The utilization of a supply and use model for prospecting the electricity market

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Abstract

This paper further explores the basic characteristics of a Brazilian supply and use table based model as presented at the XVI IIOA International Conference held in Istanbul (*"A procedure for scenarizing by changing direct input coefficients observing a supply and use tables framework"*). Alternative procedures to structure the model in order to suit to different requirements raised by analyzing the impacts of changes either in the demand or the supply side will be reported. Additionally, procedures to deal with different conditions of data availability in different years will also be accounted for. Results of its application for prospecting electricity consumption trends in Brazil will be also reported and discussed. The text is the result of planning work at a Brazilian electric utility, CPFL – Companhia Paulista de Força e Luz, and thus, in spite of its theoretical content inspired by the Leontief principles, its is aimed at the .development of practical management tools, being its eventual academic contribution an additional gain.

Introduction

This paper reports the first results of the application of a supply and use model to support decision making related to the supply of retail electricity. It is based on another work already presented at the 2007 IIOA International conference, when the feasibility and advantages of utilizing a supply and use table (SUT) based model in substitution of the Leontief inverse was defended and illustrated by some examples related to the Brazilian economy. Ever since, different versions of the one presented at Istanbul were developed and tested in function of the planning and management needs of an electricity utility. In result, new issues led to new developments as it will be described. A more rigorous analytical method to balance the model was developed, and, besides the assessment of the impact of changes of final demand in total production, new procedures were devised to perform the assessment in the other way round, i.e., of changes of production in final demand.

It is important to make clear that the method here described is supposed to be a mathematical instrument to be used along a qualitative counterpart performed by economic analysts, i.e, its aim is to give a quantitative modelling background to economic analysis that is regularly carried out to support electricity consumption forecasts. This leads to a quantitative-qualitative counterpoint whereby it is expected that the inconsistencies accruing from either purely mathematical or purely verbal approaches are, at least in part, overcome. Reversely, it is also expected that the combination of the analytical virtues inherent of each of those two approaches lead to more reliable and better supported conclusions.

As it will be seen, although encompassing systemically all the major macroeconomic transactions of the Brazilian economy as presented by its official supply and use tables, the modeling algorithms are relatively simple and of easy reproduction and understanding, for, besides reliability, simplicity and agility are of utter importance for analytical tools applied in a permanent decision-making environment which deals with markets changing at a daily pace. For this same reason, special attention is paid to more formal issues involving the presentation and interfaces of the model, which, the more friendly they are, the better.

New ways of structuring the model

As mentioned in the Introduction, depending on the issue to be approached the model is runned in two alternative modes, so as to meet one of two major purposes:

- ✓ Demand driven mode, so as to devise plausible electricity market futures raised by changes in total economic production induced by the economic final demand (evolution of exports, consumption and investment).
- ✓ Supply driven mode, so as to assess impacts in the opposite direction, i.e., from changes of total production in the intermediate and final consumptions. In the electricity business this is fundamental in order to evaluate impacts such as the ones introduced by new technologies, or yet by electricity shortages in the intermediate and final consumption.

Additionally, these two modes have to be combined in order to balance the modeled SUT when, besides final demand, value added and domestic production are already available. This is the case for modeling SUT's in more recent years for which reference SUT tables are not yet available, but data on value added and domestic production is already published (as happens with 2007 and 2008). These two alternative ways are schematically described respectively in figures 1 and 2.

[Fig 1: The model, its environment and use: exogenous final demand]

[Fig.2: The model, its environment and use: exogenous total production]

The first approach shown above (Fig.1) is equivalent to the Leontief equation, $X=(I-A)^{-1}Y$, giving the same solution. The total production transpose vector X' is the total line of the national production output of the modeled supply table. This result, previously, was obtained by means of an Excel VBasic interactive routine[1].

In the present version, in both cases above the result is obtained analytically by solving the following system of equations:

$$DQ - X = 0$$

$$-Q + BX = -E.$$

In the first case, E, D and B are exogenous, and X and Q are endogenous. In the second, X becomes exogenous and E endogenous. Anyway this results in a system of (m+n) equations and variables, where[2]:

$m =$ number of commodities;

$n =$ number of industries;

$D = [d_{ij}] =$ nxm matrix $= V(<Q>)^{-1}$, being $<Q>$ the mxm diagonal of Q;

$V = [v_{ij}] =$ mxn make matrix which represents the amount of commodity j produced by industry i;

$Q = [Q_j] =$ mx1 column vector of national production ouput by commodity;

$B = [b_{ij}] =$ mxn matrix $= U(<X>)^{-1}$, being $<X>$ the nxn diagonal of X;

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[1] PAIXAO, P. (2007).

[2] The notation is the same as the one used by MILLER R.E.; BLAIR P.D. (1985), pp. 162-165.

$U = [u_{ij}]$ = mxn intermediate consumption matrix which represents the amount of commodity j consumed by industry i;

$X = [X_i]$ = nx1 column vector of industry total output;

$E = [E_i]$ = mx1 column vector of commodities final demand.

This analytical solution allows a better understanding of the logic of the model, and, most of all, to track back causal relations so as to explain, or alternatively adjust, the behavior of specific variables. The variables are the components of the $[Q_j]$ and $[X_i]$ vectors, in the firs case, and $[Q_j]$ and $[E_i]$ in the second. It should be noted that, in the second case (X exogenous), in order to reach a single solution, m has to equal n, i.e., the procedure works only for square SUT's.

When E is exogenous, it is obtained by summing up the columns of a commodities by final demand activities table at basic prices, which observe the same proportionality to the total by column as the Brazilian final demand table at basic prices of the 2005 IO matrix as published by IBGE, the Brazilian national statistics authority[3]. The totals by columns at basic prices, on their turn, are obtained by subtracting from the final demand column totals at purchaser's prices, as published threemonthly by IBGE, product taxes and imports, also obtained by proportionality to those totals at purchaser's prices observed in 2005.

In respect to B, it can be obtained directly from the IO IBGE publication of 2005, which would mean to adopt the same intermediate consumption modes of that year. Alternatively, if the values of X and of value added by industry are already

[3] Instituto Brasileiro de Geografia e Estatística.

available, as it is the case for 2006, the value added observed figures constrain B to be obtained by adjustment with basis on the identity

$T = X' - W$, being

$T = [T_j]$ = Totals of the intermediate consumption table (U) columns at purchaser's prices;

$X' = [X_i]'$ = (1xn) vector = transpose of $[X_i]$;

$W = [W_j]$ = (1xn) vector = value added by industry.

Once T is found, its values at basic prices can also be found by subtracting the lines of imports and product taxes by industry, which are calculated as proportional to their values in 2005. With those values, and X, one can find a first version of the U matrix utilizing an observed B matrix of the closest possible past year, which however has to have adjusted its the totals of columns (T) and lines (S).

U is adjusted by means of an interactive procedure[4], and that includes the correction of negative elements. B, thus found, can always be readjusted to acceptable values by changing the values of X, once X is exogenously determined.

The new value of B, then, can be fed into the demand driven SUT model, which now will produce the same results for X, Q and W provided E is maintained the same. Thus, in the final of the day, we have two models ready for simulations departing from the same initial values, one good for assessing impacts of final demand changes in total production, and the other for assessing impacts in the other way round, by varying the total production to find out how demand will change. Besides, we managed to have the demand driven model adjusted to observed values of total production and value added as desired. In case just $[W_j]$ is available, as it is the case for 2007 and 2008, the same

[4] The detailed description of the adjustment procedures are rather long to be comprised here, and will be explained in future work.

results can be obtained by determining an initial value of X using the first (demand driven) approach, and them utilizing it to adjust the supply-driven model so as to obtain a suitable B matrix as above.

Example of application

The method above described was followed in order to obtain a 12x12 2008 SUT demand driven model for Brazil, observing final demand at purchaser's prices and value added by industry as published by IBGE, and which has been utilized to run alternative scenarios of future electricity consumption.

This section will describe how this model operates and the sort of results it produces, showing that it helps in the identification not only of how electricity nationally consumed responds to economic growth changes, but also how it responds to economic structural changes. A step by step explanation is provided showing how impact scenarios have been generated in order to analyze impacts of changes in final demand in national energy consumption. As above mentioned, special attention is devoted in providing interfaces so as to allow the direct intervention of management personal in the running of alternative impact scenarios as well as an easy to understand presentation of the results.

For starting the procedure an entry table is provided where input data can be typed, simulating as many line vectors of final demand changes as desired, being the first line reserved to reset the model (Fig. 3).

[Fig.3 Entry table for simulating changes of final demand in 2009 in relation to 2008]

The major results are displayed in R$ of 2005 and in the form of national accounts identities, showing both the aggregate amounts resulting from the simulation, as well as their percentual changes in relation to the base year as exemplified respectively in figs 4 and 5 for the Medium Scenario.

[Fig.4 Presentation of the major economic results, Medium Scenario (MMR$ of 2005)]

[Fig 5 Major economic results, percentual changes 2009/2008, Medium Scenario]

It is important to point out that the headings of the economic magnitudes are actually buttons of a worksheet. By clicking them one can find out how each of the figures displayed was obtained. Thus, one can track back, for instance, how each product transaction changed so as to get the total production displayed by clicking on the button “Domestic Production” and so getting to the production table where the figures adding up to the total of MMR$ 4,454,499 are shown (Fig.6).

[Fig 6 Domestic production, 2009, Medium Scenario]

In the same way, a complete set of impacts in the totality of the SUT variables can be easily produced.

The alternative scenarios generation procedure starts to run by prompting the user to choose an SUT table as basis of comparison for future impacts, which in this example is a table constructed for the Brazilian economy at the end of 2008. Once this choice is made, he is prompted to point out his desired entry hypotheses among those typed in the entry table, as well as to name the scenarios to be produced. In response, the model produces for each alternative scenario a report that shows two tables. The first shows the resulting impacts in electricity consumption by the following consumption classes: Households, Industry, Commerce and Other (Fig.7)[5].

[Fig. 7 Aggregate impact display]

The second scenario table breaks down the percent growth totals so as to identify how the change of each entry economic variable, shown in the first column on the left, contributed to the result (Fig.8). One can see that the bottom lines of both tables display the same total impact by consumption class and GDP, which now is detailed by final demand activities and imports. This is an important guide to assess how electricity can be affected by changes in the structural behavior of final demand.

[Fig.8 Contribution of changes in final demand variables and imports to the impact on national electricity consumption]

Challenges and possibilities

At the present stage the model is restricted to operate under some limited conditions:

- ✓ Square 12x12 SUT’s;
- ✓ National level of aggregation;
- ✓ Yearly basis;
- ✓ Linear relations;
- ✓ Electric intensities measured discretely on an yearly basis

[5] Those are the sectors utilized by the Brazilian official energy planning authority – Empresa de Pesquisa Energética – in their regularly published projection of electricity consumption reports, and they were selected so as to ease the comparison of forecasts.

Each of those items imply both in challenges and possibilities. The square 12x12 tables, besides solution limitations imposed by the linear equations systems, also fulfill future forecasting procedure developments, for they allow the decomposition of square A matrixes into square D and B matrixes. This opens the possibilities of expanding existing forecasting techniques utilizing A matrixes[6] by expanding them into SUT square tables, which could considerably improve the quality of the current projections. The 12x12 dimension can be easily expanded to higher values, limited however, at the moment, to 55x55, for the higher dimension of the IO tables made available by IBGE in Brazil are limited to 110x55. The 12x12 dimension, however, is highly convenient, for it is compatible with the summarized 12x12 SUT series published by that Institute, and also by their three monthly national accounts reports.

The aggregation at the national level can be broke down to the state level, for there are techniques already available at the Economics Department of the University of São Paulo, developed by professor J. Guilhoto, that are already under test for the purposes of electricity market projections. However, to get down to the level of regions such as the ones served by electric utilities, further methodological evaluation will be needed.

The tables are structured on an yearly basis for that is their publication period as observed by IBGE. This brings the inconvenience of a very limited number of past time series observed data, for the most updated SUT series runs from 2000 to 2006. This

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[6] For instance, the work developed by professor G. HEWINGS and his team at REAL, in the University of Illinois.

problem, however, shall be overcome by constructing SUT's on a 12 month basis, but at the end of every three months, in consonance with the three monthly national accounts series released by IBGE.

Matrix linear relations are of great advantage when tackling complex systems such as SUT's. However, they can be also considered a limitation when one takes into consideration the interdependence between SUT's subsystems which can not be explained just by the matrix interrelations, e.g., the relations between final demand and value added. So, there is a need to devise complementary algorithms that would lead to more adequate modeling of a number of relations between no only economic variables and subsystems, but also between economic an energy variables.

This brings to the electricity intensity issue. Discrete yearly measurements certainly lead to excessive deviations, and thus to higher than acceptable error margins. It is expected that the structuring of SUT's at each three months, and the consequent increase of number of events available for regression and other related temporal series analyses, will allow the working out of more reliable correlation curves, including functions relating electricity consumption with value added and other alternative economic variables. Besides, correlations with other fuels shall be a next step.

Additionally to the above, another kind of possible development has been raised more recently by the need of updating the methodology presently utilized in Brazil for quantifying the social cost of electricity shortages (the so-called "deficit cost") in monetary terms. This is an important figure for pricing electricity and for establishing the marginal cost of the national grid system expansion. The method presently adopted already utilizes input-output analysis, but based on data of 1996, and the Brazilian national electricity authority (ANEEL) is seeking for more updated procedures. This is a problem that can be approached also by the supply-driven mode of application here presented. There are already available Brazilian input-output matrixes for the years of 2000 and 2005, which, combined with the SUT based modeling methods here proposed, can become an updated and efficient tool to approach the issue.

Conclusions

The model has strong potentials for becoming a powerful tool for planning and management. Although its applications so far have been restricted to the electricity market, as an input-output tool it can be useful for analyzing the effects of economic change in any kind of activity or social variable provided they are suitably relatable to a system of national accounts. The new supply-driven approach, now joined to its final demand-driven counterpart, broadens the reach of its application possibilities, which can now encompass impacts in final demand and value added caused by changes in the production side. Further work, however, is necessary in order to get the methodology fully operational, involving structural improvements and more friendly interfaces to ease its direct operation by its users.

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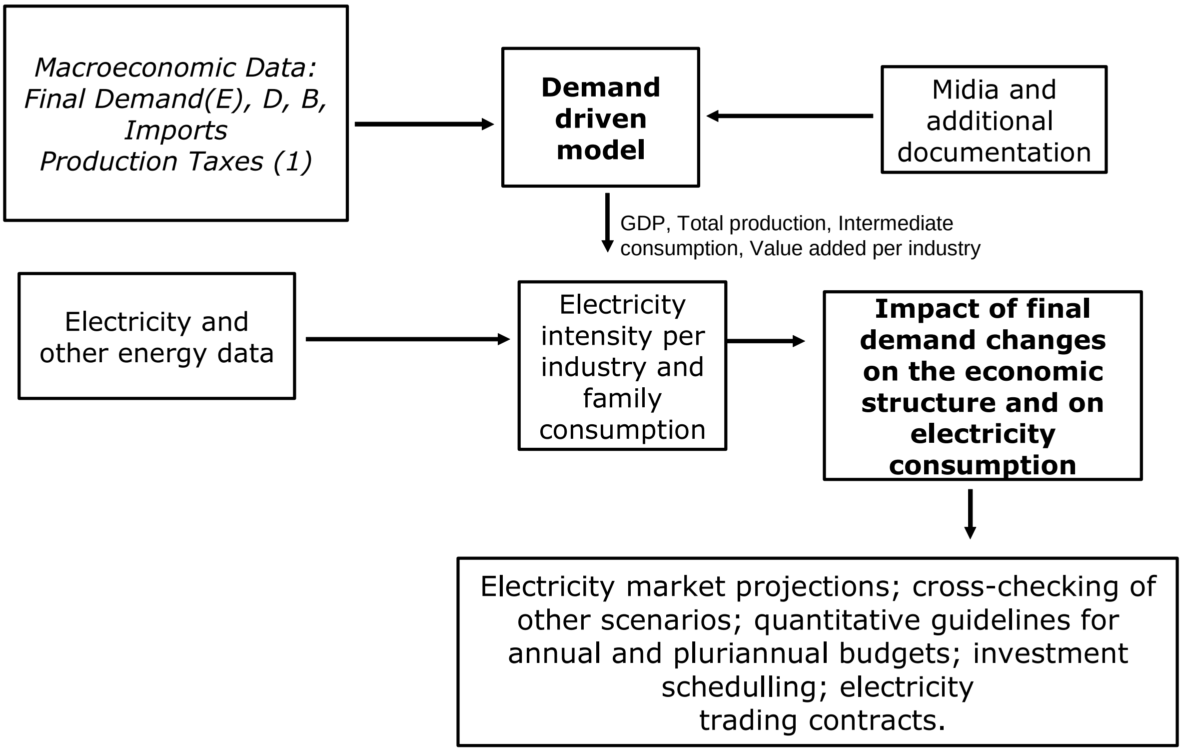
Figures and tables

Fig 1: The model, its environment and use: exogenous final demand



(1) For variable symbols see p.5 and following

Fig.2: The model, its environment and use: exogenous total production

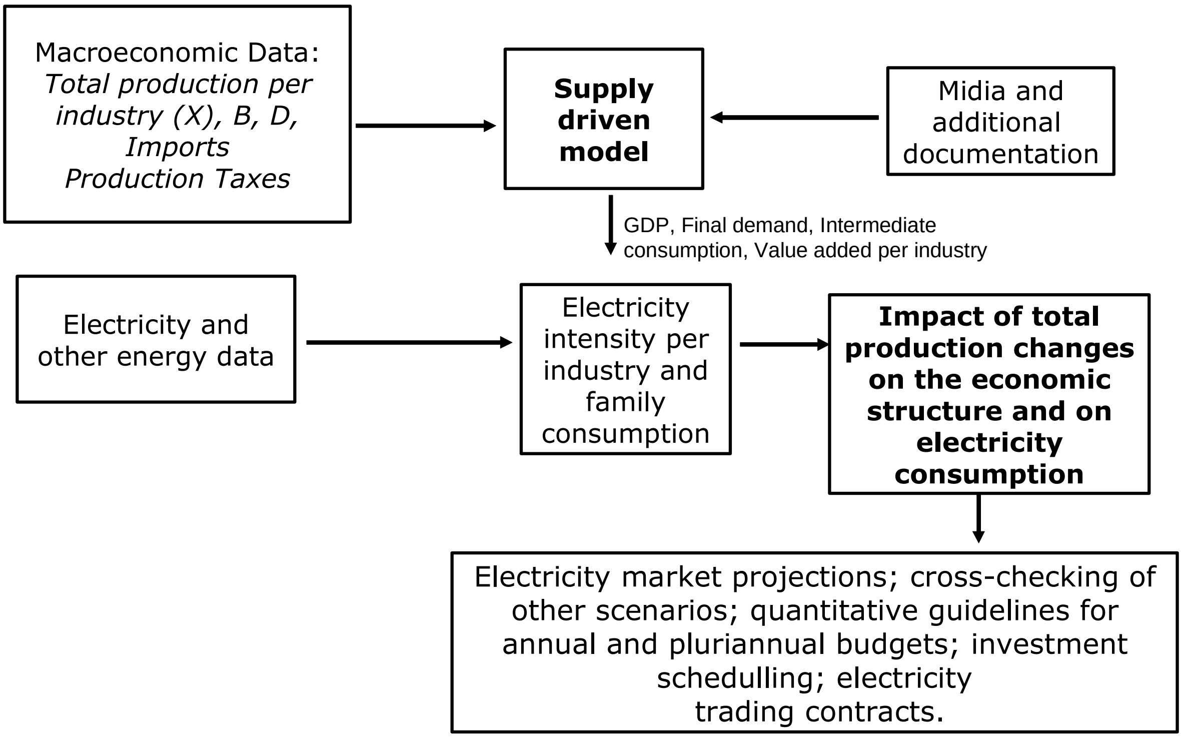


Fig.3 Entry table for simulating changes of final demand in 2009 in relation to 2008

Hypotheses	Exports	Govern.	Non-Profit Institutions	Househ.	GFCF	Stocks variation	Imports
Reset	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
High	-8,00%	2,00%	3,50%	3,50%	2,00%	3,00%	-9,00%
Medium	-10,00%	1,00%	1,00%	1,00%	-2,00%	1,00%	-11,00%
Low	-13,00%	0,00%	0,00%	0,00%	-10,00%	1,00%	-13,00%
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...

Fig.4 Presentation of the major economic results, Medium Scenario (MMR$ of 2005)

2009, MEDIUM SCENARIO - MAJOR ECONOMIC RESULTS					
GDP =	**FinalDemand -**	**Imports**			
2.499.524	2.872.731	-373.207			
GDP =	**Domestic Demand +**	**(X-M)**			
2.499.524	2.546.948	-47.425			
GDP =	**Value Added +**	**Production Taxes**			
2.499.524	2.125.315	374.209			
GDP =	**Domestic Production -**	**Interm Cons +**	**Prod Taxes**		
2.499.524	4.454.999	-2.329.684	374.209		
GDP =	**Remuneration +**	**Mixed Income +**	**Surplus +**	**Other Taxes**	**Prod Taxes**
2.499.524	985.684	232.103	877.788	29.740	374.209

Fig 5 Major economic results, percentual changes 2009/2008, Medium Scenario

MEDIUM SCENARIO - MAJOR ECONOMIC RESULTS - IMPACT 2009/2008					
GDP =	**FinalDemand -**	**Imports**			
0,84%	-0,88%	-11,00%			
GDP =	**Domestic Demand +**	**(X-M)**			
0,84%	0,43%	-17,31%			
GDP =	**Value Added +**	**Production Taxes**			
0,84%	0,99%	0,00%			
GDP =	**Domestic Production -**	**Interm Cons +**	**Prod Taxes**		
0,84%	-0,79%	-2,35%	0,00%		
GDP =	**Remuneration +**	**Mixed Income +**	**Surplus +**	**Other Taxes**	**Prod Taxes**
0,84%	1,11%	0,02%	1,08%	1,54%	0,00%

Fig 6 Domestic production, 2009, Medium Scenario

	1 Agriculture	2 Mining industry	3 Transformation industry	4 Electricity, water and gas	5 Construction	6 Comerce	7 Transport, storage and post services	8 Information services	9 Banking and insurance	10 Rental and real estate services	11 Other services	12 Public administration, health and education	**Total**
1	209.521	0	0	0	0	0	0	0	0	0	0	195	**209.716**
2	137	132.058	4.224	0	0	0	0	0	0	0	2	0	**136.422**
3	16.284	1.832	1.506.063	0	0	1.473	0	3	0	2	36	1.840	**1.527.533**
4	0	0	35	155.234	0	0	0	0	0	0	0	3.005	**158.274**
5	0	30	365	0	218.486	2	4	0	0	0	0	0	**218.888**
6	9	94	443	0	0	371.343	98	0	0	71	15.030	1.395	**388.483**
7	0	0	0	0	0	1.107	208.456	0	0	0	0	2.386	**211.948**
8	0	0	0	0	0	393	0	160.671	0	0	0	221	**161.285**
9	0	0	0	0	0	0	0	0	260.784	0	0	0	**260.784**
10	20	287	1.328	424	661	1.586	306	226	481	205.099	21.980	713	**233.109**
11	0	0	0	57	0	8.909	6	2	0	28	454.443	8.927	**472.372**
12	0	0	0	0	0	0	0	0	0	0	0	476.184	**476.184**
Total	**225.971**	**134.301**	**1.512.459**	**155.714**	**219.147**	**384.812**	**208.869**	**160.902**	**261.265**	**205.200**	**491.491**	**494.867**	**4.454.999**

Fig. 7 Aggregate impact display

Scenarios	**Year**	**Electricity Consumption (GWh)**					**GDP growth**	
		Households	**Ind**	**Com**	**Other**	**Total**	**GDP**	
Base	**2008**	94.663	215.907	62.233	55.895	428.698	2.478.786	**IncElasticity**
Medium	**2009**	95.609	219.928	62.748	56.046	434.332	2.499.524	
Growth (%)		**1,00%**	**1,86%**	**0,83%**	**0,27%**	**1,31%**	**0,84%**	**1,57**

Fig.8 Contribution of changes in final demand variables and imports to the impact on national electricity consumption

2009 - Impact on national electricity consumption by changes in final demand activities and imports								
FD Activity	**Change**	**Impact on electricity consumption**					**Impact on GDP**	
		Households	**Ind**	**Com**	**Other**	**Total**	**GDP**	**IncElasticity**
Exports	-10,00%	0,00%	-3,48%	-0,94%	-1,15%	-2,04%	-1,46%	1,40
Government	1,00%	0,00%	0,07%	0,12%	0,63%	0,13%	0,20%	0,68
Non-Profit Institutions	1,00%	0,00%	0,01%	0,03%	0,00%	0,01%	0,01%	0,60
Households	1,00%	1,00%	0,78%	0,85%	0,35%	0,79%	0,60%	1,31
GFCF	-2,00%	0,00%	-1,03%	-0,24%	-0,23%	-0,58%	-0,39%	1,48
Stocks variation	1,00%	0,00%	0,05%	0,01%	0,00%	0,03%	0,02%	1,70
Imports	-11,00%	0,00%	5,45%	1,00%	0,66%	2,98%	1,86%	1,60
Total impact		**1,00%**	**1,86%**	**0,83%**	**0,26%**	**1,31%**	**0,84%**	**1,57**