Overcoming the difficulties of developing and transferring an input-output model for electricity consumption forecasts to the users

Paixão, Paulo and Buratini, Ricardo and Guilhoto, Joaquim José Martins

University of São Paulo, CPFL Energy, University of São Paulo

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Overcoming the Difficulties of Developing and Transferring an Input-Output Model for Electricity Consumption Forecasts to the Users

Paulo Paixão
University of São Paulo

Ricardo Buratini
CPFL Energy

Joaquim José Martins Guilhoto
Department of Economics, FEA - University of São Paulo
REAL, University of Illinois; and CNPq Scholar

Abstract

This paper relates an ongoing experience of developing and transferring the knowledge required to understand and operate a regionally disaggregated supply and use input-output model. This R&D project is financed by ANEEL, the Brazilian regulatory agency for electricity generation and distribution, and it is conducted in partnership between an electricity utility company, CPFL, and the Department of Economics at the University of São Paulo (FEA/USP) in Brazil. A brief account of the model theoretical structure is provided, from which three major improvements are expected: a) a better impact assessment 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. In order to establish an in-company team capable of applying the model in response to their day to day managerial demands, a training program was devised in order to make them as familiar as possible with the necessary input-output theoretical background, and also skillful enough so as to efficiently apply the model. The paper relates the challenges that have been found in doing so, which means not only transferring academic knowledge to an audience not familiarized to input-output economics within a time schedule severely constrained by the pressure of daily work, but also to match this knowledge to the company technical interests.

Contents

Introduction

In Brazil, by law, the electricity utilities are obliged to destine 1% of their net revenues per year for R&D on energy and for energy efficiency programs in the electricity sector, the deployment of those resources being monitored by the national electricity regulatory agency ANEEL[1].

In this paper is made an account of the process of transferring the theoretical concepts needed to operate a new input-output forecasting model, intended to be the result of one of such programs, to the technical team responsible for electricity market forecasting of CPFL[2].

CPFL is a utility responsible for electricity generation, transmission and distribution through several affiliates in the sates of São Paulo and Rio Grande do Sul. The R&D project is focusing the municipalities served by two of these affiliates, Paulista and RGE. The first distributes electricity for 234 municipalities in the state of São Paulo, and the second for 262 municipalities in the state of Rio Grande do Sul.

On the other hand, FIPE[3], the CPFL partner in the project, counts in its team with several researchers from de Institute of Economics of the University of São Paulo with large experience in the main disciplines required by the project, namely, input-output modeling, computable general equilibrium (CGE) modeling and regional economic analysis. This was fundamental for the feasibilty of the project.

Once the model is running, three major immediate improvements are expected: a) a better impact assessment of structural economic changes on the consumption of electricity; b) analyses tailored to the specific regional boundaries of Paulista en RGE areas of operation; and c) the identification of direct and indirect changes on electricity consumption accruing from regional development.

The Project

Basically, the objective of the R&D project is to develop a scenarios generation methodology to evaluate how changes in economic activity will directly and indirectly influence sectorial and regional production, taking into account the utilities regional peculiarities. The economy will be disaggregated into 110 products and 56 sectors, and geographically to the municipality level.

The major products to be obtained are scenarios structured according to the Brazilian supply and use tables' (SUT's) framework for each municipality, so as to enable their geographic aggregation according to the utilities planning needs,

[1] Agência Nacional de Energia Elétrica.
[2] Companhia Paulista de Força e Luz
[3] Fundação Instituto de Pesquisas Econômicas

particularly when related to electricity commercialization and the expansion of the grid.

Though destined for electricity market projection activities, the project is of economic nature. Thus, it is supposed to produce economic variables tailored for a better understanding of the economy-electricity consumption relationship, so as to pave the way for more accurate electricity market forecasts.

The model

The structure of the model is outlined in figure 1, where we can see it from the highest (world) to the lowest level of aggregation (municipalities). There we can distinguish two main modeling branches: projections (the upper part of the figure) and data base (the lower part).

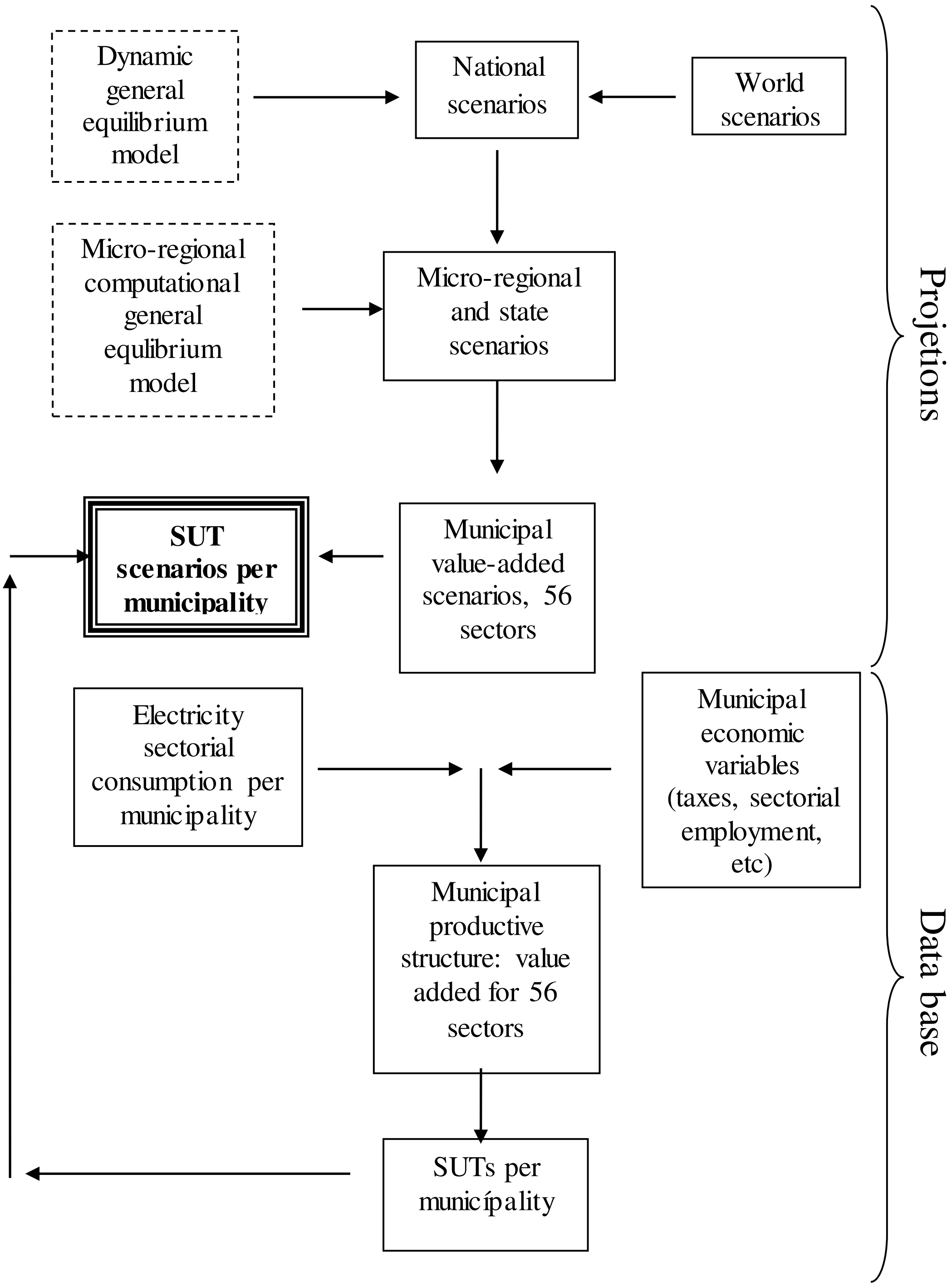
Regarding projections, at the higher levels of aggregation they are supplied by two models provided by FIPE: a dynamic general equilibrium model and a micro-regional[4] computational general equilibrium model. Those models support the building of national scenarios compatible with world scenarios, as well as micro-regional and state scenarios. From them, are obtained the industry value added projections at the municipal level, closing one of the branches for structuring the municipal SUT projections.

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

As figure 1 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 regionalization innovative methods.

[4] 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 557 micro-regions, of which 35 are located in Rio Grande do Sul and 63 in São Paulo.

Figure 1 - Model flow diagram



Training

Training has been a major item of concern, so as to overcome the risk of a project failure due to the lack of professional capability to implement its results at the operational level. Thus, in order to establish an in-company team capable of applying the model in response to their day to day managerial demands, a training program was devised in order to make them as familiar as possible with the necessary input-output theoretical background, and also skillful enough so as to efficiently apply the model.

The training content corresponding to the first part of the training program, which was in progress by the time of producing this paper, is shown in the appendix. Its closing item, “The Social Accounting Matrix”, make the bridge for the second part that will deal with global equilibrium modeling.

The trainees are a small group of 5 people, composed of experienced statisticians and economists, including one PhD and one MSc, all of them involved with electricity market forecasting, but none of them familiar with input-output analysis as a working tool.

Below follows an account of some issues considered as most relevant for the training process effectiveness in what concerns to the transfer of knowledge.

The importance of the users feedback

Dimensioning the depth of the transferred knowledge

If we have a look at the appendix, we notice that there is a good ground of theoretical content to be covered for the available training time (33 hours). In what follows, we relate the main issues and challenges that have been found for doing so.

Transferring or receiving knowledge?

To start with, a basic question should be asked: who is transferring knowledge to whom? Obviously, part of it has an easy answer, for is up to the trainers to convert the training content items described in the appendix into not only formal but also useful knowledge in face of the trainees day to day tasks. However, the trainees play also a role in conducting this process, particularly in what refers to its “useful” part.

A basic reason for this may be assigned to some major differences between what we can call “academic” and “business” approach, as summarized below.

Academic approach	Business approach
Emphasis on theoretical backgrounds so as to develop further knowledge	Emphasis on accountable models so as to improve decision making
Variables and coefficients	Physical and monetary quantities

In short, academic knowledge is research driven and business knowledge is decision making driven. While in universities and other academic institutions new knowledge is oriented towards the improvement of knowledge itself, knowledge in the business world is instrumental for sound decision making. Accordingly, the academic texts aim at the universal application of what they advocate, thus prioritizing the use of matrix algebra expressed by formal equations, variables, and coefficients, in what concerns input-output analysis. On the other hand, as sound decision making is the aim of the knowledge developed in the business world, formal mathematical analysis tends to be replaced by more straightforward procedures, where physical and monetary quantities prevail.

These differences end up by generating constant questioning from the trainees during the training sessions, such as “what actually these equations do mean?”, or “what is the practical application of this?”. Embedded in this sort of questioning there is a considerable deal of knowledge on what matters in the practical world sent back from the trainees to the trainers.

As a matter of fact, in the experience here related, the trainees have changed the training dynamics and content rather significantly in more than one occasion. Three examples are given below.

Example 1 - Demand or supply side models?

Once the trainees had learned the basics of the final demand driven Leontief model applications, with basis on their working experience they required also that supply driven models should be included in the program, and that is why the Ghosh model became part of it. Although the importance of demand is unquestionable for electricity market forecasts, supply side models respond to important issues such as those raised by planning for new investments in the expansion of the grid. However, it is not clear yet whether these applications cannot be efficiently tackled also by the demand side approach.

Example 2 - Tendency on emphasizing impact analysis

Complicated questions about the near future, followed by pressure on immediate answers, are typical of a utility market forecast team daily work. Thus, it is not surprising that the trainees were very keen on techniques and procedures that could ease their life on that, and so on overemphasizing the importance of impact analysis.

However, although input-output analysis is a premium technique for impact assessment, to concentrate just on that would mean to throw away its extensions on medium and long term forecasting. And medium and long term forecasting is of major importance for the utilities interests, for on that depends the soundness of their medium and long term electricity trading contracts, where the bulk of their money flows is concentrated, letting alone their investment programs.

This is a point that will require a good deal of convincing work by the trainers so as to get the trainees to dedicate part of their precious time on learning and practicing on to them rather unfriendly new fields such as social accounting matrices and general equilibrium modeling.

Example 3 – Understanding type II multipliers

To explain the meaning of type II multipliers was not an easy task. Taking as example employment multipliers for the primary sector in 2008 in Brazil, for a 3x3 I-O matrix, the type 2 multipliers were introduced by the following sequence:

Leontief inverse = **L** =

	Primary	Secundary	Terciary
Primary	1,11	0,10	0,02
Secundary	0,38	1,59	0,20
Terciary	0,20	0,35	1,30

Direct employment coefficients =

Primay	Secondary	Terciary
61,20	8,50	22,17

Derivation of type II multipliers:

$$\begin{vmatrix} 61,20 & 0,00 & 0,00 \\ 0,00 & 8,50 & 0,00 \\ 0,00 & 0,00 & 22,17 \end{vmatrix} \times \begin{vmatrix} 1,11 & 0,10 & 0,02 \\ 0,38 & 1,59 & 0,20 \\ 0,20 & 0,35 & 1,30 \end{vmatrix} = \begin{vmatrix} 68,22 & 6,43 & 0,98 \\ 3,23 & 13,51 & 1,68 \\ 4,42 & 7,82 & 28,84 \end{vmatrix}$$

$$\mathbf{75,87} \quad \mathbf{27,75} \quad \mathbf{31,50}$$

To stick to this sequence to clarify the doubts on the practical meaning of the solutions obtained proved to be a hard task, for things tended to get entangled when getting to the matrix algebra involving the multiplication of a diagonal by an inverse matrix.

However, the nature of the doubts led to an alternative formulation, by dismembering the Leontief inverse in its direct and indirect components:

$$\mathbf{L} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + \begin{bmatrix} 0{,}11 & 0{,}10 & 0{,}02 \\ 0{,}38 & 0{,}59 & 0{,}20 \\ 0{,}20 & 0{,}35 & 0{,}30 \end{bmatrix}$$

Then, given the direct employment coefficients =

Primay	Secondary	Terciary
61,20	8,50	22,17

The type II multiplier for the primary sector, for instance, could be derived by a sum of direct multiplications:

61,20 + 0,11x61,20 + 0,38x8,50 + 0,20x22,17 = **75,87**

To understand that the value of 61,20 is the direct effect, and why the remaining were the indirect effects, then became easier. This manner, so, was a much more straightforward way to explain the obtention and meaning of type II multipliers. This is an example of how the "what is the meaning of this formula?" and "what is the use of that?" kind of questioning end up by leading the trainer to more accountable and effective transfer of knowledge.

Focus on the users business

The sooner the training activities merge with the trainees' routine tasks the better. Thus, the closer the examples and exercise given get to their daily demands, the better. Three examples on how this aim has been followed are given below.

Example 4 – Examples and exercises related to actual practice

From the introductory examples and exercises on input-output theory, the concern on showing the practicability of what was being learned took place. To illustrate the definition of matrix, for instance, an example extracted from Dowling, E.T., 2001, was utilized, whereby the products sold by a chain of stores was presented in matrix form:

Store	Products A	B	C	D
1	120	110	90	150
2	200	180	210	110
3	175	190	160	80
4	140	170	180	140

The matrix algebra operations were exemplified from this basic definition, so as to show how matrices can be useful for stock control, ranking the commercial performance by product and store, and so on.

Example 5 – Up-to-date national accounts used as economic flows

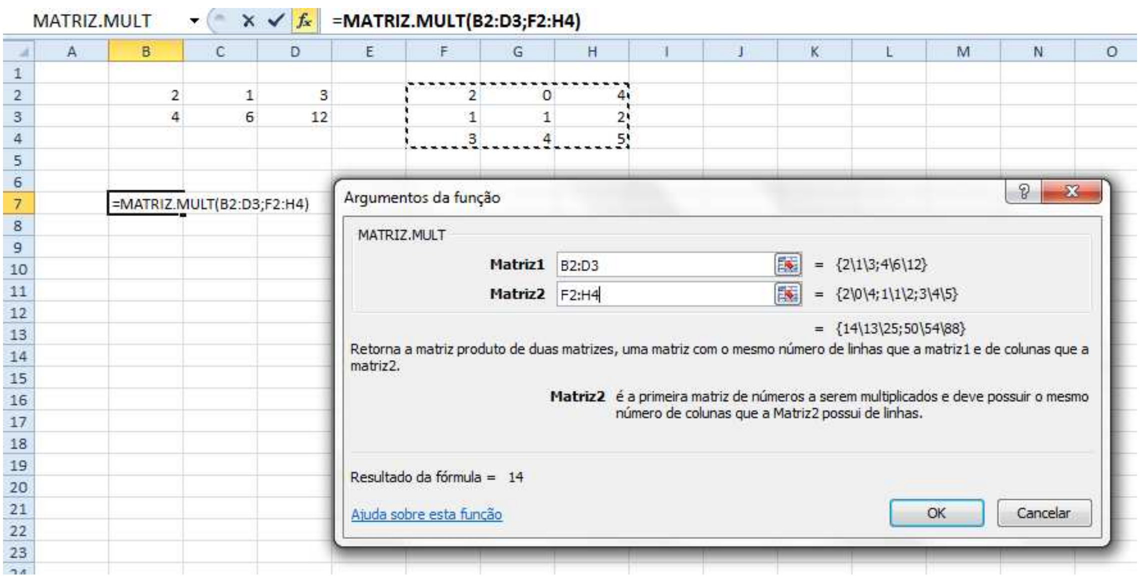
When getting to economic matters, actual and updated national accounts figures were utilized throughout, so as to give an applied analytical flavor to examples and exercises, which might be useful for the trainees to perform their jobs.

The figure below, which depicts a 3x3 version of the Brazilian input-output matrix flows for 2008, was the basis for several exercises calculation of the Leontief model and impact analysis.

	Primario	Secundario	Terciario	CI	Exportação	Governo	ISFLSF	Famílias	FBCF	VarEst	DF	Total
Primario	22.956	142.507	5.564	**171.027**	29.855	45	0	56.318	15.290	6.851	**108.359**	**279.386**
Secundario	58.383	794.194	262.669	**1.115.246**	257.738	3.893	0	549.582	418.158	24.690	**1.254.061**	**2.369.307**
Terciario	23.580	405.063	542.500	**971.143**	97.208	605.336	31.332	881.519	66.099	7.292	**1.688.786**	**2.659.929**
CI e DF pb	**104.919**	**1.341.764**	**810.732**	**2.257.415**	**384.801**	**609.275**	**31.332**	**1.487.419**	**499.547**	**38.833**	**3.051.207**	**5.308.622**
Importações	11.423	169.518	54.961	**235.902**	0	1.356	1.695	125.615	39.389	4.577	**172.632**	**408.534**
Impostos	10.772	138.038	86.386	**235.195**	29.494	1.474	1.960	138.819	40.595	4.217	**216.559**	**451.754**
CI e DF pm	**127.113**	**1.649.320**	**952.079**	**2.728.512**	**414.295**	**612.105**	**34.987**	**1.751.853**	**579.531**	**47.627**	**3.440.398**	**6.168.910**
VA	**152.273**	**719.987**	**1.707.850**	**2.580.110**								
VP	**279.386**	**2.369.307**	**2.659.929**	**5.308.622**								

Example 6 – Use of Excel

The utilization of Excel is also present throughout the course, for it is a major tool employed by the trainees. Step by step procedures on how to perform matrix algebra with worksheets were offered. Below it is shown one of the several displays utilized for explaining how to perform matrices multiplication with Excel.



Training and the elaboration of a friendly interface design

The importance of a friendly interface cannot be overestimated in a project of this nature. To be successful, given its innovative character, it is imperative that the users could count on a powerful "translator" of the new methodology into interactive displays written in a language familiar to them.

For its very nature, the training activities should be considered as a key source of hints on how to get to such a display. The questioning to which we referred above reflects the difficulties that the users will find to translate the new knowledge they are acquiring into effective analysis and decision making. It can become an important source of data on the paths to be deployed between the model and its interface with the users.

In order to illustrate this point, let us have a look in the table below, made with basis on the examples given above.

Questioning	Interface requirement
Demand or supply side models?	Toggle supply side/demand side with explanatory pop-up on the differences between the two.
Tendency on emphasizing impact analysis.	Toggle impact analysis/forecasting with explanatory pop-up on the applicability of each one.
Difficulties on explaining the derivation and meaning of type II multipliers.	Option to displaying type II multipliers direct and indirect components.

Concluding, an effort should be done to catalog the doubts and criticisms raised during the training sessions so as to join them as background to the interface design.

Final remarks

The account above is intended to be a contribution to the teaching of input-output economics of a very specific character, namely to high qualified professionals not familiar to the matter, but in need to master it in order to accomplish with their daily forecasting tasks.

This particularity raises some considerable difficulties, but also some considerable advantages, both due to the high educational qualification of the trainees. On the one hand, their background lead to rather complex and constant questioning on the soundness of the matters offered. On the other, however, this very background make them very helpful in the construction of more resourceful training alternatives, both in terms of content and of transfer of knowledge effectiveness.

Perhaps the main message that one can get from this paper is to strive to make the advantages instrumental to help with the difficulties, bearing in mind that this is an interactive process. Is the costumer always right? Sometimes this is true, mainly when the demands aim at more accountability and simplicity, as it is the case with example 3 above. Other times, however, not so much, as it is the case with example 1. Still, in others, not at all, as in example 2.

The experience has been proving to be an ever-present tradeoff between knowledge that has to be transferred and the users' experience and practical needs. From the success in handling this process by both trainers and trainees will depend, at a considerable extent, the success of the research project.

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Appendix – the training content, first part

INTRODUCTION

1. Matrix algebra for input-output models
    - 1.1. Matrices
    - 1.2. Addition and subtraction of matrices
    - 1.3. The null matrix
    - 1.4. Matrices multiplication
        - 1.4.1. Matrices multiplication by a number
        - 1.4.2. Vectors multiplication
        - 1.4.3. Multiplication of a matrix by another matrix
        - 1.4.4. Particular case: summation vectors
        - 1.4.5. Particular case: matrix aggregation
        - 1.4.6. Particular case: singular matrices
        - 1.4.7. Matrix multiplication with Excel
    - 1.5. Identity and scalar matrices
    - 1.6. Matrix transposition
        - 1.6.1. Matrix transposition with Excel
    - 1.7. Matrix representation of linear equation systems