# Modal composition of cargo transportation and income inequality in Brazil

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# Modal Composition of Cargo Transportation and Income Inequality in Brazil

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## Abstract

A Leontief-Miyazawa model was estimated to measure the income distribution effects of changes in the modal composition of cargo transportation in Brazil. It was calibrated for year of 2004, and considers 31 sectors (4 of which are related to cargo transportation: road, rail, water, and air), and 10 income brackets. A transfer of 10% of road transportation to rail or water was simulated. The results show that the relative impacts are small, considering the size of the Brazilian economy and the small importance of the transportation sector. Increases in the share of rail or water transportation will increase GDP and personal income, but will decrease employment. Increases in the share of rail transportation will have more positive effects on personal income and income distribution than increases in the share of water transportation. A change to water will result in a larger GDP change and a smaller number of jobs lost in comparison to a change to rail. Although rail and water present larger shares of intermediate purchases from pro-poor sectors than road transportation, the latter distributes directly more income to the low income brackets. On balance, the result is a very modest change in the Gini coefficient.

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## 1. Introduction

Brazil is a large country with a complex and inefficient transportation system. It is been argued that the problems related to this sector are at the nucleus of the so called "Brazil Cost". The process of growth generates an increasing demand of transportation of products and raw materials. Any weakness of the transportation system restricts the development not because it restricts gain possibilities through commerce, but also because a poor infrastructure can affect adversely the productivity growth in other sectors.

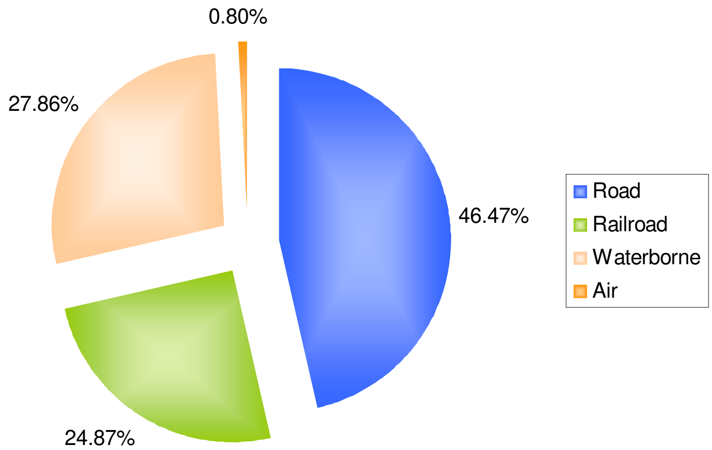
Table 1 and Figures 1 and 2 present the volume of Brazilian modal composition of cargo transportation in 2004. It is clear that road dominates, with over 46% of volume, followed by water and, in third place, rail. More than 60% of the load is transported in highways. Water transportation is second in terms of volume but accounts for only 14.2% of the total ton-km in the economy, while the share of the railroads is 21.6%.

**Table 1 – Modal Composition of Cargo Transportation in Brazil, 2004**

| Mode | Volume (ton) | | Ton-km of freight (million) | |
|---|---|---|---|---|
| Road | 665.578.033 | 46,5% | 485.625 | 63.8% |
| Rail | 356.136.024 | 24,9% | 164.809 | 21.6% |
| Water | 398.965.699 | 27,9% | 108.000 | 14.2% |
| Air | 11.457.095 | 0,8% | 3.169 | 0.4% |
| Sum | 1.432.136.851 | 100,0% | 761.603 | 100.0% |

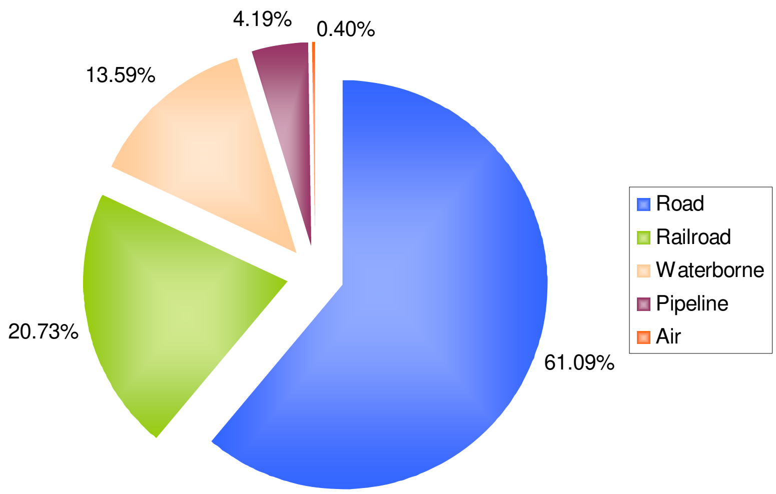
Source: CNT.

**Figure 1– Shares of Different Transportation Modes – Volume**




Source: CNT.

**Figure 2 – Shares of Different Transportation Modes – Ton-Km of Freight**




Source: CNT.

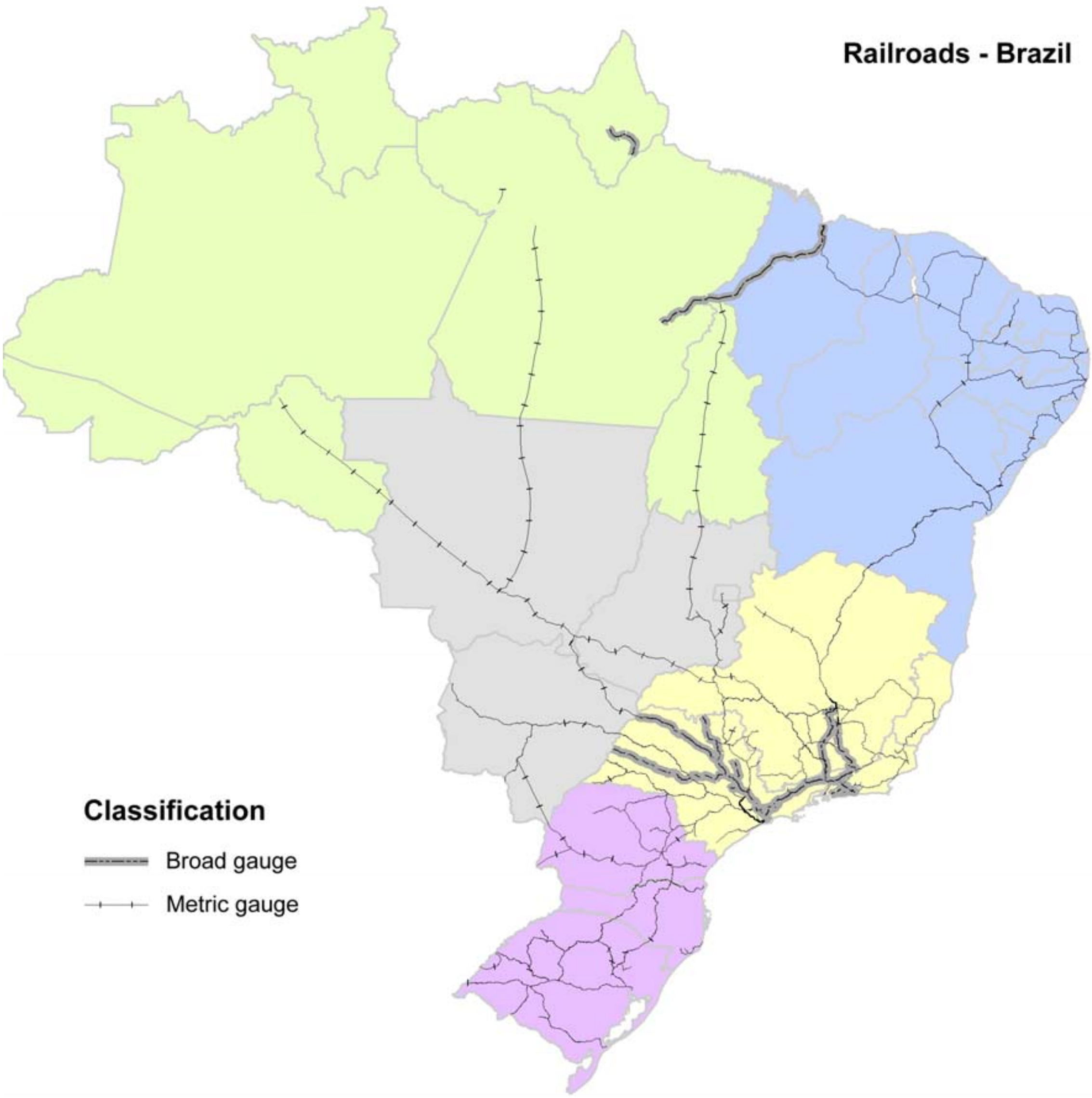
The Brazilian modal distribution of cargo transportation, excessively concentrated in the highways system, which is showed in Figure 3, is the result of a process of fast and disproportional enlargement of the road sector, relatively to the other modes. In consequence, the road network is an important instrument to the greater agility in the transportation of cargo and passengers, since the highways are fundamental links in the modern production chains, in function of their great flexibility and capability of answering fast to the demands – the highways, then, are relevant assets that should be maintained and amplified.

**Figure 3 – Highways in Brazil**


Source: Caliper of Brazil.

The actual railroad system, showed in Figure 4, has developed in an accelerated way from 1854, when it was inaugurated the first railroad, to 1920. The decade of 1940 marks the beginning of the stagnation process, stressed with the central government emphasis in the highway system. Many railroads and its branches were deactivated diminishing its length from 23,790.44 miles, in 1960, to 16,565.13 miles in 1980. The petroleum crisis in the decade of 1970 has shown the necessity of a correction in transportation policy, but the adoption of efficient provisions to recover, modernize and maintain the national railroad system were restrained by financial crisis.

**Figure 4 – Railroads in Brazil**




Source: Caliper of Brazil.

Any attempt to change the modal composition of cargo transportation will require investments and will produce many consequences into the economic system. Of special interest to this study is the impact of these possible changes on income inequality in the country. For that, a Leontief-Miazawa type of model was estimated, allowing for the estimation of the effects of changes in the participation modes of transportation on the Gini coefficient, a national indicator of income inequality. The next section presents the methodology, indicating how the impacts were measured. Section 3 describes the data used in the study, indicating sources and presenting general information on their main characteristics. The results of the estimation of the model are presented and discussed in Section 4. The last section concludes the study.

## 2. Methodology

In order to analyze the impacts of changes in the modal composition of cargo transportation in Brazil, a Leontief-Miazawa type of model will be estimated. The input-output relationships are considered, but so are the sectoral distribution of income to households in different income brackets, and the sectoral allocation of consumption expenditures by households.

### The Static Model

The intersectoral flows existing in a given economy, which are determined by both technological and economic factors, can be described by a system of simultaneous equations represented by

$$X = AX + Y \qquad (1)$$

where $X$ is a (n x 1) vector with the total output of each sector, $Y$ is a (n x 1) vector of final demand for each sector, and $A$ is a (n x n) matrix of technical coefficients of production (Leontief, 1951). The sectoral final demands are usually treated as exogenous to the system and, therefore, the output vector is uniquely determined given the final demand vector, that is,

$$X = (I - A)^{-1} Y \qquad (2)$$

where $I$ is the (n x n) identity matrix and $(I - A)^{-1}$ is the (n x n) Leontief inverse matrix.

The vector of final demands, however, is the sum of a vector of consumption demands and a vector of exogenous demands (i.e., government expenditure, investment, and exports):

$$Y = Y^c + Y^e \qquad (3)$$

where $Y^c$ is the (n x 1) vector of consumption demand and $Y^e$ is the(n x 1) vector of exogenous demand.

Considering that consumption demand are related to income, in the tradition of Keynes and Kalecki (see Miyazawa, 1960, 1963, and 1976, Keynes, 1936, e Kalecki, 1968 e 1971), the multisectoral consumption function is defined as

$$Y^c = CQ \qquad (4)$$

where $C$ is a (n x r) matrix with the consumption coefficients, and $Q$ is a (r x 1) vector with the total income of each income group.

Let $E$ be a matrix whose elements $e_{ik}$ represent the total amount of the $i^{th}$ commodity consumed by the $k^{th}$ income group, and $c_{ik}$ be defined as

$$c_{ik} = \frac{e_{ik}}{q_k} \qquad (5)$$

Since "(...) the consumption structure generally depends on the structure of income distribution" (Miyazawa, 1976, p. 1), it is necessary to include the way income is distributed by sector. The income-distribution structure can be represented by the simultaneous equations

$$Q = VX \qquad (6)$$

where $V$ is a (r x n) matrix with the value-added ratios. The simultaneous equations (6) represent the fact that the productive structure prevailing in a country is associated to a corresponding structure of income distribution.

Let $R$ be a matrix whose elements $r_{kj}$ represent the income of the $k^{th}$ group earned from the $j^{th}$ sector. Then, $v_{kj}$ is given by

$$v_{kj} = \frac{r_{kj}}{x_j} \qquad (7)$$

To solve static model we start by substituting (3), (4), and (6) into (1), getting

$$X = AX + CVX + Y^e \qquad (8)$$

whose solution is $X = (I - A - CV)^{-1} Y^e \qquad (9)$

Moreover, it is convenient to express the matrix in (9) as the product of $B = (I - A)^{-1}$ - which reflects the production flows - and another matrix reflecting the endogenous consumption flows, that is,

$$X = B(I - CVB)^{-1} Y^e \qquad (10)$$

Finally, substituting (10) into (6), the multisectoral income multiplier is given by

$$Q = VB(I - CVB)^{-1} Y^e \qquad (11)$$

which shows that the income for each group (and, of course, the aggregate income) will have different values depending on the sectors' shares in the exogenous final demand (Miyazawa, 1963 and 1976).

### 2.2. The Dynamic Model

The model derived in sub-section does not take into account time lags. To make the model more realistic, one should account for the fact that changes in the sectoral output levels do not cause changes in consumption (through changes in the different income groups) immediately, but only after a certain period of time, that is,

$$Y_k^c = CVX_{k-1} \qquad (12)$$

where *k* means a time period, and *k-1* means the previous time period. Equation (8) then becomes

$$X_k = AX_k + CVX_{k-1} + Y^e \qquad (13) \qquad \text{or} \qquad X_k - BCVX_{K-1} = BY^e \qquad (14)$$

which is a non-homogeneous system of first-order linear difference equations with constant coefficients.

Given the one-period lag between production and consumption in (12), equation (14) can be used to analyze the dynamic behavior of the model and, in particular, the convergence of the system to the steady-state solution in (8). The solution of equation (14) is given by the sum of the complementary solution - i. e., the solution of the homogeneous system - and a particular solution - i. e., a solution for the complete system (see Goldberg, 1958). The homogeneous version of (14) is

$$X_k - BCVX_{K-1} = 0 \qquad (15)$$

and its solution is given by

$$X_k = \left(BCV\right)^k G \qquad (16)$$

where the (n x 1) vector *G* will be determined by the initial condition.

A particular solution can be found by making $X_k = X_{k-1} = X$ , i.e.,

$$X - BCVX = BY^{e} \qquad (17)$$

The solution being

$$X = \left(I - BCV\right)^{-1} BY^{e} \qquad (18)$$

The final solution is then given by the sum of (16) and (18), i.e.,

$$X_{k} = \left(BCV\right)^{k} G + \left(I - BCV\right)^{-1} BY^{e} \qquad (19)$$

Given the initial condition $X_0$, vector $G$ can be found by solving the system for $k = 0$, that is,

$$G = X_{0} - \left(I - BCV\right)^{-1} BY^{e} \qquad (20)$$

Moreover, the steady-state solution of the model is given by equation (18), and is identical to the solution of the static model (equation 10)[3].

By the theory of eigenvalues and eigenvectors (Strang 1980), matrix $\left(BCV\right)^{k}$ can be expressed as

$$\left(BCV\right)^{k} = S^{k} \Lambda S^{-1} \qquad (21)$$

[3] The fact that equations (10) and (18) are identical can be seen by an algebraic manipulation of the matrices in equation (8):

$$B\left(I - BCV\right)^{-1} = \left[\left(I - CVB\right)B^{-1}\right]^{-1}$$

$$= \left[B^{-1} - CV\right]^{-1}$$

$$= \left[B^{-1}\left(I - BCV\right)\right]^{-1}$$

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

where $S$ is a (n x n) matrix whose columns (linearly independent by hypothesis) are eigenvectors of $(BCV)$, and $\Lambda$ is a (n x n) diagonal matrix with the eigenvalues of $(BCV)$.

Substituting (21) into the homogeneous solution (16) gives:

$$X_k = S^k \Lambda S^{-1} G \qquad (22)$$

As $k$ approaches infinity, the system will converge to the steady-state solution (18) if $(BCV)^k$ goes to zero. The sufficient condition for the system to converge is that the eigenvalues of $(BCV)$, $\gamma_i$, must be in the interval $0 \leq |\gamma_i| < 1$, for all *i.*

## 3. Data description

The model described in Section 2 was applied to Brazilian data in order to assess the impacts of changes in the modal composition of cargo transportation in the country on income inequality. This section describes the data used.

### The productive structure

A Social Accounting Matrix was assembled to take care of the task at hand. Its central piece is the Input-Output table, referring to 2004. Given the recent modifications in the calculation of National Accounts in Brazil[4], the system used in Moreira et all. (2007) was updated, applying the methodology presented in Guilhoto and Sesso-Filho (2005). All productive activities of the economy were allocated to one of 35 sectors, listed in Table 2. The transportation sector, which appears was an aggregate sector in the National Accounts System, was disaggregated into four cargo sub-sectors: road, rail, water, and air, and one for passenger transportation (highlighted in the Table). In order to disaggregate the transportation sector, specific information sector was gathered from

[4] http://www.ibge.gov.br/home/estatistica/economia/contasnacionais/referencia2000/2005/default.shtm

the 2004 PAS - Pesquisa Anual de Serviços (Annual Survey of Services), by IBGE[5]. The final results are presented in the appendix.

**Table 2 - List of Sectors of the I-O Table**

| | |
|---|---|
| 1 | Agriculture |
| 2 | Mineral extraction (except fuel) |
| 3 | Petrol and gas |
| 4 | Non-metallic minerals |
| 5 | Steel and Non-ferrous metallurgy |
| 6 | Machinery and equipment |
| 7 | Electric material and electronic equipment |
| 8 | All types of vehicles |
| 9 | Wood and furniture |
| 10 | Cellulose, paper and printing |
| 11 | Rubber |
| 12 | Chemical |
| 13 | Petrol refining |
| 14 | Pharmaceutical and veterinary |
| 15 | Plastics |
| 16 | Textiles |
| 17 | Apparel |
| 18 | Shoes |
| 19 | General food |
| 20 | Other manufacturing |
| 21 | Public utility services |
| 22 | Construction |
| 23 | Trade |
| **24** | **Road Transportation** |
| **25** | **Rail Transportation** |
| **26** | **Water Transportation** |
| **27** | **Air Transportation** |
| **28** | **Passengers Transportation** |
| 29 | Communication |
| 30 | Financial institutions |
| 31 | Services to households |
| 32 | Services to business |
| 33 | Building Rent |
| 34 | Public administration |
| 35 | Non-business private services |

[5] http://www.ibge.gov.br/home/estatistica/economia/comercioeservico/pas/pas2004/default.shtm

## Sectoral distribution of income

The source of income distribution data by sector is the PNAD – Pesquisa Nacional por Amostra de Domicílios, a national survey on a sample of 389,354 individuals and 139,157 households implemented in 2004[6]. The interviewers collected information on different aspects of socio-economic conditions. Of special interest for this study is the amount of income received and the sector of activity of each person. With that we could associate persons to sectors and their respective income. We considered the monthly income in the activity referring to the sector, excluding retirement payments and domestic servants. For each sector we have the total income distributed, which were allocated to ten income classes, presented in Table 3, which also presents the proportion of income appropriated. The intervals are the ones used by IBGE – Instituto Brasileiro de Geografia e Estatística, the official statistics office.

The numbers presented in the table are also plotted in Figure 5, in which the cumulative percentage of total income is displayed in the vertical axes. For comparison purposes, the income distribution profile for the aggregate of all sectors is displayed in each graph, so that comparisons can be made. It can be seen that the transportation of passengers follows a similar pattern to the average of all sectors in classes 1 and 2 and presents less concentration there-on, which indicates that it is less conducive to income concentration than the average. On the other extreme, air transportation presents less cumulative income for all classes, meaning that it is a sector with more income concentration than the average.

[6] www.ibge.gov.br/

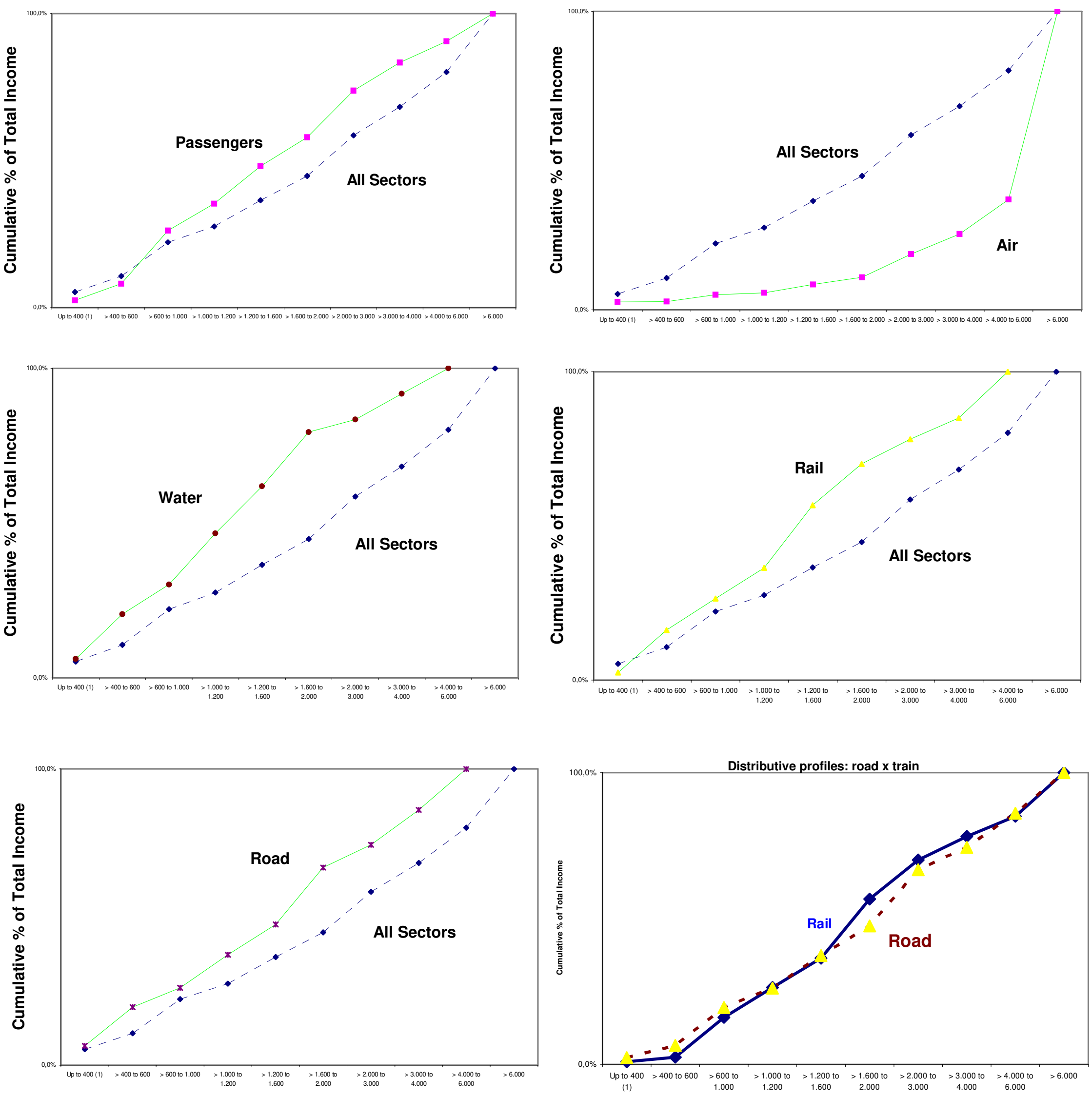
**Table 3 - Income distribution by sector**

| Income classes (R$/month) (monetary and non-monetary) | Share in Income | | | | | |
|---|---|---|---|---|---|---|
| | All Sectors | Transportation Sectors | | | | |
| | | Passangers | Cargo | | | |
| | | | Rail | Road | Water | Air |
| Up to 400 (1) | 5,3% | 2,5% | 1,0% | 2,4% | 3,5% | 2,6% |
| > 400 to 600 | 5,4% | 5,6% | 1,5% | 4,1% | 2,6% | 0,2% |
| > 600 to 1.000 | 11,5% | 18,2% | 13,8% | 13,0% | 14,4% | 2,2% |
| > 1.000 to 1.200 | 5,3% | 9,1% | 10,2% | 6,6% | 9,6% | 0,7% |
| > 1.200 to 1.600 | 8,9% | 12,8% | 10,0% | 11,2% | 16,6% | 2,8% |
| > 1.600 to 2.000 | 8,3% | 9,8% | 20,4% | 10,2% | 15,1% | 2,4% |
| > 2.000 to 3.000 | 13,7% | 15,8% | 13,4% | 19,2% | 17,6% | 7,7% |
| > 3.000 to 4.000 | 9,7% | 9,7% | 8,0% | 7,7% | 4,0% | 6,7% |
| > 4.000 to 6.000 | 11,9% | 7,2% | 6,9% | 11,8% | 8,4% | 11,6% |
| > 6.000 | 19,8% | 9,4% | 15,0% | 13,9% | 8,2% | 63,0% |
| All Classes | 100,0% | 100,0% | 100,0% | 100,0% | 100,0% | 100,0% |

Source: PNAD, 2004 (1) Includes people without income

The two more important sub-sectors, rail and road transportation, present similar profiles, distributing more income to the lower income classes. In spite of the small differences, a one-to-one comparison shows that road transportation distributes more income to lower classes, and rail transportation to middle-income classes. This provides a preliminary indication that the effect on income distribution of changes in the modal distribution of transportation among these two modes would probably have small influence on the overall income distribution.

# Figure 5 – Income distribution profiles within transportation sectors



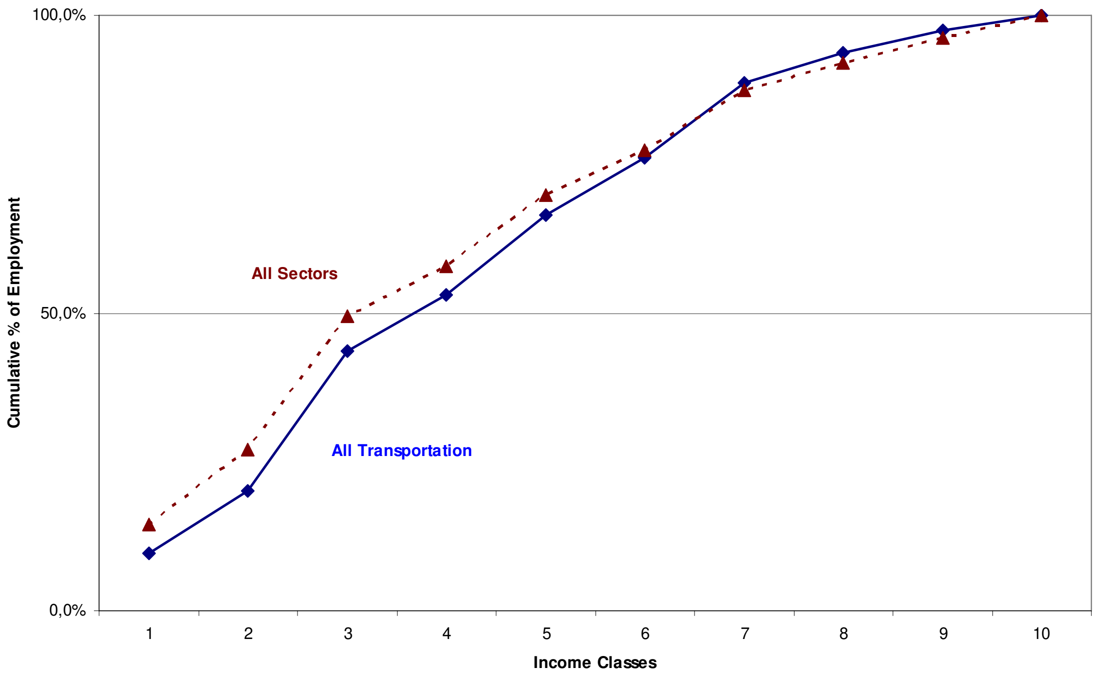

Source: Research data

## Employment by sector

PNAD also provided information on employment by sub-sector within transportation, which is displayed in Table 4. The total number of jobs in transportation in general is 3.46 million, the two largest users of labor being road transportation, with 1.561 million employers, and passenger transportation, with 1.553 million. Rail is the smallest employer, with 53,013 jobs. The aggregate of all sub-sectors is responsible for 3.93% of total employment in Brazil. This share is higher for income classes 3 to 8, and lower in the two extremes of the distribution, indicating that employment in transportation is relatively more intense in the middle income classes, especially in classes 6 and 7.

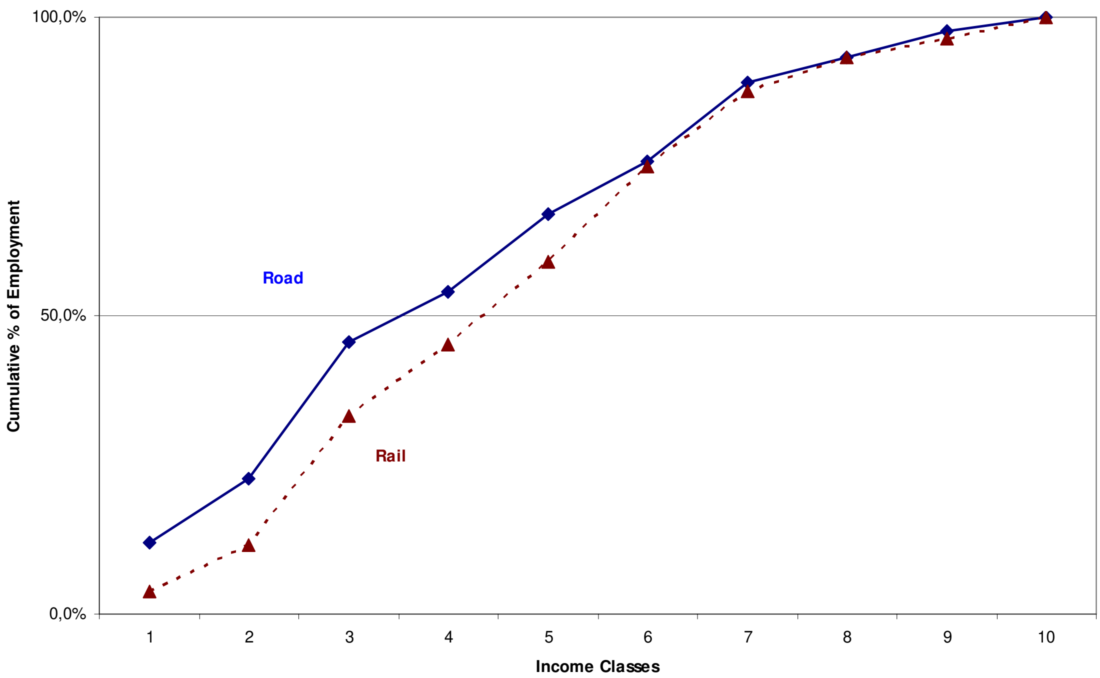
For all sub-sectors but air transportation, the bulk of employment comes from the five lowest income brackets. As compared to all sectors in the economy, the cumulative percentage of employment across income classes, as displayed in Figure 6, is smaller in the low-income classes, meaning that the profile of use of labor is more concentrated. As Figure 7 indicates, road transportation uses more labor than rail transportation in the lower income classes.

**Figure 6 – Distribution of employment by income classes**



Source: Table 4

**Figure 7 – Distribution of employment: road x rail**




Source: Table 4

**Table 4 - Employment by sub-sector within transportation**

| | Income Classes | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | All Classes |
| **Number of Employees** | | | | | | | | | | | |
| Rail | 2.037 | 4.129 | 11.456 | 6.322 | 7.312 | 8.528 | 6.704 | 2.980 | 1.610 | 1.935 | 53.013 |
| Air | 3.390 | 1.688 | 14.465 | 3.328 | 7.398 | 5.634 | 12.986 | 7.351 | 13.198 | 8.576 | 78.014 |
| Passengers | 119.858 | 175.177 | 395.568 | 164.550 | 216.373 | 147.348 | 183.024 | 78.222 | 38.795 | 34.035 | 1.552.950 |
| Water | 20.215 | 12.195 | 41.708 | 19.672 | 31.901 | 28.313 | 31.084 | 16.999 | 9.726 | 8.294 | 220.107 |
| Road | 187.132 | 168.773 | 356.389 | 132.193 | 201.350 | 139.964 | 205.801 | 65.727 | 67.910 | 36.482 | 1.561.721 |
| All Transportation | 332.633 | 361.962 | 819.586 | 326.066 | 464.334 | 329.787 | 439.600 | 171.277 | 131.240 | 89.322 | 3.465.805 |
| All Sectors | 14.411.658 | 11.546.593 | 19.837.852 | 7.220.592 | 10.024.344 | 6.395.858 | 8.364.594 | 3.800.058 | 3.391.335 | 3.252.071 | 88.244.954 |
| **Shares** | | | | | | | | | | | |
| Rail | 0,01% | 0,04% | 0,06% | 0,09% | 0,07% | 0,13% | 0,08% | 0,08% | 0,05% | 0,06% | 0,06% |
| Air | 0,02% | 0,01% | 0,07% | 0,05% | 0,07% | 0,09% | 0,16% | 0,19% | 0,39% | 0,26% | 0,09% |
| Passengers | 0,83% | 1,52% | 1,99% | 2,28% | 2,16% | 2,30% | 2,19% | 2,06% | 1,14% | 1,05% | 1,76% |
| Water | 0,14% | 0,11% | 0,21% | 0,27% | 0,32% | 0,44% | 0,37% | 0,45% | 0,29% | 0,26% | 0,25% |
| Road | 1,30% | 1,46% | 1,80% | 1,83% | 2,01% | 2,19% | 2,46% | 1,73% | 2,00% | 1,12% | 1,77% |
| All Transportation | 2,31% | 3,13% | 4,13% | 4,52% | 4,63% | 5,16% | 5,26% | 4,51% | 3,87% | 2,75% | 3,93% |
| **Cumulative percentage** | | | | | | | | | | | |
| Rail | 3,8% | 11,6% | 33,2% | 45,2% | 59,0% | 75,0% | 87,7% | 93,3% | 96,3% | 100,0% | |
| Air | 4,3% | 6,5% | 25,1% | 29,3% | 38,8% | 46,0% | 62,7% | 72,1% | 89,0% | 100,0% | |
| Passengers | 7,7% | 19,0% | 44,5% | 55,1% | 69,0% | 78,5% | 90,3% | 95,3% | 97,8% | 100,0% | |
| Water | 9,2% | 14,7% | 33,7% | 42,6% | 57,1% | 70,0% | 84,1% | 91,8% | 96,2% | 100,0% | |
| Road | 12,0% | 22,8% | 45,6% | 54,1% | 67,0% | 75,9% | 89,1% | 93,3% | 97,7% | 100,0% | |
| All Transportation | 9,6% | 20,0% | 43,7% | 53,1% | 66,5% | 76,0% | 88,7% | 93,6% | 97,4% | 100,0% | |
| All Sectors | 14,6% | 27,1% | 49,5% | 57,9% | 69,8% | 77,4% | 87,5% | 92,1% | 96,1% | 100,0% | |

Source: PNAD, 2004

## Consumption patterns by sector

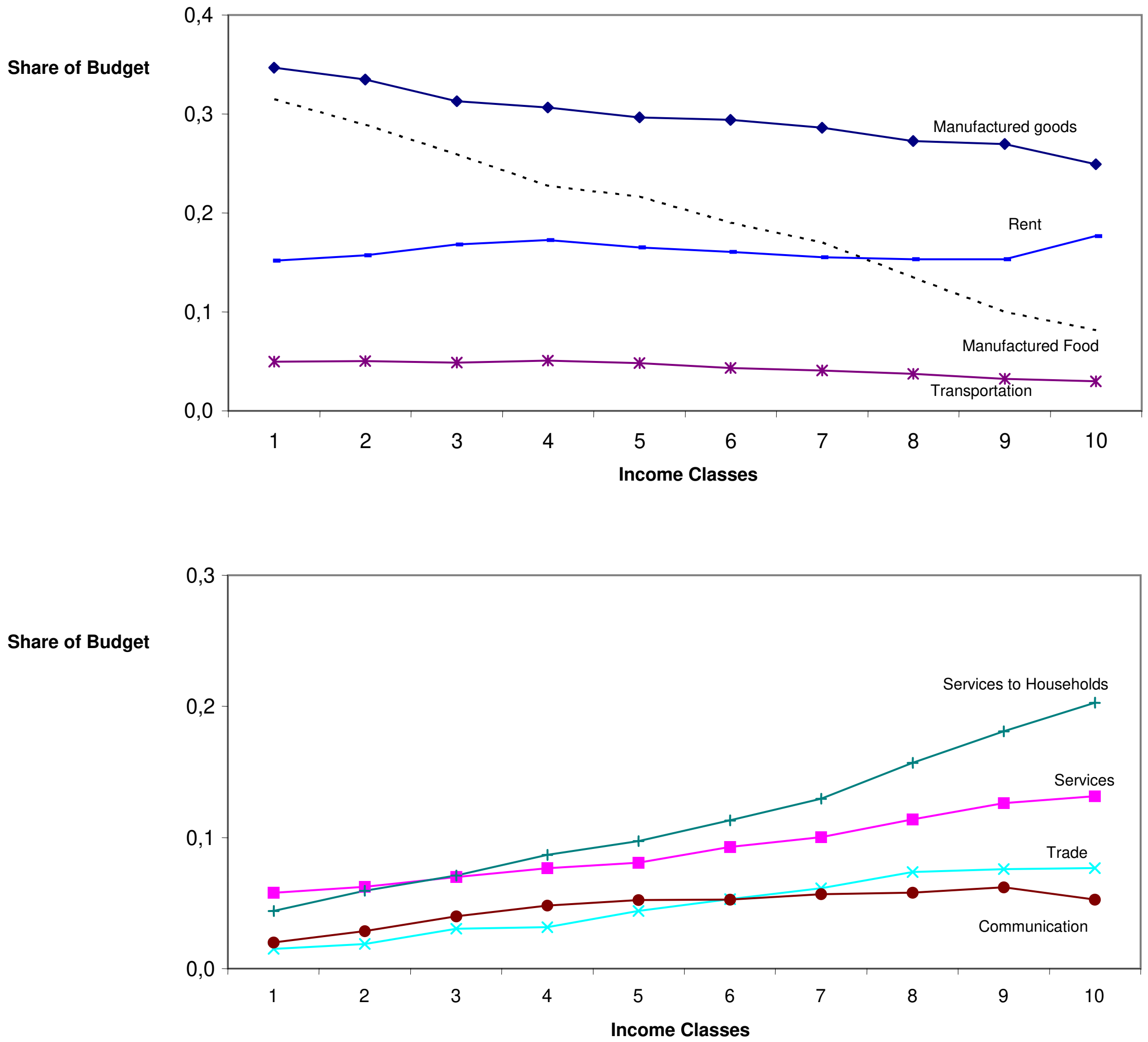
The Brazilian household expenditure survey, POF, was implemented in 2002 and 2003. Its information includes monetary and non monetary income, as well as monetary and non monetary consumption. A total of 48.470 households were interviewed, and for each one, the sources of income were identified, as well as the expenditure pattern. Expenditure by households was allocated to 10,429 types of goods and services in POF 2002/2003. These were aggregated to the 80 types of goods and services types, presented in the national accounts, and originally used in this study. We have thus estimated expenditure patterns on 80 different goods and services by each income class. With this information we were able to identify the consumption patterns of households in each of the ten income brackets considered in the income distribution section, for all sectors studied.

Figure 8 presents some information on consumption patterns by income class, for highly aggregate groups of products. It is clear, as expected, that poorer households spend a larger percentage of income on Manufactured Food, Manufactured Goods, and Transportation. These products clearly present decreasing importance on household's budget as income increases. On the other hand, Services in General, Services do Households, Trade, and Communication, present a clear up-ward trend from low to high income classes.

Transportation refers to household expenditure on this item. It includes expenditure with urban transportation (bus, taxi, subway, train, boat, and others), purchase, maintenance and fuel for private vehicles, expenditure on travel (bus, airplane etc.), parking, toll, parts for vehicles, and insurance. It shows a slight declining trend as income levels increase, especially after the fourth lowest income class. Considering the sub-sectors, the share of consumer expenditure on road transportation decreases as income grows, and increases for air transportation. For rail, the share increases until the 7$^{th}$ income bracket, and then decreases.

This sort of information is available for each sector, allowing for the calculation of the induced effects of any shock to the system. This provides de direct effects, in the sense that it portrays the first round of consumer expenditure. The amount spent by poor households on road transportation, for example, will increase the activity of that sector, which will in turn distribute income to different households. Such income will be spent in all sectors of the economy, according to the consumption coefficients. The final effects will include all rounds and dimensions of the production system, and might differ from the direct ones presented in this section.

**Figure 8: Share of different goods services in budget**




Source: POF – Pesquisa de Orçamentos Familiares 2002/2003 (IBGE)

### 3.5. Intersectoral relations and income inequality

The information on income distribution by sub-sector within the transportation sector indicates that the rail and road transportation present a similar profile, as can be seen in Figure 5. In spite of this general observation, the lines indicate that road transportation distributes income more intensively for the three lowest income classes, and that rail transportation does so for the 6$^{th}$, 7$^{th}$, and 8$^{th}$ classes.

This information indicates that a more intensive use of trains in Brazil will have an income concentration impact. However, in order to assess the full impact, other aspects have to be taken into consideration. Income is distributed to households, which in turn spend it according to the consumption patterns already shown. The final impact will depend on which sectors income is spent, regarding their distributive profile. Income distributed to low-income households might be spent in sectors with a concentration profile, and vice-versa.

But there is another way to determine the final impact, which is the profile of interrelationships between sectors regarding the input-output part of the model. In order to illustrate that, we present in Table 5 the percentage of purchases made by each sub-sector within transportation from sectors with lower-than-average inequality. Those were defined in Moreira et all. (2007), who estimated the final impact in the national income inequality of identical increases in production in each sector of the economy, considering the direct, indirect, and induced effects. If the marginal increase in production produces an inequality index (Gini) lower than the national average, the sector contributes do diminish inequality, and are labeled pro-poor in this study. Thus, the table presents the share of purchases from the sub-sectors within transportation which are made from sectors which promote reduction of inequality.

As can be observed, road cargo transportation is the sub-sector with the lowest share of purchases from pro-poor sectors, 45%. Rail cargo transportation is in the other extreme, purchasing 68% of its inputs from sectors with interrelationships within the productive system with sectors that produce lower-than-average income inequality. Thus, considering this aspect of the problem, it is expected that a change from roads to rail would promote an improvement in income distribution in the country.

**Table 5 - Profile of intermediate purchases**

| | | % of intermediate purchases from pro-poor sectors |
|---|---|---|
| Passengers | | 51,9% |
| Cargo | Water | 58,1% |
| | Air | 52,5% |
| | Rail | 68,2% |
| | Road | 45,4% |

Source: Research Data

Although these partial analyses are important to understand the mechanics through which changes in the modal distribution of transportation will influence income inequality, it is necessary to consider all factors simultaneously, which is done in the next section.

## 4. Results

The main aspect to be simulated is a change in the modal composition of cargo transportation that puts more emphasis on rail and less on roads. In terms of production value, the shares in the 2004 Input-Output table were those presented in Table 6.

Table 6 – Modal Shares in the Input-Output System

| | Intermediate Consumption | | Final Demand | | Total Consumption | |
|---|---|---|---|---|---|---|
| | R$ Million | Share | R$ Million | Share | R$ Million | Share |
| Road | 50,004 | 61.59% | 9,277 | 13.91% | 59,281 | 40.09% |
| Rail | 4,238 | 5.22% | 2,543 | 3.81% | 6,781 | 4.59% |
| Water | 8,582 | 10.57% | 5,291 | 7.93% | 13,874 | 9.38% |
| Air | 2,779 | 3.42% | 3,932 | 5.89% | 6,710 | 4.54% |
| Passengers | 15,584 | 19.20% | 45,654 | 68.45% | 61,238 | 41.41% |
| Sum | 81,186 | 100.00% | 66,698 | 100.00% | 147,884 | 100.00% |

Source: Research data

Two simulations were carried out: a transfer of 10% of the activity level of road transportation to rail, and the same transfer to water transportation. It should be stressed that in absolute terms, the simulations transfer a total of R$ 5,928 million, which represents only 0.17%, of the total production value of the Brazilian economy.

Summary results of the simulations are presented in Tables 7 and 8, while the detailed results are presented in the appendix.

As Table 7 indicates, the simulated change from road to rail will have a small positive impact on aggregate personal income (+0.019%) and on GDP (+0.0026%), and a negative impact on employment (-0.091%). The positive effect on GDP and personal income is due to the fact that the intersectoral multiplier for rail is larger than for road transportation. For each R$ of increase in road transportation, there is an increase in aggregate GDP of R$ 1.895, considering direct, indirect and induced effects. The same number for rail transportation is slightly larger, R$ 1.903. These small differences explain the small aggregate increase in GDP and personal income. An extra R$ million of road transportation generates a total of 83.4 jobs in the economy (also, direct + indirect + induced); the same number for rail transportation is 70.0, what explains the negative impact on employment.

In terms of income distribution, a very small improvement in the Gini index is observed (in the tenth digit after the decimal point). Rail transportation is the sector with the largest share of intermediate purchases from pro-poor sectors, as shown in Section 3.5, meaning that the indirect effects contribute to an improvement in income distribution. It was also shown, in Section 3.2, that road directly distributes a slightly higher percentage of income to the lower classes, and this factor contributes to diminish the positive effect of the intersectoral intermediate purchases. It was also shown that the income distribution profiles of road and train are quite similar. On balance, the favorable intermediate consumption effect overcomes the negative effect, producing the small improvement in the overall income distribution.

Table 8 shows the effects of a change from road to water. The results indicate that there is practically no change in aggregate personal income (+0.000012%), and a small improvement in GDP (+0.0043%). Employment decreases by 0.065%. The results on aggregate GDP are larger than in the simulation of a change from road to rail. For each R$ of increase in water transportation, there is an increase in aggregate GDP of R$

1.909, considering direct, indirect and induced effects, slightly larger than the number for road and also rail transportation. An extra R$ million of water transportation generates a total of 73.9 jobs in the economy (direct + indirect + induced), smaller than the number of jobs created by road transportation (83.4), explaining the aggregate decrease in employment.

In terms of income distribution, as in the previous case, there is also a very small improvement, as measured by the Gini index (also in the tenth digit after the decimal point). The case is similar to the change from road to rail: water transportation buys a larger share of intermediate inputs than road from pro-poor sectors (58.1% versus 45.4%), and distributes slightly less direct income to the lower classes. Again, the positive effect on income inequality of pro-poor intermediate purchases overcomes the negative impact of direct income distribution.

**Table 7 - Impacts Overall the Economy of a Transfer of 10% of the Activity Level in the Road System to the Rail System**

| | Before | After | Change Values | Change % |
|---|---|---|---|---|
| Personal Income [a] | 1,255,042 | 1,255,284 | 242 | 0.019% |
| GDP [a] | 1,941,498 | 1,941,548 | 50 | 0.0026% |
| Employment [b] | 88,244,954 | 88,164,235 | -80,719 | -0.091% |
| GINI Index [c] | 0.4860704672 | 0.4860704671 | -0.0000000001 | -0.000000014% |

Notes: a. R$ Million; b. number of persons; c. the value of the Gini index differs from the official figures, because it was estimated taking into consideration the input-output system.

Source: Research data

**Table 8 - Impacts Overall the Economy of a Transfer of 10% of the Activity Level in the Road System to the Waterways System**

| | Before | After | Change Values | Change % |
|---|---|---|---|---|
| Personal Income [a] | 1,255,042 | 1,255,042 | 0.16 | 0.000012% |
| GDP [a] | 1,941,498 | 1,941,582 | 84 | 0.0043% |
| Employment [b] | 88,244,954 | 88,187,862 | -57,092 | -0.065% |
| GINI Index [c] | 0.486070467196 | 0.486070467203 | 0.00000000001 | 0.0000000015% |

Notes: a. R$ Million; b. number of persons; c. the value of the Gini index differs from the official figures, because it was estimated taking into consideration the input-output system.

Source: Research data

## Conclusions

The goal of this work is to measure the income distribution effects of changes in the modal composition of cargo transportation in Brazil. A Leontief-Miyazawa type model with a base year 2004 was constructed, disaggregated into 31 sectors (4 of which related to cargo transportation: road, rail, water, and air), and 10 income brackets.

Transfers of 10% of the activity level of road transportation either to rail or to water transportation were simulated, and the results presented impacts on GDP, aggregate income, employment and Gini index changes. Since the system is linear, the direction of the changes will not change with the size of the percentage of activity changed from road to other transportation modes, although the sizes of the impacts will vary.

The results show that the relative impacts are small, considering the relative size of the change simulated in relation to the Brazilian economy. Increases in the share of rail or water transportation will be better for GDP, personal income and income distribution, but it will decrease employment. Increases in the share of rail transportation will have more positive effects on personal income and income distribution than increases in the share of water transportation. A change to water will result in a larger GDP change and a smaller number of jobs lost in comparison to a change to rail. These results are explained by the lower direct employment coefficients of rail and water (26.3 for road, 7.8 for rail, and 15.9 for water) and by their lower aggregate employment generators (83.4 for road, 70.0 for rail, and 73.9 for water).

This study focused only on the distributional aspects of possible changes in the modal composition of cargo transportation in Brazil, without consideration of aggregate efficiency and price changes, aspects that are beyond the scope of this work. Possible efficiency improvements due to changes in the modal composition can lead to increased aggregate production and changes in the sectoral structure of the economy, since different sectors rely differently on distinct modes of transportation and, therefore, will not be affected equally. Given the present sectoral structure, the direction of the effects are the ones presented above. In general, a reduction in the share of road transportation will produce positive impacts in GDP, personal income, and income distribution, but will produce negative impacts on employment.

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