Supply and Use Tables at the Municipal Level For Prospecting Electricity Markets

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Paper Presented at the

22nd International Input-Output Conference

Lisbon, Portugal, July 15-18, 2014

Abstract

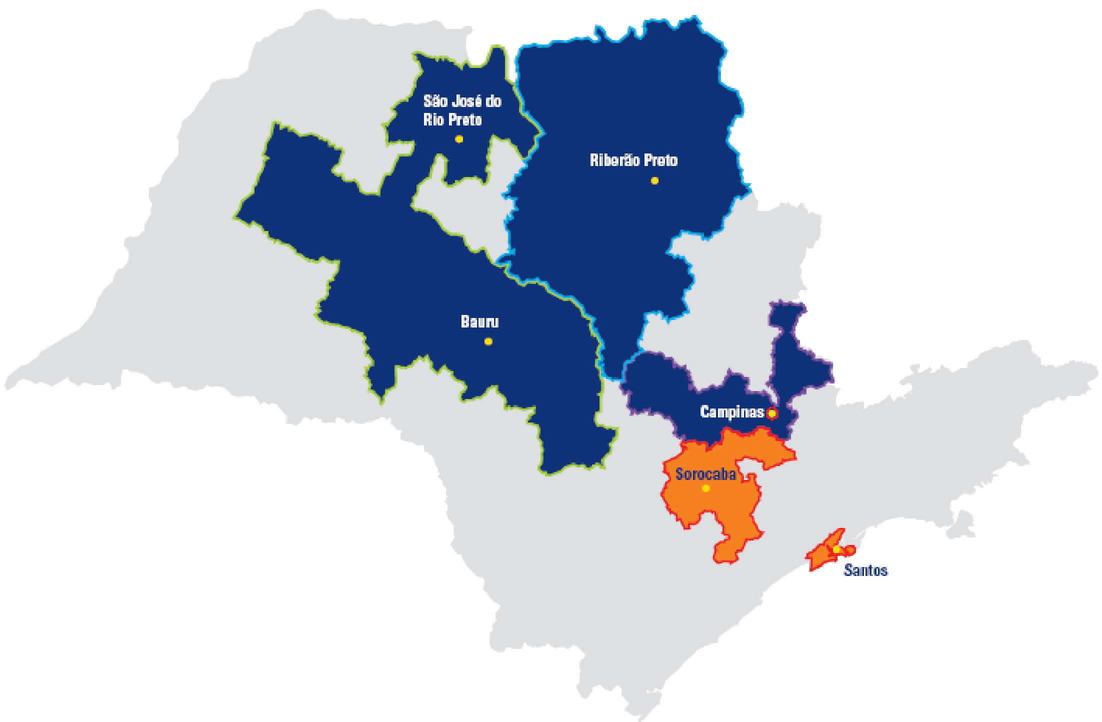
The present paper reports on the results of a research carried out in partnership between a Brazilian company of electricity generation and distribution, CPFL, and the Department of Economics at the University of São Paulo (FEAUSP) in Brazil. The project was financed by ANEEL, the Brazilian regulatory agency for electricity generation and distribution, and had as a result an input-output model that improves the assessment of the impacts of structural economic changes on the consumption of electricity, by taking into due account the diversities of regional development. By tailoring the supply and use tables and the results in function of the regional boundaries of the CPFL area of operation, and of its "geo-electrical sub-regions", the identification of direct and indirect changes on electricity consumption accruing from alternative regional development scenarios was made possible, including the effects of changes outside the Company area into its electricity market. An account of the model theoretical structure, which involved the construction of supply and use tables at the municipal level, is provided. The model is already part of the market prospecting methodology of the utility company, and some practical examples of its applicability are given in the text.

The project and its objectives[1]

The prospecting of electricity markets requires the consideration of a diverse set of variables, ranging from consumer preferences and technological change, to climate and economic conditions. Pervading this whole set is the geographical factor, conditioning the behavior of all those variables to regional comparative advantages and disadvantages.

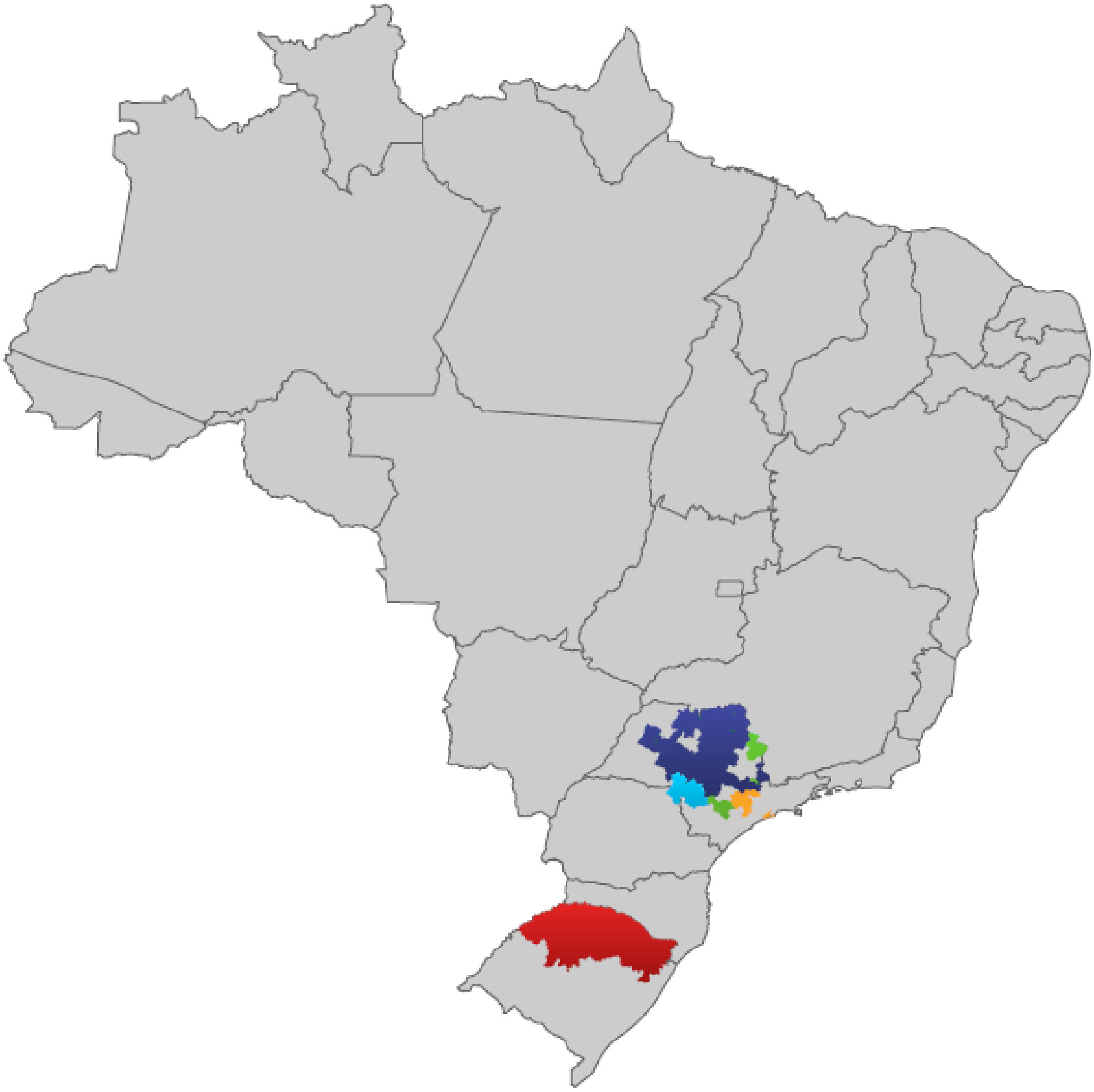
This has been a considerable setback to electricity distribution companies with large concession areas, such as CPFL, Companhia Paulista de Força e Luz, which sponsored this research project. The company is responsible for electricity generation, transmission and distribution through several affiliates in the sates of São Paulo and Rio Grande do Sul, supplying electricity to around 18.7 million inhabitants. The R&D project focused on the municipalities served by the three larger of these affiliates, CPFL Piratininga, CPFL Paulista, and RGE. The first of them, represented in blue in the map below, distributes electricity to 234 municipalities, and the second, in orange, to 27 municipalities, both in the state of São Paulo. RGE covers 262 municipalities in the state of Rio Grande do Sul. The location of these three affiliates in the Brazilian map is shown on Figure 2, RGE being in red.

Figure 1 - Paulista and Piratininga regions in the state of São Paulo



[1]A brief account of this project in its early stages, its objectives, and its modeling outline, has already been presented at the 20th IIOA conference in Bratislava, see *Overcoming the Difficulties of Developing and Transferring an Input-Output Model for Electricity Consumption Forecasts to the Users.*

Figure 2 –The regions considered in the IO model, in the Brazilian map



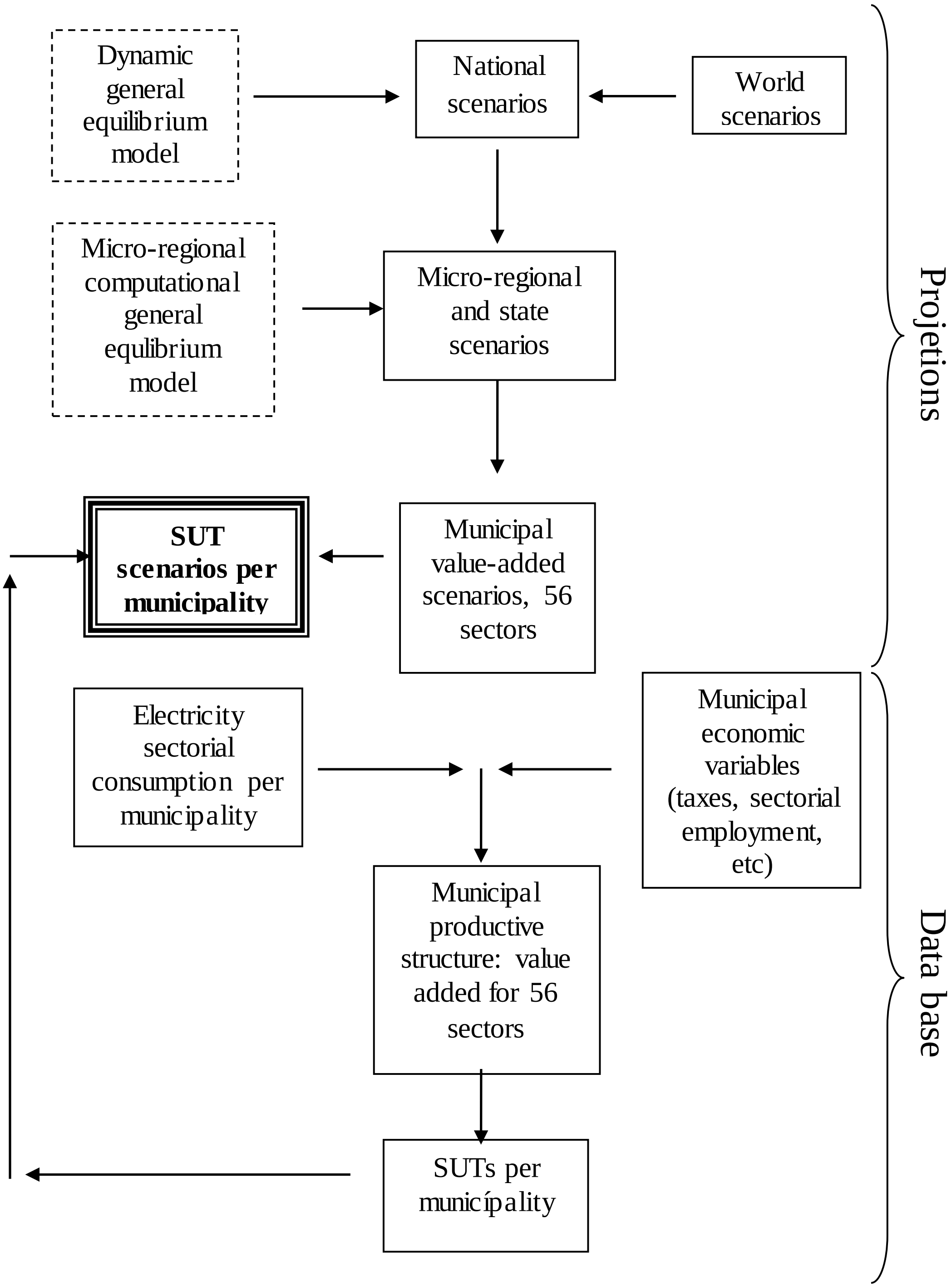
Those regions, as the map shows, cover a wide geographic area, with remarkable economic and social differences. Thus, the major objective of the project was to fulfill the need of measuring not only this diversity in economic terms, but also their alternative patterns of growth, so as to capture how they could result in different patterns of electricity consumption. More specifically, three major improvements are implemented: a) a better impact assessment of the effects of structural economic changes on the consumption of electricity; b) analyses tailored to the specific regional boundaries of the CPFL area of operation; and c) the identification of direct and indirect changes on electricity consumption accruing from regional development.

The model

General outlines

The model logic follows the diagram shown in figure 3.

Figure 3 Model logic diagram



In figure 3, we can see how the work went on from the highest (world) to the lowest level of aggregation (municipalities). We can also distinguish two main modeling parallel activities: projections (the upper part of the figure) and data base construction (the lower part).

Regarding projections, at the higher levels of aggregation they are supplied by two models provided by FIPE[2]: a dynamic general equilibrium model and a micro-regional computational general equilibrium model. Those models support the construction of national scenarios compatible with world scenarios, as well as state and micro-regional[3] scenarios. Sectoral value added projections at the municipal level are derived from them, providing one part of the information necessary for structuring the municipal SUT projections.

The other part is covered by the data base building, where the bulk of the innovation to be accomplished by the study is concentrated. The lower the level of aggregation, the less is the availability of the variables utilized for building SUTs. Thus, the task of building municipal SUTs requires quite a deal of research on how to identify and correlate variables available at the municipal level so as to get the best possible estimates to fill municipal data into the same SUT structure as the national one.

As figure 3 indicates, the municipal SUT scenarios are to be obtained by the matching of those two modeling branches, in a process designed to join both advanced practices of projection with innovative methods of regionalization. Those scenarios were aggregated, according to the operational and administrative requirements of CPFL, into 31 so-called “geo-electrical regions”, with different numbers of municipalities, ranging from 4 to 95 each.

For all those municipalities and those geo-electrical regions, the economy was disaggregated according to the supply and use tables of IBGE: 110 products and 56 sectors. The geo-electrical regions SUTs where obtained by aggregating those municipal SUTs accordingly.

The scenarios were constructed for 2013, 2016 and 2019, as defined by CPFL needs.

Modeling procedures

Brazil and the World

Scenarios for the world and for the country and its regions were generated by two models provided by FIPE: a dynamic general equilibrium model and a micro-regional computational general equilibrium model. Those models were just taken as given, not being part of the research.

Working out the municipal SUTs

In order to obtain the supply and use tables at the municipal level, economic variables were worked out for each municipality as specified below, where all values are in R$

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[2] “Fundação Instituto de Pesquisas Econômicas”, a research foundation connected to the Economics Department of the University of Sao Paulo

[3] Micro-regional refers to micro-regions as definied by the Brazilian official statistical agency IBGE (Instituto Brasileiro de Geografia e Estatística). Accordingly, the country is divided into 558 micro-regions, of which 35 are located in Rio Grande do Sul, and 63 in São Paulo.

1.000.000 of 2008. The methodology estimates municipal values compatible with known data at the national level and, in some cases, at the state level.

a) **VP** - Value of production of 110 products for each municipality. Those values are compatible with their state and national aggregates for each product.

b) **DS** - Domestic sales of each municipality and of each product for the rest of the country, including internal sales.

c) **EX** - Exports to other countries, by product and by municipality. Those values are compatible with the national exports of each product and with the National Accounts.

d) **DD** - Domestic demand - Value of the purchases of each of the 110 products from the other municipalities of the country, including internal transactions.

e) **VPs** - Value of production for each of the 56 production sectors. Those values are compatible with their state and national aggregates for each sector.

f) **VAs** - Value added of 56 sectors for each municipality.

g) **ICs** - Intermediate consumption for 56 sectors for each municipality.

h) Regional accounts – Municipal gross domestic product and final demand activities, such as Households Consumption, Investment and Government Consumption. Includes also aggregated values (all products and sectors) of Value of Production, Domestic Sales, Domestic Purchases, and Imports.

In order to allocate the national production to each municipality, municipal production data published by specialized agencies, when available, were adopted and adjusted so as to become compatible with their national counterparts. In the cases that production figures were not available, aggregate municipal wages were utilized as proxies. In certain cases, additional adjustments were found necessary, such as for oil and gas royalties in the case of Rio de Janeiro, or government spending, for public education.

Once the production structure of each municipality was estimated, the evaluation of their sales destination took place, starting with the exports to other countries, by state, and then allocating them to the municipalities, taking into account data of origin and destination of exported products, so as to avoid over-estimation of exports by municipalities with ports.

Following that, procedures were taken in order to estimate the intermediate consumption and final demand of both domestic and imported products for each sector and each municipality. For such, it was necessary to translate production by products into production by sectors, which was performed with the help of the state supply and use tables. Use coefficients were derived from them, for both domestic and imported products, for the 56 sectors, plus the final demand activities of government consumption, household consumption and investment.

That coefficients matrix, which was the same for every municipality of a given state, was them employed to calculate an estimated demand of both domestic and imported products for each municipality. Those estimated values, however, had to be adjusted so as to comply with their aggregated state and country counterparts.

In order to do that, the supply of domestic goods by municipality was calculated as the difference between the value of production and exports. The participations of the products in the total estimated demand by sector were then multiplied by the total supply thus obtained, resulting in a consistent demand by domestic product, for total supply must equal total demand. For the demand for imported products, the same procedure was followed, but rather easier to apply, for the total imports by products are available in the National Accounts.

With the information on value of production, exports, domestic demand, imported demand, and domestic supply by municipality, it was possible to derive the commercial flows with other Brazilian regions. A major issue was to identify these commercial flows. At first, an "impedance" matrix was generated, based on the minimization of transportation time between micro-regions, with data supplied by the National Plan of Logistics and Transport (PLNT) of 2007.

It was then possible to establish, for each municipality, the values of their sales and purchases, by each of the 110 products, to and from the local economy, the remaining of their concession areas, the remaining of the state, the remaining of Brazil and the remaining of the world. Besides, it was possible to consolidate those data with intermediate consumption, final demand activities (exports, consumption and investment) and imports from the rest of the world, for each municipality.

In order to get to the municipal supply and use tables, it was then necessary to determine those flows at the municipal level, and for each product and sector. A first step was to determine this by state, and that was accomplished by means of two models: The Leontief-Strout model[4], and the input-output gravitational model by Wilson[5].

As a result, two sets of production and use tables for each municipality were obtained. The use tables, comprising 110 products and 56 sectors, show the intermediate consumption and final demand destinations for each product. Their last rows contain the local intermediate consumption, taxes on imports and products, income data (wages and salaries, social contributions, gross operating surplus and gross mixed income), value added at factor costs, other production taxes and subsidies, gross value added and value of production. The origins of purchases in other municipalities of the concession area and in the rest of the state are at the bottom of the table. The production tables for 56 sectors and 110 products show the destination of the production, by sector.

CPFL

Aggregation patterns

In order to model the response of the CPFL regions to changes in demand, ranging from the geo-electrical region to the national level, aggregation patterns were tailored according to the utility affiliates concession areas. The geo-electrical regions is the lower level of geographical aggregation, and the national territory is the upper level, with three intermediate levels: the utility affiliate business unit[6] containing the geo-electrical region, the affiliate concession area, containing the business unit, and the state of Sao Paulo or Rio Grande do Sul.

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[4] Leontief, W.; Strout, A. (1963). "Multiregional Input-Output Analysis". In: BARNA, T. (Ed.). *Structural Interdependence and Economic Development*. 1. ed. New York: St. Martin's Press, 1963. chap. 2, p. 119-50.

[5] Wilson, A.G. (1970). *Entropy in Urban and Regional Modeling*. Londres: Pion Limited, 1970. 166 p.

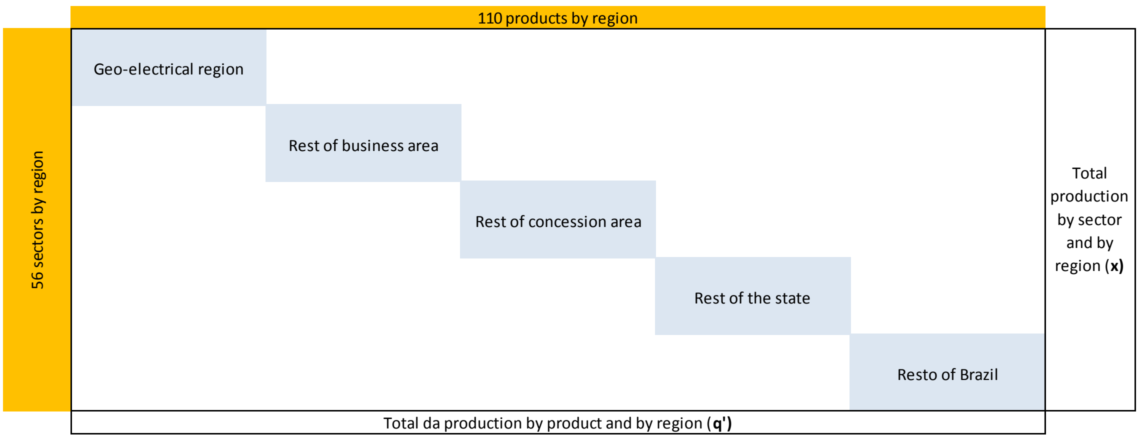
[6] Administrative regional divisions adopted by the Company in order to manage its business.

File systems

By aggregating the supply and demand data worked out for the municipalities of each geo-electrical region, a system of four Excel files was created, as described below:

1. **Supply files** – Five transposed supply tables of 56 sectors by110 products, respectively for the geo-electrical region, the rest of the business unit, the rest of the area of concession, the rest of the state, and the rest of Brazil.
2. **Use files** – One use table of 550 products and 280 sectors, aggregating the five geographical levels, including now the inter-regional trade flows. The value added transactions and the employment by sector lines were also included.
3. **Leontief Inverse files** – Those tables comprise the transformation of the commodity by industry, into industry-by-industry tabulations, as well as the derivation of the Leontief Inverse, following the industry-by-industry/industry technology version of the commodity-industry approach (MILLER, R.E.; BLAIR, P.D, 2009, chapter 5). Accordingly, the following calculations are performed:
   a. **V & D**
      i. Matrixes **V** of 280 sectors x 550 products, containing in the main diagonal the five production tables described in the Supply files above, as shown in figure 4.

Figure 4 – Organization of the supply tables by region



      ii. Matrixes **D**, "market share", obtained by dividing the matrix **V** columns by the total production by product.

   b. **U & e** – Reproduction of the use tables described above, including the **U** matrix, which shows inputs of 550 products (110 by region) for 280 sectors, for the five levels of aggregation.
   c. **Z & VA & y**
      i. **Z** is a 280 x 280 matrix containing the intermediate consumption flows, obtained by the multiplication **DU**.

ii. **VA** is the value added matrix, with all its components, for 280 sectors. It is complemented by a line vector $\boldsymbol{\ell}$ of employment by sector.

iii. The column vector $\Delta\mathbf{y}$ is the entry for exogenously defined marginal changes of demand for 56 sectors, for each level of aggregation, totalizing 280 elements, having zeroes as default values.

d. **A & L & x** – Obtaining the input sector-by-sector coefficient matrix **A,** of the Leontief inverse **L,** and of the total production impact column vector $\Delta\mathbf{x}$ resulting from the entries in $\Delta\mathbf{y}$, as described below.

i. $\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1}$ with **x** being the total output obtained by summing up the columns of **V**.

ii. **L** = Leontief inverse = $(\mathbf{I}\text{-}\mathbf{A})^{-1}$.

iii. $\Delta\mathbf{x} = \mathbf{L}\Delta\mathbf{y}$ = impact on total production resulting from a final demand change $\Delta\mathbf{y}$.

iv. **Impacts (values)** – Impacts in the intermediate consumption matrix **Z** resulting from $\Delta\mathbf{x}$, as well as in **VA** and in the employment vector $\boldsymbol{\ell}$.

v. **Impacts (%)** – The same as above, but in percentage.

e. **Interface tables** – Those tables are simplifications of the tables in d, used to feed friendly interfaces and to couple with electricity projection models. They contain just **Z** , **VA** and $\boldsymbol{\ell}$ as initial states, an entry table for the final demand activities that sum up to $\Delta\mathbf{y}$**,** and the Leontief inverse **L**, so as to obtain $\Delta\mathbf{x} = \mathbf{L}\Delta\mathbf{y}$**.**

Each of those systems were projected for each time horizon established for the scenarios, 2013, 2016 and 2019, thus totaling 93 = 31 x 3 scenario systems.

Results

The results will be shown with the help of some practical examples. First, an investment of R$ 1 billion in the agricultural sector will be simulated in the Southeast Business Unit of Paulista, but with two regional options of deployment, the municipality of Campinas or the municipality of Águas de Lindóia. The two are very different, both in what concerns economic activity and population. While Campinas is one of the major business centers of the interior of the state of São Paulo, with over 1 million inhabitants, Águas de Lindóia is a relaxing resort with around 17,300 inhabitants. Although the example is not very realistic, it will be useful to show the functionality of the model.

Table 1 shows the results for Águas de Lindóia, and table 2 the results for Campinas. Besides the impact on the geo-electrical region, it shows also how the impacts spread all over its aggregation path, which means the remaining of its business unit, of its concession area, of the State, and of the Country, as well as in those aggregated areas.

As one should expect, the effects on Águas de Lindóia are considerably more accentuated than in Campinas, therefore more attention should be paid to ensure the required electricity supply infrastructure.

Table 1 - Impact of investing R$ 1 billion in the agricultural sector of Águas de Lindóia on its geo-electrical region

Value of Production (R$ Millions of 2012)									
	G. Region	R.of BusUnit	R.of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	15.799	236.521	312.062	2.115.935	5.183.645	252.321	564.382	2.680.317	7.863.963
After	16.906	236.600	312.115	2.116.280	5.183.879	253.506	565.622	2.681.902	7.865.781
%	7,01%	0,03%	0,02%	0,02%	0,02%	0,47%	0,22%	0,06%	0,02%
Value Added (R$ Millions of 2012)									
	G. Region	R.of BusUnit	R.of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	6.578	89.999	146.600	983.915	2.616.056	96.577	243.177	1.227.092	3.843.148
After	7.079	90.014	146.617	984.019	2.616.160	97.093	243.709	1.227.728	3.843.888
%	7,62%	0,02%	0,01%	0,01%	0,00%	0,53%	0,22%	0,05%	0,02%
Compensation of employees (R$ Millions of 2012)									
	G. Region	R.of BusUnit	R.of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	2.710	35.485	60.507	380.313	1.009.860	38.196	98.702	479.015	1.488.875
After	2.819	35.491	60.513	380.350	1.009.888	38.310	98.822	479.172	1.489.060
%	4,02%	0,02%	0,01%	0,01%	0,00%	0,30%	0,12%	0,03%	0,01%
Emprego (Número de Pessoas)									
	G. Region	R.of BusUnit	R.of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Antes	187.945	1.916.577	4.146.091	20.151.994	84.735.665	2.104.522	6.250.613	26.402.606	111.138.271
Depois	213.178	1.916.773	4.146.396	20.153.572	84.740.605	2.129.951	6.276.346	26.429.918	111.170.524
%	13,43%	0,01%	0,01%	0,01%	0,01%	1,21%	0,41%	0,10%	0,03%

It is interesting to notice also that, in the case of Campinas, the effects on the remaining areas are lower than in the case of Águas de Lindóia, showing its higher degree of self-sufficiency.

Table 2 - Impact of investing R$ 1 billion in the agricultural sector of Campinas on its geo-electrical region

Value of Production (R$ Millions of 2012)									
	G. Region	R.of BusUnit	R.of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	92.579	159.741	312.062	2.115.935	5.183.645	252.321	564.382	2.680.317	7.863.963
After	93.988	159.781	312.078	2.116.054	5.183.879	253.769	565.847	2.681.902	7.865.781
%	1,52%	0,02%	0,01%	0,01%	0,00%	0,57%	0,26%	0,06%	0,02%
Value Added (R$ Millions of 2012)									
	G. Region	R. of BusUnit	R. of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	45.975	50.602	146.600	983.915	2.616.056	96.577	243.177	1.227.092	3.843.148
After	46.563	50.605	146.606	983.953	2.616.160	97.168	243.775	1.227.728	3.843.888
%	1,28%	0,01%	0,00%	0,00%	0,00%	0,61%	0,25%	0,05%	0,02%
Compensation of employees (R$ Millions of 2012)									
	G. Region	R. of BusUnit	R. of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	17.938	20.258	60.507	380.313	1.009.860	38.196	98.702	479.015	1.488.875
After	18.078	20.259	60.509	380.326	1.009.888	38.337	98.846	479.172	1.489.060
%	0,78%	0,01%	0,00%	0,00%	0,00%	0,37%	0,15%	0,03%	0,01%
Employment (Number of jobs)									
	G. Region	R. of BusUnit	R. of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	933.110	1.171.412	4.146.091	20.151.994	84.735.665	2.104.522	6.250.613	26.402.606	111.138.271
After	959.507	1.171.465	4.146.266	20.152.680	84.740.605	2.130.972	6.277.239	26.429.918	111.170.524
%	2,83%	0,00%	0,00%	0,00%	0,01%	1,26%	0,43%	0,10%	0,03%

Let us now turn to table 3, which shows the effects on the geo-electrical region of Campinas of a third option, whereby the same investment is allocated in the state of São Paulo, but outside the Paulista concession area. We can see that, as it should be expected, those effects are smaller, but they still happen, spreading all over the concession area, and therefore must be taken into account by the Company business and investment planning. That, actually, as already mentioned, was one of the major reasons for contracting the R&D project.

Table 3 - Impact on the geo-electrical region of Campinas of investing R$ 1 billion in the agricultural sector elsewhere in the state of São Paulo

Value of Production (R$ Millions of 2012)									
	G. Region	R.of BusUnit	R.of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	92.579	159.741	312.062	2.115.935	5.183.645	252.321	564.382	2.680.317	7.863.963
After	92.592	159.784	312.100	2.117.425	5.183.879	252.376	564.476	2.681.902	7.865.781
%	0,01%	0,03%	0,01%	0,07%	0,00%	0,02%	0,02%	0,06%	0,02%
Value Added (R$ Millions of 2012)									
	G. Region	R. of BusUnit	R. of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	45.975	50.602	146.600	983.915	2.616.056	96.577	243.177	1.227.092	3.843.148
After	45.980	50.608	146.613	984.526	2.616.160	96.588	243.201	1.227.728	3.843.888
%	0,01%	0,01%	0,01%	0,06%	0,00%	0,01%	0,01%	0,05%	0,02%
Compensation of employees (R$ Millions of 2012)									
	G. Region	R. of BusUnit	R. of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	17.938	20.258	60.507	380.313	1.009.860	38.196	98.702	479.015	1.488.875
After	17.939	20.260	60.511	380.462	1.009.888	38.200	98.711	479.172	1.489.060
%	0,01%	0,01%	0,01%	0,04%	0,00%	0,01%	0,01%	0,03%	0,01%
Employment (Number of jobs)									
	G. Region	R. of BusUnit	R. of ConArea	R. of State	R. of Brazil	BusUnit	ConArea	State	National Total
Before	933.110	1.171.412	4.146.091	20.151.994	84.735.665	2.104.522	6.250.613	26.402.606	111.138.271
After	933.187	1.171.506	4.146.374	20.178.852	84.740.605	2.104.693	6.251.067	26.429.918	111.170.524
%	0,01%	0,01%	0,01%	0,13%	0,01%	0,01%	0,01%	0,10%	0,03%

Conclusions

The model is now being implemented at CPFL, were all its potentialities have been highly praised. A major challenge at the moment, however, has been to make its full analytical features operational within the agility required for provisioning alternative scenarios in the pace of the electricity market dynamics, which implies a daily and continuous decision making process. A friendly interface, which is part of the R&D program, is in development with that purpose. With that accomplished, it will become a new alternative of applying regional input-output analysis to the day to day business management of a large company.

References

MILLER, R.E.; BLAIR, P.D. **Input-output analysis: foundations and extensions**. Second edition. Cambrige, Cambridge University Press, 2009.