AGGREGATE Z-FACTOR: AN APPROACH FOR ESTIMATING ADDITIONAL COSTS ON BRAZILIAN ENERGY MEGAPROJECTS

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Abstract

Decisions about energy supply are usually based on cost minimization – a winning project is usually picked among similar alternatives by providing the lowest cost per unit of energy delivered. Nonetheless, megaprojects are prone to construction cost overruns and delays. These factors may change the optimal decision for a given project. This paper proposes a method to estimate the effects of construction cost overruns (CCO) on the results of energy infrastructure for Brazil. Results include regional impacts on industrial productivity, local content policies and the cost of importing equipment, among additional factors, like delays and changes of scope, that are computed on a single aggregate factor, named Z Factor.

Keywords – Construction cost overruns; Megaprojects; Energy; Infrastructure

1. Introduction

Decisions about energy supply are usually based on cost minimization – a winning project is usually picked among similar alternatives by providing the lowest cost per unit of energy delivered. Nonetheless, megaprojects are prone to construction cost overruns and delays. These factors may change the optimal decision for a given project. The causes may vary from poor management - including technical, economical, behavioral and political circumstances (Ansar et al., 2014) - to chaotic dynamics (Olaniran et al. 2015). Also, planners tend to be overly optimistic about the required construction time and the costs and benefits of megaprojects, especially in the financing phase of a project.

A review of the literature shows that the underperformance of large infrastructure projects is a global phenomenon. Regarding the energy sector, based on a sample of 401 electricity generation projects in 57 countries, Sovacool, Gilbert, & Nugent (2014) found that hydropower and nuclear power plants have high construction cost overruns (CCO) and suffer from longer and more frequent construction delays than solar and wind projects. Ansar et al. (2014) point out that, especially in developing countries, smaller-scale projects should be the preferred choice due to the long construction periods required for megaprojects. Their analysis show that the cost-benefit ratio of hydropower plants with large reservoirs is worsened by CCO in 75% of the projects, and that 96% of them ended up costing more than originally planned.

Specifically, in the oil & gas sector, megaprojects have become the norm with CCO affecting an estimated 69% of refining projects globally, with 79% facing construction delays (EY, 2014). Two recent refinery complexes under construction in Brazil (RNEST and COMPERJ) are facing long delays, and will have taken more than 10 years to build by the time they are finished. As a matter of fact, chances are that one of them, the COMPERJ complex, will never be implemented, although a significant fraction of its initial CAPEX was already expended[1].

Regarding the power sector, the construction cost of the Belo Monte hydropower plant is a highly contentious issue. According to Norte Energia (Norte Energia, 2011), its initial cost in 2010 was US$ 11.3 billion, but currently, with over 50% of the construction complete, the amount approaches US$ 27 billion[2]. Also, the Angra 3 nuclear power plant construction[3] restarted in 2010 with a US$ 10 billion budget so far for the megaproject, which is much higher than originally budgeted. Construction delays are also rampant. Angra 3 was supposed to come online in 2015, but the expected operation start year is now 2018 (Eletronuclear, n.d.). In Brazil, a recent assessment revealed an average 49% CCO and 106% construction time increase, with energy projects generally faring worse (Frischtak, 2016).

In short, Brazilian infrastructure megaprojects are particularly prone to delays and CCO. This increases the lead time before a project begins to bring in revenue. Moreover, infrastructure bottlenecks lead to losses in productivity, with some Brazilian regions more heavily impacted than others. This paper proposes a method to estimate the effects of CCO on energy infrastructure in Brazil. Regional impacts on industrial productivity, local content policies and the cost of importing equipment, among additional factors, like delays and changes of scope, are computed on a single aggregate factor, named Z Factor (for zillions), described in the next section.

2. Methodology

To estimate the deviation of investment costs (CAPEX) of megaprojects in Brazil as compared to international parity, this paper considers three main overarching contributing factors: (i) the differences in the infrastructure quality of ports, roads and communication among Brazilian regions that impact industrial productivity (Section 2.2); (ii) the cost of importing equipment, materials and services, and the impact of local content requirement laws, the so-called Location Factor (Section 2.2); and (iii) delays, poor definition of scope and project contingencies (Section 2.3).

These three factors are computed on a single aggregate factor, named Z Factor, as described by the Equation 1 below.

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[1] Petrobras press release. 22 July 2016. Available at http://www.investidorpetrobras.com.br/en/press-releases/comperj-project

[2] According to Ansar, Flyvbjerg, Budzier, & Lunn (2014), the mean overrun for major dam projects is 100% over original estimates, so that the Belo Monte complex could, indeed, end up costing US$27 billion; http://www.bloomberg.com/news/articles/2014-03-13/megadams-are-dismal-investments.

[3] According to Portugal-Pereira *et al*. (2016), there is a general increasing trend of overnight construction cost and lead time for nuclear power plants worldwide, suggesting a negative learning curve effect.

$$Z_{ij} = \left(Loc_i / Eff_j\right) * (OC) \quad (1)$$

Where Z_{ij} is the construction cost overrun factor per technology *i* and region *j*; *Loc* is the location factor per technology *i*; *Eff* measures the loss/gain on region *i* industrial productivity due to infrastructure constraints absence (or presence); and *OC* represents the delays, scope and contingencies for all technologies and regions. The *Z* factor components are described in the next subsections.

2.1 - Regional Productivity (Eff)

The estimation of the regional productivity factor was based on Schettini & Azzoni (2015). The authors use a panel data to develop an indicator based on a production function for the impact of local infrastructural efficiency of transportation, communications, and utilities over industrial productivity of the Brazilian mesoregions. Their results show the loss of efficiency due to the lack of infrastructure. To compute them on a regional level, the mesoregions coefficients were averaged, resulting in five regional productivity factors. The national average efficiency rate was found to be 0.81. The North and Mid-West regions endure the lowest gross efficiency rates due to precarious infrastructure (0.71 and 0.76, respectively), while the South and Southeast regions have the highest gross efficiencies (both 0.86). The Northeast region's efficiency is the closest to the national average at 0.80.

To derive regional multipliers for the CAPEX investment costs of megaprojects, the relative infrastructure efficiency of each region was calculated by dividing the gross regional efficiency rates above by the national infrastructure index (0.81). This resulted in both the South and the Southeast regions having relative efficiencies above the national average, leading to positive industrial productivity multipliers of 5.1% and 6.1%, respectively, while the North and Mid-west regions had negative multipliers of -12.2% and -6.7%, respectively. The Northeast region approaches the national average, with an index of -1.4%. Table 1 shows the regional results.

Table 1 - Average Relative Regional (j) Industrial Productivity

Region	Relative Productivity (%)
North	-12.2%
Northeast	-1.4%
Southeast	5.1%
South	6.1%
Mid-West	-6.7%

Source: based on Schettini & Azzoni (2015)

2.2 - Location Factor and Local Content (Loc)

To convert the investment required for a given enterprise from one geographic location to another location factors indices were applied. Costs in Brazil were measured against a cost reference, namely CAPEX costs in the United States, which were assumed to have a location factor of 1.

In this study, we assumed an optimistic scenario with exemption of social contributions for machinery and equipment imports. The 38% added cost represents the additional cost of bringing products and services into Brazil. It includes freight and insurance costs, a one-time import fee, customs expenses, as well as additional Brazilian taxes known as IPI and ICMS[4]. This is in line with an assessment made by Gerbasi da Silva (2013) considering energy investments are made exempt from taxes known as PIS/COFINS[5]. Also, a study by Intratec (2016) estimated the location factor for Brazil to be 1.38 in January 2010 – i.e., on average, plant costs in Brazil were 38% higher than those in the United States.

However, not all equipment is imported as Brazil boasts a significant industrial base, so these added costs are applied selectively. The Table 2 below presents the nationalization indexes applied in the location factor used in this study.

Table 2 - Local Content by Technology (i)

Technology	Local Content (LC_i)*
Hydropower	1.00
Refinery	0.50
Thermal Coal	0.65
Thermal Natural Gas	0.78
Nuclear	0.60

Source: based on GDF Suez (2010), ONIP (2012) and Eletronuclear (n.d.)
* Share of total expenses made in Brazil.

The location Loc_i factor of imported goods and services for each technology *i* is then calculated by the formula:

$$Loc_i = 1.38 * (1 - LC_i)/(Eff_i + 1) \quad (2)$$

where LC_i is the Local Content share of technology *i* as shown in Table 2; and Eff_i is the factor for Regional Infrastructural Efficiency described in the previous section.

Regarding hydropower plants, the Brazilian engineering sector has the expertise required for the construction of dams, so that the local content index approaches 100%, given that all major equipment, such as turbines, valves, controllers, generators and hydraulic steel structures are manufactured in the country.

For large-scale thermal power plants, however, the Brazilian industry does not manufacture large enough boilers, turbines or generators, so they are imported. Nevertheless, a considerable part of the equipment, components and services used for the implementation of a thermal power plant is local.

[4] IPI = Imposto sobre Produtos Industrializados; ICMS = Imposto sobre Circulação de Mercadorias e Serviços. Moving merchandise within Brazil also has its costs, for example via ICMS, which is applied when goods move between states.

[5] Both the *Programa de Integração Social* (PIS) and the *Contribuição para Financiamento da Seguridade Social* (COFINS) are taxes levied to fund social security programs such as unemployment insurance, retirement and so on.

For coal power plants, it is estimated that about 35% of the CAPEX is imported (Pires, n.d.), implying 65% of local content. For natural gas power plants, the turbines, automation equipment, heat recovery steam generators and firefighting systems are usually imported, resulting in an overall rate of 78% local content (GDF Suez, 2010).

For nuclear power plants, according to Eletronuclear (n.d.), the domestic industry will have active participation in the supply of equipment for Angra 3 amounting to something around 54%, a little more than Angra 2 (50,4%), built between 1981 and 2000. This study conservatively assumes that about 60% of the cost of development is a reasonable share of national content, even though the goal for post-Angra 3 nuclear power plants is 75% (Eletronuclear, n.d.).

For refineries, ONIP (2013a) reports local content indexes for 16 expansion and modernization projects executed between 2006 and 2011, totaling some US$ 15 billion in investments. The engineering services recorded local content of 99%; materials, 68%; goods, 52%; and equipment, 44%. The overall local content index for Petrobras's eight refineries was 85% (ONIP, 2013b). This study assumes a conservative view and considers that greenfield refineries would have a local content of 50%, mostly related to goods and equipment, an estimate in line with EY (2014).

2.3 - Delay, Scope and Contingency (OC)

This study considers three main components representing additional costs incurred over the projects initial budget: delay, scope and contingency. These components sum up to a single factor OC. The KPMG (2015) construction survey reveals an average contingency factor of 10% of the total estimated costs of megaprojects, an average delay factor of 20% and a 20% factor related to poor scope definition, which adds up to a 50% overrun for megaprojects. Furthermore, the same 50% overrun factor was identified on an earlier survey conducted by KPMG (2008). In line with KPMG (2008) and KPMG (2015), this study adopts a conservative perspective and takes as a reference for all regions and technologies a 50% overrun – a premium that reflects additional investment costs incurred during the construction of the plant, such as changes in design, additional labor requirements, insurance and so on.

3. Results

The *Z* Factor for each geographic region is calculated from its components *Loc*, *Eff* and *OC*, as detailed in Equation 1 before.

The results reflect regional disparities within Brazil with regards to CAPEX investment costs of similar projects. For example, a refining plant in the Southeast has an estimated *Z* factor estimated of 1.70, which means that, under the current conditions, in Southeast a new refinery would cost 170% than a refinery in the Gulf of Mexico. However, if located in the North of Brazil, a *Z* factor estimated at 2.04 would be applied over the total cost of the same plant.

The analysis also reveals the impact of foreign content over megaprojects in Brazil. Naturally, the Z factor for technologies with lesser foreign content is lower than for technologies with a greater number of imported part. But, even hydropower plants, that have a 100% local content (as described in Table 2) have their total cost influenced by factors like delay or scope changes. For instance, the impact on the total cost of a hydropower plant for the South and the Southeast regions is estimated between 1.41 and 1.43, respectively, when compared to costs practiced in the United States.

The Table 3 shows the resulting location *Z* Factor coefficient for the megaprojects cost overruns, per region and per technology.

Table 3 – Estimated megaprojects cost overruns by region and technology

Technology by Region	Eff	Loc	OC			Z Factor
			Delay	Scope	Contingency	
NORTH	- 0.12					
Hydropower		1.14	0.20	0.20	0.10	1.71
Refinery		1.36	0.20	0.20	0.10	2.04
Coal power		1.29	0.20	0.20	0.10	1.94
Natural gas power		1.24	0.20	0.20	0.10	1.85
Nuclear		1.27	0.20	0.20	0.10	1.91
NORTHEAST	- 0.01					-
Hydropower		1.01	0.20	0.20	0.10	1.52
Refinery		1.21	0.20	0.20	0.10	1.81
Coal power		1.15	0.20	0.20	0.10	1.73
Natural gas power		1.10	0.20	0.20	0.10	1.65
Nuclear		1.13	0.20	0.20	0.10	1.70
SOUTHEAST	0.05					
Hydropower		0.95	0.20	0.20	0.10	1.43
Refinery		1.13	0.20	0.20	0.10	1.70
Coal power		1.08	0.20	0.20	0.10	1.62
Natural gas powers		1.03	0.20	0.20	0.10	1.55
Nuclear		1.06	0.20	0.20	0.10	1.59
SOUTH	0.06					
Hydropower		0.94	0.20	0.20	0.10	1.41
Refinery		1.12	0.20	0.20	0.10	1.69
Coal power		1.07	0.20	0.20	0.10	1.60
Natural gas power		1.02	0.20	0.20	0.10	1.53
Nuclear		1.05	0.20	0.20	0.10	1.58
MIDDLE WEST	- 0.07					
Hydropower		1.00	0.20	0.20	0.10	1.50
Refinery		1.21	0.20	0.20	0.10	1.81
Coal power		1.14	0.20	0.20	0.10	1.72
Natural gas power		1.09	0.20	0.20	0.10	1.64
Nuclear		1.12	0.20	0.20	0.10	1.69

4. Final Remarks

This paper proposed a method to estimate the effects of CCO on the total costs of energy infrastructure projects in Brazil. Brazilian infrastructure megaprojects are particularly prone to delays and CCO. Higher costs and the longer construction times can have significant impacts on the optimal solutions of least-cost optimization studies and, consequently, on investment decisions that are based on least-cost criterion. If this study's CCO estimates (Z factor) were included on the initial projects budgets, the total cost could reach a up to two times the project's initial value, depending on the region and technology considered.

The continental scale of Brazil implies an additional difficulty to precisely estimate what are the real megaprojects CCO. The average regional relative efficiency does not reflect all the particularities found inside the country. In that sense, to calculate each of the megaprojects CCO, in a case by case study, would be the most recommended, but the lack of public data is a limitation. Future research is also required to develop more accurate estimates of the delay, change of scope and contingency factors. These limitations do not invalidate the method proposed, that could capture the main factors affecting the megaprojects construction costs.

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