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Analysis of the structure and location of charcoal production in Brazil - time period from 1980 to 2008

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Abstract: This paper analyses the impacts of the steel production enlargement and environmental policies on the structure and location of charcoal production in Brazil during the time period from 1980 to 2008, pointing out regional differences in the steel and charcoal structure production in Brazil. Both statistic and interpretative analysis of secondary data, organized in tables or graphs, are used, paying special attention to the similarities and differences amongst data. The main findings of the paper are: (1st) although charcoal is an archaic energy source, it still represents 3% of the Brazilian energetic matrix and is used in the industrial sector (especially in the steel industry) in which there are steelmakers that use coal (to produce flat steel) or charcoal (if they produce long steel); (2nd) the charcoal production trend is directly associated to its industrial use (the correlation coefficient between these two variables is 0.963 in time period from 1980 to 2008); (3rd) due to the impacts of industrial and environmental government policies, charcoal production in the North and Northeast Regions of Brazil are mainly conducted by small producers making use of native forests; (4th) also in the North and Northeast Regions of Brazil, independent producers of pig iron are prevalent (exporting most of their production) while the environmental law enforcement is weaker in relation to other Brazilian regions; (5th) large charcoal producers (using mostly planted forests) are prevalent in the Southeast Region of Brazil, where environmental law enforcement is stronger and where both integrated steelmakers based on charcoal or on coal are present; (6th) the concentration of charcoal production has increased in Brazil, but inequality among the producers has decreased. The largest producers (using 10,000 or more hectares) account for 8.4% of Brazilian charcoal production in 1980 and 15.6% in 1996, despite the Gini coefficient among charcoal producers being reduced from 0.793 to 0.757 in the same years, respectively; (7th) regional differences according to inequality and concentration of charcoal production among Brazilian regions have taken place and are specified and analyzed in the paper. The paper suggests some policies that can increase charcoal production in Brazil with more balance in relation to both its regional distribution and having less negative impacts on the environment.

Keywords: Charcoal, Steel Sector, Regional Differences, Brazil.

1 - Introduction

Charcoal is used in Brazil's steel sector as both a temperature-reducer and an energy source. In the blast furnace, charcoal and iron ore are placed together because the charcoal leaves the iron free to join with the carbon, and charcoal burning creates high temperatures (around 1,500°C) inside the furnace, which are necessary to melt ore particles.

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According to the Brazil's Steel Institute (2009), during the iron ore reduction process, the iron becomes liquid and is known as pig iron or first-melting iron. Pig iron is a carbon-iron alloy with a high level of carbon (around 4% as stated by Zylbersztanj in 2000). This material is very fragile and its chemical composition depends on its application. The pig iron used in the steelmaking process contains 0.5% of silicon, although the foundry pig iron has between 2% and 3% of silicon.

Brazil has two types of pig iron makers: independent and integrated producers. The former produces pig iron to sell in the market and the latter uses its pig iron production to be transformed in steel within the mills owned by the same company.

The independent pig iron producers are grouped in the pig iron industry, which addresses its production to the steel industry (in the form of steelmaking pig iron) as well as to foundries (in the form of foundry pig iron). The steelmakers are grouped in the steel industry and can buy pig iron from the independent producers or can integrate it with the steel process. In this paper, these two industries (the pig iron and steel industries) are together referred to as steel sector.

Currently, Brazil is the 6th largest producer of pig iron and the 9th largest producer of crude steel in the world. The steel sector in Brazil has a unique practice of using charcoal or coal to producer pig iron, although the pig iron industry uses only charcoal.

In 2008, according to AMS (2009), Brazil consumed 33 million cubic meters of charcoal in the industrial sector; 52.6% produced using roundwood from planted forests and 47.4% from native forests. The independent producers demanded 72.3% of total charcoal produced and the integrated steel mills demanded 17.3%, followed by producers of ferroalloys (9.6%) and producers of ductile iron pipe (0.8%).

2 - Objective

This paper aims to analyze the impacts of steel production enlargement and environmental policies on the structure and location of charcoal production in Brazil during the time period from 1980 to 2008, pointing out regional differences in the steel and charcoal structure production in Brazil. This period shows a rising environmental concern about the production processes and the expressive changes in structure and size of the Brazilian steel sector, which is the main consumer of charcoal in Brazil.

3 – Review of the literature

Many papers have been written about charcoal in Brazil, however, those related to the aim of this paper can be divided into four groups: (1st) papers that analyze the relationship between charcoal production and the domestic steel sector; (2nd) papers analyzing the environmental issues related to the production and demand of charcoal; (3rd) papers that estimate the charcoal supply and demand equations in Brazil; and (4th) papers analyzing charcoal prices' time series and forecasting future prices.

The main papers that analyze the relationship between charcoal production and the domestic steel sector are: Braga (1979), Osse (1982), Ferreira (2000a), Hübner (2007), and Morello (2009). Braga evaluates the influence of charcoal quality in the pig iron production relative to the use of coal in the case of Acesita's company, nowadays belongs to ArcelorMittal Stainless Brazil. This paper concludes that the charcoal produced by an integrated company is better than the charcoal bought from other producers, because less the first one is used to produce one ton of steel. At the end of 1970's, the producers of charcoal were trying to improve their techniques (using hydrolyzes instead of carbonization) to achieve the same level of production capacity as the coal blast furnace had at that time.

Osse (1982) gathers information about charcoal consumption and the steel industries' forest activities in Brazil, focusing on reforestation activities before and after the 1966 Forest Code (law 5,106), which compels steel industry to implement their own forests. The author emphasizes that Brazil is one of the few countries that maintains the charcoal-based steel industry even after the coal was introduced.

Ferreira (2000a) points out some qualities of the charcoal in the steel production in relation to the use of coal, such as the high capability of carbon sequestration from the iron and oxygen regeneration, as well as the charcoal can provide better quality for the pig iron produced in relation to the one based in coal. The author mentions the fact that the Minas Gerais State's government had invested in carbonization technologies and improvement of furnaces during the 1980's, generating a large amount of research. However, as the impact of the second oil price shocks was lessening, the research was gradually abandoned.

Recently, private innovation is emerging, such as charcoal production technologies developed by Bricarbras, a Hübner Group Company, as described by Hübner (2007). The company has developed a charcoal production unit that uses a carbonization kiln with vertical metal cylinders consisting of a non-continuous charcoal production system. This new

production unit permits an easier monitoring, process improvement and guarantees the quality of charcoal.

Morello (2009) discusses the environmental and energetic issues concerned with the charcoal-based steel production in Brazil, especially the illegal use of native forest to produce charcoal, which was allowed in the past. The author advocates forest fomentation to involve farmers in the planting of trees to be used to produce charcoal, because this fomentation splits the risks and costs between farmers and steel makers.

Brito (1990), Medeiros (1995), Bezzon (1998) and Ferreira (2000b) are examples of authors that address the environmental issues linked to the production and demand of charcoal.

Brito (1990) suggests that policy makers, involved with energy and forest sectors, to pay more attention to the roundwood as an energy source in Brazil. In the case of charcoal use, the author highlights the importance of accurately evaluating the availability of raw forest materials and the use of more appropriate production technologies. The author emphasizes the compatibility of both macroeconomic policies and planning strategies to keep biomass as an industry energy source.

Following the same research area as Brito (1990), Medeiros (1995) emphasizes that the main challenge of energy planning is the balancing of energy and environmental issues in the steel sector. The author attributes the scarce use of the new available technologies as the main cause of charcoal waste and suggests including the environmental negative impacts as production cost in a way to incorporate environmental issues in the economic planning.

According to Bezzon (1998), the rational and sustainable use of charcoal contributes to control some negative environmental issues such as deforestation and pollution, and permits the charcoal to be an attractive energy source. However, its current production process is characterized by the predominance of low-efficiency technologies, resulting in low conversion rate of roundwood into charcoal and conducting to more intensive forest exploitation. To overturn this situation, the author suggests some new techniques able to increase the charcoal added value such as the controlled pyrolysis with high pressure (generating charcoal to industrial and housing use) and further activation (generating activated charcoal for cleaning and produce purely drinking water). The new technologies may provide more competitiveness to charcoal as a temperature-reducer in relation to coal inside the steel sector.

Ferreira (2000b) compares the pollution effects of using coal versus charcoal in the steelmaking process. Charcoal use is ecologically more viable, because for each ton of crude steel produced the charcoal sequesters 16.34 tons of carbon dioxide and regenerates 1.54 tons of oxygen, taking all production cycle from planting eucalyptus to the steel production. Whereas for each ton of coal-made steel, 1.65 tons of carbon dioxide is released and 1.54 tons of oxygen is fixed. Besides this evidence, while the use of coal releases 7 kg of sulfur dioxide (SO_2) inside the atmosphere, the charcoal has no emission of this residue.

Teixeira et al. (1983), Fontes et al. (2004), and Uhlig (2008) estimated supply and/or demand equations of charcoal in Brazil.

Teixeira et al. (1983) estimated the supply curve of charcoal used in the Minas Gerais' steel sector using the ordinary least square method (OLS) during the time period from 1976 to 1980. The long run and the short run price elasticity of supply were 0.135 and 0.398, respectively, both showing charcoal supply as price inelastic.

Fontes et al. (2004) estimated the supply and demand equations of charcoal during the 1974 to 2000 period. The explanatory variables for the supply equation were: charcoal price, nominal exchange rate, salary, and interest rate. Explanatory variables in the demand curve were: charcoal price, pig iron production, and GDP per capita. Applying the two-stage least squares method to estimate the simultaneous equations determined that the demand was price inelastic (elasticity of -0.15) and very sensitive to the pig iron production alteration (elasticity of 1.02), while the supply is sensitive to the charcoal price (elasticity of 1.25) and to salary alteration (elasticity of -2.31). Fontes et al (2004)'s finding for supply price elasticity is different from the Teixeira et al (1983)'s finding. According to Fontes et al (2004)'s finding charcoal supply is price elastic against the price inelasticity found by Teixeira et al (1983)'s paper.

Uhlig (2008) estimated the charcoal and firewood consumption through the Wisdom Model – Woodfuels Integrated Supply/Demand Overview Mapping. Taking these results, the author specifies a city level supply-demand matrix for charcoal in order to compare with those obtained by the Brazilian Energy Balance (BEB). This comparison allows for the identification of hotspots concerning the supply problem, i.e., areas where demand outstrips supply of roundwood for energy purposes. Even though the estimate of total consumption differs somewhat from those of the BEB, this alternative method seems to be appropriate. However, expressive differences appear between Uhlig's estimative and BEB in relation to

charcoal consumption among the Brazilian sectors. The most critical wood fuel production hotspots are located in states of Mato Grosso do Sul, Minas Gerais, and Bahia.

Rezende et al. (2005) and Coelho Júnior et al. (2006) are some of the papers analyzing charcoal prices' time series and forecasting future prices.

Rezende et al. (2005) estimated a model that forecasts charcoal prices for four regions of the state of Minas Gerais, from January 1981 to December 2003. The SARIMA model was found to be more suitable for forecasts of prices in the four studied areas.

Coelho Junior et al. (2006) analyzed the historical series of native and planted-forest made charcoal prices from January 1999 to December 2004, aiming to find a model that forecasts charcoal prices. They also used the SARIMA model; however, for planted forest-made charcoal prices, the model with order two provided better adjustment, while for the native forest-made charcoal prices, the model with order zero provided better adjustment. These results demonstrate differences in the trend among the two price series.

From the above explanation, we can conclude that no article in the literature has completely addressed the objective of this paper.

4 - Methodology and Dataset Used

The paper uses statistic and interpretative analysis of secondary data, organized in tables or graphs, considering information regarding charcoal production from both planted and native forests, charcoal production destination, and some productive features of charcoal producers. Dataset comes from: the Brazilian Energy Balance (BEB), the Brazilian Institute of Geography and Statistic (IBGE); and from the yearbooks published in the beginning by Abracave (Brazilian Association of Charcoal Producers) and, following its dissolution, by the Forestry Association of Minas Gerais State (AMS).

The Brazilian Ministry of Mines and Energy releases annually the Brazilian Energy Balance to determine the share of charcoal in the Brazilian energy matrix; the aggregated values of production, import and export of charcoal as well as the charcoal consumption, the latter determined according to each economic sector. The BEB's information is available from 1970 to 2008.

Annually, IBGE surveys the vegetal extractive and silviculture production's numbers, which differs from the Brazilian Energy Balance dataset. That survey can be used to determine the ratio of planted forest-produced and native forest-produced charcoal according

to total produced charcoal, and also the charcoal production of each Brazilian State. This paper includes IBGE's vegetal extractive and silviculture survey's dataset from 1980 to 2008.

IBGE also conducts the Agriculture Census, which determines the value and amount of charcoal produced according to the producer's landownership condition, the groups of economic activity and the destination of production. The information is available for the years 1980, 1985, 1995, and 2006.

Abracave's Yearbook provides data about charcoal consumption by economic sector and by source (native forests versus planted forests), for each Brazilian state during time period from 1976 to 1997. After 1997, AMS has released this publication, which has data available until 2008.

Considering the similarities and differences from the four dataset sources abovementioned and their time availabilities, this paper analyzes the structure of charcoal production in Brazil from the 1980's to 2008. This period covers the increase of environmental issues and significant changes in the Brazilian steel sector, which is the main consumer of charcoal.

5 – Results

5.1 – Charcoal share in the Brazilian energy matrix

Despite charcoal being an archaic form of energy, it has the important feature of being a renewable source and has been used for decades in Brazil, especially in its industrial sector. As shown in Table 1, the charcoal share within the Brazilian energy matrix has decreased from 5.3% in 1988 to 2.7% in 2008; but is still important, with a share around 3% since 1995.

Table 1 – Composition of final energy consumption by source in Brazil, selected years.

| Sources | 1988 | 1990 | 1995 | 2000 | 2005 | 2007 | 2008 |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|
| Natural Gas..... | 2.3% | 2.4% | 2.7% | 4.1% | 6.8% | 7.2% | 7.4% |
| Coke and By-Products..... | 6.0% | 4.8% | 5.5% | 5.4% | 5.1% | 4.9% | 4.7% |
| Hydraulic and Electricity..... | 13.6% | 14.8% | 15.5% | 16.6% | 16.5% | 16.4% | 16.3% |
| Firewood..... | 14.3% | 12.3% | 8.9% | 7.9% | 8.2% | 7.6% | 7.4% |
| Sugar Cane Products..... | 14.1% | 13.9% | 14.9% | 11.5% | 14.5% | 16.6% | 17.9% |
| Oil and By-Products..... | 42.4% | 44.8% | 47.1% | 48.9% | 42.9% | 41.4% | 40.3% |
| Charcoal..... | 5.3% | 4.8% | 3.4% | 2.8% | 3.2% | 2.9% | 2.7% |
| Others..... | 2.0% | 2.0% | 2.0% | 2.6% | 2.8% | 3.1% | 3.3% |

Source: Brazilian Energy Balance database.

The stable share of charcoal in the Brazilian energy matrix during the first decade of the 21st century is due to its industrial consumption, which represents 90% of the total consumption of charcoal in Brazil in the 2000's, up from 70% in the early 1970's. The increase in industrial consumption of charcoal has taken place in the steel industry and replaces mainly oil consumption, especially after the two oil choke prices in the 1970's. Housing consumption of charcoal decreased between 1970 and 2008, because of increased cooking gas and electricity usage for cooking and heating.

Table 2 – composition of final energy consumption of charcoal by sector in Brazil, selected years.

| Sectors | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2008 |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Housing..... | 27.5% | 19.5% | 19.4% | 13.9% | 10.4% | 8.8% | 8.5% | 8.3% | 8.6% |
| Commercial..... | 2.0% | 1.5% | 1.5% | 1.1% | 0.9% | 1.1% | 1.3% | 1.1% | 1.3% |
| Public..... | 0.0% | 0.0% | 0.1% | 0.1% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% |
| Agriculture and Livestock..... | 1.2% | 0.4% | 0.2% | 0.1% | 0.2% | 0.1% | 0.1% | 0.1% | 0.1% |
| Industrial..... | 69.3% | 78.6% | 78.7% | 84.8% | 88.5% | 89.8% | 90.1% | 90.5% | 90.1% |

Source: Brazilian Energy Balance database.

Within the industrial sector, the consumption of charcoal for the pig iron and steel industries is expressive, accounting for 85% of the total industrial consumption of charcoal (Table 3). However, the steel sector is losing its share in the industrial consumption of charcoal for the cement and iron alloys industries, which are also replacing oil with charcoal as an energy source.

Table 3 – composition of industrial consumption of charcoal by industry in Brazil, selected years.

| Industries | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2008 |
|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Cement..... | 0.0% | 0.0% | 3.1% | 13.9% | 6.4% | 6.4% | 5.4% | 4.4% | 4.4% |
| Pig Iron and Steel..... | 94.5% | 94.8% | 87.9% | 72.9% | 80.4% | 80.7% | 84.4% | 84.9% | 83.7% |
| Iron Alloys..... | 4.5% | 3.5% | 5.3% | 8.0% | 6.7% | 8.6% | 9.9% | 10.1% | 11.2% |
| Mining and Pelletization..... | 0.0% | 0.0% | 0.7% | 1.1% | 0.6% | 0.0% | 0.0% | 0.0% | 0.0% |
| Others..... | 0.9% | 1.7% | 3.0% | 4.1% | 5.9% | 4.3% | 0.3% | 0.6% | 0.7% |

Source: Brazilian Energy Balance database.

5.2 Impacts of the steel production enlargement and environmental policies on the structure and location of charcoal production in Brazil

During the first Getulio Vargas' government (from 1930 to 1945), the existence of basic sectors of the economy (such as the steel industry) was seen as a strategy to promote industrialization and to keep mineral reserves under governmental control. In April 1941, a state-owned steel industry named *Companhia Siderúrgica Nacional* (CSN) was created and became the largest producer of flat steel and the first steel enterprise to use coal in the Brazilian steel industry (CSN, 2008). According to Mangabeira (1993, p. 65), cited by De Paula (2002), the purpose of the CSN was to improve industrial development in Brazil and to reduce the Brazilian industry's external dependence.

The second Getulio Vargas' presidential term (from 1951 to 1954) stimulated development projects through state-owned companies, and growing demand favored the steel sector. The National Bank of Economic Development (BNDE), founded in 1952, made some viable investments included in the Juscelino Kubitschek's government plan (from 1956 to 1961), called "fifty years in five years". The latter started the automobile industry in the country, increasing the demand for pig iron and flat steel. This demand was supplied by the coal-based steel industries, which were enlarged during both Getulio Vargas' governments (from 1930 to 1945 and from 1951 to 1954).

From 1940 to 1963, when industrialization was the main government goal, the steel industry was favored by the demand created for infrastructure and civil construction and for the flourishing automobile industry. Civil construction demanded mostly long steel products, which were produced using charcoal. Railroad construction and the automobile industry demanded foundry pig iron, which was supplied by the independent producers who also used charcoal.

According to Baer (1970), independent producers of pig iron were established in Brazil as a result of industrial incentives. This is because in the 1950's, in two regions of Minas Gerais (the western region and Belo Horizonte Metropolitan Area), many iron ore reserves were previously located in these regions, and also because the automobile industry established in Southeast region of Brazil. In addition, the pig iron independent producers supplied eventually the steel industry with pig iron.

Concerned with the environmental issues involving the steel sector, the Belgo-Mineira's Steel Company announced its reforestation project in 1953. This project was developed to supply roundwood for charcoal production, because there weren't many native

forests available near its industrial plant (OSSE, 1983). This practice came from both environmental law enforcement and the private sector's decision. Since 1934, the First Forest Code had established the rational use of forests. Thirty-one years later, the 1965's Forest Code had established the requirement of charcoal-based steel mills having their own forest, native or planted, for sustainable exploitation. According to 21st article of 1965 Forest Code (Law 4,771):

The charcoal, firewood or other forest raw material based companies, such as steel and transportation firms, are required to have their own forests to be exploited rationally or need to plant, directly or through an enterprise, forests designated to its own roundwood supply. (BRASIL, 1965)

Because of this requirement, the charcoal-based steel mills began an integration process towards planted forest-based charcoal production. The ArcelorMittal Brazil Company has planted forests through its colligate Acesita Energy Company; the Belgo-Arcelor Brazil Company has planted through the CAF-Santa Bárbara Company (which provides also charcoal to the independent producers); the V&M Brazil Company is backed by V&M Forestry; and the Gerdau Company has received charcoal from Gerdau Forest Company.

Law 5,106, from September 2nd, 1966, established fiscal incentives to stimulate tree plantation. The 1st article of this law states:

Individuals and companies established in Brazil can rebate from their taxable income the amount invested in forestation and reforestation projects, observing the requirements of this act. (BRASIL, 1966)

In 1967, the responsibility to approve and manage the concession of these fiscal incentives was centralized into the Brazilian Institute of Forest Development (IBDF). However, during the first half of the 1970's, the government reduced the total maximum limit of tax incentives, and in 1974, special types of loans were created to manage tree plantations (Morello, 2009).

In the first half of the 1970's, the government created a fund to promote reforestation (the Fiset-reforestation). As soon as a company had enrolled for Fiset, it would choose to allocate a share of its income tax to a specific reforestation project, becoming a shareholder of the company which would receive money from Fiset. According to Morello (2009), the largest part of the country's reforested area was created during the 1970's and the 1980's, the same lifetime of Fiset. Fiscal incentives for reforestation lasted until 1988.

Since the 1990's, forest-based industries have planted their own forests or have encouraged farmers to plant forests for industrial use. Figure 1 shows the evolution of eucalyptus plantations in the state of Minas Gerais that have been planted by the steel sector. The geometric growth rate of tree plantation area conducted by integrated steel mills was 11.76% per year from 2001 to 2008, and the geometric growth rate of tree plantation conducted by independent producers of pig iron was 25.47% per year during the same period.

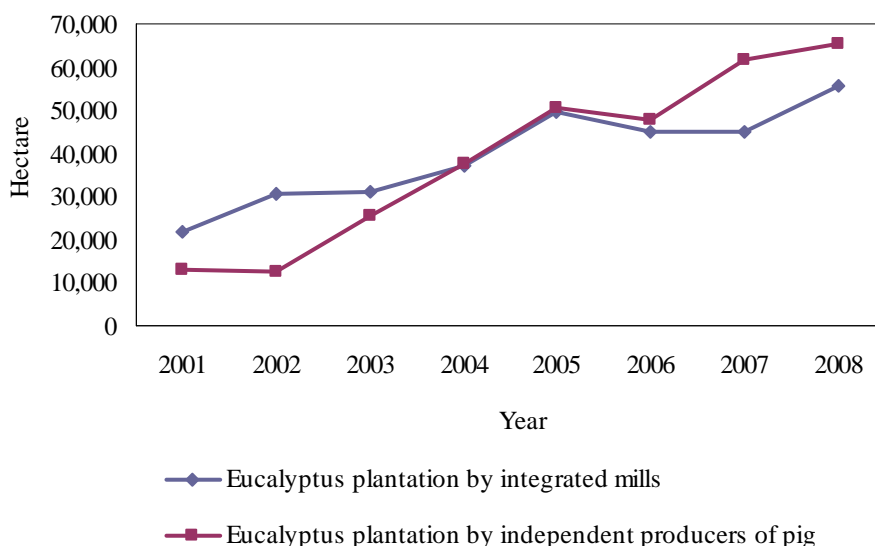


Figure 1 – Evolution of annual eucalyptus plantation in the state of Minas Gerais (values in hectares) from 2001 to 2008.

Source: data from AMS (2009).

During the 1970's, the steel sector growth was stimulated by some Federal programs and the flourishing capital goods industry that was installed in the country. The first National Steel Plan in 1971, the first National Development Plan (from 1972 to 1974), and the second National Development Plan (from 1975 to 1979) stimulated the steel sector growth through the allocation of federal government funding. This occurred as the steel sector became a backbone for capital goods industry's expansion.

In the first half of the 1970's, the charcoal-based steel industry took the advantage of the first oil crisis in 1973, because charcoal was an advantageous option compared to coal use.

According to Andrade & Cunha (2003), the government's industrialization police stimulated the import substitution of basic inputs and especially favored the steel industry. From 1974 to 1980, US\$ 13.5 billion was invested in the steel sector, 77% through the state-owned holding Siderbrás, according to De Paula (2002). These investments were focused on the expansion of three huge state-owned and coal-based integrated mills, which monopolized the production of flat coated carbon steel, i.e., CSN, Cosipa, and Usiminas.

At the end of 1970's, through the Carajás Iron Project, the production of pig iron was stimulated in a region between the states of Maranhão and Pará, because the Vale do Rio Doce Company was allowed to explore iron ore reserves in that area. Consequently, charcoal production followed the same trajectory as pig iron production, but was facilitated by the wide native forest areas available for exploitation.

During the 1980's, other coal-based integrated mills (controlled by Siderbrás) started their activities, producing only semi-finished steel (cases of Tubarão Steel Company in 1983 in the state of Espírito Santo, and Açominas in 1986 in the state of Minas Gerais). According to Andrade & Cunha (2003), the domestic demand for steel products was retracted during the 1980's, which motivated the steel industry to increase its exports, even though the lower international prices were reigning in this period.

In the following decade, the privatization process caused many impacts onto the steel industry, which had a slower growth in output (De Paula, 2002). According to Fonte (2003), the privatization process permitted an increase in the capital/labor ratio inside the steel sector, because new partners became shareholders of the existing companies. The new funding allowed the steel companies to become part of the integrated industrial groups and/or financial holdings with the aim of improving the scale of economy and competitiveness, through activities linked to steel production.

Charcoal production and its industrial consumption have a high correlation as showed in Figure 2 (1980-2008's correlation coefficient is 0.963). Domestic production of charcoal is almost completely sold in the domestic market; and charcoal exports have been only recorded after 1993 and represent approximately 0.12% of Brazil's domestic production. Thus, the charcoal production can be explained mostly by the domestic industrial consumption, which is determined mainly by the consumption of the steel and pig iron industries.

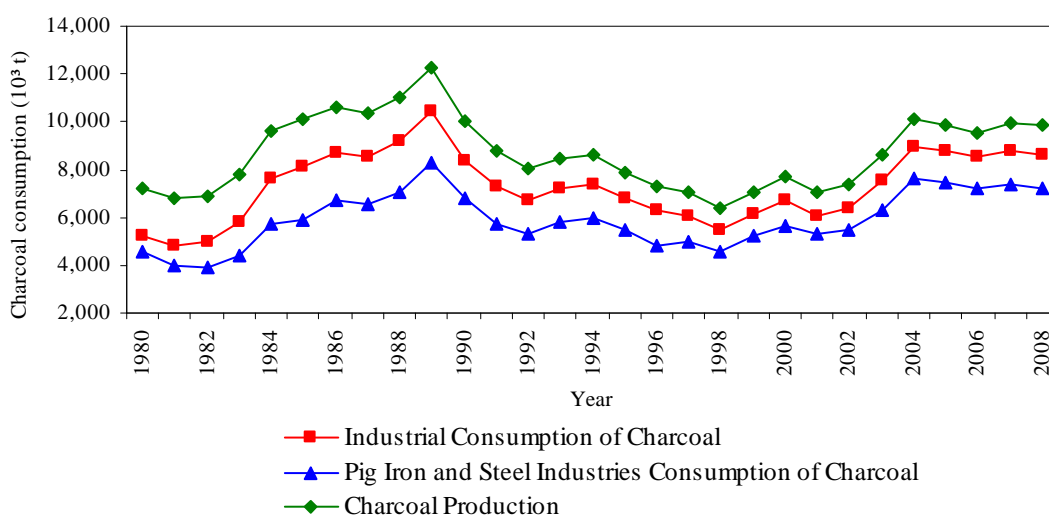


Figure 2 – Charcoal production, industrial consumption of charcoal, and pig iron and steel industries consumption of charcoal from 1980 to 2008.

Source: Brazilian Energy Balance database.

5.3 - Structure of charcoal production in Brazil

Charcoal production in Brazil is concentrated in Southeast region, which was responsible for 56% of 2006's charcoal production. The other regions have smaller shares: Northeast (18%), North (12%), West Center (11%) and South (3%), see Figure 3.

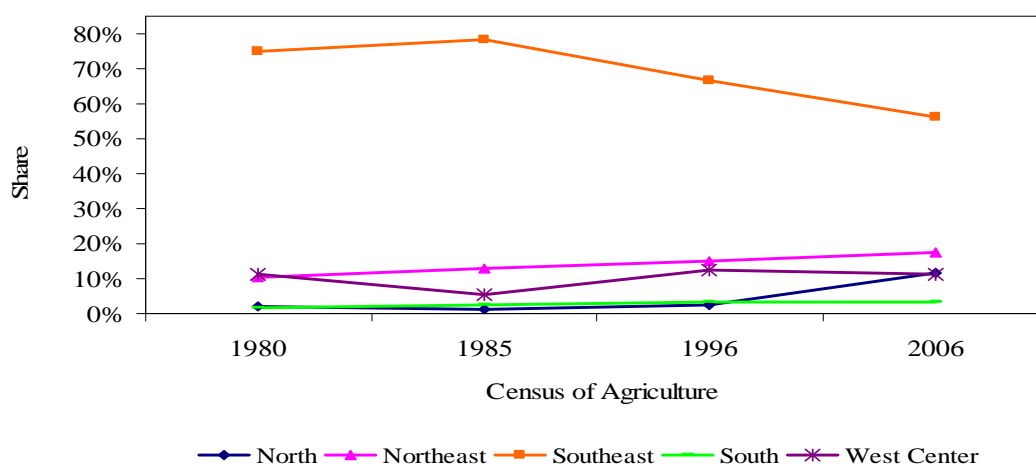


Figure 3 – Regional shares in Brazil's charcoal production in 1980, 1985, 1996, and 2006.

Source: Agriculture Census' database.

However, the Southeast region's share has reduced during the time, from 75% in 1980 to 56% in 2006, while the North and Northeast regions' shares have increased during the same period. The North region's share has increased from 2% to 12%, while the Northeast

region's share has grown from 10% to 18% in 1980 and 2006, respectively. The West Center region, after reduction in 1985, has re-assumed the same participation level in 2006 as it had in 1980, i.e., 11%.

This new territorial configuration of charcoal production happens because charcoal producers are looking for cheaper roundwood in boundary forest areas, aiming to reduce the production cost of pig iron and to increase profitability.

According to the Agriculture Census' database, Brazilian Southeast and West Center regions have most of their shares of charcoal production coming from planted forests, while the North and Northeast regions have most of their charcoal productions coming from native forests. This configuration is partially caused by the stronger environmental legislation enforcement in the Southeast and West Center regions (compared to other Brazilian regions), even though environmental legislation has the same norms across the country. More intensive law enforcement in some regions marginalizes illegal and migrant charcoal producers. Moreover, the native forests have been exhausted in the Southeast and West Center regions due to the previous expansion of economic activities.

The number of charcoal producers in 1980 was 184,448; increasing to 313,327 in 1985; and reaching to 249,558 in 1996, which represents a reduction of 20% comparing to the 1985 number (according to Agriculture census' database). Nevertheless, in 2006, the number of charcoal producers was even lower, 44,228, implying a reduction of 82% compared to the 1996 number. However, charcoal production increased from 1996 to 2007, returning to the level reached in the second half of the 1980's. This behavior is explained by the increasing participation of the largest charcoal producers in total production, as shown in Table 4. The largest producers (handling 10,000 or more hectares) accounted for 8.4% of the Brazilian charcoal production in 1980, 11.7% in 1985, and for 15.6% in 1996. The greater participation of the largest producers is due to increased environmental law enforcement, which makes the illegal exploitation of native areas to be sprayed and nomadic, making the major consumer of charcoal seek their own regulated forest areas. The latter favors the existence and expansion of largest producers at the expense of smaller producers of charcoal.

The Gini coefficient between 1980 and 1996 shows a reduction from 0.793 to 0.757, respectively (Table 4), indicating the unequal distribution of the charcoal production among the producers had been reduced.

Table 4 – Number of producers, share in total charcoal production by group of total area (hectare), and Gini Coefficient – Brazil's Agriculture Census of 1980, 1985, and 1996.

| Groups of total area (hectare) | | Census of Agriculture - 1980 | | Census of Agriculture - 1985 | | Census of Agriculture - 1996 | |
|--------------------------------|-----------------------------------|------------------------------|---------------------------|------------------------------|---------------------------|------------------------------|---------------------------|
| | | Informants | Share in total production | Informants | Share in total production | Informants | Share in total production |
| Brazil | Total..... | 184,448 | | 313,327 | | 249,558 | |
| | Less than 10..... | 116,971 | 6.9% | 228,059 | 8.6% | 153,901 | 7.0% |
| | 10 until less than 100..... | 49,188 | 14.3% | 58,710 | 17.6% | 69,107 | 15.1% |
| | 100 until less than 1,000..... | 14,543 | 29.1% | 20,593 | 30.0% | 16,171 | 20.1% |
| | 1,000 until less than 10,000..... | 1,522 | 27.8% | 2,143 | 23.3% | 975 | 36.9% |
| | 10,000 and more..... | 85 | 8.4% | 95 | 11.7% | 63 | 15.6% |
| | No declaration..... | 2,139 | 13.6% | 3,727 | 8.8% | 9,341 | 5.4% |
| Gini Coefficient | | 0.793 | | 0.786 | | 0.757 | |
| South | Total..... | 2,351 | | 3,254 | | 3,946 | |
| | Less than 10..... | 562 | 16.3% | 693 | 14.1% | 764 | 21.5% |
| | 10 until less than 100..... | 1,582 | 51.1% | 2,264 | 54.7% | 2,948 | 67.8% |
| | 100 until less than 1,000..... | 167 | 20.4% | 277 | 22.5% | 214 | 9.5% |
| | 1,000 until less than 10,000..... | 37 | 11.9% | 19 | 8.7% | 16 | 0.6% |
| | 10,000 and more..... | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| | No declaration..... | 3 | 0.4% | 1 | 0.0% | 4 | 0.6% |
| Gini Coefficient | | 0.256 | | 0.246 | | 0.019 | |
| Southeast | Total..... | 11,845 | | 18,805 | | 6,845 | |
| | Less than 10..... | 642 | 2.2% | 1,371 | 1.9% | 761 | 1.6% |
| | 10 until less than 100..... | 4,037 | 12.3% | 8,384 | 16.2% | 3,290 | 10.8% |
| | 100 until less than 1,000..... | 4,587 | 32.9% | 6,376 | 31.4% | 2,180 | 23.8% |
| | 1,000 until less than 10,000..... | 878 | 25.4% | 1,011 | 25.7% | 387 | 36.9% |
| | 10,000 and more..... | 63 | 11.0% | 63 | 13.4% | 47 | 21.5% |
| | No declaration..... | 1,638 | 16.1% | 1,600 | 11.2% | 157 | 5.4% |
| Gini Coefficient | | 0.350 | | 0.446 | | 0.658 | |
| West Center | Total..... | 1,441 | | 849 | | 719 | |
| | Less than 10..... | 389 | 4.2% | 190 | 19.3% | 62 | 2.8% |
| | 10 until less than 100..... | 462 | 7.1% | 207 | 16.1% | 319 | 9.8% |
| | 100 until less than 1,000..... | 337 | 10.1% | 313 | 42.5% | 187 | 15.1% |
| | 1,000 until less than 10,000..... | 116 | 65.1% | 105 | 15.1% | 75 | 54.5% |
| | 10,000 and more..... | 7 | 0.9% | 9 | 2.9% | 4 | 7.6% |
| | No declaration..... | 130 | 12.5% | 25 | 4.1% | 72 | 10.1% |
| Gini Coefficient | | 0.598 | | 0.116 | | 0.510 | |
| Northeast | Total..... | 23,322 | | 35,228 | | 43,964 | |
| | Less than 10..... | 12,243 | 32.1% | 21,409 | 33.2% | 26,988 | 48.0% |
| | 10 until less than 100..... | 8,877 | 36.6% | 11,007 | 36.9% | 13,959 | 36.5% |
| | 100 until less than 1,000..... | 1,902 | 20.9% | 2,571 | 23.5% | 2,559 | 10.8% |
| | 1,000 until less than 10,000..... | 98 | 6.7% | 134 | 5.9% | 127 | 3.7% |
| | 10,000 and more..... | 3 | 0.0% | 0 | 0.0% | 2 | 0.0% |
| | No declaration..... | 199 | 3.7% | 107 | 0.5% | 329 | 1.1% |
| Gini Coefficient | | 0.294 | | 0.343 | | 0.159 | |
| North | Total..... | 145,489 | | 238,164 | | 191,570 | |
| | Less than 10..... | 103,135 | 37.8% | 196,795 | 52.4% | 124,608 | 26.1% |
| | 10 until less than 100..... | 34,230 | 24.5% | 28,913 | 15.6% | 47,304 | 24.7% |
| | 100 until less than 1,000..... | 7,550 | 26.2% | 9,815 | 22.9% | 10,753 | 11.2% |
| | 1,000 until less than 10,000..... | 393 | 11.2% | 657 | 8.0% | 353 | 33.4% |
| | 10,000 and more..... | 11 | 0.1% | 17 | 0.4% | 10 | 1.7% |
| | No declaration..... | 169 | 0.2% | 1,967 | 0.8% | 8,542 | 3.0% |
| Gini Coefficient | | 0.411 | | 0.334 | | 0.486 | |

Source: values calculated from Census of Agriculture database (1980, 1985, and 1996).

However, there are differences in concentration and inequality levels, and different trends of charcoal production among the Brazilian regions. Although the South, the West Center and the Northeast regions have reduced inequalities among their charcoal producers, the Southeast and the North regions have increased inequalities.

According to the AMS database, the consumption of native forest-made charcoal surpassed the consumption of planted forest-made charcoal between 1993 and 2003, and both have almost been equal since 2004 (see Figure 4). The increase in native forest-made charcoal share from 1998 to 2004 occurred because independent producers of pig iron increased their consumption of charcoal. These producers demanded 14.30 million cubic meters of charcoal in 1997 and 27.59 millions in 2004, while the demand of other industrial consumers (integrated steelmaking, iron alloys, ductile iron pipe, and others) remained the same.

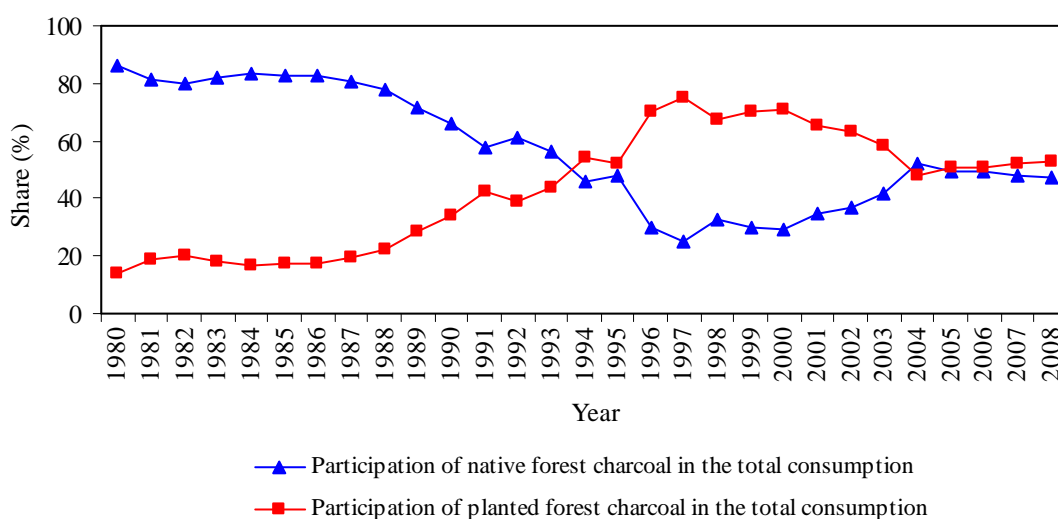


Figure 4 – Participation of native forest charcoal and planted forest charcoal in the total consumption from 1980 to 2008.

Source: AMS database.

According to Ferreira (2000a), the evolution of steel technology required roundwood standardization in the charcoal production. Consequently, some tree species were selected in order to improve the following features of charcoal: yield (conversion rate of roundwood in cubic meters of charcoal), amount of carbon fixed, and charcoal density.

The charcoal quality and prices can be differentiated between planted forest and native forest through physical and chemical characteristics, as stated by Coelho Júnior et al. (2006). In regards to the physical characteristics, the ideal feature for this differentiation is the roundwood density (mass per volume unit). According to the mentioned authors, the native

forest has a set of species that produce charcoal with different qualities, while the planted forest-made charcoal is homogeneous, having higher quality and better price.

Regarding the chemical characteristics, such as the amount of ash present in the charcoal, native forest-made charcoal has bigger amount of ash due to the species variability used in the production. Coelho Junior et al. (2006) point out also that less dense species produce higher amounts of ash because they are quickly charred.

Native forests and other native vegetation (such as tropical savanna, Atlantic forest and *caatinga*) have only exploitation costs, because no implementation cost is required. Otherwise, planted forests have costs of implementation, maintenance and exploitation. The implementation cost increases the production costs of planted forest-made charcoal in relation to the production cost of native forest-made charcoal.

5.4 Location of charcoal production and demanding units

Figures 5 and 6 present the locations of native forest-made charcoal production in 1990 and 2008, respectively. Figure 6 also shows the locations of steel firms in Brazil. The main findings after comparing the two maps are: (1) producers of charcoal that produce 20 to 200 thousand tons are concentrated in regions where the independent producers of pig iron are located; (2) native forest-made charcoal production has expanded to the North and Northeast directions from 1990 to 2008; (3) the biggest native forest-made charcoal producers are disappearing, as high levels of production (above 200 thousand per year) has not been seen since 1990.

Comparing the 1990 and 2008 planted forest-made charcoal production locations (Figures 7 and 8), we observe: (1st) in 1990, no planted forest-made charcoal production was seen in the state of Maranhão (whereas production occurred in 2008); (2nd) most of the planted forest-made charcoal is concentrated in Southeast region, near the integrated steelmakers location.

In the western and central parts of the state of Maranhão, a reforestation program is taking place and has been funded through the earnings from pig iron exports. This initiative aims to improve the environmental responsibility of these producers, since production that takes place in this region is mostly exported to countries in the Northern Hemisphere, where environmental legislation enforcement is stronger than in Brazil and there are worldwide environmental worries.

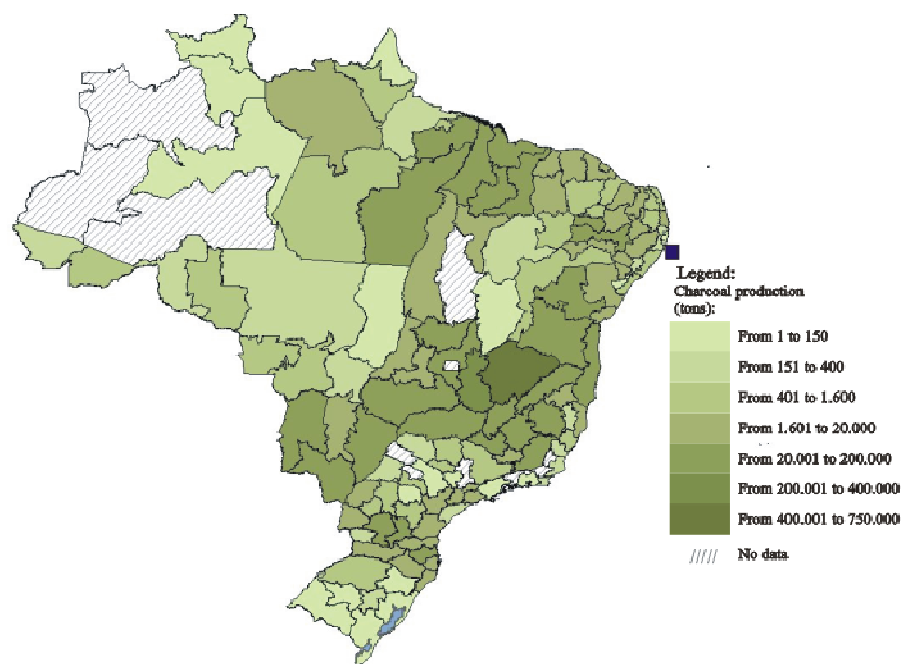


Figure 5 – Locations of charcoal production (tons) from native forests according to Brazilian regions in 1990.

Source: IBGE Vegetal Extractive and Silviculture Production database.

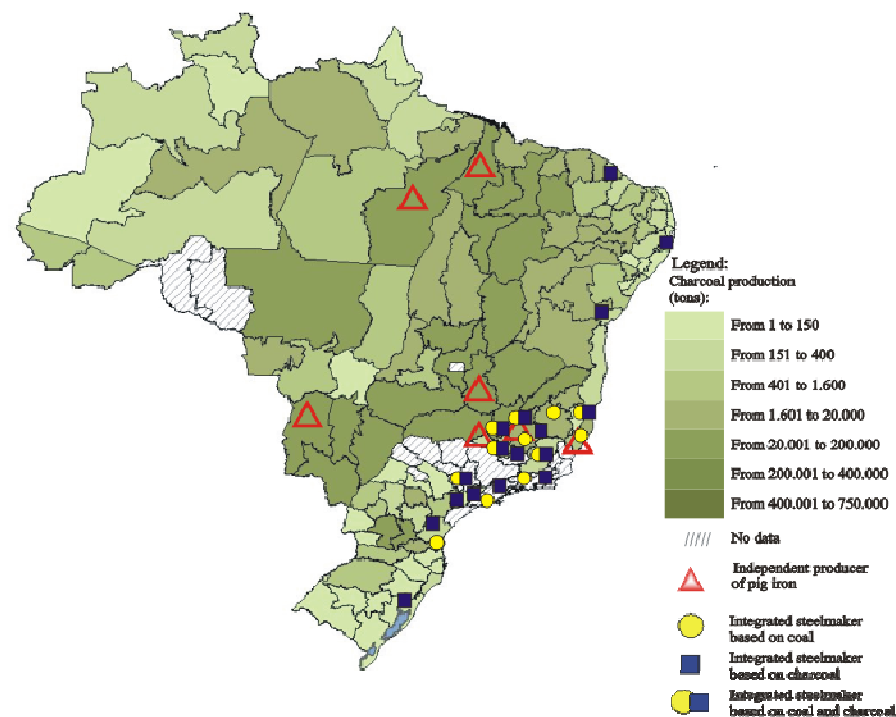


Figure 6 – Locations of charcoal production (tons) from native forests, of integrated steelmakers, and of areas of independent producers of pig iron - according to Brazilian regions in 2008.

Source: IBGE Vegetal Extractive and Silviculture Production database, Sindifer, and BSI.

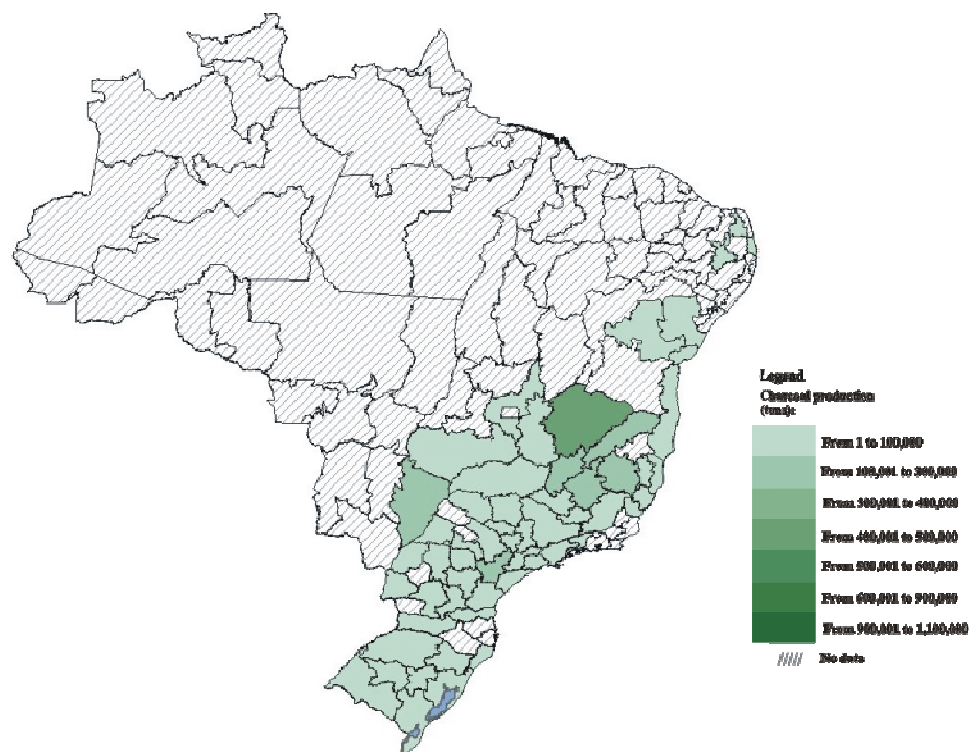


Figure 7 – Locations of charcoal production (tons) from planted forests according to Brazilian regions in 1990.

Source: IBGE Vegetal Extractive and Silviculture Production database.

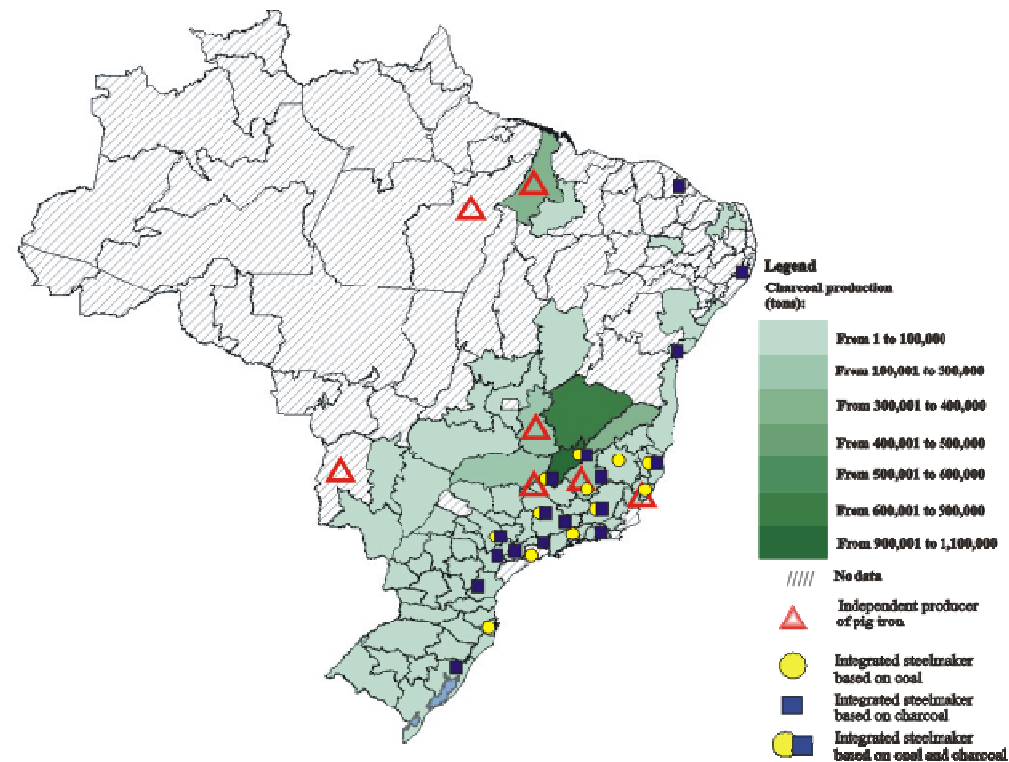


Figure 8 – Locations of charcoal production (tons) from planted forests, of integrated steelmakers, and of areas of independent producers of pig iron - according to Brazilian regions in 2008.

Source: IBGE Vegetal Extractive and Silviculture Production database, Sindifer, and BSI.

Among the seven economic groups acting in the Brazil's steel industry, five are integrated (representing 23 out of 28 existing mills). Of these, only the Gerdau Group has both integrated and semi-integrated mills. Of the integrated companies, ArcelorMittal Stainless Brazil and ArcelorMittal Long Steel use both coal and charcoal in their pig iron production systems, whereas ArcelorMittal Tubarão, CSN, Gerdau, Usiminas, and Açominas/Cosipa use only coal. Gerdau Long Steel and V&M Brazil use only charcoal as temperature-reducer in their blast furnaces.

The temperature-reducer technology used in the steel production is dependent on the type of product that wants to be created. Steel companies operating in the long products segment use charcoal as a temperature-reducer, while companies in the flat steel segment use coal in their blast furnaces. This distinction occurs because production of flat steel requires a larger scale, which is only possible by using coal.

6 - Conclusions

The trends of charcoal and steel productions are highly correlated in Brazil, because the steel industry is the main consumer of charcoal. Native forest-made charcoal producers are located near the independent producers of pig iron, while planted forest-made charcoal producers are located near the integrated steel mills, which are required to maintain their own supply of roundwood for charcoal production. Native forest-made charcoal producers are smaller than the planted forest-made charcoal producers and most of the first producers operate outside of the law, exploiting native forests in remote Brazilian areas, especially in the North and Northeast regions.

As environmental law enforcement becomes more effective, charcoal producers need to have their own areas and to log them properly, which will favor the existence and expansion of larger charcoal producers.

Together with environmental policies, industrial enlargement policies determine also the charcoal production structure in Brazil during the last fifty years. During the 1940's and 1950's, the main state-owner company's investments prioritized the latent basic sector in the country, which demanded flat steel, encouraging steel production based on coal. During this period, the charcoal production did not suffer directly inciting impacts of industrial policies.

However, during the 1970's and early 1980's, charcoal regained importance as a substitute for coal in the face of increasingly high prices of petroleum-made products. The import substitution policy favored the steel industry as a whole and, consequently, the

production of charcoal. Although the domestic demand was stagnant during the 1980's, the steel industry maintained production levels as it increased its orientation to exports, despite lower international prices.

The Brazilian peculiarity maintains a share of its steel industry based on charcoal, even though the global trend was to replace this source with coal, making the charcoal a constant in the Brazilian energetic matrix. Thus, the structure and locations of charcoal production in Brazil are closely related to the steel industry evolution and the environmental law enforcement.

Some economic policies can be suggested to improve charcoal production in Brazil with more balance in relation to regional distribution and decreasing negative environmental impacts. Such policies are divided into two groups: policies that aim to encourage the use of planted forests instead of the exploitation of native forests; and policies that aim to reduce inequality among charcoal producers in different regions.

The first group presents policies that should be directed at the pig iron industry, because this segment is the largest consumer of native forest-made charcoal. Fiscal incentives and subsidized loans can be used to stimulate reforestation that can supply planted roundwood to produce charcoal. Respecting each region's particularities, another policy is to promote rational management of native forests through ecological-economic zoning (EEZ) programs. In these programs, as stated by Bacha (2004), regions are defined according to their economic ability and the ecological benefits of local native vegetation.

In order to reduce inequality among producers, it is possible to incentivize small producers of charcoal to increase their production. A policy like this could grow to a national scale, however, greater emphasis should be given to the South and North regions, in which inequality among the charcoal producers have increased from 1980 to 1996.

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