

# Taxation and Welfare: the case of Rubber in the Brazilian Amazon (1870-1910)

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*“The demand for India-rubber, the principal and staple product of the [Pará] province, has diminished and is diminishing, in consequence, in a great measure, of the quantity recently produced on the West Coast of Africa and in our East Indian possessions, and in some degree from its having, for many purposes, been superseded by gutta-percha, and its application to other purposes relinquished.*

(...)

*I am compelled, most unwittingly, to arrive at the conclusion, that, for a considerable period, there is no probability of any increase in the trade of the province of Pará”.*

## 1. Introduction

Mr. Vredenburg, British Consul at Pará, could not be more wrong when he wrote the report quoted above on 3<sup>rd</sup> July 1858. Rubber exports from Pará would soon explode and become the second most important article of trade for Brazil, ranking just below coffee. After the discovery of the vulcanisation process by Charles Goodyear the potential applications of rubber greatly expanded. Rubber was then the preferred material for the confection of gaskets for steam engines, so that this raw material accompanied steel and iron wherever factory machinery, mining pumps, and railroads were installed. Rubber was also essential in machine belting and tubing, and in buffers between railway carriages. In sum, rubber is a hydrocarbon, a polymer of isoprene, elastic because of its organisation in long, crinkled chains, with many applications and directly connected to the Industrial Revolution that was taking place in Europe and in the United States.<sup>2</sup>

Rubber exports were more than 14% of total Brazilian exports in the 1890s and a quarter of total exports in the 1900s. The Brazilian rubber golden age is usually dated from the mid-1880s, when exports exceeded the £1 million mark, to 1912 when a peak of more than £16 million was reached. Peak rubber exports were almost equivalent to those of coffee, but in less exceptional years during the boom in the 1900s rubber exports were between a third and a half of coffee exports.<sup>3</sup>

The history of this rubber boom in the Amazon is shrouded by myths and legends that reflect the high profits accrued in a region that was considered by most, a pre-capitalist society. In this context, Manaus Opera House is paradigmatic: the building is a monument to the rubber bonanza. Inaugurated in December 1896, its central nave can accommodate 640 people in the auditorium including three floors with box seats. Today it is part of the Brazilian National Patrimony, preserved in its original style: eclectic and neo-classical architecture built with materials and labourers brought from Europe. In Belém, the main rubber hub, another sumptuous theatre was built from rubber proceeds some years earlier, in 1874: Teatro da Paz (Theatre of Peace).

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<sup>2</sup> Dean (1987, p. 9).

<sup>3</sup> Abreu and Fernandes (2005, p. 10).

During the rubber boom, it was said that Manaus diamond *per capita* consumption was the largest in the world, men walked with canes topped in gold and silver, children went to convent schools in Paris or Lausanne and almost 2,500 inhabitants took first-class tickets to Europe every year. Houses were decorated in *Parisien* style where “pre-dinner drinks were usually sipped from silver champagne goblets set on Carrara marble-topped tables with bases of solid gold”<sup>4</sup>. In addition, it was also said that Havana cigars were lighted with bank notes of 500 *milréis* (equivalent to 20 pounds at 1900 exchange rate) and that every toothache was treated in Europe.<sup>5</sup> Exaggeration or not, these descriptions of the rubber boom reflect the rapid wealth that flowed to the region from 1870 to 1910, capturing the imagination of many people around the world and fuelling immigration. Droughts in northeast Brazil contributed for the inflow of immigrants, especially *cearenses* (from Ceará State), who worked as rubber tappers but stories about the Amazon black gold, as rubber was nicknamed, also attracted fortune seekers from abroad.

However, the story is not so positive as at first appears: the rubber boom is also known for the infamous Putumayo scandal which from 1907 to 1914 uncovered the exploitation of thousands of Indians in the border of Peru and Colombia. Thanks to an American, named E. Hardenburg, who gathered evidences while in Peru, the “Civilised” public was told that Indians were constantly beaten, enslaved, mutilated, tortured and slaughtered in order to placate *Rubber Barons’* greed for rubber.<sup>6</sup> In Brazil, such labour exploitation was less frequent for Brazilian rubber producers seldom achieved the level of territorial power of their counterparts in Peru. Nonetheless, this does not imply that there were no big producers of rubber in Brazil as some were even bigger than their counterparts in the neighbouring countries. They were just less apparent probably due to the existence of so many big rubber producers in Brazil, by far the largest exporter supplying circa 60% of world demand for rubber<sup>7</sup>. It does not follow either that exploitation of labourers, be they Indians or *Cearnses*, did not occur in Brazil: the literature on Brazilian Amazon has indeed stressed the misfortunes of rubber tappers who were often subjected to some form of debt-peonage, bondage, semi-serfdom or indenture system. That exploitation, in turn, was possible due to the control of the means of production, that is, the land and the trees that grew on the Amazon Forest. Moreover, it was also usually argued that foreign export houses, in turn, were able to exploit Brazilian rubber producers through their monopoly over credit and their direct contact with markets abroad. In this view, exploitation of the rubber tappers was translated into exploitation of rubber producers with most of the surplus from Brazilian control of the rubber market remaining in the hands of foreign export houses.

The aim of the paper is to show that Brazilian rubber exporters faced a relatively inelastic demand which, in theory, should indeed have allowed them to capture substantial monopoly rents. However, recent literature on the Brazilian Rubber Boom has advanced that competition was present in all stages of the rubber chain (including, among exporters) and that cartelisation was virtually impossible. Supposedly, this would have precluded the capture of monopoly rents by Brazilian rubber exporters, but it is argued here that the role of the government has been so far neglected: inelasticity of demand for Brazilian rubber allowed the government to

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<sup>4</sup> Collier (1968, p. 22).

<sup>5</sup> Prado and Capelato (1981, p. 300).

<sup>6</sup> Collier (1968), Stanfield (1998) and Serier (2000).

<sup>7</sup> The advent of the Republic in 1889 brought easier access to land titles and many estate owners consolidated and increased their holdings by legal means or foul. See Weinstein (1983, pp. 165-191).

capture monopoly profits even under a perfect competitive market. How much of this surplus could have been captured and how much was actually generated is then the main issue dealt with in this paper.

In order to address this issue, the paper presents a quantitative approach, aiming to show the extension of Brazilian market power and how the region (optimally?) profited from it. An Almost Ideal Demand System (AIDS) is computed using data on import of rubber from the UK and the US balance of trade statistics. From the results obtained, elasticities of demand for Brazilian rubber will be obtained. Furthermore, a welfare analysis is carried out under different scenarios of government intervention in the market, with focus on Brazilian government taxation on rubber exports.

The paper is organised in 6 sections, including this introduction. **Section 2** presents a description of the econometric model and the data used in the estimation of the elasticity of demand for Brazilian rubber. **Section 3** discusses the estimation output under different scenarios for the elasticity of substitution and for the elasticity of foreign supply. The following section analyses the economics of taxation, stressing that the actual export tariff levied by the government was well below its optimum level (**Section 4**). **Section 5** thus computes the welfare effect of the actual export tariff and the counterfactual welfare effect had the government set the tariff at the optimum level. The results indicate that the government could have doubled the welfare effect. Finally, **Section 6** concludes the paper.

## 2. Model and Data Description

As explained in the introduction, the underlying idea of the paper is to analyse Brazilian market power on crude rubber and the first step is then to compute the elasticity of demand facing Brazilian rubber exporters. There are several ways of computing these elasticities though. One possibility would be to estimate demand and supply equations for the whole market jointly. However, in order to add up crude rubber supplies from several different parts of the world, that procedure would require the assumption that rubber was a complete homogenous commodity. In view of large quality differentials, this procedure does not seem to be satisfactory; especially in view that quality is an important feature of our story here. Furthermore, by this procedure we would not be able to obtain an estimate for the elasticity of demand for Brazilian rubber which is exactly the object of this paper. Another estimation procedure would be to estimate a separate demand and supply system for different countries/regions but this procedure would treat each rubber source as a totally different commodity, leaving no room for complementarity or substitutability among the sources: crude rubber was not a homogenous product at all but different grades of crude rubber were substitutes to some extent and sometimes they could also be mixed to achieve some desired minimum quality. Moreover, this procedure would require information about supply conditions in all rubber producing regions, something that does not seem feasible for the exercise here.

The estimation procedure proposed here is thus based on an Almost Ideal Demand System (AIDS)<sup>8</sup> which provides a framework that is general enough to be used as a first-order approximation to any demand system (see Appendix for a theoretic discussion of the model). Although it initially assumes that the supply of all

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<sup>8</sup> For a discussion about Almost Ideal Demand System, refer to the seminal article by Deaton and Muellbauer (1980). For applications of the model see Alston *et al.* (1990) and Alston *et al.* (1994). Finally, for economic historians, Irwin (2003) article is a good example of application of the model to the analysis of an historical case: cotton during the Antebellum USA.

rubber sources is perfectly elastic (which might be a strong assumption in some cases but which will be corrected later on here), that procedure gives a measure of the relationship between any given pair of crude rubber source. From the estimation output, it is possible to say if rubber sources were complementary or substitute, or if they were normal or inferior goods, for example. Under this setting, equation 1 below is the specification to be estimated here.

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log \frac{x}{P} \quad (1)$$

$$\text{where } \log P = \sum_k w_k \log p_k \quad (2)$$

where  $w_i$  is the budget share of country  $i$ ,  $\alpha_i$  is the intercept,  $p_j$  is the implicit price for rubber from all sources  $j$  and  $x$  is the amount of money spent on rubber by country  $i$ . Lastly,  $P$  is the Stone's Price Index as defined in Equation 2, which is used because implicit prices for rubber are collinear.<sup>9</sup> Theoretically, homotheticity, homogeneity and symmetry should be imposed in the estimation to assure that the microeconomics behind the model will hold. Homotheticity would require that all  $\beta_i$  coefficients summed to zero whereas under homogeneity (of degree zero in prices) all  $\gamma_{ij}$  summed up should equal zero for each equation. Finally, homogeneity requires that  $\gamma_{ij} = \gamma_{ji}$  for all  $i$  and  $j$ .

Under AIDS, changes in real expenditure operate through the  $\beta_i$  coefficients: it is positive for a luxury good and negative for necessities. Since the model does not represent directly a demand system, we need to retrieve from equation 1 above the true values for the elasticity of demand and for the elasticity of substitution between any given pair of crude rubber sources. According to Alston *et. al.*<sup>10</sup>, the compensated elasticity of demand for the  $i$ th good with respect to the  $j$ th price is defined as below:

$$\eta_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i} w_j \quad (3)$$

where  $\delta_{ij}$  is the Kronecker delta that is equal to one if  $i = j$  and zero otherwise. The standard error of the elasticity is given by  $\gamma_{ij}$  divided by  $w_i$ . The elasticity of substitution is also implicit in the parameters estimated and is defined as:

$$\sigma_{ij} = 1 + \frac{\gamma_{ij}}{(w_i w_j)} \quad (4)$$

where  $i \neq j$ , with an associated standard error calculated as the standard error of  $\gamma_{ij}$  divided by  $w_i w_j$ .

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<sup>9</sup> Under high collinearity, small changes in data might produce wide swings in the parameter estimates which may have very high standard errors and low significance levels even in the case when they are jointly significant and the  $R^2$  of regression is quite high. Furthermore, coefficients may present the "wrong" sign or implausible magnitudes. However, this does not seem to be the case here, as it will be clear later on, coefficients do show plausible magnitudes, expected sign and are quite robust. Moreover, collinearity increases the likelihood of Type II error, i.e, the likelihood of accepting the null hypothesis that a certain parameter is equal to zero increases. And, since this does not work in favour of the results here rather the contrary, it is possible in this case to simply disregard collinearity, especially because its correction would entail either dropping a variable or making the coefficients biased. Neither would help in the analysis: dropping a variable would embody losing information whilst biasing estimators would turn inferences from point estimators useless.

In our sample here the correlation between BRC and BRZ prices (see definition along the text) is 94.2%.

<sup>10</sup> Alston *et al.* (1994).

The own-price elasticities of demand for rubber given by equation 3 still assumes that rubber supply is perfectly elastic and that rubber exporters in countries like Brazil would rapidly adapt to any change in price. This is not a reasonable assumption and then we still need to take into account the elasticity of supply for different sources of rubber. Since our goal is to analyse the Brazilian market power on rubber, we can follow Irwin (2003) and compute the elasticity of export demand facing the Brazilian rubber exporters,  $\eta_{BRZ}$ , which is dependent upon the Brazilian market share,  $S$ , the elasticity of substitution between Brazilian and other varieties of rubber,  $\sigma$ , the elasticity of foreign export supply,  $\varepsilon$ , and the elasticity of demand for Brazilian rubber,  $\eta$ :

$$\eta_{BRZ} = \frac{\varepsilon[(1-S)\sigma + S\eta] + \sigma\eta}{S(\sigma - \eta) + \eta + \varepsilon} \quad (5)$$

According to equation 5, the elasticity of demand for Brazilian rubber will be smaller, (a) the smaller the elasticity of demand for rubber in general; (b) the smaller the elasticity of Brazilian rubber supply and; (c) the smaller the elasticity of substitution between Brazilian rubber and the other sources of rubber<sup>11</sup>.

In sum, the methodology here will be to estimate an AIDS for crude rubber. Besides looking at the properties of the estimation, like Adjusted-R<sup>2</sup>, Durbin-Watson Statistic, Unit Root Tests, etc., we will focus on the parameters  $\beta_i$  which will give us a measure of how necessary the different rubber sources were. The second step will then be to retrieve the elasticity of substitution between different rubber sources (through equation 4) and the own-price elasticities (through equation 3) which, in turn, will be corrected by equation 5 for the more reasonable case in which rubber supply is not perfectly elastic.

The dataset used in the estimation was constructed by the author from British and American trade data. The ‘Parliamentary Paper Series’ provide a detailed account of UK imports and exports from 1853 onwards from which it is possible to compute quantities and implicit prices for rubber by country of origin. A similar dataset was constructed for the US from ‘the Report from the Register of the Treasury of the Commerce and Navigation of the United States’. However, US data allows computation of implicit prices for rubber only from 1869 onwards.

Since up to 1910 Brazil possessed the largest market share (60.8%) and no other single country consistently exceeded the 10% mark, the other countries had to be aggregated in groups, notably in view that their territory often changed as consequence of colonial policies or simply due to independence or incorporation by another. Since British colonies (whose combined market share from 1870 to 1910 reached 14.0%) played a decisive role in the demise of Brazilian rubber boom, it is interesting to evaluate the elasticity of demand for their wild rubber before plantations came into place. Moreover, using this taxonomy implies that the results here are readily comparable with Fernandes (2007) where the author estimated elasticities of rubber demand from US and British data separately. Here, data for the USA and Britain once converted into the same unit measure were summed up, discounting off the trade between these two countries.

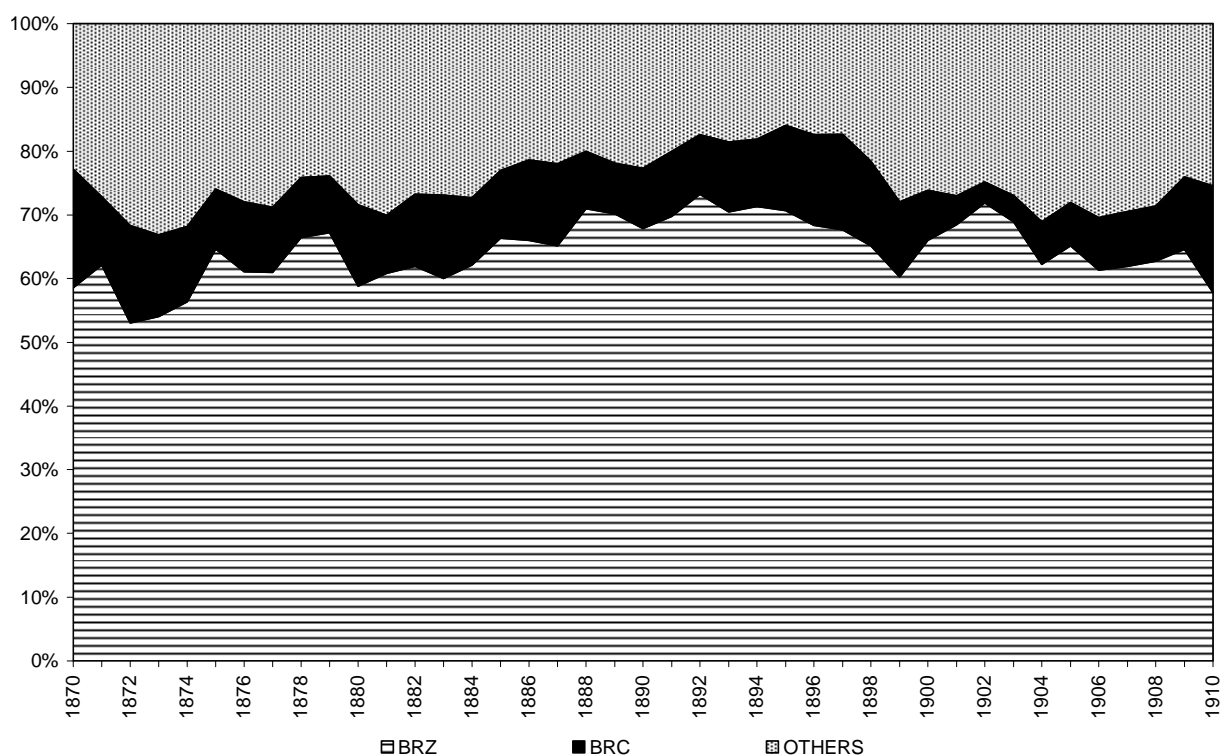
Brazil is defined in the same way in the British and American data but it is very likely that Brazilian figures (BRZ) include production of neighbouring countries such as Bolivia, Venezuela and Colombia since Belém city in Brazil developed as the main rubber hub in the region. In the British data, ‘British Colonies’

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<sup>11</sup> Van Duyne (1975, p. 603).

(BRC) comprise ‘Channel Islands’, ‘New South Wales’, ‘British West Indies’, ‘British East Indies’, ‘British India’, ‘Madras’, ‘Bombay & Scinde’, ‘India Singapore & Ceylon’, ‘Singapore & Eastern Straits’, ‘Ceylon’, ‘Federated Malay States’, ‘Borneo’, ‘Mauritius’, ‘Aden’, ‘Australasia’, ‘British West Coast Africa’, ‘British East Coast Africa’, ‘British South Africa’, ‘Natal’, ‘Zanzibar & Pemba’, ‘Gold Coast’, ‘Lagos’, ‘Nigeria’, ‘Sierra Leone’, ‘Gambia’, ‘Niger Protectorate’ and finally ‘Other British Possessions’. In the US data, BRC includes ‘British Honduras’, ‘Dominion of Canada’, ‘New Foundland’, ‘Labrador’, ‘Canada’, ‘British West Indies’, ‘British Guiana’, ‘British East Indies’, ‘British Australasia’, ‘British Africa’ and ‘Other British Possessions’. Altogether, the sample accounts for 67-84% of all rubber imported into UK and the USA (see Figure 1 below).

**Figure 1: Market Share in Rubber (Value): Brazil, British Colonies and Others (1870-1910)**

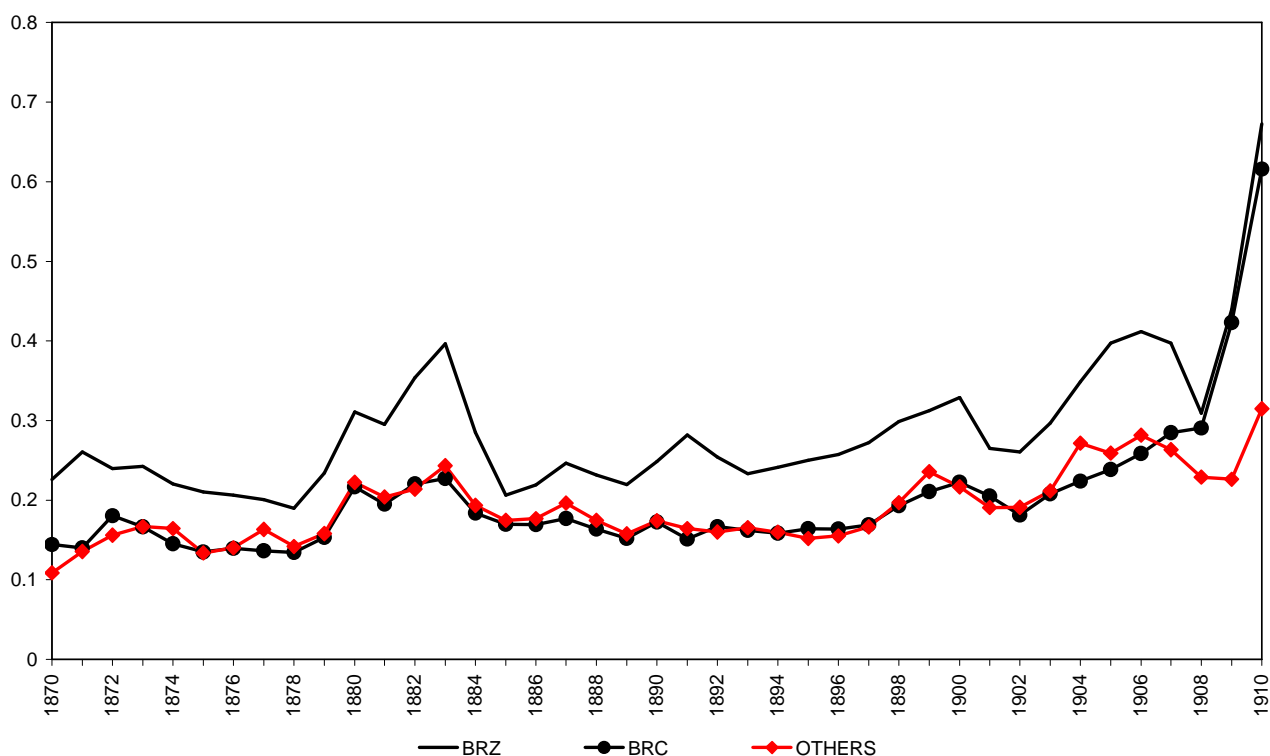


Source: The Parliamentary Paper Series (several issues) and Report from the Register of the Treasury of the Commerce and Navigation of the United States (several issues).

Implicit prices were computed as the official value divided by the quantity exported and they differed hugely across countries and showed a general upward trend across time (especially at the end of the sample). For instance, in the British dataset the coefficient of variation of prices across countries for the period 1855-1910 (there is no value of rubber exports for either 1853 and 1854 to compute implicit prices) can be as large as 0.52 (in 1909) and it shows general upward trend after 1858. As it will be discussed in this paper, the reason of this seems to be explained by the exercise of monopoly power by Brazil (and some degree of marketing the differentiation of Brazilian rubber) that pushed Brazilian rubber prices up, impelling other competing countries to produce lower quality rubber at lower prices (with the possible exception of south-east Asia where quality improved over time due to the domestication of a Brazilian rubber tree known as *hevea brasiliensis*): note that here it is not a matter of high prices inducing production of more costly substitutes but rather high prices

inducing production of low quality rubber to be mixed with Brazilian rubber. Furthermore, remember that no other country except Brazil was capable of supplying adequately the world market and in spite of its high prices, Brazil did not see its position in the world rubber market undermined until 1910 when its market share started to decline rapidly due to Asian plantation competition. Moreover, the fact that Brazil's market share was higher in value than in quantity additionally suggests that either (or both) Brazil was capable of cornering the market (or exercising some degree of market power) or the country exported a better quality of rubber (something that finds support from contemporary evidences and from the type of rubber tree the Brazilian Amazon possessed).

**Figure 2: Implicit Prices of Crude Rubber (£ per kg), 1870-1910**



Source: The Parliamentary Paper Series (several issues) and Report from the Register of the Treasury of the Commerce and Navigation of the United States (several issues).

### 3. Estimating Market Power

From the dataset described in the previous section, a set of equations (in the form of equation 1) will be jointly estimated. In practice, our estimation will then have two equations: one for Brazil and another one for the British Colonies. For Brazilian rubber, we will be estimating the Brazilian market share (dependent variable) against the price of Brazilian rubber, the price of British Colonial rubber and a variable that capture overall physical demand of the market as it is defined as the total expenditure on crude rubber (total imports of crude rubber) divided by an average price of the raw product. Analogously, for British colonial rubber, we will be estimating the British Colonial share (dependent variable) against the price of Brazilian rubber, the price of

British Colonial rubber and a variable that capture overall physical demand of the market as it is defined as the total expenditure on crude rubber (total imports of crude rubber) divided by an average price of the raw product.

The system was then estimated using Iterative Seemingly Unrelated Regressions (SUR) with only symmetry imposed and the results are reported in the Appendix. Homotheticity was not imposed since the system here is equivalent to the one in which one extra equation for “all remaining countries” had been deleted whose  $\beta$  coefficient would be given by the adding-up restriction.<sup>12</sup>

The Adjusted-R<sup>2</sup> indicates a reasonably good fit for BRZ equation (0.49) and a poor fit for BRC (0.11). Durbin Watson statistic suggested positive serial correlation in both equations possibly due to omission of price expectations or inflexibility in the short run, as a result of long run contracts between buyers and sellers. Even though the estimated coefficients remain unbiased and consistent, they are not efficient anymore. Augmented Dickey-Fuller tests on residuals in level for BRZ equation (not reported here) indicated that the null hypothesis that the residuals follow a unit root is rejected at 11%. The null hypothesis of unit root is also rejected in first difference at 0.1% confidence level. For the BRC equation, null hypothesis can only be rejected in second differences at 0.1% confidence level.

Remember that under AIDS, changes in real expenditure operate through the  $\beta_i$  coefficients: it is positive for a luxury good and negative for necessities. According to the estimates presented in the Appendix, Brazilian rubber is a luxury good whereas British Colonial rubber is a necessity (both statistically significant at 1% confidence level). However, since the coefficients are very close to zero, changes in the quantity of crude rubber consumed do not cause a significant change in terms of market share: for instance, whenever overall consumption of rubber increased there was only a small decrease of Brazilian market share and a slight increase in the British Colonies’ market share. This might further indicate that rubber supply might have been lower in BRZ compared to BRC.

Applying equation 3 to the estimated parameters of the AIDS model in the Appendix, we can retrieve the own-price and cross-price elasticities of demand. According to Figure 3 below, the own price-elasticity of rubber for British Colonies was -0.02 (not statistically significant though<sup>13</sup>) and for Brazil -1.32 (highly significant: t-stat = -18.85<sup>14</sup>). The elasticity of substitution between Brazilian and British Colonial rubber was not significant but indicate that it might have been positive (+0.29)<sup>15</sup>, i.e., the two rubber sources were considered substitutes.

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<sup>12</sup> In fact, to be strictly correct, the estimated equation should have included a price variable for “all remaining countries”. However, the micro properties do not change and the system is equivalent to impose that the coefficients of these prices were equal to zero. All qualitative results are robust to specification changes and it was just chosen here the minimal specification required to support the hypothesis put forward here, i.e., that Brazil possessed market power in world rubber market that once exercised would have generated positive net welfare effect. Furthermore, it must be stressed that estimates are invariant to the equation deleted. See Barten (1969).

<sup>13</sup> Indeed, the price elasticity for British Colonial rubber was seldom statistically significant and sometimes would even change the sign, becoming positive. This probably has to do with the interaction between British and American demand for British Colonial rubber as discussed in Fernandes (2007).

<sup>14</sup> The price elasticity of Brazilian rubber is indeed very robust. For all time periods and for different specifications, the elasticity always registered a negative sign and its point value changed very little. See Fernandes (2007) for other specifications.

<sup>15</sup> The cross elasticity proved to be statistically significant for the regressions within the period 1880-1910. Its value was always positive indicating that the two rubber sources were indeed substitutes.

**Figure 3: Implied Elasticities of Demand for Rubber (1870-1910)**

	Mkt Share	Beta	BRZ	BRC
<b>BRZ</b>	64.14%	0.08	-1.32	0.29
		6.24	-18.85	0.57
<b>BRC</b>	10.43%	-0.03		-0.02
		-3.00		-0.05

Note: t-statistics below each estimate

It must be stressed again here that own-price elasticities of demand for Brazilian rubber computed above should not be confused with the elasticity of export demand that Brazilian rubber exporters faced (from this point onwards we will ignore the British Colonial rubber as it did not register a statistically significant estimate nor is it important for the analysis here). We should then correct the own-price elasticity of demand for Brazilian rubber by applying equation 5 in order to obtain the actual elasticity of demand that Brazilian rubber exporters faced. In doing so, we find that the demand for Brazilian rubber was somewhat elastic but less elastic than the demand for US cotton in the Antebellum period: -1.1 (assuming elasticity of substitution of 0.8<sup>16</sup>, elasticity of rubber supply from other producers as 1.0 and market share of 64.1%) against -1.7 for US cotton. Figure 4 below presents the elasticity of demand for Brazilian rubber under different scenarios for the elasticity of supply from another producers ( $\epsilon$ ) and elasticity of substitution between Brazilian rubber and another types of rubber ( $\sigma$ ).

**Figure 4: Implied Elasticity of Rubber Demand faced by Brazilian Exporters under Different Scenarios, 1870-1910**

elasticity of substitution ( $\sigma$ )	Elasticity of Foreign Export Supply ( $\epsilon$ )				
	0,00	0,50	1,00	1,50	2,00
0,50	-0,83	-0,91	-0,94	-0,96	-0,97
0,80	-1,07	-1,09	-1,10	-1,11	-1,11
1,00	-1,18	-1,19	-1,19	-1,20	-1,20
1,30	-1,31	-1,31	-1,31	-1,31	-1,31
1,50	-1,38	-1,38	-1,38	-1,38	-1,38
1,80	-1,46	-1,47	-1,47	-1,47	-1,48
3,00	-1,65	-1,70	-1,73	-1,75	-1,77
5,00	-1,79	-1,89	-1,97	-2,04	-2,09
$\infty$	-2,06	-2,34	-2,61	-2,89	-3,17

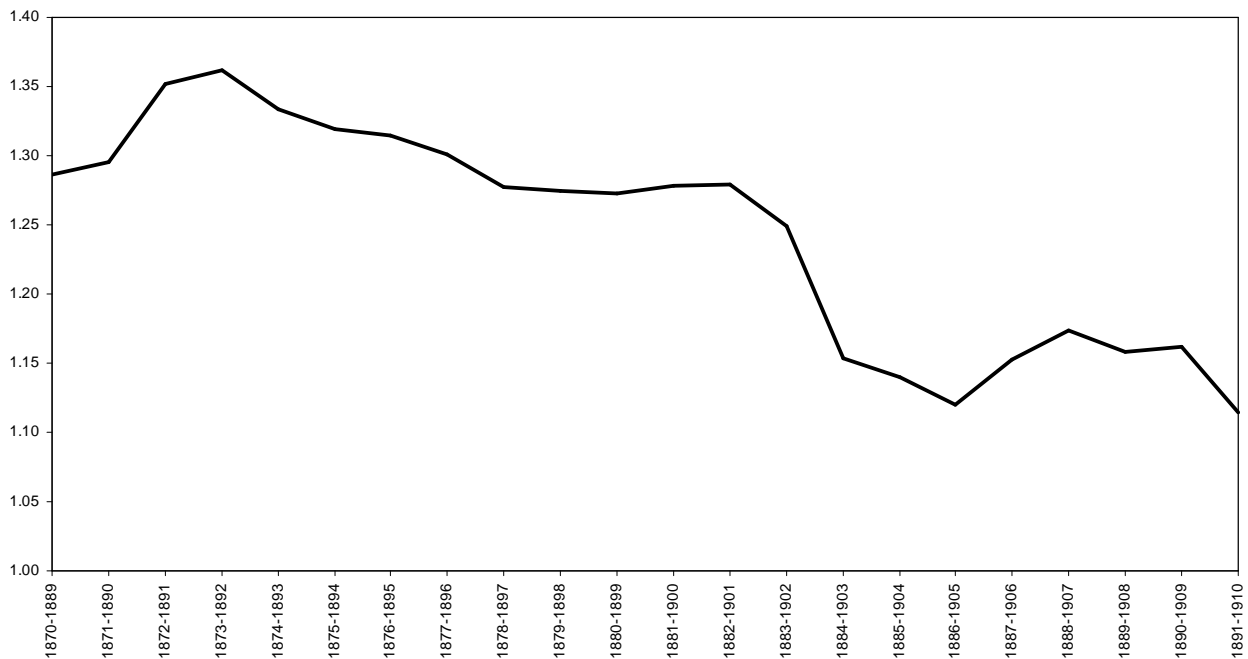
From Figure 4, it is possible to infer that, except in the case in which rubber is considered a homogeneous commodity (equivalent to have an elasticity of substitution equals to infinity), elasticity of demand for Brazilian rubber should have lain somewhere between -0.8 and -2.1. Comparing with Irwin's estimates for cotton during the antebellum period, from 1870 to 1910 rubber might have been more inelastic insofar as the elasticity of substitution between Brazilian rubber and rubber produced in British Colonies might have been as

<sup>16</sup> Note that this refers to the elasticity of substitution between rubber from British Colonies and Brazil computed for 1885-1910.

low as 0.8, which, according to Figure 4, would suggest an elasticity of demand around -1.10.<sup>17</sup> Anyway, for rubber it is very unlikely that the elasticity of substitution was actually higher than 1.8<sup>18</sup>, which would mean that the elasticity of demand for Brazilian rubber would have laid within the 0.8-1.5 range. Therefore, demand for Brazilian rubber from 1870 to 1910 seems to have been more inelastic than the demand for US cotton during the Antebellum period, especially because in the case of rubber the government was intervening in the market quite a lot through an export tariff, implying that the demand for Brazilian rubber might have been even more inelastic. We will come back to that point later on here.

Furthermore, it should be highlighted here that the demand for Brazilian rubber was becoming more and more inelastic with the passage of time. From Figure 5 below, it can be seen that at the peak of the rubber boom, the elasticity of demand was probably very close to one (-1.1). If the elasticity of substitution is assumed to be 0.8, the elasticity of demand for Brazilian rubber could have been as low as -0.94.

**Figure 5: Elasticity of Demand for Brazilian Rubber, 20-year Moving Windows (1870-1910)**



Note: The graph above was computed using the elasticity in absolute value. It further assumes a constant elasticity of foreign supply ( $\epsilon$ ) at 1.0 and an elasticity of substitution ( $\sigma$ ) at 1.3. All estimates are statistically significant at 10% confidence level.

Crude rubber was not a homogeneous commodity at all, registering huge differences in terms of quality and physical properties of the material (notably in terms of tensile elasticity). For instance, gutta-percha, a native tree from Malaya and the Dutch East Indies, was a non-elastic variety of rubber and owed its commercial use for insulation of (submarine) cables and for outer casing of golf balls. In turn, *hevea* trees, from the Amazon region

<sup>17</sup> However, using the same parameters as Irwin, i.e.,  $\sigma = 3$  and  $\epsilon = 0.5$ , rubber would be equally elastic: -1.7 for rubber against -1.7 for cotton.

<sup>18</sup> This belief is based on previous estimates on Fernandes (2007) and also from other several different specifications (and different time periods) estimated by the author and not reported anywhere. The elasticity of substitution between Brazilian and British Colonial rubber was usually below 1.8.

(especially in the Brazilian part), produced the best quality of crude rubber, being the most suitable material for high value added products. Therefore, the higher the quality of the crude rubber, the more applications it would have and of course, the higher the price: prices indeed reflected quality and there were several different grades of rubber in the market whose prices could differ by 3.1 times. Note that quality was also associated with the crude rubber production technique. Rubber was produced from the latex of the tree and would generate the best quality only if the tree was tapped with care. Depending on the dexterity of the rubber tapper the latex could coagulate once in contact with the air (or depending on the type of tree as well), and the more care they had, the less impurities the crude rubber might have had.

For certain manufactured products, there was a limit to substitution from higher to lower grades of rubber, and therefore there were limits to substitute for Brazilian rubber. Thus from Figure 1 it can be seen that Brazilian market share was not challenged until 1910 and that there was a premium on Brazilian rubber expressed as high prices (see Figure 2).

Therefore, due to the relative inelasticity of demand for Brazilian rubber, it can be said that conditions existed for monopoly profits to be generated, had some oligopolistic (or monopolistic) structure emerged. In another paper (new version in preparation) I challenge the assumption that an oligopolistic structure could not have emerged in Brazil in more depth but for the purpose of the present paper, we do not even need to show that the current literature on Brazilian Amazon was mistaken. In fact, we only need to stress here that the literature missed the role of the government and how taxation could have ensured that monopoly profits were generated even under perfect competition among exporters of rubber in Brazil. That is exactly the subject of our next section and our results here seem to provide further evidence to Frank and Musacchio's rubber chain analysis for they acknowledge that even though competition was present at every link of rubber chain, Brazil was able to reap monopoly profits before about 1900.<sup>19</sup> Here, it seems that it would have been possible to exploit Brazilian market power on rubber even during the first decade of the twentieth century.

#### **4. The Economics of Taxation: Impact on Elasticities**

Even if we believe that conditions in the rubber market prevented its oligopolisation and that free entry might have even precluded collusion agreements, it was shown in the previous section that conditions existed for the appropriation of monopoly profits and both contemporary and more recent literature neglected the possibility that government may have ensured (partial) monopoly profits for the Treasury.

Following Irwin (2003) and Abreu and Fernandes (2005), it is possible to understand why an entire country can be taken as a sole player in rubber market even when production occurs in a decentralised way: government interventions in the market affect all producers to the same extent and a certain level of production can be assured by government control of rubber price. Indeed, the government possessed several mechanisms to pursue this goal: nationalisation of rubber production, licensing scheme, stockpiling, export tariff and import tariff over goods that affected the rubber cost structure.

Firstly, the government could have ensured that the monopoly outcome would have been reached if the government had bought out (or simply appropriated) all rubber production units, something similar to the case of

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<sup>19</sup> Frank and Musacchio (2006, p. 288).

guano production in Peru.<sup>20</sup> Even though this mechanism was not impossible to be applied, it would have faced strong opposition from the Amazonian elite which, especially after the proclamation of the Republic (1889), had direct access to the government<sup>21</sup>. Secondly, the government could have regulated the amount of rubber produced through a licensing scheme similar to what Chile did in saltpetre.<sup>22</sup> However, this would have depended upon the ability of the government to ensure their directives and to prevent smuggling, something very difficult to apply due to the geography of the Amazon basin: had the government policy pushed prices to a level high enough to compensate for the risk of smuggling, rubber trade would have probably been shifted to Mato Grosso state or to one of the neighbouring countries (note that after the proclamation of the Republic in Brazil in 1889 taxation on rubber became a State prerogative). Thirdly, stockpiling could have been used to create some sort of “valorisation” policy, as São Paulo and Federal governments successfully did for coffee<sup>23</sup> in the first four decades of the twentieth century and that was unsuccessfully pursued in 1911 and 1912 for rubber. Fourthly, export tariff was constantly used by State governments, especially after the advent of the Republic in 1889 (and by the federal government in Acre territory after it was bought from Bolivia in 1903) and even though the initial aim was just to generate essential revenues for Pará and Amazonas states, there were consequences in terms of incentives for rubber production: the quantity produced was indeed influenced by government interventions. Lastly, import taxes over rubber inputs, directly affects the cost of production which would result in less rubber being produced as well. This mechanism was largely used by Federal government (sometimes even applied to merchandises from other states of Brazil).

As explained above, nationalisation of rubber production did not occur, a licensing scheme did not emerge and stockpiling was not successfully pursued from 1870 to 1910. Furthermore, since import taxes were not under the control of state authorities (and because the federal government was more concerned with issues relating to coffee rather than rubber) and its impact was too indirect to provide an estimate of its cost impact, only export tax effect on welfare will be analysed here.

Let’s see then how the export tax could have been used as a way to achieve the maximum level of regional welfare. Figure 6 shows an export market in partial equilibrium. Point *A* corresponds to equilibrium in a perfectly competitive market: rubber domestic producers would sell the quantity  $Q_1$  where rubber export supply equals rubber export demand at the world price  $P_1$ . The optimal quantity of exports is equivalent to the monopoly outcome,  $Q_2$ , corresponding to the point at which the marginal cost of rubber export supply equals the marginal revenue from exports. At this point the country generates the highest producer surplus.

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<sup>20</sup> In 1841, Peru asserted its rights of ownership over guano deposits. In 1849, the Peruvian government awarded a single contract for extracting guano to a prominent local entrepreneur, Domingo Elías, who was later succeeded by Andrés Álvarez Calderón. According to Miller and Greenhill (2006, p. 243),

*“(…) [a] central feature of these contracts after 1849 was the employment of merchants to transport and sell guano overseas on consignment for a limited term, in return for a commission and other payments for their services. The Peruvian government stipulated both the quantity of guano to be exported and the price at which it should be sold.”*

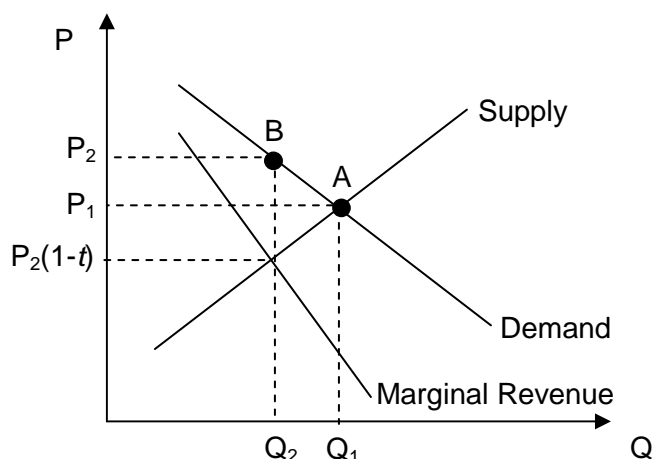
<sup>21</sup> For instance, the first governor of Pará under the Republic was Justo Chermont who was an active figure in Companhia Mercantil do Pará, a rubber trade company established by the famous Baron of Gondoriz (João Caetano Gonçalves Vianna, a Portuguese-born merchant) with the intention of cornering rubber trade in Belém through the acquisition of large stocks of rubber. See Weinstein (1983, pp. 137-164).

<sup>22</sup> Abreu and Fernandes (2005) and Miller and Greenhill (2006).

<sup>23</sup> Bacha and Greenhill (1992) and Abreu and Fernandes (2005).

In the simplest case where the government intervenes into the market through the imposition of an export tax only, its optimal level,  $t$ , would simply be the reciprocal of the price elasticity of rubber export demand. The marginal revenue of commodity exports can be expressed as  $P^* \left( 1 - \frac{1}{\eta_{BRZ}} \right)$ , where  $P^*$  is the world price and  $\eta_{BRZ}$  is the (positive) elasticity of rubber export demand as defined before. Since the rubber domestic price (i.e. the price actually received by rubber exporters) would be given by  $P = P^*(1-t)$ , equating marginal revenue to rubber domestic price yields the optimal export tax:  $t = 1/\eta_{BRZ}$ .

**Figure 6: Competitive and Monopoly Market Equilibria**



From Figure 4, it is then possible to compute the implicit optimal export tariff, which is just the reciprocal of the absolute value of the elasticities reported there. First of all, even in the counterfactual scenario in which rubber is considered a homogeneous product, optimal export tariff would have been as high as 32% and under more realistic assumptions ( $\sigma = 0.8-1.5$ ), it could have reached 93% (with 68% as a lower bound).

**Figure 7: Implicit Optimal Export Tariff**

elasticity of substitution ( $\sigma$ )	Elasticity of Foreign Export Supply (e)				
	0,00	0,50	1,00	1,50	2,00
0,50	120%	110%	106%	104%	103%
0,80	93%	92%	91%	90%	90%
1,00	84%	84%	84%	84%	84%
1,30	76%	76%	76%	76%	76%
1,50	73%	72%	72%	72%	72%
1,80	69%	68%	68%	68%	68%
3,00	61%	59%	58%	57%	56%
5,00	56%	53%	51%	49%	48%
$\infty$	49%	43%	38%	35%	32%

Note that these optimal export tariffs were supposed to be levied in excess of an existing one which amounted to 17.6% *ad valorem* on average from 1870 to 1910 (see Figure 8 for the evolution of the Export Tariff levied by the government). Thus, if the government had not intervened in the market, the optimal tariff could have reached 127.5% (with a lower bound at 97.2%), assuming  $\sigma$  would lie between 0.8 and 1.8<sup>24</sup>. In turn, under the same assumptions, the elasticity of demand that Brazilian rubber producers would face, had the government not levied any export tariff would have laid in the interval -0.78 to -1.03<sup>25</sup>. Therefore, in the absence of government taxation, the demand facing Brazilian rubber exporters might have been quite inelastic implying that there were definitely grounds for appropriation of monopoly rents by the government during the rubber boom. In this context, taxation increased the welfare of the region but apparently there was room for even more welfare to have been generated there.

**Figure 8: Ad Valorem Export Tariff Levied by the Government (1870-1910)**



**Note:** *Ad valorem* export taxes were computed as the ratio between the rights of rubber (total revenue generated by export tariff on rubber exported) and total value of rubber exported instead of using the actual tariff as defined by laws. The procedure adopted here captures the true tariff burden insofar as government always established official prices for rubber which sometimes differed quite substantially from market prices. For Acre territory, *ad valorem* export tariff was computed from 1904 to 1910 (note that Acre was officially part of Brazilian Federation only after 1903), resulting in 17.35% on average. For Amazonas, there were figures for 1871-72, 1881, 1884, 1885, 1896 and from 1899 to 1910 and its *ad valorem* export tariff was on average 17.34%. Finally, in Pará, the most important rubber exporter state, *ad valorem* export tariff amounted to 17.89% from 1885 to 1910.

**Sources:** Data were gathered from several Provincial Presidential Reports, *Relatório da Fazenda do Amazonas* (1918) and LeCointe (1922).

## 5. Welfare Analysis

Once having computed the optimal export tariff, it is possible to evaluate the gains from the actual export tax and the counterfactual gain had the government increased the tariff up to its optimum level. This welfare gain would depend upon the elasticity of Brazilian rubber supply, as it is defined as the consumer surplus extracted

<sup>24</sup> This is just the computation of  $(1+TRF\_EXP)*(1+TRF\_EXP\_OPT)-1$ ; where TRF\_EXP is the actual export tax levied by the government and TRF\_EXP\_OPT is the optimal export tax as of Figure 7.

<sup>25</sup> These elasticities were computed as the (negative) inverse of total optimum export tariff range.

from foreign consumers,  $(P_2 - P_1) * Q_2$ , minus the domestic deadweight loss,  $\frac{1}{2} * (Q_1 - Q_2) * (P_1 - P_2 * (1 - t))$ . In turn, the change in rubber price in international markets is given by:

$$\Delta p = \frac{\epsilon_{BRZ}}{\epsilon_{BRZ} - \eta_{BRZ}} \Delta \tau \quad (6)$$

where  $\Delta p$  is  $P_2 - P_1$ ,  $\epsilon_{BRZ}$  is the elasticity of Brazilian rubber export supply and  $\Delta \tau$  is the change in export tax. Note that when  $\epsilon_{BRZ}$  approaches infinity  $\Delta p \rightarrow \Delta \tau$ , i.e., Brazilian rubber producers could integrally pass through the tax burden to consumers. Analogously, when  $\epsilon_{BRZ} = 0$ , Brazilian producers are unable to push prices up and they internalise the whole tax burden.

Thus the welfare gain of taxation depends not just upon the elasticity of demand that Brazilian rubber producers faced but also upon the elasticity of Brazilian rubber supply. In that regard, it should be emphasised that there was no significant change in productivity per rubber tapper, inasmuch as there was no change in production methods from 1870 to 1910. Rubber extraction technique varied according to the type of rubber sought and extraction methods were very simple. According to Roberto Santos, the average rubber tapper would operate in 1.33 trails (each trail was comprised of 123 rubber trees on average) and would produce around 255kg of rubber per year.<sup>26</sup> Productivity would depend then on the exhaustion of the tree and the type of tree (e.g., *hevea brasiliensis* would provide not only the highest quality of rubber but also register the highest productivity). Since these factors were not under the control of the rubber state owner (it was a given of the nature, since there was no plantation scheme in Brazilian Amazon worth of note), it is fair to say that increases in production would occur only extensively: adding more rubber tappers to more rubber trees and applying more capital, in the form of advances for the tapping season.

The absence of any major improvements in techniques might have resulted in a high inelasticity of supply due to a claimed shortage of labour even though during the boom, Amazon population increased fourfold, from 278.3 thousands in 1860 to 1.2 million in 1910<sup>27</sup>, as a result of immigration from other parts of Brazil, notably from Ceará State.<sup>28</sup>

In sum, Brazilian rubber supply responsiveness would directly depend on the availability of workers and we would expect that in periods of high immigration, Brazilian rubber supply might have been more elastic whereas in periods of low immigration to the region, the opposite might have been true. Indeed, tentative estimations of regressing total Brazilian exports of rubber against different combinations of variables such as a constant, lagged prices (or current price), population and a time trend, give an elasticity of supply well below 1, probably close to 0.25. Indeed, according to Weinstein,

<sup>26</sup> Santos (1980, pp. 77-86).

<sup>27</sup> In this regard, see Akers (1912, pp. 67-70 and 80-81), Woodroffe (1916, pp. 1-24), Santos (1980) and IBGE (1987).

<sup>28</sup> There was also international migration but it was concentrated at the end of our period here and the numbers were completely dwarfed by the mass of immigrants coming from other regions of Brazil.

*“contemporary observers frequently commented on the fact that the volume of Amazonian production was almost completely unaffected by price fluctuations, since the aviador [intermediary] lacked an efficient method of increasing or reducing his ‘tapper-client’ output.”*<sup>29</sup>

The real welfare effect of the actual export tariff levied by Amazonian governments, assuming an elasticity of foreign export supply of 1.0 and an elasticity of substitution of 1.3 (which is the middle point between 0.8 and 1.8 we used here before) would amount to £139,139 (at 1910 prices) on average per year. This value was obtained by first applying the elasticity of demand of -1.32 to equation 6, giving us the price change, had the tariff not been levied. This new counterfactual price ( $P_2$ ) was used to compute the correspondent new counterfactual quantity of rubber exported from Brazil ( $Q_2$ ). As mentioned earlier on, the net welfare gain was calculated as the consumer surplus extracted from foreign consumers,  $(P_2 - P_1) * Q_2$ , minus the domestic deadweight loss,  $\frac{1}{2} * (Q_1 - Q_2) * (P_1 - P_2)$ . This value was finally transformed into 1910 prices using Rousseaux Price Index.<sup>30</sup> Assuming that the elasticity of Brazilian rubber supply ( $\epsilon_{BRZ}$ ) was 0.25, Real Net Welfare generated by taxation would amount to £139,139 on (yearly) average in 1870-1910 and, if the elasticity of Brazilian rubber supply is assumed to be 0.50, it would amount to £244,497 on a yearly average over the same period, equivalent to 1.3% and 2.3% of the average Amazonian GDP (1870-1910)<sup>31</sup>, respectively.

Assuming the elasticity of Brazilian rubber supply ( $\epsilon_{BRZ}$ ) as equal to 0.25, Figure 9 below shows the same computation for a 20-year moving windows which indicates that with the passage of time, the government was generating a higher real net welfare because: a) The value of rubber trade was increasing over time and; b) Rubber was becoming more inelastic.

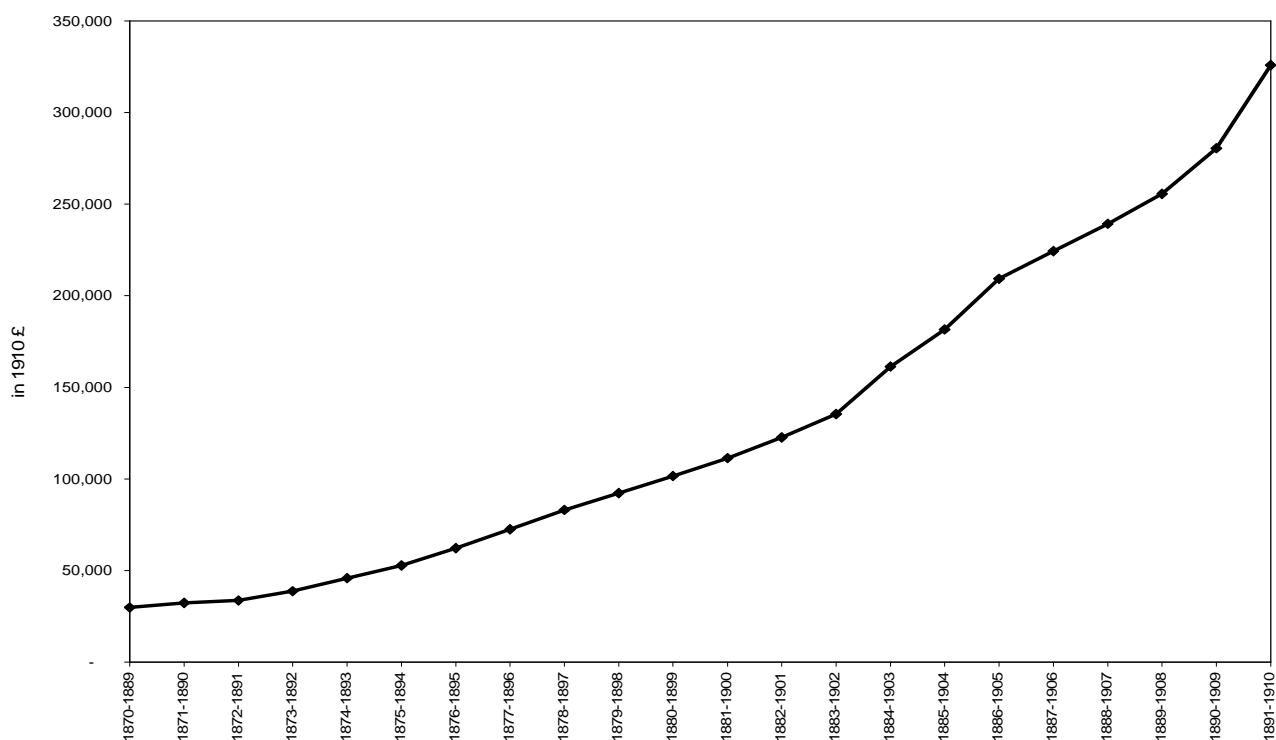
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<sup>29</sup> Weinstein (1983, p. 157).

<sup>30</sup> Mitchell (1962, pp. 471-473). Results do not change significantly if we apply Sauerbeck Price Index from Mitchell (1962, 474-475).

<sup>31</sup> GDP figures from Santos (1980) were converted into sterling pounds using Ipea Dataset available at <http://www.ipeadata.gov.br/>.

**Figure 9: Real Net Welfare of the Export Tariff, 1870-1910 (in 1910 £)**

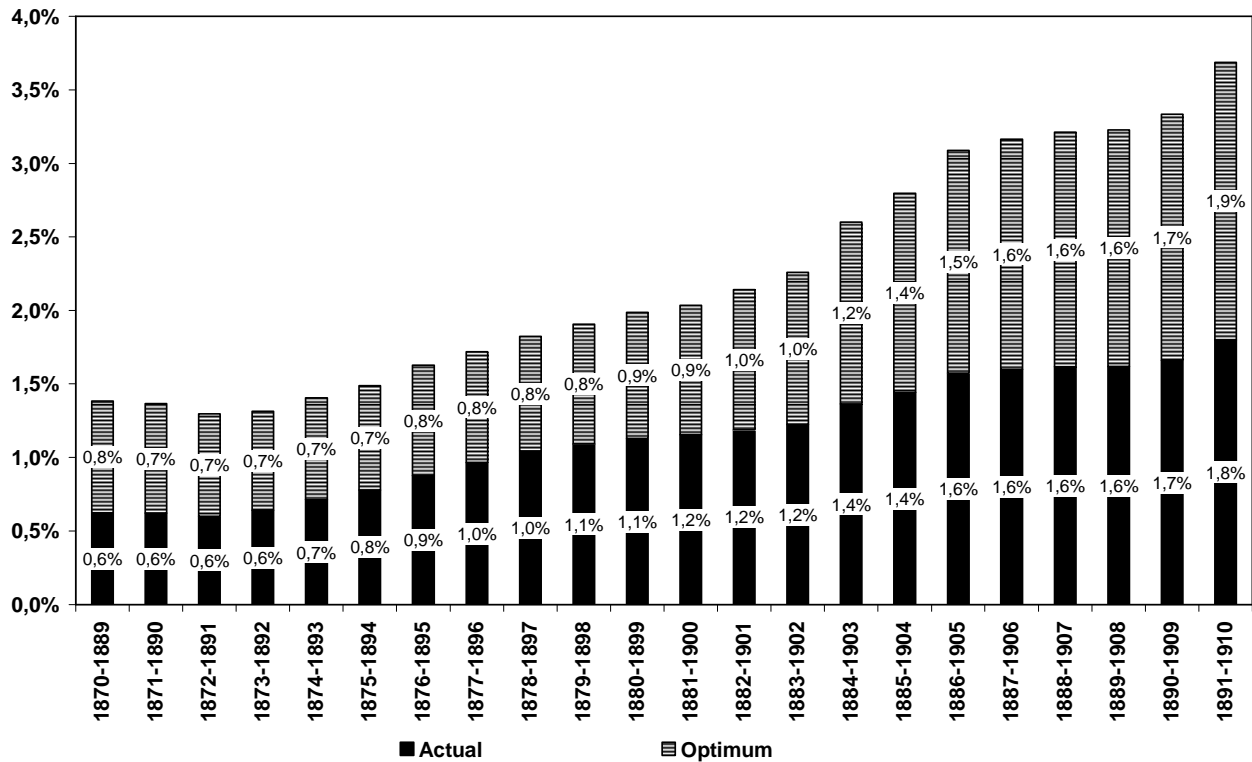


Santos (1980) provided an estimate of the Amazonian GDP from 1870 to 1910 (on a 5 year basis) which was converted into pounds and then interpolated to provide a full Amazonian GDP series between 1870 and 1910. Then I computed GDP averages over the same periods as of Figure 9, so that we can assess the magnitude of the welfare generated by government taxation. According to Figure 10 below, the government could have generated a welfare effect as high as 1.9% of the overall GDP of the region during the last 20 years of the rubber boom (1891-1910), three times larger than what the government could have generated at the beginning of the period. Furthermore, it can be inferred that the government was increasing the net welfare effect generated by the export tariff in a context in which the GDP of the region was also increasing.

It is also possible to compute the welfare effect, had the government increased the tariff up to the optimum level. Still assuming the elasticity of Brazilian rubber supply ( $\epsilon_{BRZ}$ ) as equal to 0.25, over the whole period, the government could have generated an extra 1.3% (£133,846 at 1910 prices)<sup>32</sup>, doubling then the welfare effect that it was already generating with the export tax. Over time, the government could have initially generated on average £38,525 per year (0.76% of GDP) from 1870-1889 whilst at the end of the period this welfare would have amounted to £341,444 per year (1.89% of GDP) in the period 1891-1910. Figure 10 summarises the actual and optimal welfare effect from government taxation on rubber within a 20-year moving window from 1870 to 1910.

<sup>32</sup> Assuming the elasticity of Brazilian rubber supply ( $\epsilon_{BRZ}$ ) as equal to 0.50, the Real Net Welfare effect generated would be £267,810 on average per year during the period 1870-1910, or 2.6% of GDP.

**Figure 10: Real Net Welfare of the Export Tariff, 1870-1910 (% of Amazonian GDP)**



In sum, had the government set the export tariff at the optimum level, an extra welfare gain would have been accrued by the government. Assuming that the elasticity of Brazilian rubber supply ( $\epsilon_{BRZ}$ ) was equal to 0.50, from 1870 to 1910, the total possible welfare that the Amazon Region could have amassed was £268,017 per year on average (at 1910 prices), equivalent to 2.6% of the region's GDP. However, given the fact that crude rubber was getting more inelastic over time (and that rubber trade was increasing very fast), the total welfare effect could have been as high as 3.7% of the region's GDP from 1891 to 1910.

## 6. Conclusion

In this paper, an Almost Ideal Demand System for rubber was calculated using data from UK and US Balance of Trade from 1870 to 1910, from which it was possible to compute elasticities of demand for Brazilian rubber as well as cross-elasticities between Brazilian and British Colonial rubber. The results indicate that from 1870 to 1910 the demand for Brazilian rubber was very inelastic: had the government not set any export tariff, the elasticity of demand that Brazilian exporters faced might have laid within the -0.78 to -1.03 range.

The paper then shows that the literature on Brazilian rubber has neglected the fact that the government was able to ensure the monopoly outcome even under a high degree of competition amongst Brazilian rubber exporters and under a high inelasticity of supply. Indeed, the government possessed several mechanisms to pursue this goal: nationalisation of rubber production, licensing scheme, stockpiling, export tariff and import tariff over goods that affected the cost structure of rubber gathering in Brazil. It was argued here that the export tariff and the import tariff were the main instruments actually used by the government but the welfare analysis here focused on the export tariff only.

Under reasonable assumptions, results here suggest that the optimum export tariff laid in the 97.2%-127.5% interval but the government levied only 17.6% on average in the years for which data were available (1870-1910). Had the government imposed the optimum export tariff, welfare could have been increased as much as £341,444 per year from 1891-1910, equivalent to 1.89% of Amazonian GDP in the period. This welfare would have been generated on top of 1.80% that had already been generated by the government when it set the export tariff at 18.9% in the same period (1891-1910).

In short, the paper thus shows that the Amazonian State governments were indeed generating positive welfare gains for the Amazon region through taxation, regardless of how competitive the rubber market was. Moreover, the results further indicate that there was room for the government to extract monopoly rents even in a context of high inelasticity of Brazilian rubber supply. Therefore, the results show the extension of market power Brazil possessed in rubber market and suggest that the government could have ensured the maximum regional welfare at the rubber consumer's expense. This conclusion seems to contribute a great deal for the debate about the rubber boom in the Brazilian Amazon and about taxation in general.

First, the elasticities of demand computed here expands our understanding of the developments taking place in the industrialising countries, especially in the USA and in Britain which were the main rubber consumers. From 1870 to 1910, rubber found more and more applications and became an increasingly strategic commodity: with such an inelasticity of demand it is likely that developments in the Brazilian Amazon were influencing the development of rubber industrial process in the USA and in the UK. Moreover, their dependence on rubber pushed the Amazon region into such a specialisation of production that the region became a virtual monoproducer of rubber; importing everything else. Therefore, the region is an interesting case study of trade specialisation due to comparative advantage.

This trade specialisation changed the pattern of integration of the region into the world economy and the paper here supports Frank and Musacchio's view that there was no economic imperialism in the Amazon as the rubber chain does not fit into the model of peripherality of raw material and centrality of manufacture. That traditional formulation suggests that production in the periphery (Brazil) should have developed in tandem with impulses emanating from the industrial core (USA and Europe). That pattern would ensure that profits in the periphery would either be held down (so as to maximise profits at the industrial core) or be high in order to ensure profitability from investments flowing from the industrial core. It is not surprising that for a quite long period, given the high inelasticity of demand for Brazilian rubber, manufacturers in the core economies were tied to developments occurring within the Brazilian Amazon, diametrically contrary to the traditional assumption of economic imperialism.

However, economic imperialism cannot be completely dismissed since the tax policy was constrained by (foreign) export houses' lobby. It is true that not all export houses were foreign-owned or foreign-managed but whenever they were not, they might have relied upon a cooperative local elite. The government might have maximised its revenues in a context of pressure from export sector and the latter's imperfect access to the government, but there should be no doubt that the government could have reaped much more monopoly profits than it actually did. Even though it was only mentioned briefly here, the issue of why export houses failed to

collude or why there were high costs of bargaining is not thoroughly analysed in this paper and what it is probably still missing here is an analysis of the political economy of taxation on rubber.

It might have been the case that a monopsony could have emerged and it seems that the disputes among different countries for rubber, especially between the United States and Britain, were more important to explain the enhanced government's room for manoeuvre than just natural characteristics of market organisation in Brazil as claimed by Barham and Coomes (1996). In this context, competition in rubber trade might have been the result of competition among imperialist countries and cannot be solely credited to market organisation within Brazil. On the other hand, it is possible that the government was not ensuring the maximum level of welfare due to dispute on the regional level among the three States (Pará, Amazonas and Acre<sup>33</sup>) that comprised the Amazon region. If Amazonian States were trying to divert the trade towards their own jurisdiction (in order to increase their own tax revenues), the maximisation of their own revenues might have differed from the regional optimum level of taxation, leading to a sub-optimal outcome.

Finally, the paper not only contributes to the understanding of the effects of taxation and its welfare impacts but also to the economic history of the Amazon region. In providing the first measure of elasticity of demand for Brazilian rubber and carrying out a welfare analysis, the paper showed that there was room for extraction of monopoly rents from rubber trade even in a context of high degree of competition in the market. In other words, the paper brings the role of the government to the fore by analysing the impact of taxation on the region's welfare.

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<sup>33</sup> Acre was in fact a Federal Territory.

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### A.1. AIDS (1870-1910)

Estimation Method: Seemingly Unrelated Regression

Date: 02/05/08 Time: 17:39

Sample: 1870 1910

Included observations: 41

Total system (balanced) observations 82

Linear estimation after one-step weighting matrix

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	-0.90	0.24	-3.76	0.03%
C(11)	-0.15	0.04	-3.44	0.10%
C(12)	-0.05	0.03	-1.41	16.18%
C(100)	0.08	0.01	6.24	0.00%
C(20)	0.75	0.22	3.48	0.08%
C(22)	0.10	0.04	2.82	0.62%
C(101)	-0.03	0.01	-3.00	0.37%

Determinant residual covariance 0.00

Equation: BRZ\_MKT = C(10) + C(11)\*LOG(BRZ\_PRC) + C(12)  
\*LOG(BRC\_PRC) + C(100)\*(LOG(X)-LN\_PRICE)

Observations: 41

R-squared	0.53	Mean dependent var	0.64
Adjusted R-squared	0.49	S.D. dependent var	0.05
S.E. of regression	0.04	Sum squared resid	0.05
Durbin-Watson stat	1.17		

Equation: BRC\_MKT = C(20) + C(12)\*LOG(BRZ\_PRC) + C(22)  
\*LOG(BRC\_PRC) + C(101)\*(LOG(X)-LN\_PRICE)

Observations: 41

R-squared	0.18	Mean dependent var	0.11
Adjusted R-squared	0.11	S.D. dependent var	0.03
S.E. of regression	0.03	Sum squared resid	0.03
Durbin-Watson stat	0.69		

### A.2. Symmetry Test (1870-1910)

Wald Test

Test Statistic	Value	df	Probability
Chi-square	6.93	1	0.85%

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(12) - C(21)	-0.15	0.06

Restrictions are linear in coefficients.