formation, export) the dollar value of each category of goods and services purchased.

1. Introduction

One of the benefits often associated with extractive industry projects is the creation of employment opportunities. Employment opportunities can be divided up into: (1) direct employment, which includes jobs within a mining company such as in-pit truck drivers; (2) indirect employment, which includes jobs outsourced by a mining company to contractors such as catering services; and (3) induced employment, which includes jobs resulting from a mining company's direct and indirect employees spending money in the domestic economy. An example for induced employment would be an additional waiter/waitress employed at a local restaurant that caters to mine workers.

Indirect and induced employment data metrics are often estimated through multipliers. However, it is very difficult for third parties to assess a multiplier estimate's accuracy because there is no standard methodology for measuring multipliers and multiplier studies rarely publish a multiplier estimate's underlying assumptions and calculations. Nevertheless, these employment multipliers remain critically important to understand for communities surrounding mining projects.

This handbook aims to provide government officials and civil society with the necessary knowledge to understand how models for the estimation of employment multiplier work. It also provides step-by-step instructions on how a simple multiplier model can be replicated and what input values are needed to countercheck multiplier estimates. Furthermore, considerations are provided that may lead to adjustments of the multiplier results from the simple model (such as surrounding context and characteristics of the mining project).

This handbook is not meant to substitute more advanced employment multiplier models. Project specific studies should continue to be commissioned. Instead, this handbook aims to help third parties better understand how employment multiplier studies work and empowers third parties to engage with mining companies and/or governments regarding employment estimates. This handbook encourages more transparency of employment multiplier studies, which have historically omitted clarification on the underlying assumptions and calculation methods.

Employment opportunities is one of the most important variables that communities consider when deciding whether to support the go ahead of a mining project. Mining companies should provide transparency with respect to employment multipliers as it is important for securing social license.

This handbook leads the user through the computational steps of Type I multipliers. It does not cover Type II multipliers (induced employment) given that local spending data that is required for the computation of these multipliers is rarely publicly available. Type I multipliers translate a known or assumed direct effect into an estimated total impact including both the direct and indirect effects. For example, 100 jobs in a new mine (direct effect) might lead to 50 more jobs in the restaurant catering sector (indirect effect), i.e. selling lunches to the mining company for its workers. The total impact would be 150 jobs, and consequently the employment Type I multiplier would be 1.5 (150 total jobs divided by 100 direct jobs).

Available techniques to assess the employment multiplier effect

The two main modeling techniques used to estimate employment multipliers are the input-output (IO) model and the computable general equilibrium (CGE) model. These two techniques are described and compared in this section.

a. Input-Output model

The central element is the IO table, which is constructed based on “supply” and “use” tables. The IO table describes the dollar value of output that each industry sells to the other industries, as well as the dollar value of inputs purchased by each industry from the other industries (see further detail in section 4). Some countries’ governments make IO tables publicly available, but the underlying data – especially the disaggregated data by regions – is rarely made public. As reported by Eurostat, “[...] For each [European Union] Member State, the supply-use tables at basic prices were estimated with the available supply use tables (at purchaser's prices) and (in part confidential) auxiliary valuation data. Due to confidentiality reasons, the supply-use tables at basic prices are published only at the level of EU-27 and euro area.” The British Office for National Statistics states, “The Supply Table is published in summary form only because of disclosure rules prohibiting the publication of data that may be traced to a single contributor.”

The IO table is used to build a model of inter-industry response to changes in final demand by converting the IO table into a fixed input share table. The resulting matrix of input shares – also called matrix of technical coefficients – can be used to derive estimates of the total response of the economy to changes in the final demand of any industry. This process is explained in more detail in section 4.

Advantages:

The ability to build on the publicly available IO tables is a major advantage of these models, in terms of data collection and organization. The IO tables are the result of systematic measurement of trade between any two industries (or sectors, depending on the level of aggregation) in the economy. Data for the analysis are conveniently organized in matrix form. IO modeling continues to be a very popular approach worldwide, especially in developing countries. One of the reasons is that the basic formulation is politically neutral and only relies on measurement of trade between firms.

Another advantage of the IO technique is its simplicity and transparency. IO models are easy to use. The transparent nature of the model makes it easier to understand how the results were derived.

Disadvantages:

The IO model relies on four rigid assumptions: 1) there is no product or service supply constraint; 2) there are constant returns to scale²; 3) fixed input structure for each industry; and 4) fixed output ratios among products produced. Thus, the IO model assumes that an industrial structure (the operations and relationships within a given industrial sector) remains unchanged by an economic event. An increase in demand, for example, is assumed to not have an impact on the price, which is clearly not the case for most goods. Consequently, the technique often results in overstatements of the impacts, whether positive or negative, on employment and Gross Domestic Product (GDP).

It is also important to note that the data available in national accounts sometimes lacks accuracy, especially for low-income countries. Therefore, even when supply-use tables or IO tables are available for these countries, the information contained is not completely reliable. This is a limitation for any model that relies on the IO structure.

b. Computable General-Equilibrium models

CGE modeling tries to reproduce the structure of the whole economy and therefore the nature of all existing economic transactions among diverse economic agents (such as economic/productive sectors, households, and the government, among others). The CGE analysis therefore captures a wider set of economic impacts derived from the implementation of a specific policy reform.

There are three main resources required to run a CGE model: 1) a significant amount of data, such as information about existing transaction flows among economic agents (Social Accounting Matrix) and productive sectors (which is the IO table); 2) values for all parameters necessary to establish elasticities to prices for consumers and producers; and 3) a specific software to run the model, usually GAMS (General Algebraic Modeling System).

The empirical component of the CGE model is an IO table. Each transaction flow in the IO table is disaggregated into two components: price and quantity. Both the price and quantity components are allowed to adjust in response to the economic event being analyzed. In the majority of CGE models, firms or producers are assumed to maximize profits. In addition, product and factor markets are assumed to be competitive. Profit maximization dictates that firms act to minimize costs and factors are responsive to price changes. Households are assumed to maximize utility in their consumption decisions, responding to price differences across goods and services. Finally, prices adjust for goods, services, and availability of primary factors of production (labor and capital) to equate demand and supply.

CGE models can estimate aggregate effects on trade, production, employment, fiscal balance, household income, and even poverty and inequality. This is because CGE models allow for the distinction of different types of households (e.g. high and low-income). With CGE models it is possible to evaluate distributive effects within the economy, and therefore identifying winners and losers at different levels (sectorial, firm, household, and geographic). This can serve as inputs for the design and the implementation of compensatory policies or trade adjustment

² Constant returns to scale describe a situation whereby a company's output always increases by the same proportional change as the change in inputs

programs. More details about the steps required to develop a CGE model are described in Annex A.

Advantages:

The main advantage of CGE modeling in comparison to other quantitative methods relies on its potential to capture a much wider set of economic impacts. Thus, it is possible to evaluate the implementation of a policy reform as well as the distributive effects within the economy at different levels of disaggregation.

Disadvantages:

Collecting updated, high quality, multiregional data, building Social Accounting Matrixes, and programming and choosing parameter values in a CGE model is a very time-consuming process. Furthermore, it may not yield more accurate estimates than the IO model, especially when using countries with weak institutional collection of statistics.

A second caution should be made about the interpretation of the results. Interpretation of results should be focused more on magnitudes, directions, and distributive patterns rather than the specific numeric outcomes. Results from CGE models should therefore be used as “road maps” for policy implementation, which should be complemented by additional analytical work using alternative quantitative methods.

c. Comparing necessary inputs

The following table compares IO models and CGE models in terms of the information they require in order to be used for policy analysis. The table highlights that a CGE model requires additional data to that necessary for the computation of an IO model.

Inputs to the models	
IO model	CGE model
IO table and wages paid to households for each industry in the economy	IO table and wages paid to households for each industry in the economy
Employment data by industry (if employment multipliers are the focus of analysis)	Employment data by industry (if employment multipliers are the focus of analysis)
	Structure of the model <ul style="list-style-type: none"> - Types of households to include (high-income/low-income), markets for primary factors of production (capital and labor) skilled/unskilled workers - Level of aggregation of the industries, since including all disaggregated industries can become too demanding for the model to be solvable (by contrast, IO models can include all

	<p>disaggregated industries)</p> <ul style="list-style-type: none"> - Limits to the availability of inputs (e.g.: the more skilled workers an industry wants to hire, the higher the wages it has to pay so it is limited in the number of skilled workers it can hire; the more capital an industry wants to invest, the more expensive it becomes so it is limited in the amount of capital investment it wants to carry out)
	<p>Parameter values (e.g. income elasticities, migration elasticities, and price elasticities)</p> <ul style="list-style-type: none"> - Depending on the number of sectors included, in general there will be more than one good in the economy. Therefore, goods must be aggregated in the utility function³ of the households and the function needs to be specified. - Similarly, if there is more than one input, the production function of firms will have to aggregate these inputs, and this requires additional parameters.

As discussed above, while providing a more realistic picture of the economy, the input variables and assumptions will have to rely on data availability in the country or region. Particularly in lower-income countries where data availability is problematic and where the informal economy plays an important role, these models may lead to measurement error or data with an insufficient sample size, thus undermining the conclusions of the model analysis.

d. Comparing results

It is difficult to compare the estimated impacts of the IO or CGE modeling techniques since the estimates derived vary from model to model. More importantly, significant variation in estimates can be produced using the same CGE model. This is because the flexibility of this model allows the analyst to incorporate his/her own professional judgment in determining the appropriate economic environment and initial project or policy specification.

For the CGE model, the estimated response will depend partially on the coefficients used in the theoretical structure of the model, but more importantly the economic environment of the model specified in the particular economic impact analysis.

³ The utility function measures the welfare or satisfaction of a household as a consumer from consuming a certain number of goods.

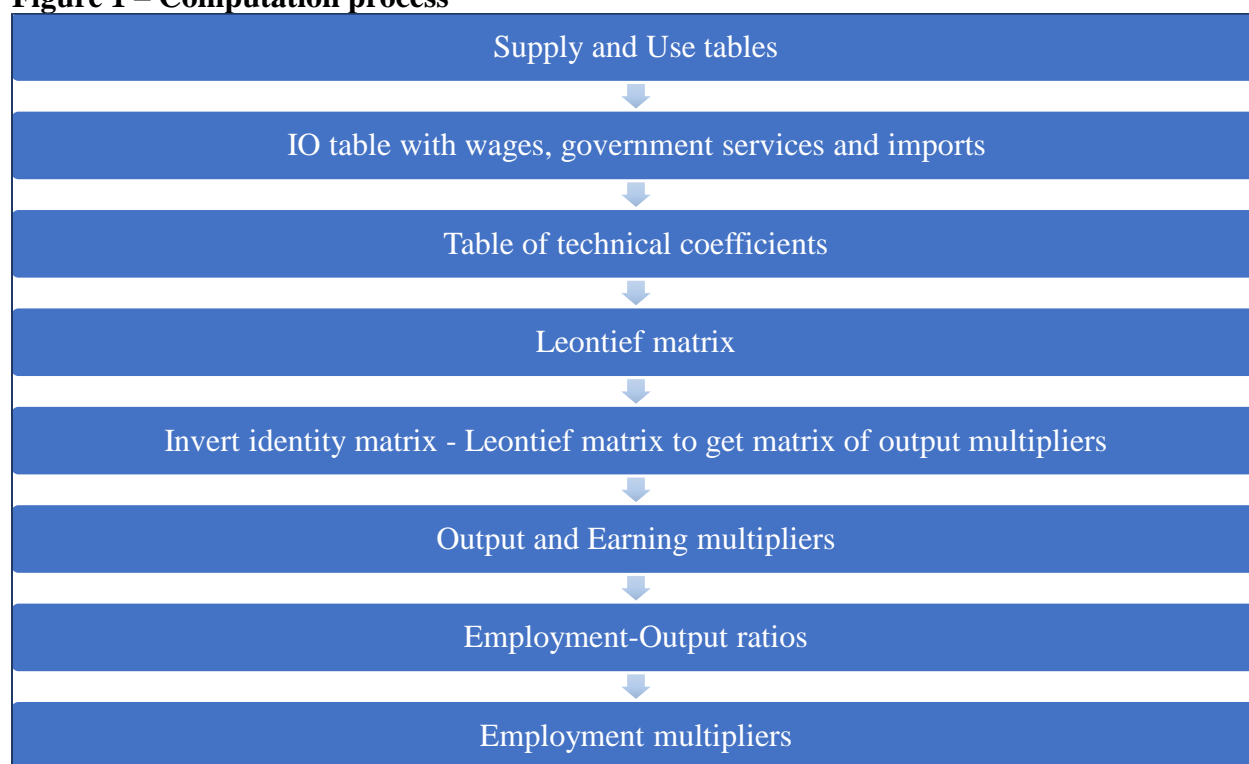
The limiting assumptions tend to overstate the economic impacts measured through the IO technique. However, for purposes of counterchecking figures, this may not necessarily be a disadvantage. If more complex models report multipliers that are bigger than those obtained using a corresponding IO model, then the assumptions and parameter values of the complex model should be subject to additional scrutiny.

The choice of an appropriate methodology for economic impact analyses must be undertaken on a case-by-case basis. Regardless of the methodology used, it is important that the assumptions underpinning the results are clearly stated. A rigorous assessment should include sensitivity analyses providing information on how changes in the assumptions affect the results.

2. Computing multipliers using Input-Output models

This section describes the process to compute multipliers using input-output models as outlined in figure 1 based on an example using South Africa, which can be replicated with the provided links.

Figure 1 – Computation process



The starting point is the IO table. This is often publicly available at the national level. Publicly available IO tables can be accessed and downloaded from the [OECD website](#), from the [World Input-Output Database](#) or from the [Global Trade Analysis Project](#) (although it includes IO tables that are not necessarily up to date). If unavailable, an IO table can be derived from supply and use tables. Eurostat (2008) gives an informative illustration of the process leading from supply and use tables to an IO table. The IO table is obtained from the supply and use table by assuming

that, for each product, the share of sales going into each industry is constant regardless of the industry supplying it. This allows the supply and use tables be combined to obtain the symmetric IO table for industries. An example is illustrated in figure 2. The accompanying excel file provides a simple generic example of how to estimate indirect multipliers with input and output tables (see last worksheet), as well as an example with data from South Africa (see step-by-step methodology below and references to various worksheet of the excel file).

Figure 2 – Supply, Use and IO tables

Supply table						
Products	Industries	Industries			Imports	Total supply
		Agriculture	Industry	Service activities		
Agricultural products		270.00	30.00	50.00	20.00	370.00
Industrial products		10.00	430.00	100.00	50.00	590.00
Services		20.00	40.00	550.00	30.00	640.00
Total		300.00	500.00	700.00	100.00	1600.00

Use table								
Products	Industries	Industries			Final uses			Uses
		Agriculture	Industry	Service activities	Final consumption	Gross capital formation	Exports	
Agricultural products		34.00	59.00	143.00	81.00	21.00	32.00	370.00
Industrial products		106.00	119.00	77.00	123.00	103.00	62.00	590.00
Services		70.00	112.00	75.00	291.00	61.00	31.00	640.00
Total		210.00	290.00	295.00	495.00	185.00	125.00	1600.00
Value added		90.00	210.00	405.00				705.00
Output		300.00	500.00	700.00				1500.00

Industry by industry input-output table (Model D)								
Industries	Industries	Industries			Final uses			Uses
		Agriculture	Industry	Service activities	Final consumption	Gross capital formation	Exports	
Agriculture		30.49	51.39	114.20	74.30	20.11	26.85	317.34
Industry		91.91	107.16	78.49	123.97	87.82	54.15	543.50
Service activities		87.60	131.45	102.31	296.73	77.07	44.00	739.17
Total		210.00	290.00	295.00	495.00	185.00	125.00	1600.00
Value added		90.00	210.00	405.00				705.00
Output		300.00	500.00	700.00				1500.00
Imports of similar products		17.34	43.50	39.17				100.00
Supply		317.34	543.50	739.17				1600.00

South Africa example:

Step 1: Download from the CCSI website the *South_africa_2011_empl_multipl* excel file, which computes employment multipliers for South Africa in 2011, starting from the IO table. The file originates from the OECD website with the link provided above. The tab with the IO table is

named *2011 SA full table (step 1)* in the Excel file. Each row of the matrix shows the USD amount (in millions) of inputs purchased by the column-industry. All row-industries which are labeled “DOM” represent domestic inputs; the row-industries which are labeled “IMP” represent imported inputs. The second-to-last row shows net taxes paid by each column-industry, which can be thought of as payment for government services. The last row can be deleted. The 6 right-most columns (before column “Output”) report million USD value of final demand by various sectors, for each row-industry. These sectors include consumers, capital producers and foreigners (under the label “Exports”).

Step 2: Labor compensation by industry is needed to acquire earnings multipliers. This can be obtained from the value-added table which can be found on the same OECD website linked above, by selecting “VAL: Value added” from the “Variable” drop-down menu (top line of the table). On this table, use the rows “LABR: Labour compensation” and “OTH_VA: Other value added.” These can be pasted at the bottom of the IO table described before.⁴The value added table for South Africa in 2011 is reported in the Excel file under the worksheet *2011 SA value added (step 2)*.

Step 3: To compute employment multipliers, one needs employment data by industry, which can generally be found on the statistics website of the country being analyzed. South Africa’s employment data can be obtained through the [Statistics South Africa](#) website. From pages 16 to 18, the quarterly value of total employment for each sector is listed. Since these are quarterly data, but the data in the IO table are annual, the average across quarters for each sector will be used. This data has been pasted into the worksheet *2011 SA Employment (step 3)*. (Note that data on the Private Households sector is not used.)

Step 4: The sectors reported in the Statistics South Africa tables are more aggregated than the IO table data. This means that the data in the IO table needs to be aggregated before being able to merge these datasets. To understand how the employment numbers are aggregated, methodology sections or descriptions of the labor force survey can be reviewed. For the case of South Africa, [this](#) publication was used. The description of the sectors on page 5 suggests that the reclassification is rather straightforward, as industries have been grouped into more general sectors. The reclassification to be used for the IO data has been included in the *Reclassification (step 4)* worksheet.

Step 5 and 6: Now that a mapping from the disaggregated industries to the more general sectors has been determined, the original IO table along the two dimensions can be aggregated. This can be done in two steps. Step 1: The sheet labeled *2011 SA dim2 (step 5)* sums by sector across columns. Step 2: The sheet labeled *2011 SA IO table_small (step 6)* sums by sectors across rows and shows the final, smaller table. Summing by row, the total dollar output produced by each domestic industry can be obtained; summing by column, the total dollar inputs purchased by each industry can be obtained. Total output and total inputs should be equal (up to rounding error). Since the breakdown of imported inputs by industry is not important, the rows labeled “IMP” will be replaced with a single row listing the sum across all rows labeled “IMP” and

⁴ These newly pasted rows do not include the 6 “Final Demand Sector” columns nor the furthest right “Output” column. Therefore, the last 2 rows of the updated table will have 7 fewer columns of data.

showing the total value of imported inputs. For the summation for labor compensation and other value added, use the worksheet created in Step 2.

Step 7: Now the table of technical coefficients can be constructed by dividing the values in each column by the total value of inputs. At this point, columns M-S in the *2011 SA IO table_small (step 6)* file describing the final demand sectors can be dropped, since they are not going to be used to compute the multipliers. The output and formulas for the calculations are reported in the worksheet *2011 SA tech (step 7)*.

Step 8: The Leontief matrix can be extracted from the table of technical coefficients. The Leontief matrix is a square matrix (i.e. the number of rows (and columns) is equal to the number of domestic industries). This means that the Leontief matrix is obtained from the table of technical coefficients by dropping the bottom rows on imports, government, labor and other value added. An identity matrix (that has all 1s on the main diagonal and 0s everywhere else) needs to be the same size as the Leontief matrix for the calculation. To compute the matrix of output multipliers, use an inverse matrix calculation of the Leontief matrix and the identity matrix. Summing across rows of the matrix of output multipliers, the total \$ increase in output for a \$1 increase in final demand for each column-industry can be obtained. These are the total output multipliers for each industry. The results and inverse Excel formula to calculate the output multipliers can be observed in the worksheet *2011 SA output mult (step 8)*.

Step 9: To compute the total output multipliers by industry, sum up for each industry the output multipliers in *2011 SA output mult (step 8)* by column (input). The total output multiplier for mining is comparable to the multiplier reported by the study by Stilwell et al., (2000). The study reports an output multiplier between 1.29 and 1.58 in the mining sector between 1971 and 1993. In the example the output multiplier is estimated at 1.56, meaning that a \$1 increase in output in the mining sector will lead to an output increase of \$1.56 across all sectors.

To compute earning multipliers, multiply labor compensation from table *2011 SA tech (step 7)* times the output multipliers from *2011 SA output mult (step 8)*. The result describes, for each industry, the direct + indirect effect on labor earnings (in \$) in the economy for a \$1 increase in the final demand of that industry. The formulas and results of this calculation can be observed in row 4 of the worksheet *SA multipliers (steps 9 and 10)*. For \$1 increase in the final demand for mining, for example, labor earnings in the mining sector is estimated to increase by \$0.32.

To estimate type I multipliers for earnings for each industry (i.e. the earnings generated in \$ in the economy for each \$ of directly generated income), divide the direct + indirect value by the direct effect. Type I multipliers for South Africa in 2011 are computed in row 5 of the worksheet *SA multipliers (steps 9 and 10)*. For \$1 of direct income/earning generated by mining, earnings in the economy increases by \$1.572.

Step 10: The final step involves calculating the employment multipliers. The dollar value of output for each sector is obtained by summing across columns for each row in the IO table. In this example output is in millions. The employment data that we have taken from the Statistics South Africa publication is in thousands of employees. Therefore, if we divide employment by total output for each sector, we obtain how many thousands of employees are used in that sector

per \$1 million of output. Rows 8 to 10 in the worksheet *SA multipliers (steps 9 and 10)* show these calculations for South Africa. We then compute employment multipliers using a similar method as for earnings multipliers using the matrix formula. The values returned by this operation describe, for each industry, the direct + indirect effect on employment in the economy (in thousands of employees) for a \$1 million increase in the final demand of that sector (see row 11 in *SA multipliers (steps 9 and 10)*). For mining, for example, it is estimated that for a \$1 million increase in the final demand in mining 13 mining jobs are created.

Finally, the Type I employment multipliers are obtained by dividing the direct + indirect effect just obtained by the employment-output ratio for each sector (see row 12 in *SA multipliers (steps 9 and 10)*). For mining, this means that for each additional mining employee, 2.4 additional people are employed throughout the economy.

3. Interpreting IO model results

As outlined above, the main constraint of getting good multiplier estimates is the quality of the data. If the input data is unreliable, then the output will also be unreliable. Furthermore, IO data is often only publicly available at the national level. However, extractive industry projects will be nested in localities where sector dynamics differ from national averages. Results therefore need to be viewed as indicative rather than exact. There are several characteristics of the mining project and local economy that can be reviewed and compared to national averages. When the project is significantly different from other projects in the economy upon which the input-output tables are based upon, the estimated multipliers should be adapted accordingly. Characteristics affecting the multipliers include:

- **Type of ownership:** state owned companies tend to employ more local workers and contract more domestic suppliers than internationally listed companies. Big multinational mining companies are likely to have higher international procurement standards and systems in place than mid-tier and smaller companies; these international standards create barriers to entry for local suppliers. Hence the multiplier for state owned mining companies and mid & small-tier mining companies are likely to be higher.
- **Outsourcing model:** some companies place greater importance on in-house expertise, while others look to outsource services to suppliers. The latter model will result in lower direct employment numbers, but higher multiplier effects if outsourcing is done domestically.
- **Size of project:** larger projects as a share of gross domestic product are likely to have a bigger impact on multipliers. However, this may be countered by the lack of constraints in the IO model as large projects are more likely to result in human and material supply constraints.
- **Type of project & commodity:** Skill requirements vary depending on the commodity mined and the mining methodology. A country with expertise to service open-pit iron-ore mines, for example, will not necessarily have the expertise to service an underground gold mine. Multipliers for the gold mining example will therefore be likely lower than the national averages until expertise is built up in that sector.

- **Mining life cycle:** Multipliers are going to vary depending on whether the mine is in its exploration, construction, production or rehabilitation phase. Direct employment will be highest during the construction phase.
- **Level of automation:** The mining sector is increasingly automating processes to reduce operating costs and improve safety in mine sites. Multipliers are likely to be lower than those estimated by IO tables if the country in question does not produce automated equipment required by the operation (it is most likely that mining operations in developing countries will have to import automated equipment including spare parts and maintenance services, which will reduce local indirect employment).

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ANNEX:

When constructing a CGE model, once the economic agents are identified and their optimizing behavior specified by algebraic equations, the parameters in those equations must be evaluated. Data on endogenous and exogenous variables obtained at a snapshot point in time are typically used for this purpose. This process is referred to as calibration. Calibration determines the values of the normalizing (or free) parameters so as to replicate the observed flow values incorporated in the social accounting matrix. This process assumes that all equations describing market equilibria in the model are met in the benchmark period.

When dealing with flexible functional forms, such as the constant elasticity of substitution or the constant elasticity of transformation, it is necessary to supplement the calibration process with these exogenously determined elasticities. Other parameters obtained from literature (econometric studies) include income elasticities, migration elasticities, and price elasticities of export demand. These parameters are used to illustrate the calibration process of the various components of the regional CGE model.

The calibration process starts with choice of units. Because in CGE analysis only relative prices matter, all prices and factor rents are normalized to unity in the initial equilibrium. With prices normalized to one, then the flow "values" in the social accounting matrix may be interpreted as a physical index of quantity in the commodity (industry) and factor markets. Once all the parameters are specified, the model is solved to reproduce the benchmark data. The solution obtained with the benchmark data is referred to as the "replication" equilibrium, assuming the benchmark represents an equilibrium outcome, given existing exogenous conditions. In addition to providing a check on the accuracy of the calibration, the replication also shows that the complete circular flows of income and expenditures are balanced. Counterfactual equilibria are obtained by introducing shocks to exogenous variables, changes in market conditions, or changes in any policy variable and rerunning the model.