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Núcleo de Economia Regional e Urbana
da Universidade de São Paulo
The University of São Paulo
Regional and Urban Economics Lab

Demographic change in Brazil and its impacts on CO2 emissions

Economic Systems Research, 2020

Terciane Sabadini Flaviane Santiago Fernando Perobelli

The debate about demographic changes and its impacts on the economy has increased

The growth in the relative share of elderly people in the age pyramid may occur in the coming decades in many parts of the world

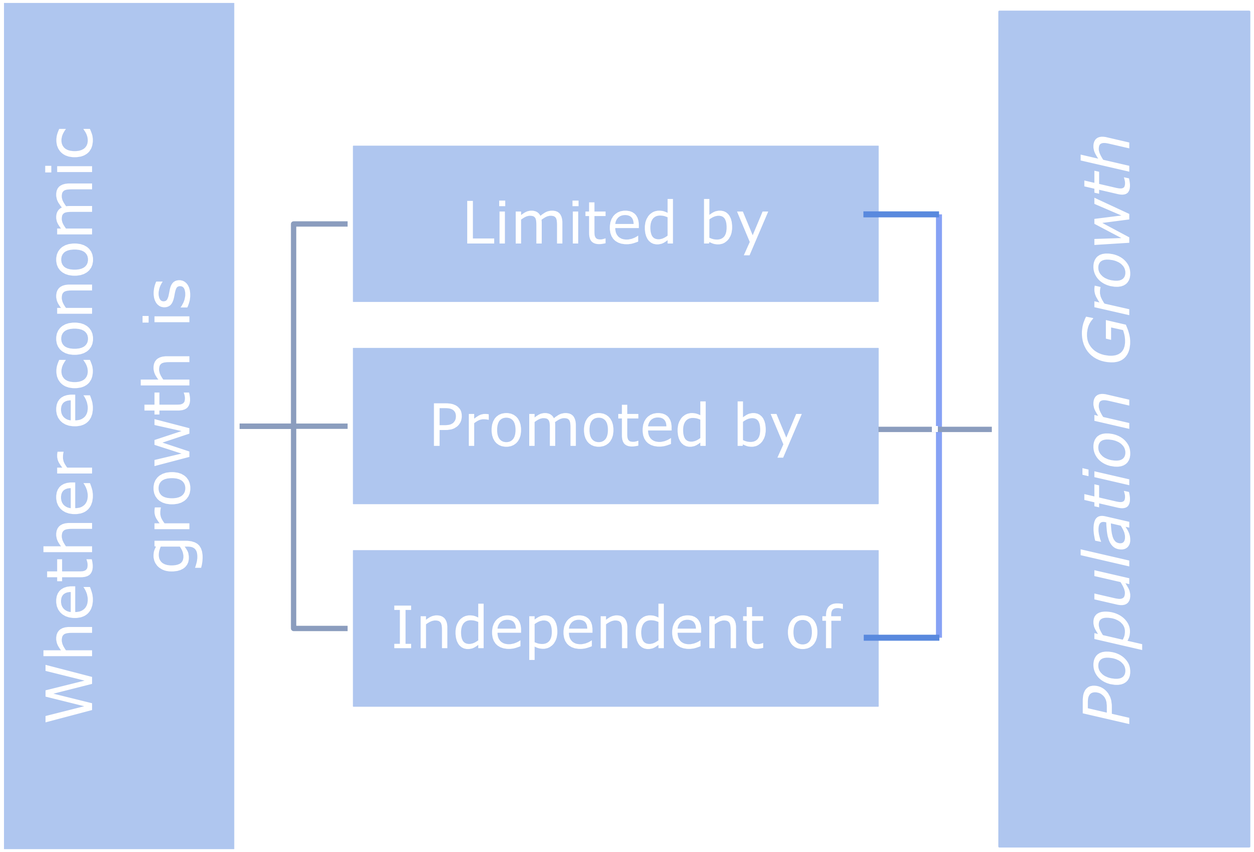
The effects on the composition of consumption, notably on energy demand and emissions, are not yet known

This article estimates the changes in the pattern of consumption in Brazil due to the changes projected in the age pyramid in 2050 and the consequences of these changes on CO_2 emissions

Outline

- Introduction
- Evidence from the Literature
- Methodology
- Database
- Results
- Final Considerations

Introduction



Introduction

Pessimistic	Optimistic
• Fast population growth is a threat to limited resources, since much of the investment needs to be used to serve growing populations	• Larger population promotes technological innovation and facilitates economies of scale

However, it is not only the population growth that matters but also the age structure

The relative share of elderly people in the age pyramid may grow in the coming decades in many parts of the world

Consider the impacts of these changes on the structure of production and consumption

A country with a high proportion of elderly people may experience lower economic growth because a large proportion of the resources will have to be allocated to serve a less productive population

The consumption patterns of younger and older people are different

However, it is not only the population growth that matters but also the age structure

This change in consumption patterns and the resulting multiplier effect across the economy will reveal opportunities for expansion for some sectors and contraction in others (Dewhurst, 2006)

Most studies on this topic find that as the population ages, the importance of health sector rises and the importance of education sector decreases

Besides that, the expenditure share for food, furniture and energy can increase with age, and the shares spent on leisure, clothing and transport can decline substantially (Lührmann, 2005)

However, it is not only the population growth that matters but also the age structure

Those changes in consumption patterns would affect the energy requirements in the economy (Bin and Dowlatabadi, 2005) and, hence, would also affect greenhouse gas (GHG) emissions

Statistical analyses of historical data suggest that affluence, consumption per capita and population growth has been the main drivers of emissions growth in recent years (Dietz and Rosa, 1997; Cole and Neumayer, 2004; Fan et al., 2006; Arto and Dietzenbacher, 2014; Malik et al., 2016)

O'Neil et al. (2010) affirmed that families can affect emissions directly through consumption or indirectly through the effects on the sectors of the economy via the production chain

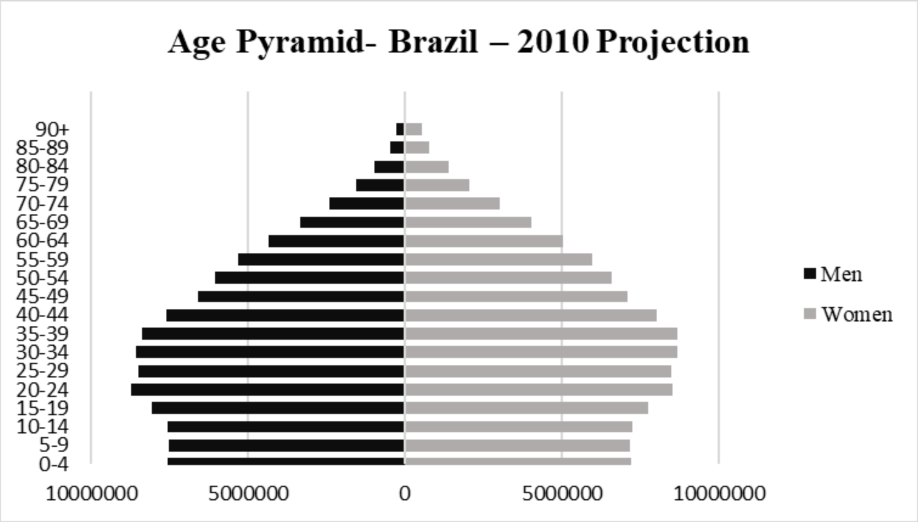
However, it is not only the population growth that matters but also the age structure

Kronenberg (2009) states that older people generally consume more heat energy and less gasoline than young people because they tend to be more sensitive to cold, and use the car less often

These changes in consumption pattern, both directly and indirectly, can affect economic growth, energy use and consequently GHG emissions, representing an important vector of emissions

Since the elderly consume less of emissions-intensive sectors, the aging population will tend to reduce emissions, neutralizing part of the positive effect of population growth on emissions

This projected demographic change affects the final demand…



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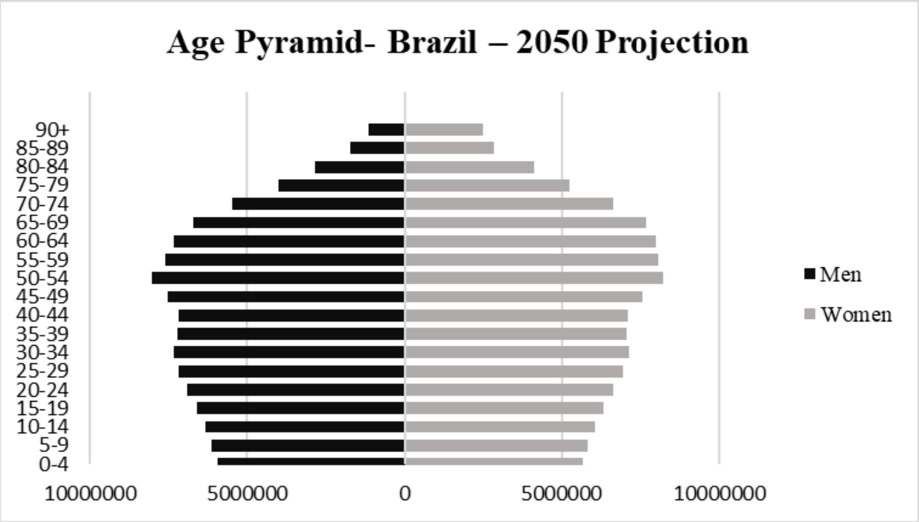

…which, in turn, generates repercussions on the production structure, energy use and emissions…

As Brazil leads the participation of developing countries' movement in the global effort to reduce GHG emissions , it is relevant to evaluate how the change of the Brazilian age pyramid will affect its future emissions ’

This article seeks to estimate the changes in the pattern of consumption in Brazil due to projected changes in the age pyramid in 2050 and the consequences of these changes on GHG, notably on CO_2 emissions.

…by changing the participation of some sectors in total production

This study focuses on CO_2 emissions because it is one of the major GHG and the energy from the combustion of fossil fuels is the main source of it

Although Brazil has a strong presence of renewable sources in its energy matrix, demand for fossil fuels accounted for 55.1% of total energy demand in 2016 (MME, 2017)

For this, projections will be made using an input–output model for the Brazilian economy for the year 2010

An input-–output model is an adequate tool because the goal of this study is to present the changes in specific consumption patterns by age group and their impacts on various sectors of the economy

Evidence for the literature

Evaluate how the population aging could affect the pattern of consumption and the composition of the different goods in the economy

Most industrialized countries are facing the phenomenon of population aging and this change will probably induce shifts in the sectoral composition of final demands (Fougère et al., 2007)

Evidence for the literature

Consumption based-approach using an input-output model: ’

- Dewhurst (2006) analyzed the effects of population aging in Scotland for 2016, disaggregating the household income column into three subsectors:
  - (i) younger families (head of household under 65 years)
  - (ii) mature families (head of household between 65 and 74 years)
  - (iii) older families (head of 75 years or older)

Methodology

In matrix terms, the solution of the model can be presented as:

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$$X = (I - A)^{-1}Y$$

An environmental input–output approach was used by incorporating sectoral CO2 emissions data to analyze the environmental impacts of changes in consumption and production

This is a method widely used in the literature (e.g. Perobelli et al., 2015; Carvalho et al., 2013; Kronenberg, 2009; Carvalho e and Perobelli, 2009; and Lixon et al., 2008)

Methodology: Projection of the Impacts of Aging on CO_2 Emissions

First step was to make a projection of the final consumption of households by sector and by age group

Second step estimated household consumption by considering the demographic projections of the Brazilian Institute of Geography and Statistics (IBGE) until 2050

Third step this projection of consumption by sector and age group was incorporated into the input–output model, making it possible to project production and emissions

Methodology: Projection of the Impacts of Aging on CO_2 Emissions

Following the method proposed in Kronenberg (2009), household consumption was disaggregated into six groups according to the age of the head of household

The families within each group are assumed homogeneous, while the composition of consumption of each group is considered constant over time

Only changes in group sizes occur, such as growth of the older group relative to the younger group

Methodology: Projection of the Impacts of Aging on CO_2 Emissions

The average household consumption:

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$$S = C\hat{h}$$

C - is the household consumption matrix by sector and age group

S - is the share matrix of the total expenditure by sector and age group

$\hat{h}$ - is the diagonal matrix of h, the vector of total consumption of the household by age group

Methodology: Projection of the Impacts of Aging on CO2 Emissions

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Total consumption matrix by sector and age group:

$$H = C\hat{n}$$

$\hat{n}$ - is diagonal matrix of n, the vector of the number of households by group

The share of consumption by sector and age group, S, is considered constant over time

The estimated vector that is going to change is n through the demographic projection

Methodology: Projection of the Impacts of Aging on CO_2 Emissions

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This assumption is in line with the goals of the article, which intends to estimate, in isolation, the changes in CO_2 emissions that could occur due to demographic changes

It is known that both S and h can change over time because of, for example, the substitution effect of changes in relative prices, income effect, or even a change in consumption patterns

However, this article intends to capture the possible impact on emissions from a change in the Brazilian age pyramid

H is the total consumption matrix by sector and age group

Methodology: Projection of the Impacts of Aging on CO_2 Emissions

The demographic and consumption projections for 2050 will be considered into the final demand of the model:

$$X = (I - A)^{-1}Y$$

Then, the resulting CO_2 emissions, and the direct and indirect effects are calculated

However, an emission intensity vector by sector is first calculated:

$$e = \hat{x}^{-1}m$$

m - is the CO_2 emissions vector that includes the sectors of the input–output model

$\hat{x}$ – the diagonal matrix of x, the vector of total output

Methodology: Projection of the Impacts of Aging on CO2 Emissions

The impact of age pyramid change on emissions is then ,

$$EM = \hat{e}(I - A)^{-1}H$$

where EM is emissions matrix that represents the impacts of aging on CO2 emissions

Database

- Input–output matrix produced by IBGE for the year 2010, which presents 67 sectors of the Brazilian economy
- POF (2008/2009)
- National Energy Balance – EPE (2009)

The first step in the preparation of the data was to aggregate the sectors of the three bases

Six age groups were defined: 1) younger than 30 years; 2) between 30 and 39 years; 3) between 40 and 49 years; 4) between 50 and 59 years; 5) between 60 to 69 years, and 6) above 70 years

Database

Distribution of families' expenditures by type of domicile in Brazil, aggregated for 15 products (in % change)

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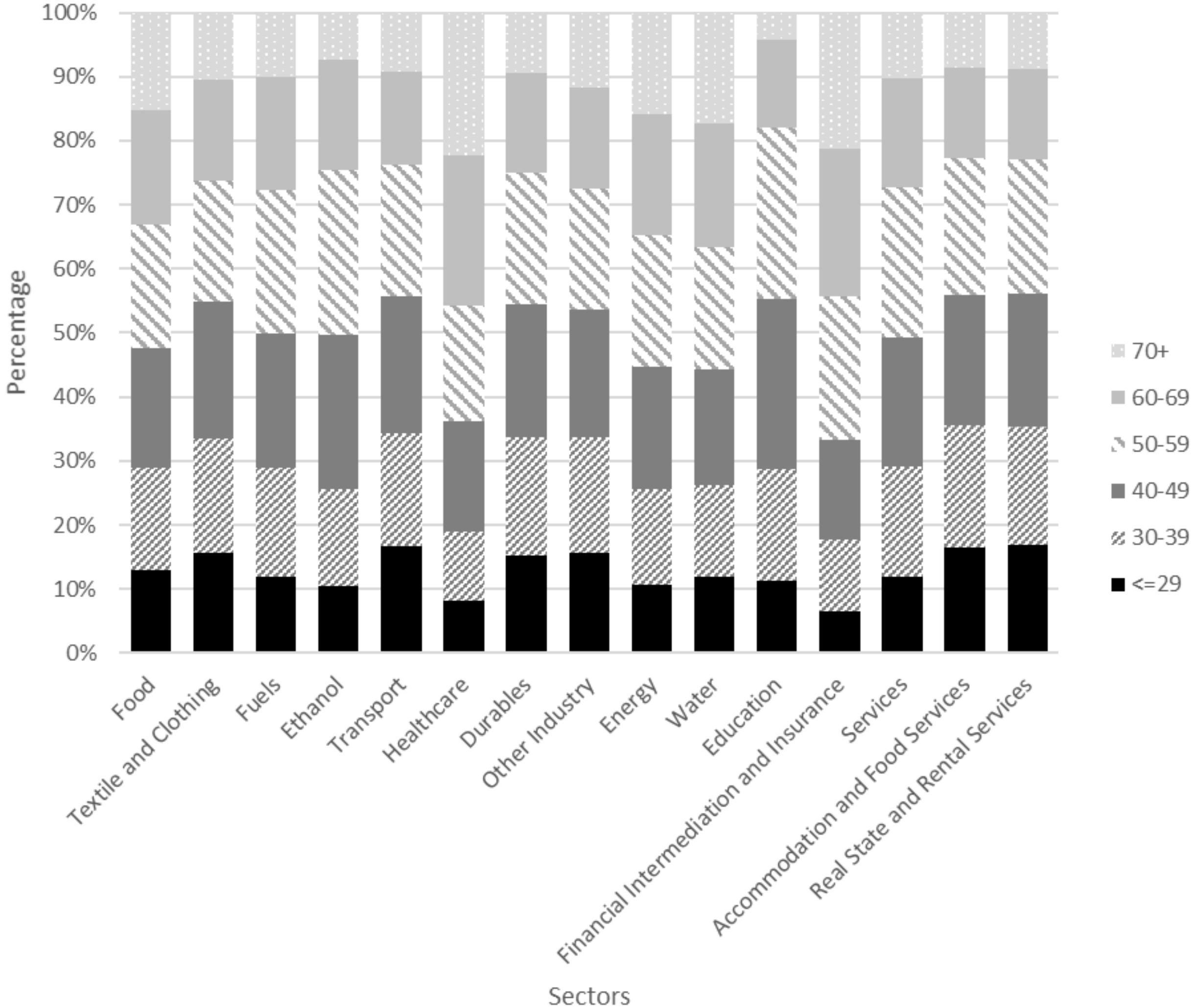
Products	Age Groups					
	<=29	30-39	40-49	50-59	60-69	70+
Food	13.70%	13.30%	12.99%	12.45%	14.22%	16.68%
Textile and Clothing	4.69%	4.13%	4.12%	3.37%	3.30%	3.01%
Fuels	2.35%	2.64%	2.69%	2.69%	2.57%	2.04%
Ethanol	0.67%	0.76%	1.00%	1.00%	0.82%	0.49%
Transport	4.35%	3.65%	3.64%	3.31%	2.86%	2.46%
Healthcare	3.40%	3.61%	4.98%	4.62%	6.93%	8.90%
Durables	6.50%	6.25%	5.84%	5.39%	4.97%	3.86%
Other Industry	4.87%	4.31%	3.86%	3.44%	3.61%	3.59%
Energy	1.96%	2.13%	2.30%	2.28%	2.57%	2.98%
Water	0.87%	0.83%	0.85%	0.85%	1.06%	1.29%
Education	2.33%	2.81%	3.58%	3.35%	2.10%	0.89%
Financial Intermediation and Insurance	4.23%	5.65%	6.62%	8.73%	11.14%	14.04%
Services	24.63%	27.66%	27.78%	29.52%	27.85%	25.87%
Accommodation and Food Services	7.00%	6.43%	5.66%	5.56%	4.49%	3.74%
Real State and Rental Services	18.46%	15.83%	14.08%	13.44%	11.52%	10.16%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Analysis and Discussion of Results



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Household footprint by expenditure category in 2010 – in share of total CO2 emissions

Analysis and Discussion of Results

Direct and indirect impacts on CO2 emissions (in Gg) of an increase by R$1 million in final demand

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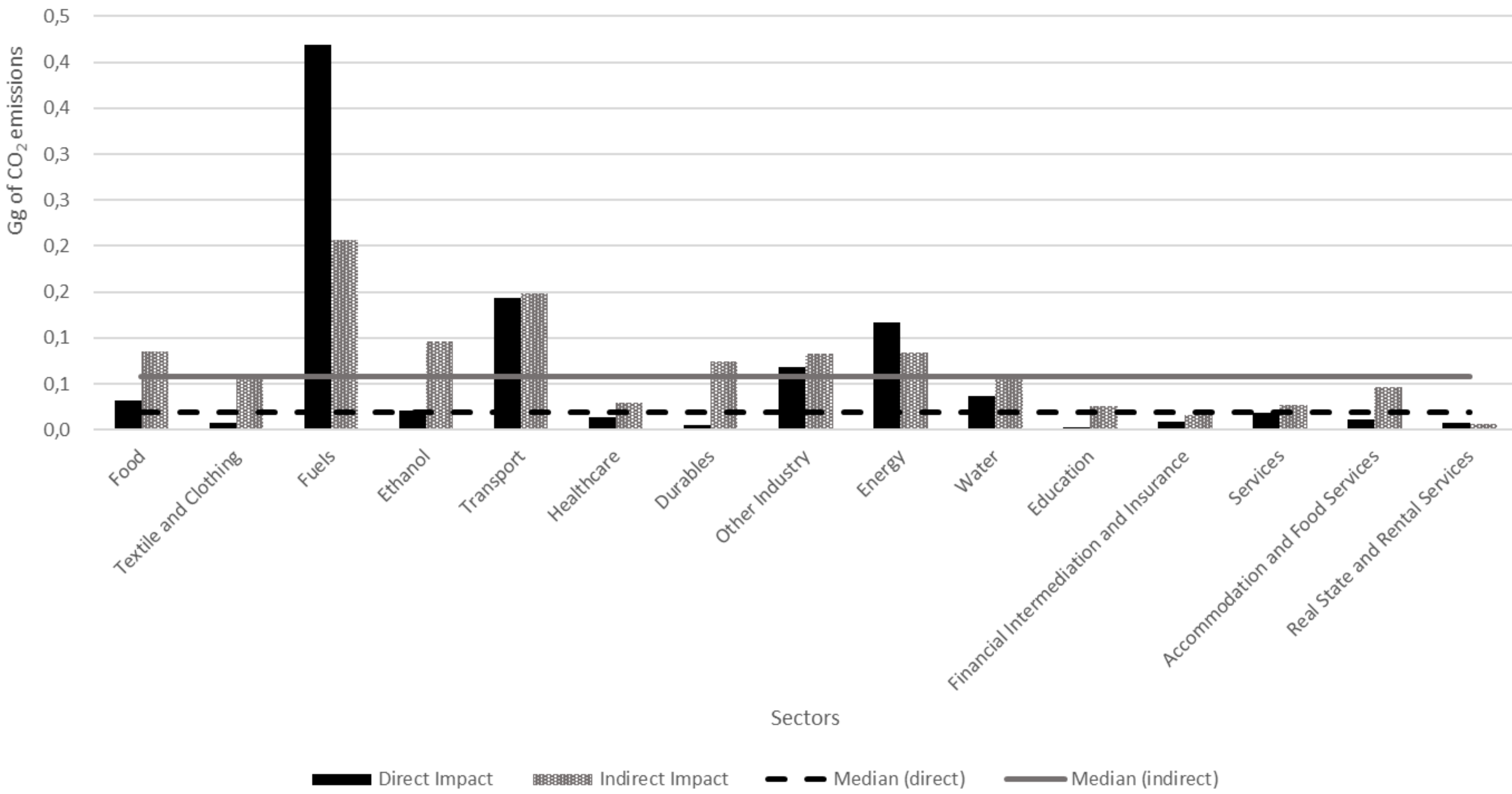
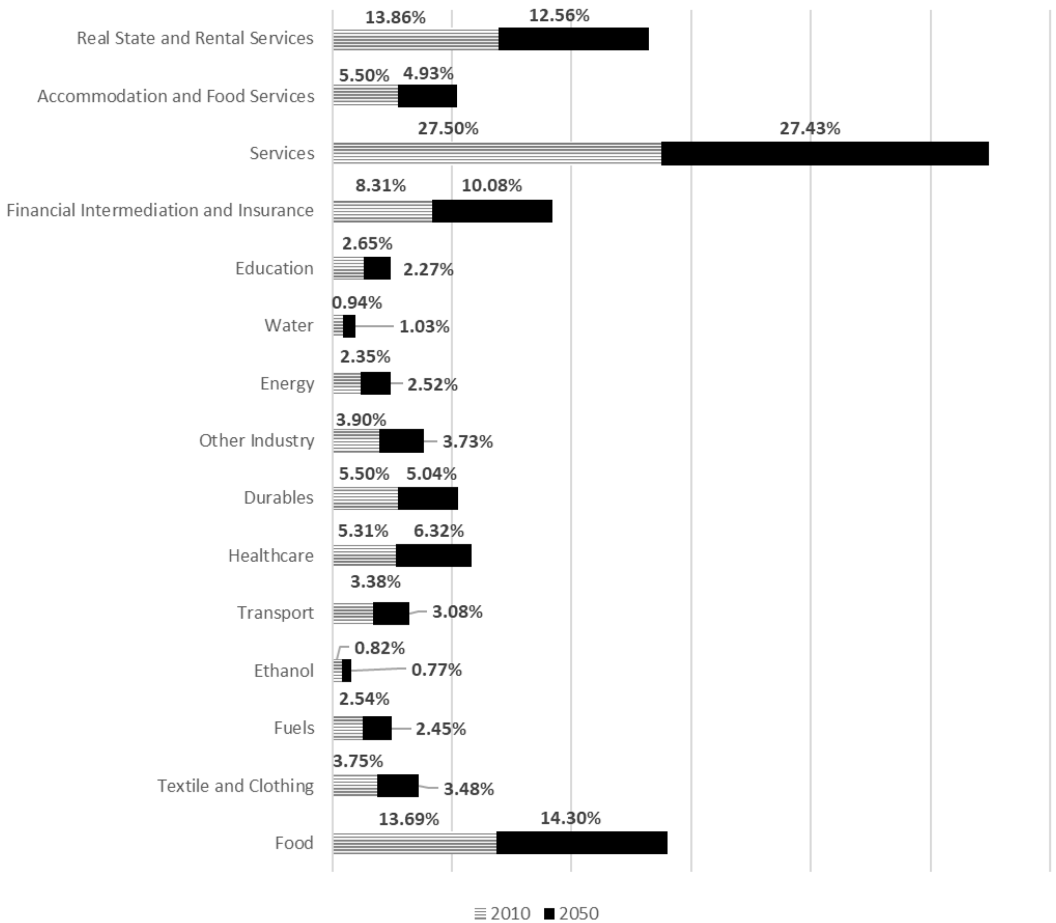


Analysis and Discussion of Results

Change in the composition of consumption vector (expenditure) by sector from 2010 to 2050



Analysis and Discussion of Results

CO2 emissions in 2010 and projected CO2 emissions in 2050 resulting from demographic change, by age group

Age Groups	2010		2050	
	Emissions Intensity	**Emissions Share**	**Emissions Intensity**	**Emissions Share**
<29	20,325.36	13%	15,304.37	4%
30-39	24,701.26	16%	36,052.49	9%
40-49	30,241.43	19%	53,598.30	13%
50-59	32,276.05	21%	79,276.13	19%
60-69	27,512.50	18%	138,505.36	33%
70+	21,069.44	13%	95,358.76	23%
Total	156,126.04	100%	418,095.41	100%

Conclusions

Demographic change has an impact on the structure of household consumption expenditure when considering different age groups

The most important impacts are observed in the healthcare and transport sectors. Household energy use is also significantly affected

Population growth, when considering the change in age structure, does not appear to cause a proportional increase in emissions

Conclusions

This result is mainly due to the reduction of participation in the consumption vector for 2050 for sectors such as fuels and transport ,

Changes in the number of individuals in each group do not generate significant changes in the structure of emissions in the sector, but they generate a change in the composition of emissions by age group

Conclusions

This article was not intended to establish definitive projections of demographic change and CO_2 emissions

The changes in the consumption patterns of each 2050 age group were calculated by considering only the population projection

The pattern of consumption within age groups is expected to change over a long period due to increased incomes, price changes, or cohort effects, for example

In addition, the input–output analysis was based on the technical coefficients of the 2010 matrix

Conclusions

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In fact, these coefficients may be affected by technological change or substitution effects. Future research, however, could incorporate such effects into a General Computable Equilibrium (CGE) model

Our results show that, unlike most developed countries, the change in the Brazilian age structure can influence the reduction pattern of emissions. Thus, the demographics characteristics as well as the economic activities structure are relevant to the

A interdependência energética entre o Estado de Minas Gerais e o restante do Brasil: uma análise inter-regional de insumo-produto

Revista de Economia Aplicada,
v. 11, p. 113-130, 2007

Fernando Perobelli Rogério Mattos Weslem Faria

Introdução

Analisa a interdependência entre o Estado de Minas Gerais e o restante do Brasil com relação ao consumo de energia ,

A análise é feita usando-se um modelo inter-regional híbrido de insumo produto por meio do qual são computadas medidas de intensidade de uso energético

Essas medidas permitem, por exemplo, avaliar o grau em que o aumento da produção de um setor de atividade dentro de Minas Gerais impacta o consumo de energia nos demais setores dentro e fora do estado

Também permite avaliar o grau em que a produção no restante do Brasil (fora de Minas Gerais) impacta o consumo de energia por setor de atividade dentro e fora do estado

Introdução

A análise desenvolvida apresenta informações ,
desagregadas segundo 14 setores de atividade, duas áreas espaciais (Minas Gerais e Resto do Brasil) e 1 tipo de energia consumida (energia total), permitindo traçar um retrato refinado dos padrões de interdependência

Os resultados obtidos apontam maior dependência do restante do Brasil em relação ao Estado de Minas Gerais do que o contrário

Metodologia

A análise desenvolvida apresenta informações ,
desagregadas segundo 14 setores de atividade, duas áreas espaciais (Minas Gerais e Resto do Brasil) e 1 tipo de energia consumida (energia total), permitindo traçar um retrato refinado dos padrões de interdependência

Os resultados obtidos apontam maior dependência do restante do Brasil em relação ao Estado de Minas Gerais do que o contrário

Formalização do Modelo de Insumo-Produto

Modelo Inter-regional para 2 regiões (L e M) e n setores

$$z_{11}^{LL} + \cdots + z_{1n}^{LL} + z_{11}^{LM} + \cdots + z_{1n}^{LM} + y_1^L = X_1^L$$

$$\vdots$$

$$z_{n1}^{LL} + \cdots + z_{nn}^{LL} + z_{n1}^{LM} + \cdots + z_{nn}^{LM} + y_n^L = X_n^L \qquad (1)$$

$$z_{11}^{ML} + \cdots + z_{1n}^{ML} + z_{11}^{MM} + \cdots + z_{1n}^{MM} + y_1^M = X_1^M$$

$$\vdots$$

$$z_{n1}^{ML} + \cdots + z_{nn}^{ML} + z_{n1}^{LM} + \cdots + z_{nn}^{MM} + y_n^M = X_n^M$$

Vendas do setor n para o setor j.

Vendas do setor n para atendimento da demanda final .

o valor da produção do setor n.

Formalização do Modelo de Insumo-Produto

Modelo Inter-regional para 2 regiões (L e M) e n setores

Representação Matricial do sistema em (1)

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

Matriz de coeficientes técnicos

$$A = Z \circ (\hat{X})^{-1} \qquad (3)$$

Coeficientes de Requerimento Direto

Formalização do Modelo de Insumo-Produto

Modelo Inter-regional para 2 regiões (L e M) e n setores

Substituindo (3) em (2), temos:

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

Manipulando (4) algebricamente temos:

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

Onde:

$$B = (I - A)^{-1}$$

Matriz de coeficientes de requerimento total

Matriz Inversa de Leontief

Formalização do Modelo de Insumo-Produto

Modelo Inter-regional para 2 regiões (L e M) e n setores

Portanto, a matriz de coeficientes de requerimento indireto será dada por:

$$C = B - A \qquad (6)$$

-

As matrizes A, B e C provêm informações numéricas sobre o grau de dependência direta, total e indireta das atividades produtivas entre setores e regiões

Formalização do Modelo de Insumo-Produto

Incorporação do setor de energia

Extensão do modelo inter-regional de insumo-produto

Construção de uma matriz híbrida de insumo-produto

Abordagem utilizada por:

- Miller e Blair (1985)
- Gowdy e Miller (1987)
- Machado (2002)
- Hilgemberg (2004)

Formalização do Modelo de Insumo-Produto

Incorporação do setor de energia

Idéia básica:

- Incluir uma linha e uma coluna (para cada região) representando o setor energético na tabela de insumo-produto Z
- A linha corresponde às vendas de energia do setor de energia para os outros setores, com a característica de que essas vendas são medidas em unidades físicas
- A coluna representa as compras do setor energia aos outros setores com essas compras medidas em unidades monetárias

Formalização do Modelo de Insumo-Produto

Incorporação do setor de energia

Formalização

Sistema (1) pode ser escrito em sua forma híbrida:

$$
\begin{aligned}
& z_{11}^{LL} + \cdots + z_{1,n+1}^{LL} + z_{11}^{LM} + \cdots + z_{1,n+1}^{LM} + Y_1^{L} = X_1^{L} \\
& \vdots \\
& z_{n1}^{LL} + \cdots + z_{n,n+1}^{LL} + z_{n1}^{LM} + \cdots + z_{n,n+1}^{LM} + Y_n^{L} = X_n^{L} \\
& e_1^{LL} + \ldots + e_{n+1}^{LL} + e_1^{LM} + \ldots + e_{n+1}^{LM} + e_Y^{L} = e_X^{L} \\
& z_{11}^{ML} + \cdots + z_{1,n+1}^{ML} + z_{11}^{MM} + \cdots + z_{1,n+1}^{MM} + Y_1^{M} = X_1^{M} \\
& \vdots \\
& z_{n1}^{ML} + \cdots + z_{n,n+1}^{ML} + z_{n1}^{MM} + \cdots + z_{n,n+1}^{MM} + Y_n^{M} = X_n^{M} \\
& e_1^{ML} + \ldots + e_{n+1}^{ML} + e_1^{MM} + \ldots + e_{n+1}^{MM} + e_Y^{M} = e_X^{M}
\end{aligned}
\qquad (7)
$$

Setor de Energia

Formalização do Modelo de Insumo-Produto

Incorporação do setor de energia

Formalização

Sistema (7) na forma matricial:

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

Onde

$$Z^{*} = \begin{bmatrix} Z^{LL} & Z^{LM} \\ e^{LL} & e^{LM} \\ Z^{ML} & Z^{MM} \\ e^{ML} & e^{MM} \end{bmatrix} \qquad Y^{*} = \begin{bmatrix} Y^{L} \\ e_{Y}^{L} \\ Y^{M} \\ e_{Y}^{M} \end{bmatrix} \qquad X^{*} = \begin{bmatrix} X^{L} \\ e_{X}^{L} \\ X^{M} \\ e_{X}^{M} \end{bmatrix}$$

Formalização do Modelo de Insumo-Produto

Incorporação do setor de energia

Formalização

Matriz hibrida de coeficientes de requerimento direto:

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

Com base em (9) é possível re-escrever (8) como:

$$A^* X^* + Y^* = X^* \tag{10}$$

Manipulando algebricamente, temos:

$$X^* = B^* Y^* \tag{11}$$

Formalização do Modelo de Insumo-Produto

Incorporação do setor de energia

Formalização

Onde

$$B^{*} = \left(I - A^{*}\right)^{-1}$$

Matriz híbrida de coeficientes de requerimento total

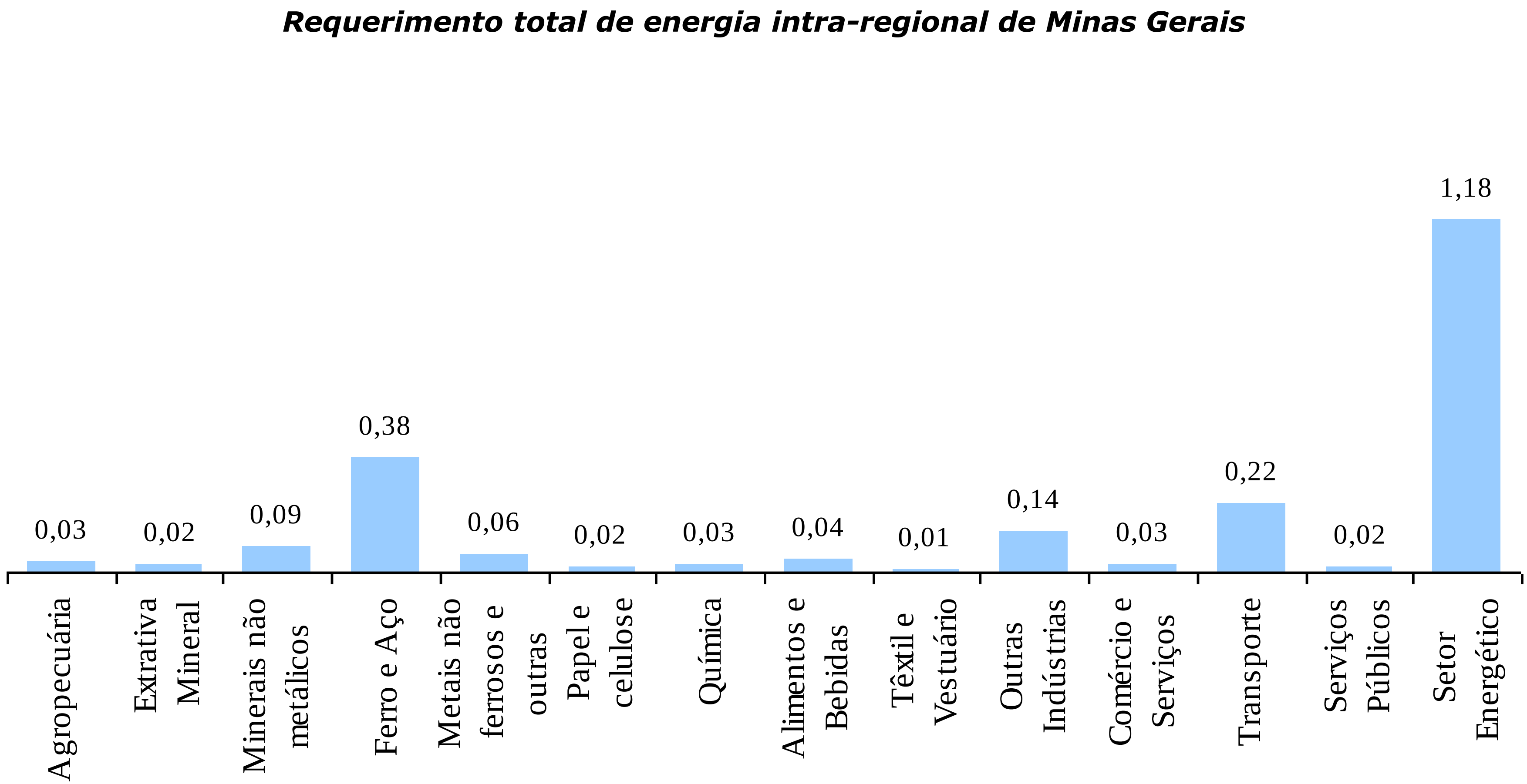
Requerimentos Totais Absolutos

	Setores	Intra	Inter
Minas Gerais	1 - Agropecuária	0,0336	0,0067
	2 - Extrativa Mineral	0,0232	0,0027
	3 - Minerais não metálicos	0,0860	0,0057
	4 - Ferro e Aço	0,3779	0,0453
	5 - Metais não ferrosos e outras metalurgia	0,0561	0,0084
	6 - Papel e celulose	0,0187	0,0022
	7 - Química	0,0289	0,0045
	8 - Alimentos e Bebidas	0,0407	0,0070
	9 - Têxtil e Vestuário	0,0099	0,0013
	10 - Outras Indústrias	0,1358	0,0198
	11 - Comércio e Serviços	0,0260	0,0046
	12 - Transporte	0,2245	0,0247
	13 - Serviços Públicos	0,0211	0,0036
	14 - Setor Energético	1,1798	0,0252
Resto do Brasil	1 - Agropecuária	0,1100	0,0500
	2 - Extrativa Mineral	0,0203	0,0068
	3 - Minerais não metálicos	0,0617	0,0201
	4 - Ferro e Aço	0,1097	0,0643
	5 - Metais não ferrosos e outras metalurgia	0,0700	0,0441
	6 - Papel e celulose	0,0700	0,0264
	7 - Química	0,1072	0,0408
	8 - Alimentos e Bebidas	0,2109	0,0961
	9 - Têxtil e Vestuário	0,0272	0,0156
	10 - Outras Indústrias	0,1842	0,0971
	11 - Comércio e Serviços	0,1421	0,0563
	12 - Transporte	0,4372	0,1047
	13 - Serviços Públicos	0,0558	0,0188
	14 - Setor Energético	1,2652	0,1613

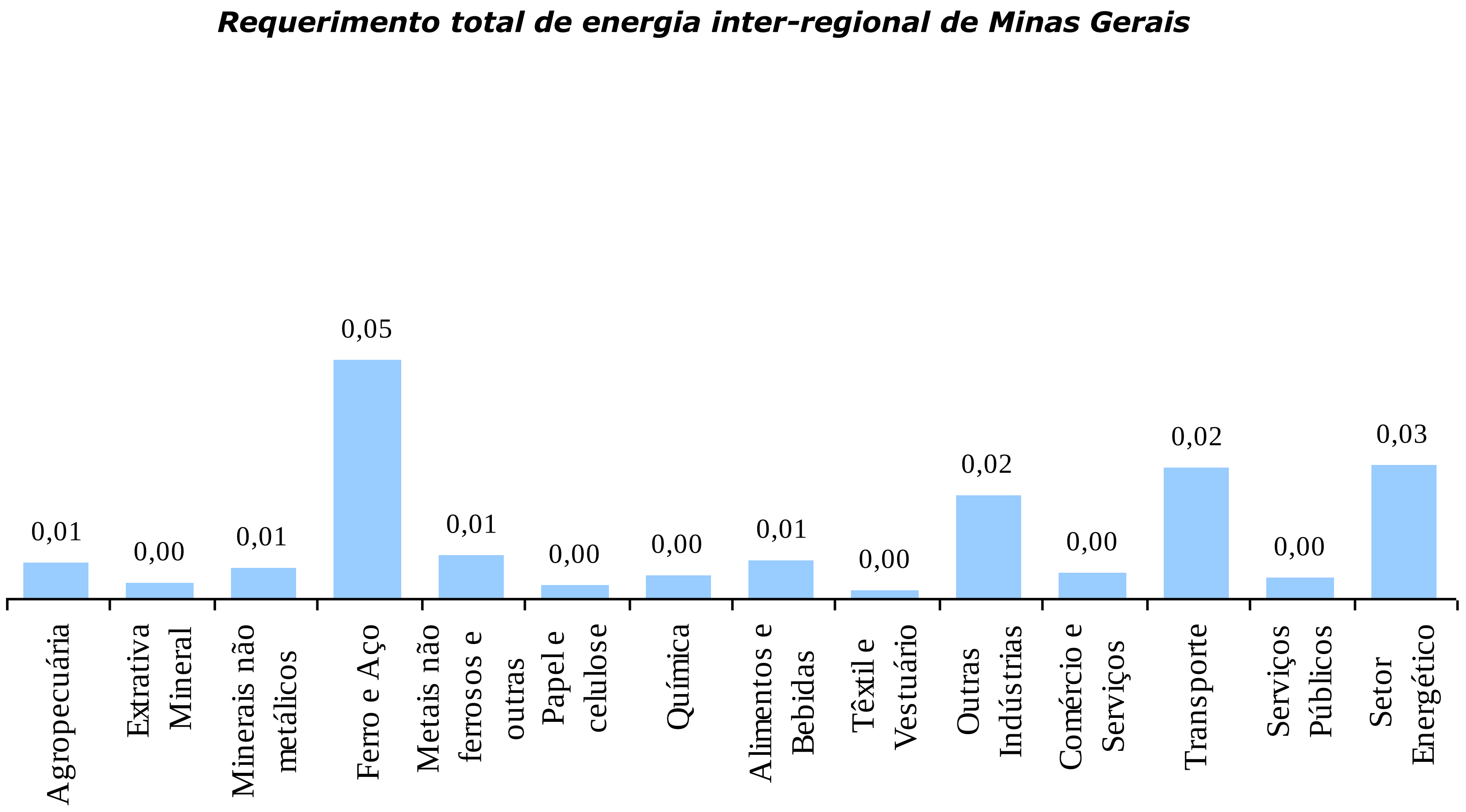
Fonte: Elaborado pelos autores

Requerimento total de energia

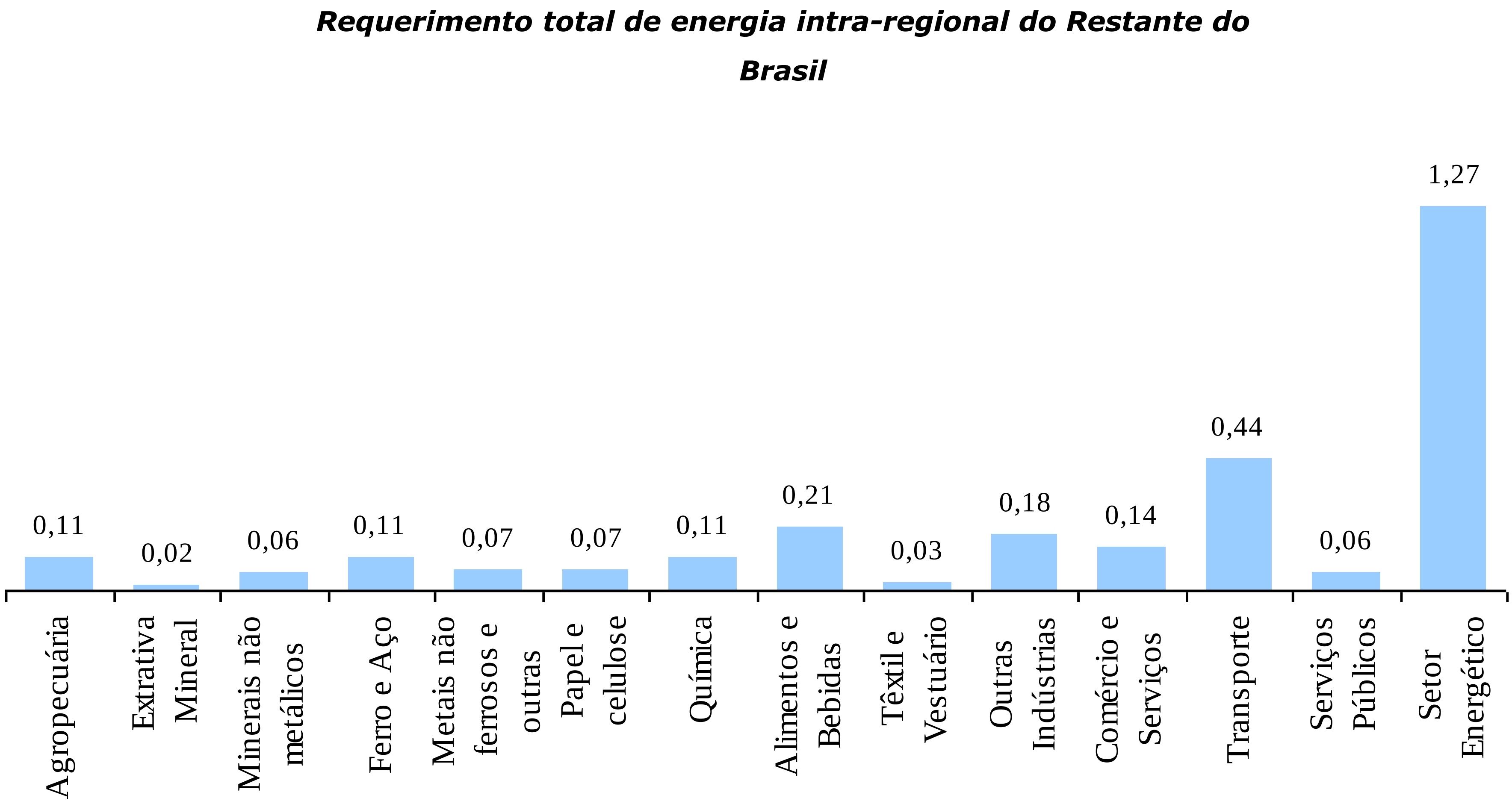
Requerimentos Totais Absolutos



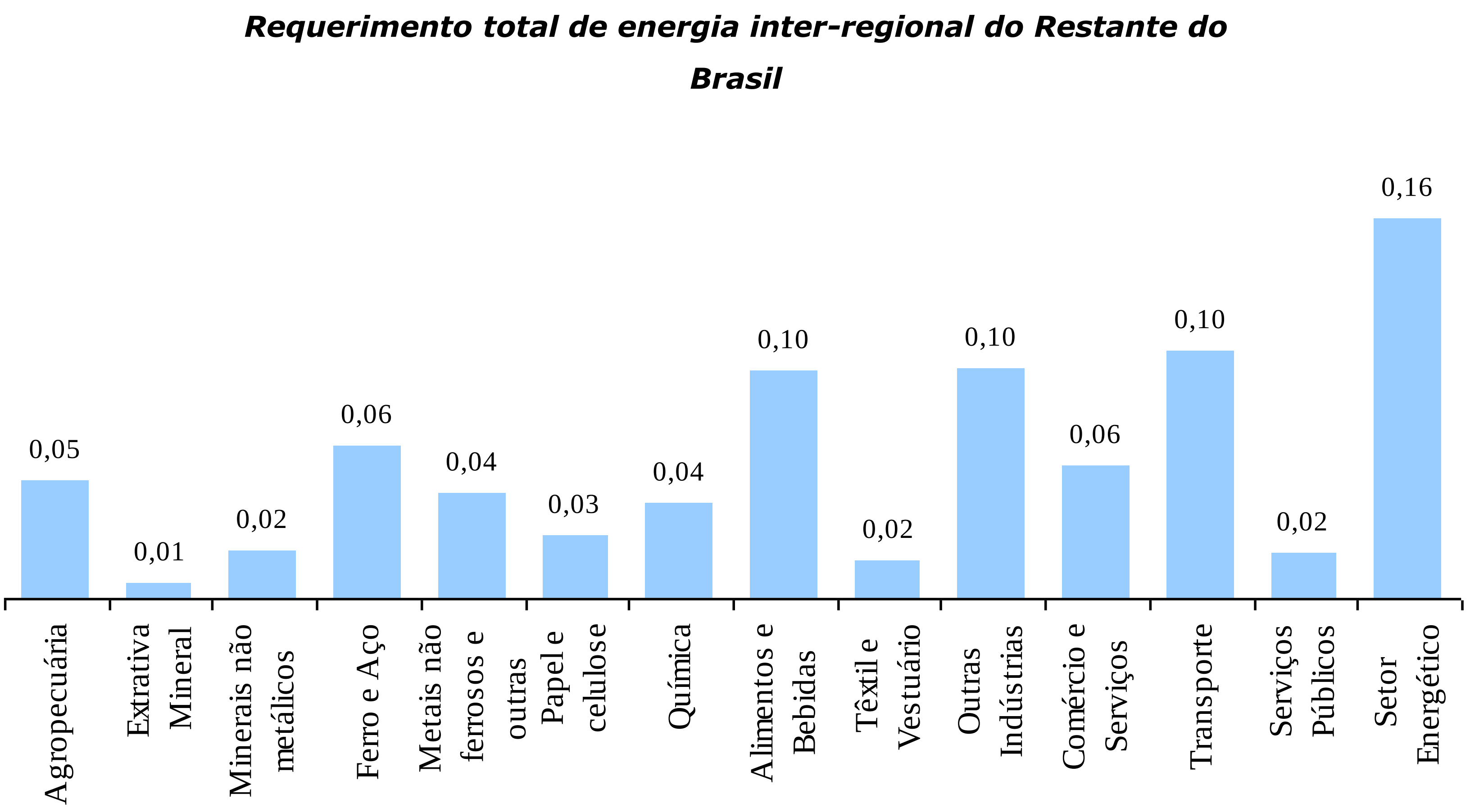
Requerimentos Totais Absolutos



Requerimentos Totais Absolutos

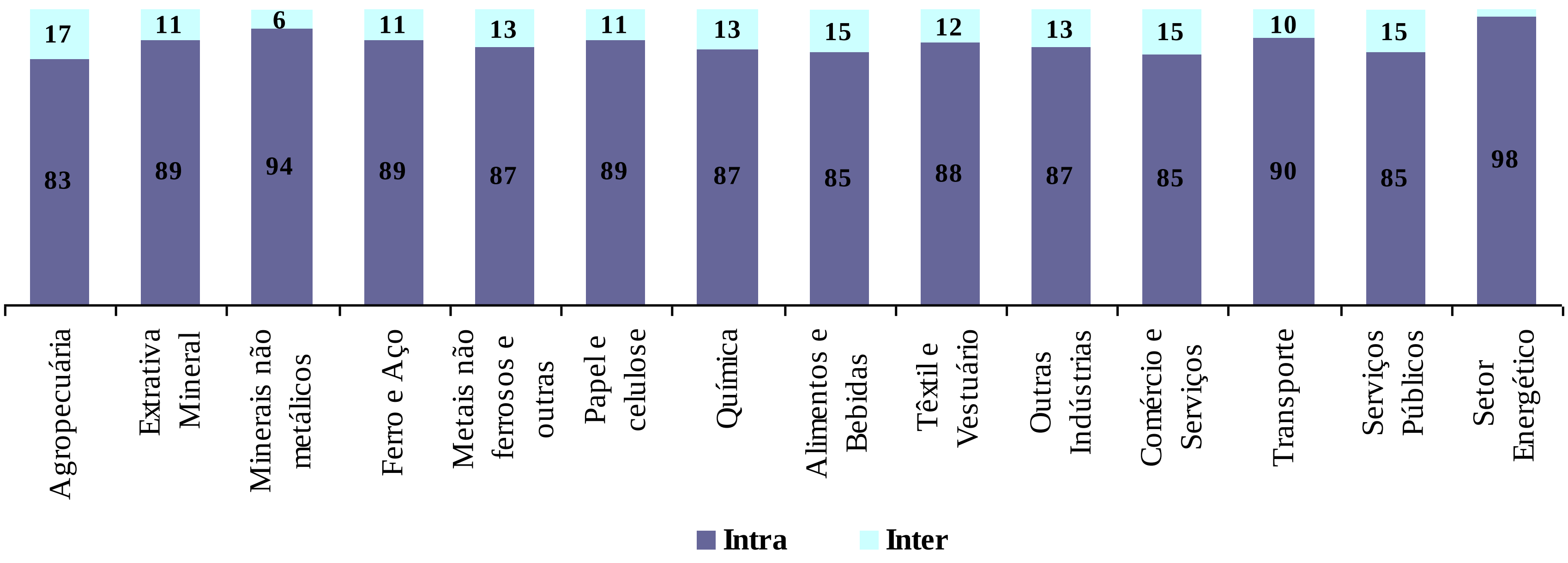


Requerimentos Totais Absolutos

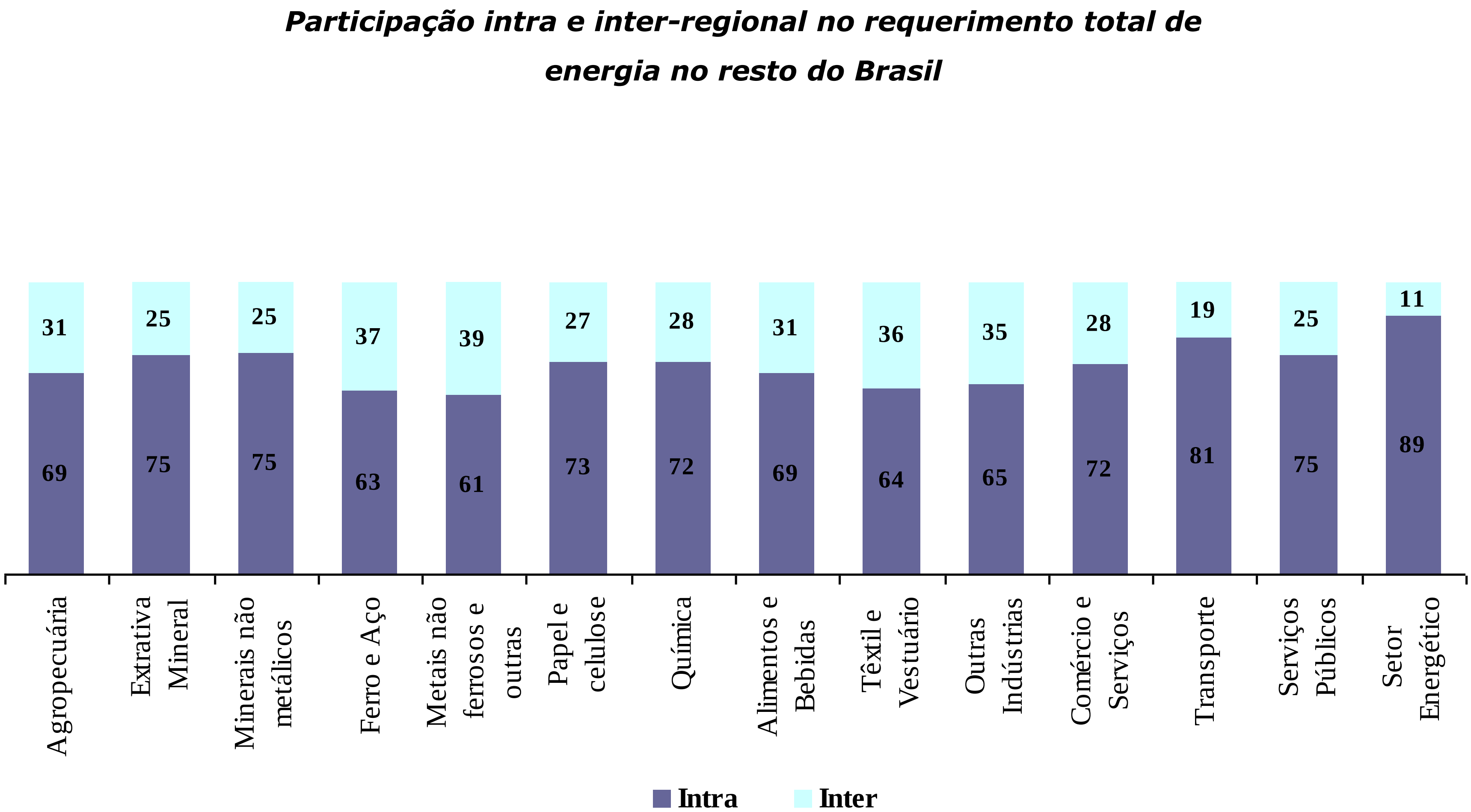


Decomposição Regional dos Requerimentos

Participação intra e inter-regional no requerimento total de energia em Minas Gerais

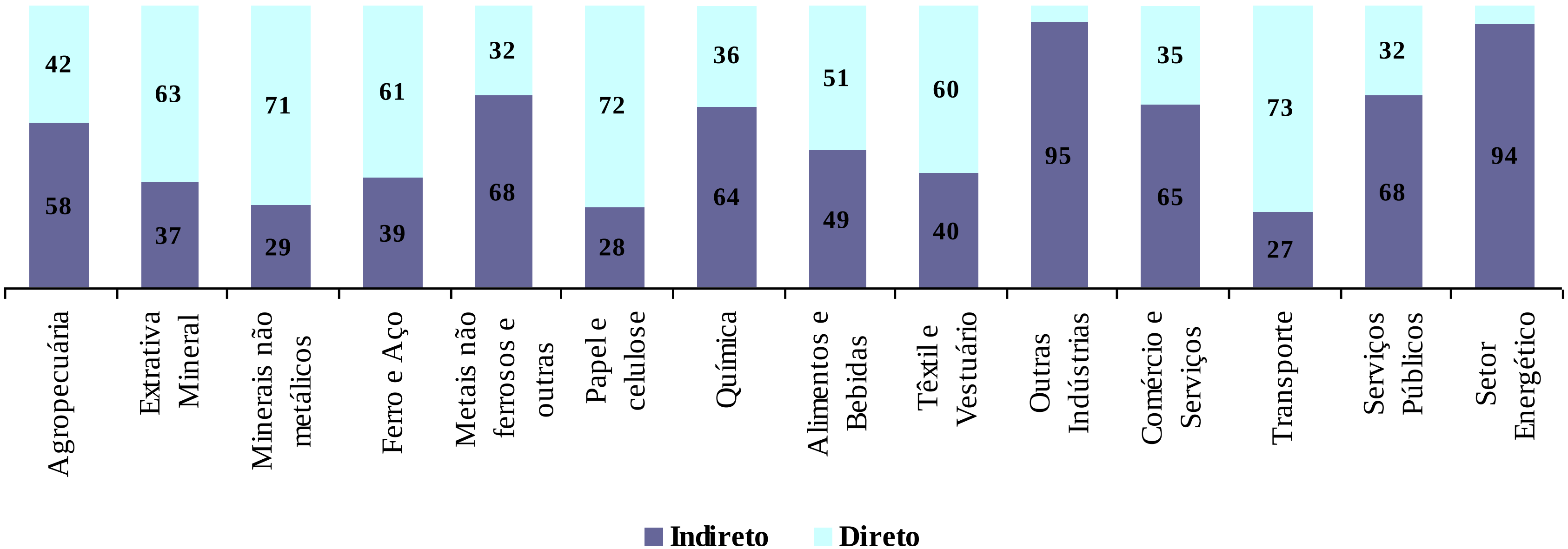


Decomposição Regional dos Requerimentos



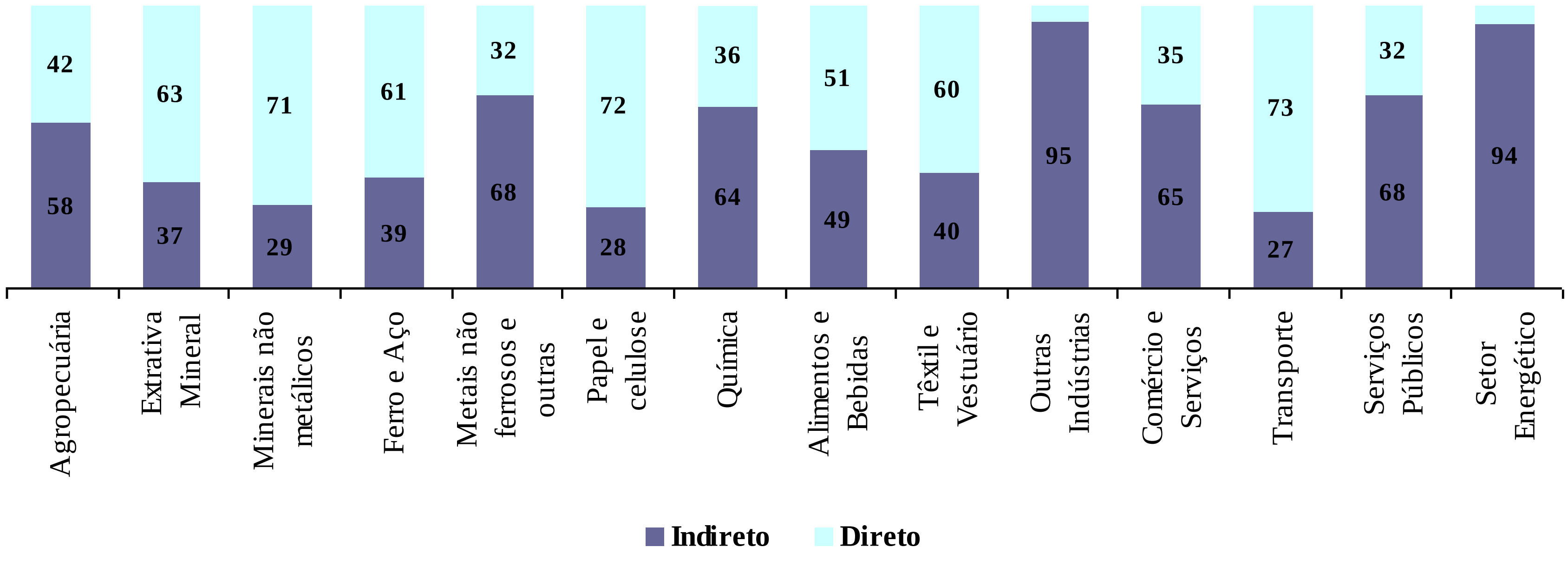
Componentes Direto e Indireto dos Requerimentos Regionais

Minas Gerais: Participação percentual setorial no requerimento total intra-regional



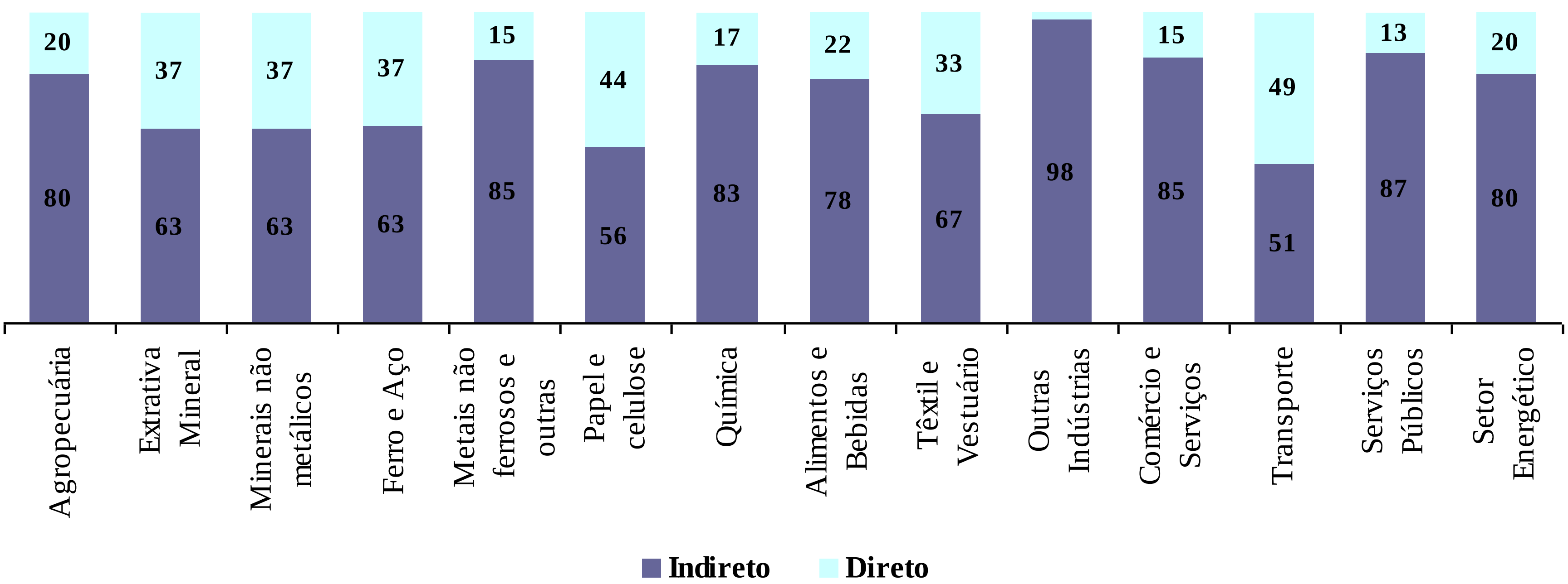
Componentes Direto e Indireto dos Requerimentos Regionais

Resto do Brasil: Participação percentual setorial no requerimento total intra-regional



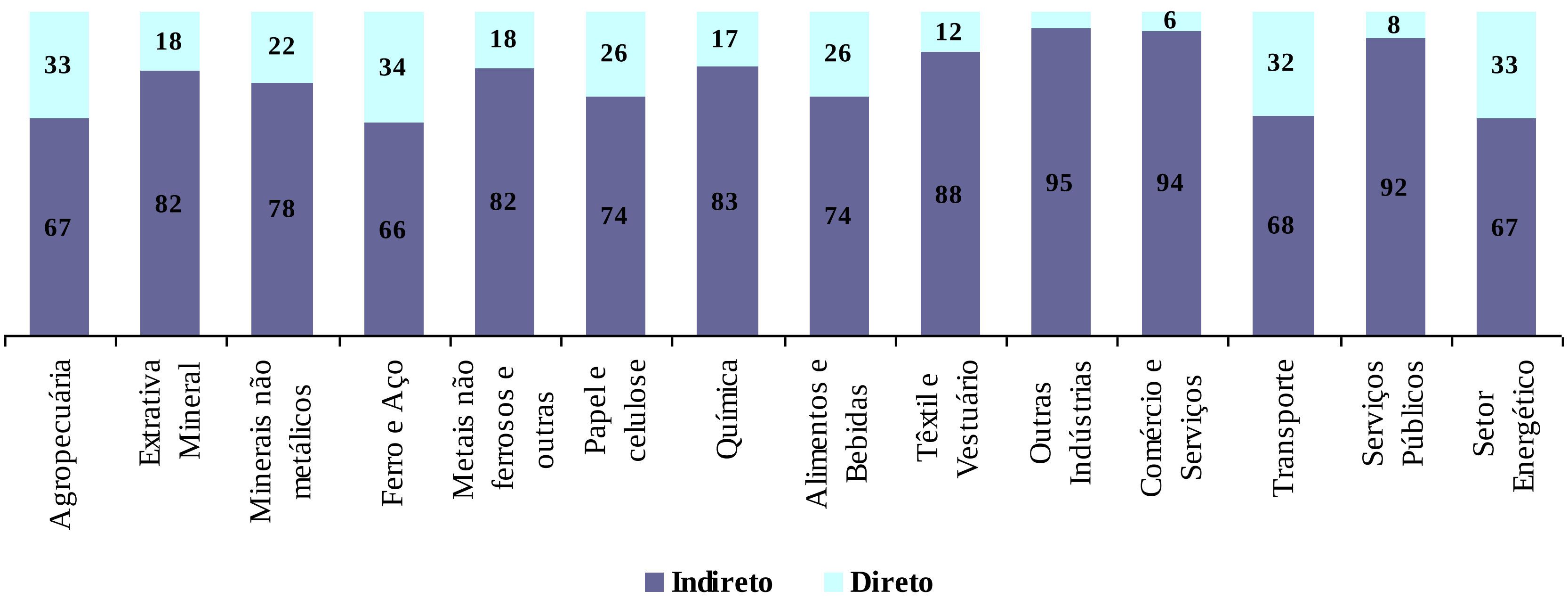
Componentes Direto e Indireto dos Requerimentos Regionais

Minas Gerais: Participação percentual setorial no requerimento total inter-regional



Componentes Direto e Indireto dos Requerimentos Regionais

Restante do Brasil: Participação percentual setorial no requerimento total inter-regional



Conclusão

A análise dos requerimentos permite visualizar os efeitos de uma mudança no uso de um recurso limitado (i.e. energia em Minas Gerais e resto do Brasil)

Antes de apresentar ao planejador energético ou ao formulador de política econômica um portfólio de alternativas para o desenvolvimento é importante ter em mente qual o impacto de tais alternativas de desenvolvimento sobre a demanda de energia

Este estudo, ao enfatizar questões como requerimentos de energia pode gerar informações importantes no que se refere à quantidade de energia necessária para o desenvolvimento e/ou crescimento de cada setor econômico