

Perobelli, Fernando; De Mattos, Rogerio Silva; Rodrigues, Weslem

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Energetic Interactions Between Minas Gerais State and the Rest of Brazil: An Inter-Regional Input-Output Analysis

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Energy interactions between Minas Gerais State and the remainder of Brazil: an interregional input-output analysis ¹

Rogério Silva de Mattos

Faculdade de Economia e Administração
Universidade Federal de Juiz de Fora, Brazil

Fernando Salgueiro Perobelli

Faculdade de Economia e Administração
Universidade Federal de Juiz de Fora, Brazil

Weslem Rodrigues Faria

Faculdade de Economia e Administração
Universidade Federal de Juiz de Fora, Brazil

Abstract

This paper analyses the interactions between the State of Minas Gerais and the remainder of Brazil with regard to energy consumption. An hybrid interregional input-output model, by means of which energy intensity measures are computed, is used to undertake the analysis. The energy measures allow, for instance, to assess the degree in which sector production in Minas Gerais impacts the energy consumption inside and outside the state. Also, the measures allow to assess the degree in which sector production in the remainder of Brazil (outside Minas Gerais) impacts energy consumption inside and outside the state. The analysis presents disaggregate information for 14 economic sectors, two spatial areas (Minas Gerais and the remainder of Brazil), and one kind of energy use (total energy), thus allowing to trace an accurate portrait of interaction patterns. A conclusion is that the methodology provides relevant information for state managers/planners in the development of efficient strategies to warrant energy supply.

Key words: input-output; requirement coefficients; interregional model.

JEL Classification: R15 e C67

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1. Introduction

Energy is a generally used input to an economy and, as a consequence, its shortage can produce adverse economic effects in the short and the long runs. For instance, in 2001 the Brazilian government had to adopt an emergency program to induce economic agents to restrain electrical energy consumption. Following a decrease in rainfalls that led the Brazilian electrical system to fail in attending expected demand, and as new electricity generation facilities depend on massive investments featured with long terms of maturation, the federal government was impelled to introduce the contention program. The program's immediate effects were increased unemployment and reduced output (e.g., Torres and Almeida, 2003). Also, energy shortage may produce long run consequences by restraining the level of aggregate investment of the economy. As long as uncertainties prevail with regard to energy supply, many investment decisions are postponed or suspended, thus jeopardizing economic growth.

In order to assure the normal energy supply, economic agents operating in the energy sector (government planning divisions, regulatory agencies and private enterprises) have been undertaken many actions, like the intensification of research efforts toward the improvement in technical efficiency and the use of alternative energy sources, the expansion of programs and campaigns toward energy conservation, the improvements in the regulatory system (as the new regulatory model introduced in 2004 for the electrical energy sector; see MME, 2004), and the development of a decennial plan for expanding the electricity generation capacity.

According to Torres and Almeida (2003), in the specific case of electrical energy, supply expansion with warranties of quantity and quality in deliveries depends on many actions involving the participation of: a) private agents – that plays a key role in leveraging investment funds to the sector, and b) institutional agents – that are responsible for setting up development policies for the sector, addressing the many issues involved in capacity expansion planning, and managing regulatory, rights concession, and environmental licensing activities.

In the planning activities for a regular energy supply, many supporting studies need to be undertaken. From the perspective of state managers, an issue of interest lies on the interdependencies/interactions between production activities of economic sectors and spatial consumption of energy. The evaluation, with appropriate tools, of such interdependencies/interactions may improve the understanding of problems related to energy

demand meeting, and, thus, provide better support for the management and planning of energy supply at state level.

This paper analyses the energy interactions between the Brazilian State of Minas Gerais and the remainder of Brazil country, taking both the economic and spatial structures into consideration. The analysis is developed using a hybrid interregional input-output model by means of which measures of energy use, known as energy requirement coefficients, are computed. These measures allow, for instance, to evaluate the degree in which the production activities in each economic sector within Minas Gerais affect energy consumption inside and outside the state. The reverse is also possible, say, the measures allow to evaluate the degree in which the production activities of sectors located in the remainder of Brazil area (outside Minas Gerais) impact energy consumption inside and outside the state.

Although the focus of analysis is energy consumption aggregated along many sources of energy, the results are presented in a disaggregate form according to 14 economic sectors and two spatial areas (Minas Gerais State and the remainder of Brazil). It was useful to trace a somewhat refined portrait of interaction patterns between Minas Gerais and the remainder of Brazil. Moreover, as indicated in the concluding section, the methodology can be easily extended to account for many different sources of energy and/or a higher number of regions.

In addition to this introduction, the paper is organized as follows: Section 2 makes a brief description of the energy consumption structure in Brazil and Minas Gerais. Section 3 presents the methodology - i.e., the interregional input-output model, and the extension of this model to incorporate the energy sector. Section 4 describes the database used in the study. Section 5 presents and section 6 discusses the empirical results. Section 7 closes the paper with some final considerations.

2. Energy consumption in Brazil and Minas Gerais

Tables 1 and 2 present data on the recent evolution of energy consumption in Brazil and Minas Gerais, respectively. The data for Brazil, available until 2004, were obtained from the National Energy Balance Report published by the Ministry of Mines and Energy (MME, 2005), and those for Minas Gerais, available only until 2003, from the Energy Balance Report of Minas Gerais published by the electrical utility *Centrais Eléctricas de Minas Gerais* (CEMIG, 2005). The

figures are presented in a same unit of measurement, *ton petroleum equivalent* (tpe), in order to allow additions and comparisons.

Energy consumption at national scale (table 1) achieved nearly 190 millions of tpe in 2004. Information on consumption by energy sources indicate a concentration in diesel fuel (32.7 millions) and electricity (30.9 millions), which together accounted for one third of total consumption in 2004. Information on consumption by economic sector point out that the transportation (51.4 millions) sector is the major consumer of energy within the country, absorbing nearly 27% of the total energy consumed. It is followed by residential consumption (21.4 millions), iron+steel (17.9 millions) and food+beverage (17.6 millions) sectors.

Data for the year 2003 reported in table 2 indicates that Minas Gerais responds for nearly 13% (23.6 millions) of total energy consumption in Brazil. The consumption structure by energy source in the state is similar to the one in Brazil: there is a concentration of consumption in energy sources like diesel fuel (3.7 millions) and electricity (3.6 millions), which together meet 30% of the states' energy demand. Two other important energy sources are firewood (3.1 millions) and wood coal (3.8 millions). The energy consumption structure by sector, however, is peculiar in the sense of being highly concentrated in the steel sector, with the production of pig iron+steel accounting for 30% of energy consumption in the state. It is followed by the transportation sector (5 millions) and residential use (3.5 millions).

Table 1 – Evolution of total energy consumption in Brasil: 2002-2004

Year	2002	2003	2004
Total Consumption	178,160	182,114	191,128
<i>By Energy Source</i>			
Diesel fuel	31,521	30,885	32,657
Electricity	27,884	29,430	30,923
Cane bagasse	17,495	19,355	20,273
Firewood	14,471	15,218	15,752
Other sources	86,789	87,226	91,523
<i>By Economic Sector</i>			
Transportes Transportation	49,163	48,160	51,432
Residencial Residential use	20,681	20,902	21,357
Food and beverages	15,839	16,659	17,599
Pig Iron and steel	15,729	16,701	17,945
Other sectors	76,747	79,693	82,795

OBS: Measurement unit: 1,000 tpe

Source: MME, 2005.

Table 2 - Evolution of total energy consumption in Minas Gerais: 2001-2003

Year	2001	2002	2003
Total Consumption	22,381	23,037	23,596
<i>By Energy Source</i>			
Diesel fuel	3,750	3,742	3,742
Electricity	3,322	3,482	3,562
Firewood	3,235	3,200	3,095
Charcoal	2,775	2,913	3,771
Other	9,299	9,700	9,426
<i>By Economic Sector</i>			
Transportation	5,154	5,119	5,048
Integrated pig iron+steel	4,351	4,609	4,627
Residential	3,735	3,688	3,541
Non-integrated pig iron+steel	1,891	1,911	2,677
Other	7,250	7,710	7,703

OBS: Measurement unit: 1,000 tpe

Source: CEMIG, 2005.

3. Methodology

Input-output analysis is often used to study the interdependencies or interactions among economic sectors of a region or country. The degree of interdependency/interaction can be evaluated with measures known as coefficients of intersector requirements. Such coefficients allow the evaluation of, for instance, the impacts that changes in final demand for a given sector produce over the other sectors of the economy (e.g., Miller and Blair, 1985). There are many possible extensions of the input-output analysis, among which, of particular relevance to this study, are the assumption of many regions and the incorporation of the energy sector. The first allows the study of sector interactions among many regions (e.g., Isard et al, 1998). For instance, the sector impacts of final demand changes in a region can be evaluated for the sectors in the same region as well as for the sectors in the other regions considered. The second extension, i.e., the incorporation of the energy sector, is of interest because the production of every good in an economy involves the use of at least one source of energy input. Thus, the inter- and intraregional sector interactions can also be evaluated and studied. This section describes an interregional input-output model with the incorporation of the energy sector along with the measures of energy interactions which were computed and analyzed in this paper.

3.1 Interregional input-output model

An interregional input-output model (IRIO) describes the money flows of goods and services throughout the economy considering different regions. In a simple case of an economy with two regions and n sectors, the IRIO model can be mathematically represented in matrix form as:

$$Zi_{2n} + Y = X \quad (1)$$

where $Z = \{z_{ij}\}$ is a $2n \times 2n$ matrix that represents the input-output table, i_{2n} is an unitary vector (all elements are equal to one) of order $2n \times 1$, $Y = \{y_j\}$ is a $2n \times 1$ vector whose elements are the final demands of both regions, and $X = \{x_j\}$ is a $2n \times 1$ vector whose elements are the sector outputs, also for both regions.

However, a more convenient way to write equation (1) is to define the following matrix of technical coefficients:

$$A = Z(\hat{X})^{-1} \quad (2)$$

where $\hat{X} = \text{diag}(X)$. Each element of A is generally defined as $a_{ij} = x_{ij}/x_j$ and corresponds to the proportion of inputs from sector i that are necessary to produce a dolar of output from sector j , with the feature that the regions of sector i and sector j can be the same or not. The elements of A are thus called coefficients of *direct requeriments* and are of two kinds: a_{ij}^{LL} and a_{ij}^{MM} are the *intraregional* coefficients, while a_{ij}^{LM} and a_{ij}^{ML} are the *interregional* coefficients. It allows to partition matrix A into four sub-matrixes, as:

$$A = \begin{bmatrix} A^{LL} & A^{LM} \\ A^{ML} & A^{MM} \end{bmatrix} \quad (3)$$

where A^{LL} and A^{MM} are matrixes of intra-regional coefficients, and A^{LM} and A^{ML} are matrixes of interregional coefficients. The system in (2) can then be rewritten as:

$$AX + Y = X \quad (4)$$

so that, after brief algebraic manipulations:

$$X = BY \quad (5)$$

where $B = (I - A)^{-1}$ corresponds to the Leontief matrix in the IRIO model. Subtracting from B the identity matrix I , it is found:

$$R = B - I$$

where R is a matrix of *net total requirement* coefficients². Note that this matrix can also be partitioned into four submatrixes:

$$R = \begin{bmatrix} R^{LL} & R^{LM} \\ R^{ML} & R^{MM} \end{bmatrix} \quad (6)$$

where R^{LL} and R^{MM} are matrixes of intraregional coefficients, and R^{LM} and R^{ML} are matrixes of interregional coefficients. It is also possible to define the matrix of indirect *requirement* coefficients:

$$Q = R - A = \begin{bmatrix} Q^{LL} & Q^{LM} \\ Q^{ML} & Q^{MM} \end{bmatrix} \quad (7)$$

where Q^{LL} and Q^{MM} are matrixes of intraregional coefficients, and Q^{LM} and Q^{ML} are matrixes of interregional coefficients.

The matrixes A , R , and Q provide, respectively, numerical information on the degrees of direct, net total, and indirect dependencies/interactions that exist among sectors and regions. The coefficients of matrix A (direct requirements) provide information on first order effects, while the ones of matrix Q (indirect requirements) provide information on second order effects, resulting from changes in final demand.

3.2 Incorporating the Energy Sector

This section presents an extension of the IRIO model to incorporate the energy sector. There are many different ways to undertake such extension and the approach followed here is based on the construction of a hybrid input-output table. This approach was used and defended by many authors, like Miller and Blair (1985), Gowdy and Miller (1987), Machado (2002), and Hilgemberg (2004).

The basic idea is to include a row and a column (for each region) representing the energy sector in the input-output table Z . The row corresponds to the sales of the energy sector made to the other sectors, with the feature that those sales are measured in physical units. The column represents the purchases of energy made from the other sectors, with the feature that those purchases (except for the energy sector) are measured in monetary units. Thus, this expanded

² The subtraction of matrix I here plays the role of extracting from B the initial requirements produced by the final demand of each sector. This procedure eliminates certain problems in the comparison of direct and indirect requirements among sectors (see Miller and Blair, 1985).

input-output table displays economic flows expressed in hybrid units, say, with some transactions represented in money values and the others in physical units.

According to Bullard and Herendeen (1975), Miller and Blair (1985), and Casler and Blair (1997), the input-output model in hybrid units is the most consistent approach to apply input-output models of physico-economic natures involving the energy use.

Hawdon and Pearson (1995), and Zhang and Folmer (1998), point some advantages accruing from the use of input-output structure to analyse issues related to the energy sector because it allows: a) a more detailed sector disaggregation than dynamic optimization and macroeconomic models; b) the incorporation of intersector energy flows either in physical or monetary units, and c) the implementation of impact analysis. Nevertheless, these models also present some limitations, such as the assumptions of: a) fixed input-output coefficients; b) constant return to scale; and c) final demand determined exogenously. It shall be stressed that such limitations, however, do not invalidate model results.

Consider equation (1) rewritten as follows:

$$Z^* i_{2(n+1)} + Y^* = X^* \quad (8)$$

where:

$$Z^* = \begin{bmatrix} Z^{LL} & Z^{LM} \\ e^{LL} & e^{LM} \\ Z^{ML} & Z^{MM} \\ e^{ML} & e^{MM} \end{bmatrix}, Y^* = \begin{bmatrix} Y^L \\ e_Y^L \\ Y^M \\ e_Y^M \end{bmatrix} \text{ e } X^* = \begin{bmatrix} X^L \\ e_X^L \\ X^M \\ e_X^M \end{bmatrix}$$

Note that Z^* represents an hybrid input-output table. The submatrixes Z^{LL} and Z^{MM} , that represent intraregional transactions, and the submatrixes Z^{LM} and Z^{ML} , that represent the interregional transactions, display their elements measured in monetary units; by their turn, the row vectors e^{LL} and e^{MM} , that represent intraregional transactions of energy, and the row vectors e^{LM} and e^{ML} , that represent interregional transactions of energy, are measured in physical units. The components Y^L , Y^M , X^L and X^M are $n \times 1$ vectors whose elements are the final demands and the sector outputs, respectively, in regions L and M .

By defining $\hat{X}^* = \text{diag}(X^*)$, it is possible to build an hybrid matrix of direct requirement coefficients:

$$A^* = Z^*(\hat{X}^*)^{-1} \quad (9)$$

from which is possible to rewrite (8) as:

$$A^* X^* + Y^* = X^*$$

After brief algebraic manipulation, one obtains:

$$X^* = B^* Y^* \quad (10)$$

where $B^* = (I - A^*)^{-1}$. It is now possible to determine an hybrid matrix of net total requirement coefficients, as:

$$R^* = B^* - I^*$$

where I^* is an identity matrix of order $2(n+1) \times 2(n+1)$.

In this work, the research interest focus on the intra- and interregional structures of interactions with the energy sector, so that the purpose is to extract from matrix A^* as well as from matrix R^* only the requirement information related to the energy sector. To accomplish this goal, define initially the following matrix composed only by zeroes and ones:

$$U = \begin{bmatrix} \mathbf{0}^{LL} & \mathbf{0}^{LM} \\ i'_{n+1} & i'_{n+1} \\ \mathbf{0}^{ML} & \mathbf{0}^{MM} \\ i'_{n+1} & i'_{n+1} \end{bmatrix} \quad (11)$$

$$V = \begin{bmatrix} i'_{n+1} & \mathbf{0} \\ \mathbf{0} & i'_{n+1} \end{bmatrix} \quad (12)$$

In matrix U , the submatrixes ' $\mathbf{0}$ ' of null elements play the role of eliminating from posterior computations the requirement information of the non-energy sectors in both regions. By its turn, the element i'_{n+1} represents an unitary vector of order $(n+1) \times 1$ and the presence of four of these vector in matrix U plays the role of incorporating the requirement information related to the energy sector in posterior computations. Matrix V is used only to compact the size of results matrixes.

It is then possible to compute the intra- and interregional requirements of energy by sector, as follows:

$$\Pi = V(U \circ A^*) \quad (13)$$

$$\Lambda = V(U \circ R^*) \quad (14)$$

$$P = \Lambda - \Pi \quad (15)$$

In the above expressions, the symbol 'o' represents elementwise product; Π , Λ , and P are $2 \times 2(n+1)$ matrixes which represent, respectively, direct, net total, and indirect energy requirements. Each of these matrixes can be partitioned into four sub-vectors of order $1 \times (n+1)$, representing the intra- and interregional requirements:

$$\Pi = \begin{bmatrix} \pi^{LL} & \pi^{LM} \\ \pi^{ML} & \pi^{MM} \end{bmatrix} \quad (16)$$

$$\Lambda = \begin{bmatrix} \lambda^{LL} & \lambda^{LM} \\ \lambda^{ML} & \lambda^{MM} \end{bmatrix} \quad (17)$$

$$P = \begin{bmatrix} \rho^{LL} & \rho^{LM} \\ \rho^{ML} & \rho^{MM} \end{bmatrix} \quad (18)$$

In sum, the $2 \times (n+1)$ matrixes Π , Λ , and P provide numerical information on the intra- and interregional structure of direct, total (net), and indirect dependency/interaction existing among sectors/regions in terms of energy consumption.

4. Data

The data needed to implement the hybrid IRIO model has to be obtained from two different sources: a) an input-output matrix, and b) an energy balance. The present work made use of data available from the interregional input-output matrix for the Minas Gerais State versus the remainder of Brazil (BDMG and FIPE, 2002); and in the case of the data on sector energy use, from both the 2005 National Energy Balance (which reports data for 2004) and the 19th Energy Balance of the Minas Gerais State (which reports data for 2003; CEMIG, 2005). As the present work makes use of the input-output matrixes (for Minas Gerais and Brazil) developed for the year 1996, only the information for this year was used.

It should be noted that the sector aggregation of the interregional input-output matrix for Minas Gerais - remainder of Brasil is different from the one reported in the energy balances for both regions. Thus, the first step of data treatment was to match these different data aggregation structures. The interregional input-output matrix of Minas Gerais – remainder of Brazil was framed based on 40 sectors while the energy balances, both the national and the Minas Gerais one, provide energy consumption figures for only 20 sectors. The matching process led to an hybrid matrix with 14 sectors.

5. Results

The IRIO model described in Section 3 allows to compute disaggregate information on the sector patterns of energetic interactions between Minas Gerais and the remainder of Brazil. For each region, it is possible to compute the intra- and interregional net total requirements, and both of these can still be divided into direct, and indirect requirements. The sequence of disaggregating procedures can be undertaken in different manners, according to the particular research interest at hand.

In this section, an analysis is presented only for the total energy requirements (matrix Λ in equation 18). It is considered initially the disaggregation into intra- and interregional requirements, and then into the respective direct and indirect components. The obtained portrait, though still partial, provides a useful perspective of the sector/spatial interactions concerning the energy use and illustrates methodology potentials for more disaggregate and detailed analysis.

The numerical results are analyzed in two parts: In the first, attention is paid to the total (net) requirements by sector and their decomposition into intra- and interregional requirements, for both Minas Gerais and the remainder of Brazil. In the second, the vectors of intra- and interregional requirements are analyzed in terms of their decomposition into direct and indirect requirements. It should be noted that the interregional requirements are considered under the *sales* perspective, say, the interregional requirements of Minas Gerais correspond to the sales of energy made by this state to the remainder of Brasil; by its turn, the interregional requirements of the remainder of Brazil correspond to the sales of energy made by that region to Minas Gerais.

5.1 (Net) Total Requirements

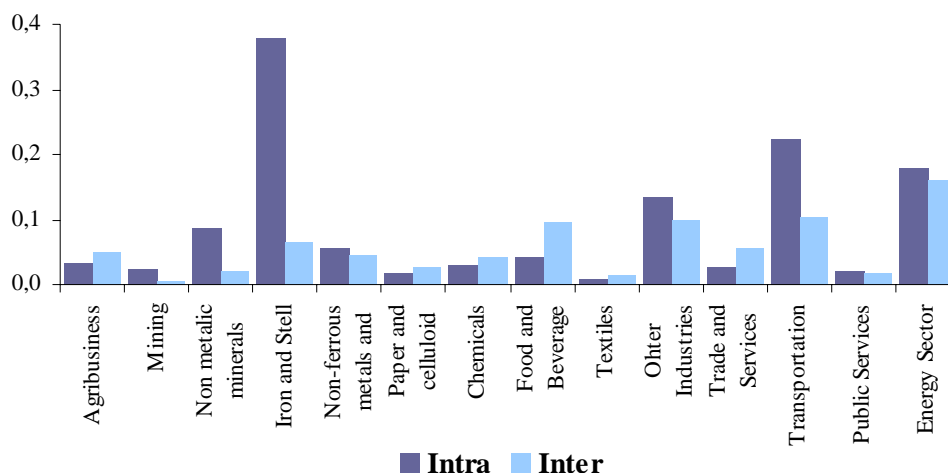
Table 3 displays, for each region, numerical figures for the intra- and interregional net total requirements for 14 economic sectors. For better visualization of results, bar graphs were made. In Graph 1, for Minas Gerais, the intraregional requirements indicate a prominent amount for Iron + Steel (0.39), followed by Transportation (0.22), Energy (0.18), and Other Industries (0.14). The inter-regional requirements (pressure from the remainder of Brazil over Minas Gerais), by their turn, display quite smaller levels, with some prominence for Energy (0.16), Transportation (0.10), Other Industries (0.10), and Food + Beverages (0.10).

In the case of the intra-regional requirements from the remainder of Brazil, Graph 2 point to the prominent role of the Transportation sector (0.44), followed by Energy (0.27), Food + Beverages (0.21), Other Industries (0.18), and Trade + Services (0.14). Interregional requirements (pressure from Minas Gerais over the remainder of Brazil), by their turn, display quite low levels as compared to the interregional ones, with some prominence only for Iron + Steel (0.05).

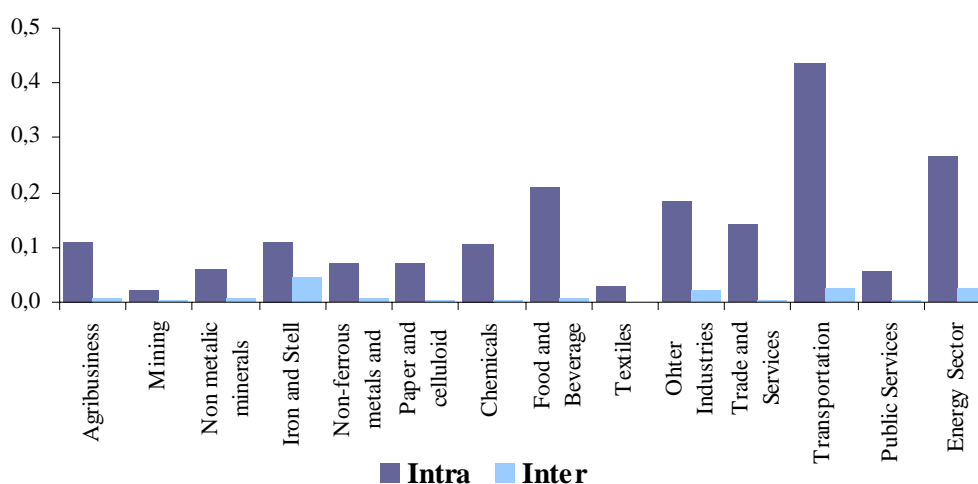
Table 3 – Energy Total Net Requirements

Sectors		Intra	Inter
Minas Gerais	1 – Agribusiness	0.0336	0.0500
	2 – Mining	0.0232	0.0068
	3 – Non metallic minerals	0.0860	0.0201
	4 – Iron and Steel	0.3779	0.0643
	5 – Non-ferrous metals and other metallurgic products	0.0561	0.0441
	6 – Paper and celluloid	0.0187	0.0264
	7 – Chemicals	0.0289	0.0408
	8 – Food and Beverage	0.0407	0.0961
	9 – Textiles	0.0099	0.0156
	10 – Other Industries	0.1358	0.0971
	11 – Trade and Services	0.0260	0.0563
	12 – Transportation	0.2245	0.1047
	13 – Public Services	0.0211	0.0188
	14 – Energy Sector	0.1798	0.1613
Remainder of Brazil	1 – Agribusiness	0.1100	0.0067
	2 – Mining	0.0203	0.0027
	3 – Non metallic minerals	0.0617	0.0057
	4 – Iron and Steel	0.1097	0.0453
	5 – Non-ferrous metals and other metallurgic products	0.0700	0.0084
	6 – Paper and celluloid	0.0700	0.0022
	7 – Chemicals	0.1072	0.0045
	8 – Food and Beverage	0.2109	0.0070
	9 – Textiles	0.0272	0.0013
	10 – Other Industries	0.1842	0.0198
	11 – Trade and Services	0.1421	0.0046
	12 – Transportation	0.4372	0.0247
	13 – Public Services	0.0558	0.0036
	14 – Energy Sector	0.2652	0.0252

Graph 1 – Net totals of energy requirements for energy produced in Minas Gerais



Graph 2 – Net totals of energy requirements for energy produced in the remainder of Brazil



5.2 Regional decomposition of net total requirements

Table 4 display the net total requirements decomposed into intra- and interregional components. The figures are measured in percentages. Graphs 3 and 4 provide a data visualization. In Minas Gerais, the interregional effects by sector are more expressive than in the case of the remainder of Brazil. In that State, the smallest percentage figure of interregional requirement is for Iron and Steel (14,5%) and the largest for Food and Beverage (70,2%). In the remainder of Brazil, interregional figures vary from 2.1% for Paper + Celluloid and Trade + Services until 29.2% for Iron + Steel.

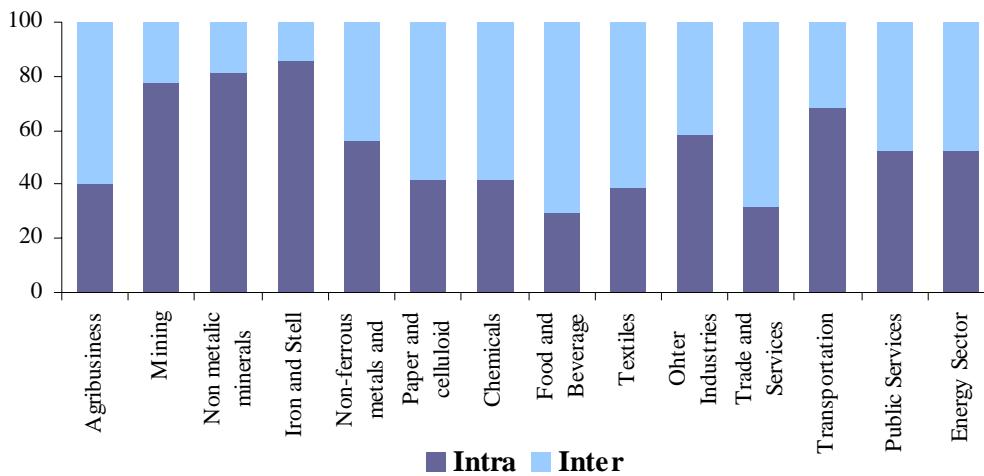
This issue naturally indicates a stronger influence from the remainder of Brazil in making demand pressures over the energy sector of Minas Gerais than the opposite. However, it is worth

to note in Graph 3 that the demand pressure of Minas Gerais (interregional requirements) over the energy sector of the remainder of Brazil is not negligible, in particular if it is taken into consideration the existence of 26 other states in the Brazilian federation.

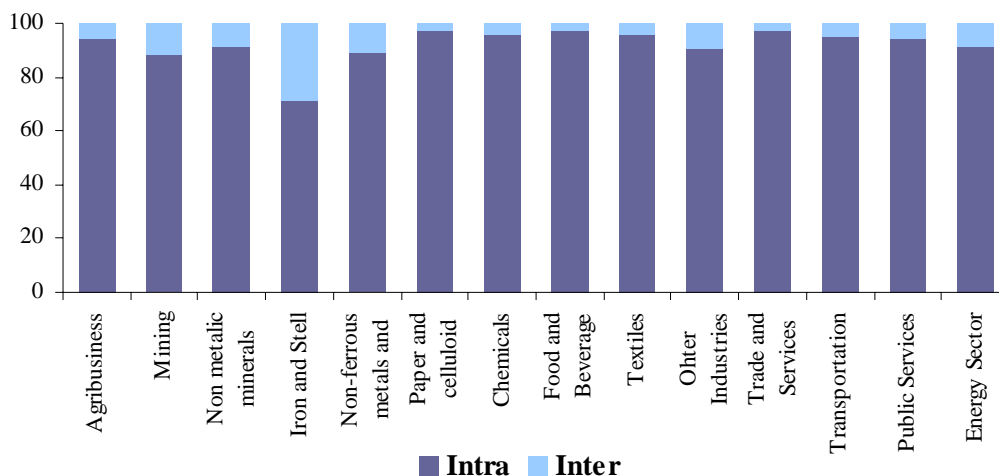
Table 4 - Intra- and interregional decomposition of net total requirements

Sectors		Intra	Inter
Minas Gerais	1 – Agribusiness	40.2	59.8
	2 – Mining	77.4	22.6
	3 – Non metallic minerals	81.0	19.0
	4 – Iron and Steel	85.5	14.5
	5 – Non-ferrous metals and other metallurgic products	56.0	44.0
	6 – Paper and celluloid	41.5	58.5
	7 – Chemicals	41.5	58.5
	8 – Food and Beverage	29.8	70.2
	9 – Textiles	38.8	61.2
	10 – Other Industries	58.3	41.7
	11 – Trade and Services	31.5	68.5
	12 – Transportation	68.2	31.8
	13 – Public Services	52.8	47.2
	14 – Energy Sector	52.7	47.3
Remainder of Brazil	1 – Agribusiness	94.2	5.8
	2 – Mining	88.1	11.9
	3 – Non metallic minerals	91.5	8.5
	4 – Iron and Steel	70.8	29.2
	5 – Non-ferrous metals and other metallurgic products	89.3	10.7
	6 – Paper and celluloid	96.9	3.1
	7 – Chemicals	96.0	4.0
	8 – Food and Beverage	96.8	3.2
	9 – Textiles	95.5	4.5
	10 – Other Industries	90.3	9.7
	11 – Trade and Services	96.9	3.1
	12 – Transportation	94.7	5.3
	13 – Public Services	93.9	6.0
	14 – Energy Sector	91.3	8.7

Graph 3 – Intra- and interregional shares in net total requirements for Minas Gerais



Graph 4 – Intra- and interregional shares in net total requirements for remainder of Brasil



5.3 Direct and indirect components of regional requirements

This sub-section analyses the intra- and interregional requirements in terms of their decomposition into direct and indirect requirements produced over the energy sectors of the two study regions. The smaller the relation *direct/indirect requirements* (DIR), the larger the multiplying power that a sector’s activity exerts over energy consumption inside a region. Sectors presenting large shares in a region’s energy demand and which at the same time display a small DIR relation are supposed to produce the stronger demand pressures over the region’s energy sector. At an opposite side, there are sectors which present small shares in a region’s energy demand and high levels for the DIR relation. In the last case, the lower are the demand pressures

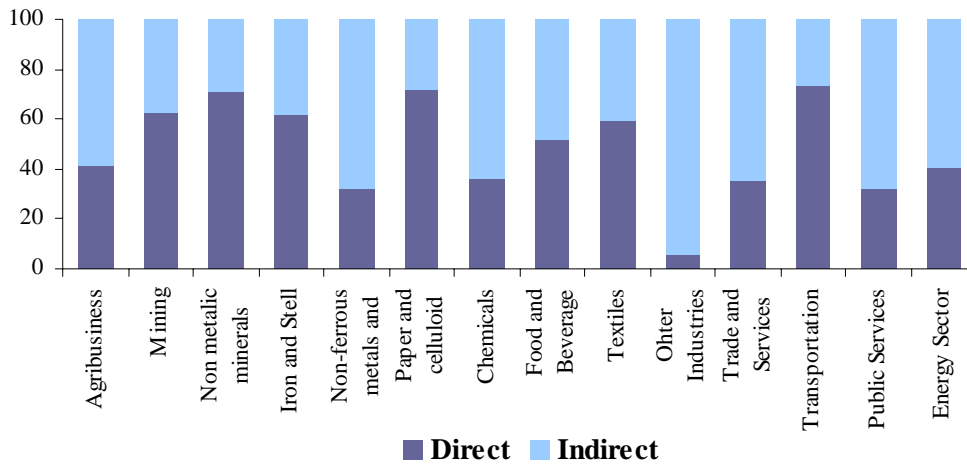
over the region's energy sector. Between the two extremes, there are sectors with varying, intermediate, degrees of importance in the pressure they exert. This perspective applies to the intra- as well as to the interregional requirements analyses.

Table 5 display data on *direct* and *indirect* components of both the intra- and interregional requirements. Graphs 5 and 6 display visualization for these data. The sector decomposition into direct and indirect requirements shows up a quite diversified sector structure in both regions. In the case of Minas Gerais, there is one sector with a share of direct requirements below 6% (Other Industries) and three sectors with shares above 70% (Non-metal minerals, Paper+Celluloid, and Transportation). It is worth to note that in Minas Gerais the Other Industries sector, which responds for a significant share in the state's total energy consumption, displays a quite small DIR relation that indicates it exerts a strong demand pressure over the energy sector of the state.

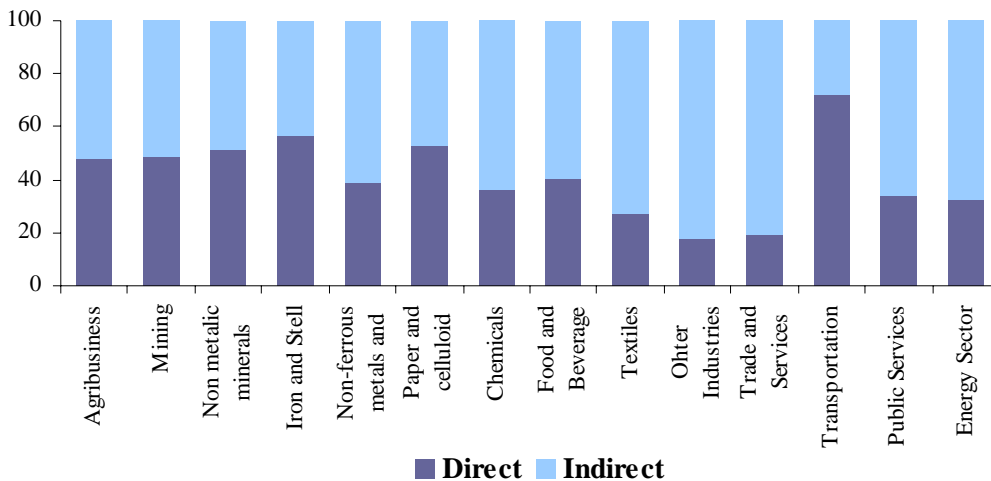
Table 5 - Sector shares in the intraregional net total requirements

Sectors		Direct	Indirect	Total
Minas Gerais	1 – Agribusiness	41.7	58.3	100
	2 – Mining	62.7	37.3	100
	3 – Non metallic minerals	70.9	29.1	100
	4 – Iron and Steel	61.3	38.7	100
	5 – Non-ferrous metals and other metallurgic products	31.7	68.3	100
	6 – Paper and celluloid	71.6	28.4	100
	7 – Chemicals	35.9	64.1	100
	8 – Food and Beverage	51.3	48.7	100
	9 – Textiles	59.5	40.5	100
	10 – Other Industries	5.3	94.7	100
	11 – Trade and Services	35.1	64.9	100
	12 – Transportation	73.2	26.8	100
	13 – Public Services	31.7	68.3	100
	14 – Energy Sector	40.5	59.5	100
Remainder of Brazil	1 – Agribusiness	47.6	52.4	100
	2 – Mining	48.6	51.4	100
	3 – Non metallic minerals	51.2	48.8	100
	4 – Iron and Steel	56.7	43.3	100
	5 – Non-ferrous metals and other metallurgic products	39.2	60.8	100
	6 – Paper and celluloid	52.6	47.4	100
	7 – Chemicals	35.7	64.3	100
	8 – Food and Beverage	40.6	59.4	100
	9 – Textiles	27.0	73.0	100
	10 – Other Industries	17.5	82.5	100
	11 – Trade and Services	19.0	81.0	100
	12 – Transportation	72.4	27.6	100
	13 – Public Services	33.6	66.4	100
	14 – Energy Sector	32.4	67.6	100

Gráfico 5 - Minas Gerais: Sector shares in the intraregional net total requirements



Graph 6 - Remainder of Brasil: Sector shares in the intraregional net total requirements



Yet for the remainder of Brazil, there are two sectors with shares of direct intraregional requirements below 20% (Other Industries and Trade + Services) and only one sector with a share above 70% (Transportation). Here also it is observed a small DIR relation for the Other Industries sector, which responds for a significant share in total energy consumption of the remainder of Brazil and, thus, exerts strong demand pressure over the energy sector of that region.

Table 6 displays, by its turn, data on *direct* and *indirect* components of interregional requirements. Graphs 7 and 8 display visualization for these data. Note the shares of direct requirements are on average smaller than for the intraregional direct requirements (see table 5; graphs 5 and 6) and that the distribution by sector is somewhat different. Note also that the DIR

relations are even smaller (for both regions) indicating a larger multiplier power of sector activities. Although more evident in the case of Minas Gerais, it also happens in the remainder of Brazil. In Minas Gerais, the sectors Other Industries (4,8%), Trade+Services (6.2%), and Public Services (8%) display prominent figures.

Table 6 - Sector shares in the interregional net total requirements

Sectors		Direct	Indirect	Total
Minas Gerais	1 – Agribusiness	33.2	66.8	100
	2 – Mining	18.4	81.6	100
	3 – Non metallic minerals	22.0	78.0	100
	4 – Iron and Steel	34.2	65.8	100
	5 – Non-ferrous metals and other metallurgic products	17.7	82.3	100
	6 – Paper and celluloid	26.1	73.9	100
	7 – Chemicals	16.6	83.4	100
	8 – Food and Beverage	25.9	74.1	100
	9 – Textiles	12.1	87.9	100
	10 – Other Industries	4.8	95.2	100
	11 – Trade and Services	6.2	93.8	100
	12 – Transportation	32.5	67.5	100
	13 – Public Services	8.0	92.0	100
	14 – Energy Sector	32.9	67.1	100
Remainder of Brazil	1 – Agribusiness	19.5	80.5	100
	2 – Mining	37.2	62.8	100
	3 – Non metallic minerals	37.3	62.7	100
	4 – Iron and Steel	36.7	63.3	100
	5 – Non-ferrous metals and other metallurgic products	15.1	84.9	100
	6 – Paper and celluloid	43.8	56.2	100
	7 – Chemicals	16.6	83.4	100
	8 – Food and Beverage	21.7	78.3	100
	9 – Textiles	33.2	66.8	100
	10 – Other Industries	2.1	97.9	100
	11 – Trade and Services	14.6	85.4	100
	12 – Transportation	48.6	51.4	100
	13 – Public Services	13.3	86.7	100
	14 – Energy Sector	20.2	79.8	100

Gráfico 7 - Minas Gerais: Sector shares in the interregional net total requirements

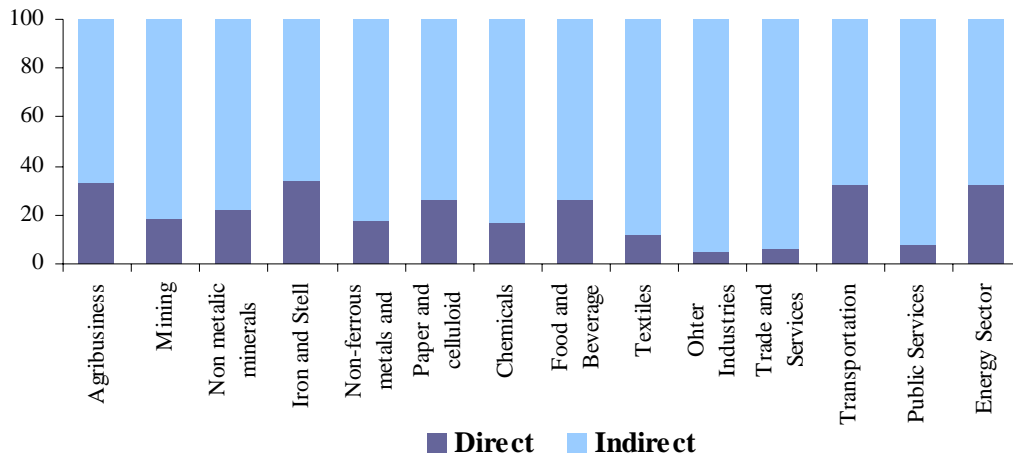
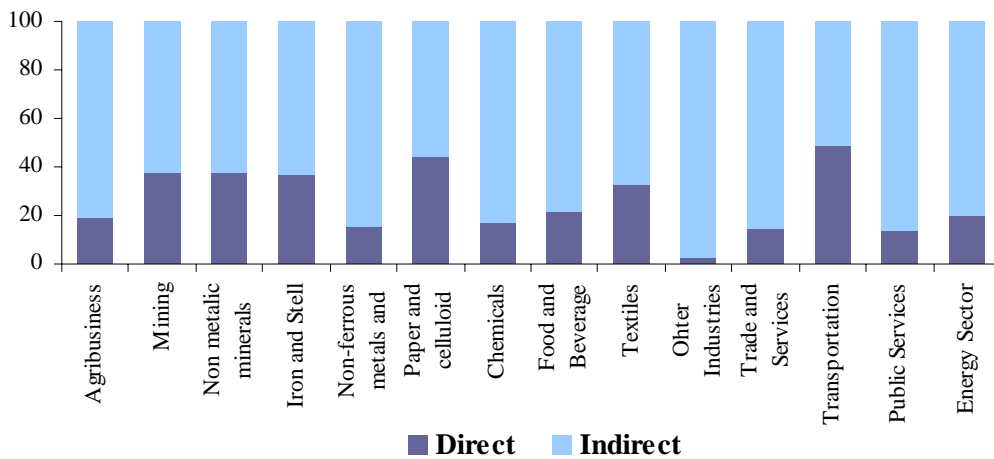


Gráfico 8 - Remainder of Brazil: Sector shares in the interregional net total requirements



6, Discussion

The methodology applied in the previous section can be useful to support planning and management activities toward efficient energy supply. From the perspective of planners/managers who play at the national level, the application is limited in the sense that it places focus on a single state. However, even in this context, important applications may be developed: For instance, the planner/manager might apply the methodology for every state of the Brazilian federation (27 states) or at least for the set of major energy consuming regions. Such kind of analysis might unveil a web of complex energy interactions, accounting for sector and

space dimensions, among the many Brazilian regions. This would certainly provide improved basis for the management and planning of energy supply.

From the perspective of state planners and managers in the Minas Gerais state, the methodology has already provided immediate results. It provided a view on the sources of demand pressures over the energy sector in Minas Gerais separating those pressures originating from sector activities inside the state proper and those originating from outside the state. The results presented in the previous section deserve now some specific considerations.

In the majority of cases, the economic sectors inside Minas Gerais make stronger demand pressures over the state's energy sector than the economic sectors outside the State. The comparison of intra- versus interregional requirements indicated that, within Minas Gerais, the sectors Iron+Steel, Transportation, Energy, and Other Industries displayed significant shares in the consumption of energy. However, though the Other Industries aggregate sector showed up as the last one of the major sectors, its low value for the direct versus indirect requirements indicated that it exerts potential demand pressures over the state's energy sector more important than it seems at first.

As pointed before, sectors outside Minas Gerais possessing larger shares in the demand pressure over the state's energy sector are those of Energy, Transportation, Other Industries, and Iron+Steel (graph 1). These sectors also display a small direct versus indirect requirements relation, in particular the Other Industries sector (table 5; graph 7).

From the view of management (short and long runs) of energy supply by the state of Minas Gerais, the results indicate that efforts of surveillance of those sector's (inside and outside the state) economic situation worth to be spent. From the view of the long run planning of energy supply by the state, the development of sector policies and the negotiations of resources and supporting actions with the federal government should consider the magnitude of the pressures those sectors exert over the state's energy sector.

7. Final considerations

This paper analyzed the energetic interactions between the Brazilian state of Minas Gerais and the remainder of Brazil country. An interregional input-output model with incorporation of an energy sector was used. The model was developed from an hybrid, regional input-output table

where the information on sales of the energy sector to the other sectors were registered in physical (tpes), not monetary, units.

The methodology allowed to identify the most relevant sectors, inside and outside Minas Gerais, for the demand pressures placed over the state's energy sector. Such an identification was based on the intra- and interregional coefficients of energy requirement of the IRIO model and also on the DIR relations present in the decomposition of those coefficients. Thus, the methodology provided relevant information for decision support to the management and policy making actions toward the normal supply of energy.

Although the application made here has been able to trace a somewhat refined portrait of energy interactions between the Minas Gerais state and the remainder of Brazil, as long as 14 economic sectors in two spatial regions were considered, it is possible to advance further the methodology by incorporating additional details and disaggregations, what opens interesting perspectives for future studies. For instance, the energy sector might be disaggregated by source of energy (petroleum, natural gas, electricity, mineral and wood coal). It is also possible to incorporate a larger number of regions/states in the IRIO model. Such research efforts may be fruitful in bringing additional relevant information both for state/regional planners and the national planner. The intakes would be improved information for a more efficient management of the energy supply by society without putting at risk the economic growth.

Referências Bibliográficas

BDMG e FIPE/USP (2002), *Matriz inter-regional de insumo-produto para Minas Gerais/Remainder of Brazil*, Belo Horizonte,

Bullard, C, W e Herendeen, R, A (1975), The energy cost of goods and services, *Energy Policy*, 3 (4): 268-278,

Casler, S, D e Blair, P, D (1997), Economic structure, fuel combustion, and pollution emissions, *Ecological Economics*, 22: 19-27,

CEMIG (2005), Balanço Energético do Estado de Minas Gerais, www.cemig.com.br

Gowdy, J, M, e Miller, J, L, (1987), **Technological and Demand Change in Energy Use: An Input-Output Analysis**, *Environment and Planning A*, 19 (10): 1387-1398,

Hilgemberg, E, M, (2004), **Quantificação e Efeitos Econômicos do Controle de Emissões de CO₂ Decorrentes do Uso de Gás Natural, Álcool e Derivados de Petróleo no Brasil:**

Um modelo Inter-regional de Insumo-Produto, Tese de Doutorado em Economia Aplicada apresentada à Escola Superior de Agricultura Luiz de Queiroz / USP,

Hawdon, D e Pearson, P (1995), Input-output simulations of energy, environment, economy interactions in the UK, *Energy Economics* 17 (1): 73-86,

Isard, W; Aziz, I,J; Drennan, M,P; Miller, R,E; Saltzman, S; Thorbecke, E (1998), **Methods of Interregional and Regional Analysis**, New York, Ashgate,

Machado, V, M, (2002), **Meio Ambiente e Comércio Exterior: Impactos da Especialização Comercial Brasileira sobre o Uso de Energia e as Emissões de Carbono do País**, Tese de Doutorado em Ciências em Planejamento Energético apresentada a COPPE / UFRJ,

Miller, R,E e Blair, P,D (1985), **Input-output analysis: foundations and extensions**, New Jersey, Prentice Hall,

MME (2005), Balanço Energético Nacional Ministério das Minas e Energia, www.mme.gov.br,

MME (2004), Novo modelo do setor elétrico, www.mme.gov.br,

Torres, M, E, L, e Almeida, P, E, F, (2003), **Infra-estrutura: sustentando o desenvolvimento**, Cap, 2 – Minas Gerais do Século XXI – BDMG,

Zhang, Z e Folmer, H (1998), Economic modeling approaches to cost estimates for the control of carbon dioxide emissions, *Energy Economics* 20: 101-120,

Anexo - Matching of sectors from the Brazilian Energy Balance with the sectors from the interregional input-output matrix for Minas Gerais/Brazil

<p>1 Agribusiness 1 Agribusiness</p> <p>2 Mining and rolling products 2 Vegetable exctration 3 Oil and gas</p> <p>3 Mining of Non-metalics 4 Mining of Non-metalics</p> <p>4 Iron and Steel 5 Steel products</p> <p>5 Non-iron metals and other metallurgies 6 Non-iron metallurgy 7 Other metallurgies</p> <p>6 Paper 8 Celluloid paper and Graphics 9 Rubber industry</p> <p>7 Chemicals 10 Chemical elements 11 Oil refinery 12 Other chemicals</p> <p>8 Food and beverage 13 Coffe processing 14 Manufacturing of vegetable products 15 Slaughter 16 Dairy products 17 Sugar processing 18 Vegetable oils processing 19 Other food products</p> <p>9 Textiles and Clothing 20 Textile industry 21 Clothing 22 Footwear</p>	<p>10 Other industries 23 Machines and Equipments 24 Electrical appliances 25 Electronic devices 26 Autos, trucks, and buses 27 Spares and other vehicles 28 Wood and furniture 29 Pharmaceuticals and veterinary 30 Plastic products 31 Miscelaneous industries 32 Public Utilities 33 Construction 34 Comunciations</p> <p>11 Trade and services 35 Trade 36 Financial institutions 37 Services to families 38 Services to enterprises 39 Property rent 40 Private non-merchantile services</p> <p>12 Transportation 41 Transportation</p> <p>13 Public services 42 Public administration</p> <p>14 Energy sector Firewood Oil and natural gas Oil extraction Oil refinery Coal and others Sugar based energetic products Electricity Residuals</p>
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Note: Boldface letters represent the sector classification according to the Brazilian Energy Balance, and normal letters the corresponding classification according to the interregional input-output matrix for Minas Gerais/Brazil.