POWER SECTOR ECONOMIC MULTIPLIER TOOL:
ESTIMATING THE BROAD IMPACTS OF POWER SECTOR PROJECTS

Methodology

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This white paper was prepared by IFC CGEDR (Evgenia Shumilkina, Results Measurement Specialist) and IFC CNGSF (Brian Casabianca, Senior Economist) with contributions from Alexis Diamond (Results Measurement Specialist, IFC CGEDR).

The note is based on the technical note prepared by Prof. Michael Lahr “Estimating Economic Impacts of New Electricity Power Generation and Transmission Facilities in Developing Nations” that proposes the use of the social accounting matrix (SAM) multiplier methodology for ex-ante assessment of the effects of power projects in the situation of limited data availability and on the work conducts by ECOMOD on application of this methodology in practice for specific countries.

The results of the work were subject to the peer review that was conducted by Robert Bacon, senior consultant of the World Bank Group Energy and Extractives Global Practice.
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I. INTRODUCTION AND OBJECTIVES

The objective of this note is to describe the methodology behind the Excel-based tool developed by the IFC to estimate ex ante economic impact of its power sector projects. The tool was designed to allow operational teams to estimate impacts of specific power sector projects in different countries with minimum data and programming requirements. Currently, the tool covers 20 developing countries in different regions of the world (complete list of the countries is provided in Appendix I).

The analysis underlying the tool is based on the social accounting matrix (SAM) multiplier methodology, an extension of the input-output multiplier methodology.

II. CHOICE OF THE METHODOLOGY

Assessing the impacts of investments in the power sector is tricky as these impacts arise through fairly complex and dynamic channels. Different methodologies were reviewed in terms of their strength and limitations practicality of use. In general, the following approaches can be used to estimate the impact of power sector projects:

- Econometric modeling
  - Regression analysis
  - Structural macroeconometric modelling
- Input-output (or social accounting matrix (SAM)) multiplier analysis
- Computable general equilibrium (CGE)- models

Traditional econometric studies that relate electricity use to GDP levels do not provide estimates for specific projects. These studies are also typically associated with serious issues (such as omitted variables) that are summarized in the recent literature review of the existing studies on the link from energy to growth (World Bank (2015)). The in-depth review identified that only three studies tested for the direction of causality, allowed for non-stationarity, and included possible major explanatory variables for both the production and demand function relationship. Two of these three studies were found to have other potential data measurement problems.
While CGE approaches might be preferable from the theoretical point of view than input-output multiplier analysis, they have much larger data and programming requirements. CGE models might be more applicable for detailed analysis when more data and resources are available (for instance, for detailed ex-post evaluation of a specific project).

The input-output (or social accounting matrix) multiplier analysis (discussed in detail below) was found to be the most appropriate for the present task. As such, it has been designed as a practical tool that IFC operational teams can apply with minimum data and programming requirements for a large set of projects in different countries. The approach is associated with a number of limitations and assumptions that are discussed in Section VII.¹

A similar approach based on input-output methodology is employed by the Netherlands Development Finance Company (FMO) in the estimation of the impact of its portfolio projects (including energy) and by CDC, the UK’s development finance institution². The summary comparison of the IFC and FMO tools is provided in Appendix III.³

### III. Multiplier Modelling: Overview

Input-output analysis involves constructing a table in which each horizontal row describes how one industry’s total product is divided among various production processes and final consumption. Each vertical column denotes the combination of productive resources used within one industry. A table of this type (Figure 1) illustrates the dependence of each industry on the products of other industries: for example, an increase in manufacturing output is also seen to require an increase in the production of power.

Figure 1: Simple industry/commodity use (input-output) table

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¹ Additional discussion of the limitations and application of the IO models can be found in World Bank (2011) and World Bank (2015).
² The CDC methodology is not publicly available at the present moment, but captures ex-ante project estimates.
Note: PCE is Personal Consumption Expenditures, PFI is Private Fixed Investment, and Govt - Government final consumption expenditures.

A social accounting matrix (SAM) (Figure 2) is an extension of the input-output matrix that adds other parts of the economy. SAM is a square matrix which captures all the main circular flows (Figure 3) within an economy in a given period.

Figure 2: Basic structure of a SAM

Source: Breisinger C., M. Thomas, and J. Thurlow (2010), Social Accounting Matrices and Multiplier Analysis, IFPRI, Washington DC.
The input-output part of SAM captures production linkages between sectors that are determined by sectors’ production technologies. These linkages can be differentiated into backward and forward linkages. Stronger forward and backward production linkages lead to larger multipliers.

**Backward production linkages** are the demand for additional inputs used by producers to supply additional goods or services. For example, when electricity production expands, it demands intermediate goods like fuel, machinery, and construction services. This demand then stimulates production in other sectors to supply these intermediate goods. The more input intensive a sector’s production technology is, the stronger its backward linkages are.

**Forward production linkages** account for the increased supply of inputs to upstream industries. For example, when electricity production expands, it can supply more power to the economy, which stimulates production in all the sectors which use power. So the more important a sector is for upstream industries, the stronger its forward linkages will be. Forward linkages are particularly important for the energy sector as it provides key input into the majority of other sectors in the economy.

Input-output tables and social accounting matrices can be used for building multiplier models to estimate the multiplier effects of exogenous shocks. When we talk about “exogenous demand-side shocks” to an economy, we are referring to changes in export demand,
government spending, or investment demand. The impacts of these shocks can have direct, indirect, induced, and second order growth effects on the economy.

IV. IMPACTS OF POWER SECTOR ACTIVITIES ON THE ECONOMY

The changes in the electricity sector are expected to have an impact on the economy through different channels as outlined below. As such, the SAM analysis captures some of these effects.

a) Direct effects. Expansion of the output of the electricity sector and employment that was created by employing additional labor and professional staff (permanent and temporary) to build (usually, over 3-5 years) and later operate (longer period of time) power plants and transmission and distribution lines.

b) Indirect effects. Engineering, procurement, and construction (EPC) activities and operation and maintenance (O&M) of the power plants or transmission and distribution lines requires supplies from other sectors like cement, cables, and other construction-oriented goods and services. The additional output and employment created in the supply chain (through backward linkages) are the indirect effects.

c) Induced effects. The additional workers brought by the expansion of the power sector itself and the sectors supplying to it (through indirect effects) now spend more - which creates additional production and employment in various other sectors throughout the economy, creating a multiplier of further demand. This spillover effect is called an induced effect.

d) Second-order growth effects. The effects come from removal or reduction of an existing constraint on production of various sectors that are linked to the power sector through forward linkages. These effects, termed “second-order growth effects” are the most crucial channel through which infrastructure projects impact economies that experience shortages in the power supply. Since power is an important factor of production, an increase in its supply induces an increase in power consumption which stimulates industrial production, growth, and employment. Secondly, an increase in
power supply helps improve overall reliability, which is a very critical constraint on industrial output and growth.

The SAM methodology presented in this paper helps to estimate direct, indirect, and induced effects from engineering, procurement, and construction (EPC) activities and O&M activities as well as the second-order growth effects from an increase in the supply of electricity.

V. **Estimating Direct, Indirect, and Induced Effects**

The section below describes how the shock to the economy in the form of power sector related expenditures (EPC and O&M) affects the economy and how the associated direct, indirect, and induced effects are estimated.

The starting point in computing the multiplier effects is the input-output (IO) table or the social accounting matrix (SAM).

The first step is to choose the exogenous accounts. The rest of the world, the government, and the investment accounts will be included in the exogenous bloc of the multiplier model. If we want to compute only direct and indirect effects, the household account will also be included in the exogenous bloc.

The next step in producing input-output or SAM multipliers is to calculate the direct requirements matrix (A). The values of the cells in the direct requirements matrix are derived by dividing each cell in a column by its column total. Each cell in a column of the direct requirements matrix A shows how many cents of each producing industry’s goods or services are required to produce one dollar of the consuming industry’s production.

Next in the process of producing the multipliers, the Leontief Inverse is calculated. An IO or SAM model can be written as:

\[ X - AX = Y, \]

where

\( X \) is the column vector of industrial gross output, \( Y \) is the column vector of exogenous final demand accounts, and \( A \) is the direct requirement matrix.
We can express this equation as:

\[(I - A)X = Y\]

or

\[X = (I - A)^{-1} Y\]

\[X = BY,\]

where

\(I\) is the identity matrix (with "1" in the diagonal, "0" in all other fields), \((I-A)^{-1}\) is the "Leontief Inverse (Matrix)" = \(B\) (or \(B'\) if induced effects are included), \(B\) (or \(B'\)) is the matrix of direct and indirect (and induced) coefficients \(b_{ij}\) (or \(b'_{ij}\)), and \(b_{ij}\) (or \(b'_{ij}\)) = "Leontief Coefficient" representing the direct and indirect (and "induced") requirements per unit of final demand for the output of sector \(j\).

Using the \(B\) (or \(B'\)) matrix, we can compute the effects of an exogenous shock on the output, valued-added, and employment in the different industries and on the household income. The output multiplier for an industry is the ratio of the direct and indirect (and induced when included) output changes to the direct output change due to a unit increase in final demand. Multiplying a change in final demand (direct impact) for an individual industry's output by that industry's output multiplier will generate an estimate of direct and indirect impacts (and induced when included) upon output throughout the economy.

We can also compute the value-added, income, and employment effects. The gross value-added (or GDP) effect is the direct and indirect (and induced when included) gross value-added changes to the direct output change, due to a unit increase in final demand. The income effects show the direct plus indirect (and induced when included) income change to the direct output change due to a unit increase in final demand. The employment effects show the direct plus indirect (and induced when included) employment change to the direct output change due to a unit increase in final demand. The employment effect in each industry is computed by multiplying the employment coefficient (number of employees per dollar of output) in that industry by the change in the output of the industry as a consequence of a shock to the final demand in an industry.

Specifically, the employment effects can be estimated in the following steps.
1. Compute the employment coefficient for each industry. For example for industry i:
   Employment coefficient \( i = \frac{\text{number of employees in industry } i}{\text{output of industry } I} \) (measured in monetary units).

2. Compute the change (using the output multiplier) in the output of the industry i due to a shock to the final demand of an industry j.

3. Multiply the change in the output of industry i by the employment coefficient of industry i. This will give the change in the number of jobs in industry i as a result of a shock in the final demand of industry j.

4. Total number of new jobs in the economy as a results of a shock to the final demand of industry j = \( \sum_i \text{change in employment in industry } i \).

VI. ESTIMATING SECOND-ORDER GROWTH EFFECTS

The supply effects of additional power availability (second-order growth effects) take into account the forward linkages of the power sector with the industries. In order to compute these effects, the industry expansion is assumed to continue along the lines of the current economy’s structure.

First, the share of each industry in the total power consumption is computed in the SAM of each country. These shares are multiplied by the additional power supply to the domestic economy emanating from each industry. The result provides an estimate of the dollar value of the additional power use in each industry. This additional power consumption is divided by the direct electricity requirement coefficient of each industry to calculate the change in the output of the industry under consideration.
The following example shows how the methodology is applied by estimating the impact from the increase in power supply (second-order growth effects) from a power plant in Bangladesh on the manufacturing sector. The estimates of the impact of the increase in power supply for other economic sectors are carried out in a similar fashion.

**Example: Bangladesh.**

Bangladesh gas-powered plant with a capacity of 341 MW. Once fully operational, the plant will produce 2946 GWh per annum at a tariff of US$ .031/ KWh. T&D losses in Bangladesh are likely to be in the 14 percent range. After taking into account losses, the amount of the additional annual power supply available for the use in the economy is US$ 78.4 mln. (in 2007 prices).

**Step 1:** Estimate the dollar value of the additional power use in the manufacturing industry. In order to do this, calculate the share of manufacturing in total electricity consumption in Bangladesh and multiply this share by the additional power supply to the domestic economy. From Bangladesh SAM 2007 the share of manufacturing in total electricity consumption corresponds to US$ 1785 mln. / US$ 4125 mln. or 43.2 percent. Therefore, the share of the new power supply that would go to manufacturing is US$ 33.9 mln. (US$ 78.4 mln. * 0.43).

**Step 2:** Calculate the percentage of electricity used in the input mix for manufacturing in Bangladesh. From the Bangladesh SAM 2007, this corresponds to US$ 1785 mln. / $46,344 mln. or 3.85%.

**Step 3:** Calculate the technical coefficient for value added for Bangladesh manufacturing. Total value-added is the earnings received by the factors of production, such as the wages and salaries paid to labor and the profits paid to capital. The share of land, labor and capital in manufacturing expenditures in Bangladesh is about 20 percent.

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4 As explained in the section VIII below, 2007 is the base year of the GTAP database used for this exercise.
5 Total value-added (across an entire economy) is also known as “GDP at factor cost.”
Step 4: Calculate the change in the output of the manufacturing sector due to increased power supply by dividing the additional power consumption by the direct electricity requirement coefficient of manufacturing. This gives US$ 33.9 mln./.0385=US$ 880.8 mln. worth of additional manufacturing sector output.

Step 5: Estimate the effect of the change in manufacturing on value added (GDP) using the coefficient of value added for the industry. Therefore, US$ 880.8 mln. * .20=US$ 176 mln. US$ 176 mln. is the increment in value-added (GDP) by manufacturing due to the increase in power supplied.

The same process is carried out for every economic sector of the Bangladesh economy that uses electricity as an input to estimate the total impact on the economy’s GDP.

The employment impact is estimated by multiplying the increase in specific sector’s output due to increase in power supply (from Step 4) by the sector’s employment coefficient.

VII. ASSUMPTIONS AND LIMITATIONS

Input-output and SAM multiplier models, when applied correctly, can be practical tools for estimating the economy-wide effects of an initial change in economic activity or in the final demand. However, these models have a number of strong assumptions and limitations, such as:

- Fixed prices: Prices are assumed to remain constant. This is a very strong assumption for economy-wide analysis if the shocks shift supply and demand. Yet, in the majority of countries that the World Bank Group is working with, the end-user tariff levels are set by the regulator for a certain period of time, and, thus, electricity prices can be considered fixed, at least, in a short run. The tariff levels are also not necessarily cost-reflective being often influenced by political considerations.

6 For more discussion on limitations and application of IO models please see World Bank (2011) and World Bank (2015).
• Constant returns to scale: This means that the same quantity of inputs is needed per unit of output, regardless of the level of production. In other words, if output increases by 10%, input requirements will also increase by 10%.

• No supply constraints: Most input-output models assume that there are no restrictions to inputs and factors of production and that there is enough to produce an unlimited product.

• Fixed commodity input structure: This structure assumes that changes in the economy will affect the industry’s output but not the mix of commodities and services it requires to make its products. In other words, there is no input substitution in response to a change in output. While this assumption might hold in the short run, in the longer run it becomes less viable.

• Fixed industry technology: An industry will always produce the same mix of commodities regardless of the level of production. In other words, an industry will not increase the output of one product without proportionately increasing the output of all its other products.

• Static nature of the model: Most IO and SAM models are static and cannot capture the dynamic impacts of investments in the power sector.

• Coefficients are often out-of-date: IO tables in the most developing countries are collected at infrequent intervals and can be several years or even a decade old and thus often do not provide an accurate representation of the current structure of the economy and the state of technology.

The estimates of the effects from an increase in power supply need to be treated with a particular care as they are based on the following assumptions:

1. An electricity shortage is a bottleneck and new supply of electricity will be fully used.
2. The distribution of electricity use continues as it was prior to the installation of new facilities.
3. There are enough available factors of productions (labor, capital, natural resources); intermediate inputs do not impose a constraint.
Regarding the first assumption, the lack of adequate electricity supply represents a serious bottleneck, given that the percent of firms identifying electricity as a major constraint is 76 in Nigeria, 52 percent in Bangladesh, and 31 percent in Georgia\(^7\).

The second assumption might hold in the short run, but with the time, as companies adjust their production to higher availability of electricity supply and the new technologies develop, this assumption will be less likely to hold.

Regarding the third assumption, the significant increase in production in almost every activity in the country would require more factors of production and intermediate inputs and would inevitably create significant price movements and some other bottlenecks in the economy. In order to properly capture these complex effects of increased power supply, interactions and constraints, CGE models might be more appropriate.

Regarding the third assumption, the data from the Enterprise Surveys provides some indication of how much more the economies are capable of producing with the existing resources if there is a reliable supply of electricity. According to the surveys, the losses of annual sales due to electrical outages are 3.7 percent for Bangladesh, 2.4 percent for Georgia, and 8.5 percent for Nigeria.

A good modelling approach needs to take into account not only the multiplier effects of the investments, but also the effects of the numerous effects generated by power shortages. Unlike CGE models, multiplier analysis cannot handle these kinds of complex effects and linkages. The results obtained with the help of input-output or SAM analysis should therefore be interpreted as being approximate and should be considered with care.

The results of the SAM multiplier analysis captures the output effects of new/more available power rather than the price effects. Such analysis might be more applicable in the situation of regulated prices and when lack of available electricity represents a bottleneck to the ability of the firms to enhance their productive capacities.

\(^7\) According to the World Bank Group’s Enterprise Surveys.
It should be also noted that the multiplier models tend to overestimate the economic effects of shocks. For instance, since the models assume linear relationships, a 5% increase in output by a given industry is matched by a 5% increase in employment in that same industry. In reality this is not necessarily the case as there might be total factor productivity gains and the marginal effect on employment will be less than proportional.

**VIII. Data**

The methodology is applied using the GTAP database - the most consistent international dataset that harmonizes data for more than 150 countries. The SAMs for the countries included in the present analysis are extracted from this database. One of the advantages of this database is that it has a separate electricity sector account for all the included countries. The most recent version of the GTAP database uses a base year of 2007.\(^8\)

The employment data comes from the ILOSTAT\(^9\) database of the International Labor Organization (ILO). The data on GDP deflators comes from the World Bank Development Indicators database. The data on the engineering, procurement, and construction (EPC) costs and on the operations & maintenance (O&M) costs for specific projects are from IFC project documents.

In order to estimate the multiplier effects of an increase in the final demand, various components of the domestic EPC and O&M expenditures were allocated among the following eleven productive activities of the multiplier model that was built for this project\(^10\):

1. Agriculture
2. Mining and fuel
3. Manufacturing
4. Electricity
5. Water
6. Construction

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\(^8\) The newest dataset GTAP 9 (base year 2011) was released in May 2015.

\(^9\) Or from the ILO database LABORSTA which is not being updated anymore.

\(^10\) This follows closely the standard classification in the national accounts for the main industries.
7. Trade
8. Transport and communication
9. Finance and insurance
10. Other services
11. Public services
REFERENCES


APPENDIX I: LIST OF COUNTRIES

The methodology was applied to 20 developing countries in different regions of the world that historically and based on the pipeline have the largest number of IFC investments. The templates were built for all 20 countries.

South Asia
India
Nepal
Bangladesh

EAP
Philippines
Indonesia

Africa
Kenya
Cameroon
Senegal
Cote D'Ivoire
Nigeria
Uganda
Ghana
Mozambique
South Africa

LAC
Mexico
Brazil

E/MENA
Pakistan
Georgia
Turkey
Egypt
## APPENDIX II: EXCEL-BASED TOOL

### Multiplier Model for the Power Sector

**Bangladesh**

<table>
<thead>
<tr>
<th>Sector</th>
<th>EPC Expenditures</th>
<th>O&amp;M Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>c_Agriculture</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c_Mining&amp;Fuel</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>c_Manufacturing</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c_Electricity</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c_Water</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c_Construction</td>
<td>104.5</td>
<td>0.0</td>
</tr>
<tr>
<td>c_Trade</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c_Transport&amp;Com</td>
<td>37.3</td>
<td>0.0</td>
</tr>
<tr>
<td>c_Finance&amp;Insurance</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c_OthServices</td>
<td>0.8</td>
<td>0.1</td>
</tr>
<tr>
<td>c_PubServices</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>142.9</strong></td>
<td><strong>0.3</strong></td>
</tr>
</tbody>
</table>

**Additional Power Supply in M 2007 USD** 78.4

*Note: Enter the shocks in 2007 prices.*

[Solution Button]
APPENDIX III: OVERVIEW OF FMO AND IFC TOOLS

The table below summarizes FMO and IFC tools used to quantify economic impacts of projects and their underlying methodologies.11

<table>
<thead>
<tr>
<th></th>
<th>IFC</th>
<th>FMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development indicators</td>
<td>Value-added (GDP)</td>
<td>GHG Emissions and Avoidance (for renewable energy projects)</td>
</tr>
<tr>
<td></td>
<td>Jobs</td>
<td>Jobs</td>
</tr>
<tr>
<td>Type of analysis</td>
<td>Ex-ante project level</td>
<td>Ex-ante portfolio level</td>
</tr>
<tr>
<td>Country coverage</td>
<td>20 individual countries (Appendix I)</td>
<td>All countries of FMO investments. Some countries are aggregated by region/level of development. In total: 23 country and regional IO tables.</td>
</tr>
<tr>
<td>Sector coverage</td>
<td>Electricity</td>
<td>All sectors of FMO investments</td>
</tr>
<tr>
<td>Methodology</td>
<td>Input-Output/SAM</td>
<td>Input-Output/SAM</td>
</tr>
<tr>
<td>Effects captured</td>
<td>- Direct</td>
<td>- Direct</td>
</tr>
<tr>
<td></td>
<td>- Indirect (backward linkages)</td>
<td>- Backward</td>
</tr>
<tr>
<td></td>
<td>- Induced</td>
<td>- Induced</td>
</tr>
<tr>
<td></td>
<td>- Second-order growth effects</td>
<td>- Forward (only for energy and infrastructure)</td>
</tr>
<tr>
<td></td>
<td>(forward linkages)</td>
<td></td>
</tr>
<tr>
<td>Source of IO/SAM data</td>
<td>GTAP 7 (base year 2007)</td>
<td>GTAP 7 (base year 2007)</td>
</tr>
<tr>
<td>Methodology for increase in electricity supply</td>
<td>Use individual country SAM to track the impact of the increase in power supply on the affected sectors.</td>
<td>Use the same specific factor.1 to national GDP for all countries. The number is based on the range of the estimates from the review of the literature.</td>
</tr>
</tbody>
</table>

11 FMO methodology is available at [http://www.fmo.nl/development-impact](http://www.fmo.nl/development-impact). CDC (UK) also applies an input-output based methodology for its project analysis, however, the methodology is not published yet.