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Stretching the Inelastic Rubber: Taxation, Welfare and Lobbies in Amazonia, 1870-1910

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Abstract

This paper examines the effect of government intervention via taxation on domestic welfare. A case-study of Brazilian market power on rubber markets during the boom years of 1870-1910 shows that the government generated 1.3% of GDP through an export tax on rubber but that it could have generated 4.7% in total, had the government set the tariff at the optimal level. National, regional and local constraints prevented the government from maximizing regional welfare. In a context of lobbies, government budget maximization may have differed from regional welfare maximization.

JEL: F14, H21, L13, L73, and N76.

Keywords: Rubber, Commodities, Market Power, Optimal Tariff, Welfare, Trade and Brazil.

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1 Introduction

The paper shows that export taxes can be used to substantially increase domestic welfare. Irwin uses antebellum US as the "quintessential example of a 'large' country that could improve its terms of trade and welfare through trade restrictions". His findings suggested that despite high American market share on cotton, a 50% export tax would have raised US welfare by a meager 0.3% of US GDP, or about 1% of the South's GDP. As will become clear, rubber in the Brazilian Amazon provides an interesting case study in which much lower export taxes (18.7%) were actually levied leading to welfare gains of more than 1% of regional GDP. Moreover, due to high market power in the world rubber market, even more welfare could have been generated via taxation. The government ability to tax was however constrained at three different levels: nationally, regionally and locally.

Substantial market power means the ability to control prices in a given market. In history, there have been only a few cases of commodity price control that, under market conditions, persisted for a very long period of time, allowing a rigorous quantitative assessment. First, market shares must be high. Although high market shares are a necessary condition for market power, they are not a sufficient one as contestability may be present. Secondly, the commodity in question needs be unique. If it is easily substituted for other commodities, market power will not be fully exercised. Thirdly, the fewest players there are in the market, the easiest it should be to achieve price control, as the costs of coordination should increase with the number of players in the market.

The rubber market fulfills all the above conditions during the period from 1870 to 1910. First, during these 41 years, the Brazilian Amazon (comprised of Today's states of Acre, Amapá, Amazonas, Pará and Roraima) possessed an unrivalled market share in the world rubber market based on both quantity and quality of its rubber production. Until 1910, rubber was mostly produced from natural sources and plantation rubber was still negligible.[1] Thanks the sheer size of the Brazilian Amazon, which by then covered an area roughly equivalent to half of continental USA, the region accounted for 60% of world rubber supply.[2] If Amazonian trees were tapped with care, they could endure several seasons and Brazilian production could thus increase sustainably by incorporating new tracts of the forest into production. It is true that rubber trees could be found in several other regions but their associated method of production invariably involved the killing of the plant. Competing rubber reserves were either (or both) exhaustible or negligible in size compared to the Brazilian Amazon.

Secondly, the region happened to possess the tree (*hevea brasiliensis*) that yielded the best rubber grade in terms of tensile elasticity. The main characteristic of rubber was exactly its tensile elasticity, a characteristic that very few other products could match, making for a very low degree of substitutability. Crude rubber was in this sense a unique material and the rubber industry reflected the versatility of this raw material. Over time, more and more rubber products were created or adapted: [bicycle and automobile] tires, submarine [telegraphic] cables, steam engine seals, rubber shoes, machine belts, hoses, waterproofed clothes, railwagon buffers, surgical products, and so forth. Rubber demand was thus constantly expanding over time.

Thirdly, despite some claims that the rubber market was contestable, this paper shows that, whatever the market organization, the government was able to profit from the Brazilian Amazon's market position through taxation. Via taxation, the government ensured that domestic welfare increased at rubber buyers' expenses, which in the case of the Brazilian Amazon, were all located abroad: the region did not consume any significant amount of rubber domestically.

Rubber provides a very interesting accounting of the exercise of market power over an extended period. The paper quantifies the welfare effect of taxation on rubber exports and examines how much additional welfare could have been generated, had the

[1] Refer to Drabble (1973) for a study of plantation rubber in Malaya.

[2] There is an extensive literature on the rubber boom, and in particular, in the [Brazilian] Amazon Rubber Boom. See, for instance, Akers (1912), Woodrofe (1916), LeCointe (1922), Drabble (1973), Santos (1980), Weinstein (1983), Barham and Coomes (1996), Frank and Musacchio (2006) and Fernandes (2009).

government set the tariff at the optimal level. Since it was always optimal to increase the tariff, the paper also explores why the government was generating a sub-optimal outcome. The underlying message is that the government may not have been irrational given some non-exclusionary explanations provided here for the government's fiscal constraint. Those are the issues dealt with in the present paper and it is envisaged that this historical example may shed some light onto other case studies such as coffee and saltpeter before 1930s or more recently oil.

The paper is organized in 8 sections, including this introduction. Next section presents a short history of the rubber boom in the Brazilian Amazon. Section 3 describes the model used to estimate market power and welfare effects of taxation whereas Section 4 discusses the database used in the estimations. Section 5 presents and analyses the results which clearly indicate that substantial welfare was generated via taxation and much more could have been amassed by the government had the tariff been increased up to the optimal level. Section 6 shows some robustness checks whereas Section 7 discusses the political economy of taxation, explaining why the government did not set the tariff at the optimal level. Finally, Section 8 concludes the paper.

2 Brazilian Rubber Boom in a Nutshell

Rubber production in Brazil started in the region around Belém, located at the mouth of the Amazon River. The development of rubber production followed the contours of the Amazon River and its main tributaries. It spread westwards in the direction of Manaus located some 1,000 miles upriver. In 1870, Manaus was only a small village whose growth would depend entirely on rubber production as the city eventually became the second most important trade hub, rivaling Belém's long-established position in the rubber trade. Even though the rivers provided access to nearly all areas of the Brazilian Amazon[3], production expanded mostly southwards due to the availability of *hevea*

[3] Not all rivers were entirely navigable though. Sometimes they were too shallow for large vessels or they just had downfalls and rapids. However, even still, most of them were accessible by canoes.

brasiliensis trees. This tree provided the best rubber grade and tappers were continuously looking for *hevea* growing areas. In this search, Brazilian production would cross national borders towards the Acre region which, until 1903, was *de jure* part of Bolivia. The region would be ultimately annexed into the Brazilian Federation as a consequence of the rubber boom.

Rubber trees were seldom found in large concentrations, and 'rubber estates' generally spanned a large area.[4] The typical rubber estate was accessible by a river and production was labor-intensive. Rubber extraction technique varied according to the type of tree, but the production methods hardly changed over the period 1870-1910.[5] Rubber production entailed a very harsh life, and the death toll was very high indeed, making the scarcity of labor in the region even more acute. Brazilian rubber supply responsiveness would then directly depend on the availability of workers and it was expected that in periods of high immigration, Brazilian rubber supply might have been more elastic whereas in periods of low immigration, the opposite might have been true.

At first, native people received presents of food, clothes, sewing machines, firearms, ammunition and even musical instruments in exchange for rubber.[6] Natives (mainly Tapuyan Indians) were then employed to navigate the canoes, clear the bush on the banks of the river for the settlement of a rubber estate and construct houses and compounds for the estate owner. *Caboclos*, comprised of peasant backwoodsmen of primarily mixed European and native ancestry, were the second source of labor in the region. Some *caboclos* had been previously involved in the collection of other extractive products and for their knowledge and experience they were also employed as *mateiros*, clearing the trails to connect from 60 to 150 rubber trees[7]. This work force was insufficient to meet the demands of the expanding rubber trade and a complementing workforce had to be found elsewhere. It is true that the perspective of high and fast

[4] Over time large rubber estates became more and more common. However, especially in the older producing areas closer to Belém, several small rubber estates continued to produce rubber throughout the rubber boom. See Weinstein (1983, pp. 170-180).
[5] Akers (1912, pp. 3-4).
[6] Woodroffe (1916, p. 28).
[7] Dean (1987, pp. 36-37).

profits attracted many fortune seekers from Europe and North-America to become rubber tappers[8], but this influx of foreign nationals was only significant at the end of the rubber boom. Moreover, this group was generally more capitalized and they usually turned into estate owners, intermediaries, importers or exporters. Throughout most of the period, estate owners had to channel capital to mobilize people from other regions of the country, notably from Ceará state (in Northeast Brazil). The push was given by several droughts that afflicted this region, especially the one in 1877/9.[9] These *cearenses* were brought to rubber estates at the expenses of the estate owners but the cost of their travel was to be paid later on from tappers' future proceeds.

Not only did the estate owner have to pay for the tappers' travel cost, but he also had to advance merchandises to the rubber tapper for an entire season. The tapper was furnished with the implements necessary for tapping and curing rubber as well as firearms, ammunition, foodstuffs and supplies such as flour, sugar, coffee, rice, lard, dried meat, beans, tobacco, salt, kerosene, soap, spirits, medicine, clothes and a few oddments.[10] The advancement in kind was particularly important in the most remote regions since this should also provide the tapper with means of living during the off-season, which sometimes lasted more than 6 months (contingent to the rainy season)[11]. Due to the short period of production, the tapper had to devote to rubber production as much of his time as he possibly could.

Due to the geography of the Amazon forest and its density, transportation was at the heart of the development of the rubber boom. People and merchandises had to be constantly mobilized to the rubber estates whereas rubber had to flow from the far reaches of the forest to Belém (or Manaus) and thence to the main rubber consumers: USA and Britain.

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[8] Burns (1965).

[9] Santos (1980).

[10] Woodroffe (1916, p. 52).

[11] The rainy or flood season ranged from November to April or May. Depending upon the rain and the terrain, the working season could sometimes last from June to October, that is, only 4 months.

These geographical characteristics meant that production remained mainly confined to the areas close to the major river gateways. Figure 1 below shows exactly how crude rubber production became concentrated along the Amazon River and its main tributaries.[12] The Figure shows the geographic dispersion of crude rubber production by cities/municipalities in the state of Pará in 1897-1898[13]. It is possible to see that there was very little production in the hinterlands[14] and that the majority of crude rubber production in that state was still taking place around the city of Belém, notably in Marajó Island.

<< Figure 1 here >>

Steamships shortened distances within the Amazon region, connecting the entire basin with Belém and abroad. However, freight rates in the region remained quite high by international standards, reflecting a combination of market power and high risk of navigation (especially in the domestic routes).[15] Telegraphs supported the development of steamships in the Amazon and pushed up trade. Interestingly, rubber had fostered the development of submarine telegraphs for gutta-percha (a low quality rubber grade, extracted from a tree that grows in Southeast Asia) was used to insulate copper cables against the water.[16] Furthermore, rubber was also important in the improvement of the efficiency of steam engines insofar as this raw material was used as seals.

Steam navigation and telegraphs gave rise to the rubber boom which, in turn, supported even further the development of the (steam) navigation and the telegraphic system. The rubber boom demanded a better communication and transport systems and the consequent increased intensity in the flow of people and merchandises

[12] I am indebted with Leonardo Monastério for helping me producing this map.
[13] *British Diplomatic and Consular Reports, n. 2140 [Annual Series], Brazil: Report for the Year 1897 on the Trade of Para and District, 1898.*
[14] However, it is possible that production was taking place further inland and just being channelled through the cities listed in the report above.
[15] See Fernandes (2009).
[16] Headrick and Griset (2001, pp. 545-550).

provided these systems with economies of scale that ensured their ulterior development. The spread of news and the improvement in the transport system also provided the region with the scarcest factor of production: labor. Furthermore, the advent of steamship navigation in the Amazon region displaced the canoes, releasing even more laborers to work in the rubber industry. Thus communication and (steam) navigation generated some integration, and the consequent move of people (and other factors of production) and flow of information, created the conditions for further development of the rubber boom by supporting a virtuous cycle that changed the economic, political and social structures of the Brazilian Amazon. In sum, without rubber, steamships might have been even more costly to operate, and the submarine telegraphic system may have never developed. Analogously, without steamships and telegraphic communication, the rubber boom might have never taken place. This virtuous cycle was strongly reinforced by the increasing demand for rubber for other uses, notably tires.

The Brazilian Amazon's 60% market share of the rubber trade during the period 1870-1910 meant that the region may have been able to extract monopolistic rents, thereby increasing its welfare substantially. But how much welfare was actually generated? How much more could have been extracted? These are the questions addressed in this paper through the analysis of taxation on rubber exports.

3 Model: Market Power & Welfare

The primary objective of the paper is thus to estimate Brazilian market power on rubber markets and investigate the welfare effect of taxation. This is carried out in four steps. First, the elasticity of demand for Brazilian rubber will be computed from an Almost Ideal Demand System. Secondly, these elasticities will be corrected for the more appropriate case in which competing supplies are not perfectly elastic. Thirdly, the welfare effect of export tariff will be estimated and, finally, the counterfactual effect of an optimal export tariff will be shown. Let's see each of these steps in detail.

3.1 Elasticity of Demand

The first step is 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; notably because quality is an important feature of the story here. Furthermore, by this procedure it is not possible to obtain an estimate for the elasticity of demand for Brazilian rubber alone which is exactly the main goal here. Another specification would be to compute a separate demand and supply system for different countries/regions but this 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 specification would require information about supply conditions in all rubber producing regions, something that does not seem feasible for the current exercise.

The estimation procedure proposed here is thus based on an Almost Ideal Demand System (AIDS)[17] which provides a framework that is general enough to be used as a first-order approximation to any demand system. It assumes that the supplies for all rubber sources are perfectly elastic (this will be relaxed below) and provides a measure of the relationship between any given pair of crude rubber sources. From the estimation output, it is possible to see 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:

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[17] 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, Irwin (2003) article is a good example of application of the model another historical case: cotton during the Antebellum USA.

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

where $\log P = \sum_k w_k \log p_k$ (2)

where w_i is the budget share of country i, a_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. 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 β_i coefficients summed to zero whereas under homogeneity (of degree zero in prices) all γ_{ij} summed up should equal zero for each equation. Finally, symmetry requires that $\gamma_{ij} = \gamma_{ji}$ for all i and j.

Although from 1870 to 1910, rubber demand and supply were constantly expanding, the demand system proposed above can still be identified. First, the AIDS model controls for the increasing size of the market (last variable in equation 1 above), i.e., it controls for parallel shifts in the demand curve. Secondly, as there was no change in the technology of rubber processing over this period[18], it is reasonable to assume that the slope of the demand curve was not changing over time. Anyway, we minimize this problem in our robustness checks when we estimate the system under a 20-year moving window: in a smaller time frame, it is even less likely that the slope of the demand changed very drastically in a context in which the technology was not changing.

[18] Rubber manufacture technology was defined by a six-step industrial process: cleansing, grinding, softening, mixing, calendering and lastly vulcanising. First, rubber balls were cut into pieces and any foreign matter was extracted. The rubber pieces were then inserted into a water-filled barrel fitted with rotating and fixed knives that would tear apart the rubber and separate it out from impurities. Secondly, the cleansed material was plasticised by grinding and compressing it against two rolling heated cylinders. Next, softeners (such as camphene) were added and the rubber was placed into the mixer where the chemicals (vulcanising agents) were incorporated. For articles built from sheets of rubber the next step would then be the calendering: rubber would be compressed against rotating cylinders so close to each other that the crude rubber would be transformed into rubber sheets. Lastly, rubber was placed into a steam-heated chamber until it achieved its vulcanised state – a state that could only be determined by an experienced worker. See Woodruff (1958, pp. 6-10), Lunn (1952, pp. 31-37) and Goodyear (1855).

From the parameters of the AIDS equation is possible to retrieve the implied price-elasticities of demand as well as the elasticity of substitution among all rubber suppliers. According to Alston *et. al.* (1994), the elasticity of demand for the *i*th good with respect to the *j*th price is defined as below:

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

where δ_{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 γ_{ij} divided by w_i. The elasticity of substitution is also implicit in the AIDS estimated parameters and is defined as:

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

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

3.2 Adjusted Elasticity of Demand

The own-price elasticities of demand for rubber given by equation 3 assume 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 as it is necessary to take into account the elasticity of supply of other sources of rubber. Since the goal is to analyze Brazilian market power on rubber, it is possible to follow Irwin (2003) and compute the elasticity of export demand facing the Brazilian rubber exporters, η_{BRZ}, which is dependent upon the Brazilian market share, *S*, the elasticity of substitution between Brazilian and other varieties of rubber, σ, the elasticity of foreign export supply, ε, and the elasticity of demand for Brazilian rubber, η:

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

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 other sources of rubber (Van Duyne, 1975).

3.3 Welfare Effect

From the elasticities of demand, it is possible to compute the welfare effect of taxation. Consider the simple static microeconomic framework below. Figure 2 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. Now imagine that the government sets an export tax, *t*.

<< Figure 2 here >>

The welfare effect of a tariff would depend upon the elasticity of Brazilian rubber supply, and it is defined as the consumer surplus extracted from foreign consumers

$$(P_2-P_1)Q_2 \tag{6}$$

minus the domestic deadweight loss,

$$\tfrac{1}{2}(Q_1-Q_2)(P_1-P_2(1-t)) \tag{7}$$

where the change in rubber price in international markets is given by:

$$\Delta p = \frac{\varepsilon_{BRZ}}{\varepsilon_{BRZ} - \eta_{BRZ}} \Delta \tau \qquad (8)$$

where Δp is $P_2 - P_1$, ε_{BRZ} is the elasticity of Brazilian rubber export supply, η_{BRZ} is the elasticity of demand for Brazilian rubber and $\Delta \tau$ is the change in export tax. Note that when ε_{BRZ} approaches infinity $\Delta p \rightarrow \Delta \tau$, i.e., Brazilian rubber producers could integrally pass through the tax burden to consumers. Analogously, when $\varepsilon_{BRZ} = 0$, Brazilian producers are unable to push prices up and they internalize the whole tax burden.[19]

3.4 Optimal Tariff and Counterfactual Welfare Effect

The final step in the analysis requires the estimation of optimum export tariffs. Consider again a simple framework as shown below in Figure 3: an export market in partial equilibrium. Now imagine that the government mimics the monopoly result by setting an export tariff (t^*) at such level that P_2 is equal to the price under monopoly. In this case where the government intervenes into the market through the imposition of an export tax, 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 η_{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 3 here >>

[19] Note that since the region is taken as a monoproducer of rubber, government welfare in this case is equivalent to the region's welfare.

The idea is then to compute this optimal export tariff and then apply the same methodology as described above to compute the welfare effect (substituting t^* for t), had the government set the tariff at the optimal level.

4 Data: Exports, Prices & Tariffs

The theoretical framework described above is very simple and, in order to be estimated, it only requires a few series. All is needed is the market share of Brazilian rubber and other competing sources, the price of Brazilian rubber and its competing sources and the actual export tariff the Brazilian government levied on rubber exports. The dataset is all new and original, collected by the author from primary sources. Market shares and prices were computed from British (Parliamentary Papers) and American (Foreign Commerce and Navigation) sources whereas the export tariff was calculated from Brazilian sources. Let's see each of these series in detail.

British and American datasets provide annual information on quantities of rubber imported from several different parts of the world with the respective value of the merchandise.[20] Dividing values by quantities, we easily obtain the implicit price of rubber traded.[21] However, as countries changed their names, territories, ceased to exist, or only exported rubber eventually, they had to be aggregated in groups. This is especially important in view that with so many rubber exporters it would not be possible to estimate the econometric system proposed here as the database possesses more than 60 different locations from where rubber was originated. The system would thus encompass some 60 equations (one for each rubber exporter) turning their parameters undetermined.

For simplification purposes, the system will be estimated using Brazil and British Colonies only: these are the two main sources of rubber in the dataset. Brazil and British Colonies accounted for 76.2% of total crude rubber imports into the UK and 74.4% of

[20] British and American datasets were merged, discounting off the trade between them.

[21] Note that since rubber prices computed in this way are C.I.F.: it was not possible to disentangle prices from insurance and freight components.

total crude rubber imports into the USA between 1870 and 1910. It is very likely that Brazilian figures (BRZ) include some crude rubber produced in neighboring countries such as Bolivia, Venezuela and Colombia since Belém (Brazil) developed as the main rubber hub in the region.[22] In the British dataset, 'British Colonies' (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'. For 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'.

In terms of value, Brazil accounted for 64.1% of all rubber imported into Britain and the USA combined, the British Colonies another 10.4% and the rest was pulverized among several different places as distant and different as Mexico, Dutch Indies and Russia.

<< Figure 4 here >>

Due to the quality of the latex of its trees (especially *hevea brasiliensis*), buyers always paid a significant premium for Brazilian rubber over other grades. Looking at Figure 5, it can be seen that, on average, British and American buyers consistently paid more for Brazilian rubber compared to rubber coming from British Colonies. In the last years of the rubber boom, Asian rubber plantations (comprised of native Amazonian

[22] Import data refer to Brazil as a whole. Lower rubber grades were produced in other Brazilian regions as well. It was not possible to decompose British and US rubber imports by region of origin within Brazil. Even though the paper is only concerned with the Amazon region, the aggregated results can and must be understood as being representative for the Amazon region as the other Brazilian regions produced very little in comparative terms. Moreover, since these regions produced lower quality rubber, in value, its proportion was even smaller.

trees, especially *hevea brasiliensis*) started to enter the market and the gap between these two rubber sources started to close.

<< Figure 5 here >>

As argued in the Introduction, the Brazilian Amazon position in the rubber market was established due to a combination of quantity and quality. Therefore, if the demand for this commodity was high enough and if substitutes were not available, the demand for Brazilian rubber may have been quite inelastic, opening room for positive welfare effects from an export tariff. The government did tax Amazonian exports, but how high was the export tariff?

Ad valorem export taxes were computed as the ratio between the rights of rubber (total revenue generated by the 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 the government always established official prices for rubber which sometimes differed quite substantially from market prices. Changes in official prices explain the spikes in Figure 6 below.

<< Figure 6 here >>

Export data was reported by national administrative units but we need here a total export tariff. 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 19.74% on average. For Amazonas, there are figures for 1870 to 1910 and its ad valorem export tariff was on average 19.92%. Finally, in Pará, the most important rubber exporter state, ad valorem export tariff amounted to 17.82% from 1885 to 1910.

Find below a table with some descriptive statistics of the series used in the paper.[23]

<< Table 1 here >>

5 Results: Market Power & Welfare Effects

From the model described in Section 2 and the data presented in Section 3, the current section will present the results, following the same structure of the model.

5.1 Adjusted Elasticity of Demand

According to the model presented above, 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, the British Colonial share (dependent variable) will be estimated 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.

Both equations (for Brazilian and British Colonial rubber) were estimated jointly by iterative SUR (Seemingly Unrelated Regression) techniques with only symmetry imposed and the results are presented in the Appendix. Symmetry was rejected (not reported here), but it was still imposed to the system to avoid double elasticity of substitution between Brazilian and British Colonial sources. Moreover, homotheticity was not imposed since the system here is equivalent to the one in which an extra

[23] Upon request, all series and results here can be obtained in excel and Eviews files.

equation for "all remaining countries" had been deleted whose β coefficient would be given by the adding-up restriction.[24]

The Adjusted-R^2 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, the null hypothesis can only be rejected in second differences at 0.1% confidence level.

Under AIDS, changes in real expenditure operate through the β_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 (income rose) there was an increase of Brazilian market share and a slight decrease in the British Colonies' market share. This may further indicate that Brazilian supply did not keep up the pace with its demand and/or that consumers regarded Brazilian rubber as of a higher quality.

[24] 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 substantial market power on world rubber market. In this particular, several different groups of countries were included in the sample and these models were estimated using different sample periods. The estimated elasticity of demand for Brazilian rubber does not change substantially in quantitative terms and is basically the same in qualitative terms. Furthermore, it must be stressed that estimates are invariant to the equation deleted. See Barten (1969).

From the parameters of the AIDS equation is possible to retrieve the implied price-elasticities of demand as well as the elasticity of substitution among all rubber suppliers. 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 Table 2 below, the own price-elasticity of rubber for British Colonies was -0.02 (not statistically significant though) and for Brazil -1.32 (highly significant: t-stat = -18.85). The elasticity of substitution between Brazilian and British Colonial rubber was not significant but indicate that it was probably positive (+0.29), i.e., the two rubber sources were considered substitutes.

<< Table 2 here >>

5.2 Adjusted Elasticity of Demand

The own-price elasticities of demand for rubber given by equation 3, and reported in Table 2 above, assume 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 here as it is necessary to take into account now the elasticity of supply for other sources of rubber. By applying equation 5 to the elasticity of demand for Brazilian rubber presented in Table 2, it is possible to obtain the actual elasticity of demand that Brazilian rubber exporters faced. The demand for Brazilian rubber was somewhat inelastic and more so compared to the demand for US cotton in the Antebellum period: -1.1 (assuming elasticity of substitution of 0.8[25], elasticity of rubber supply from other producers as 1.0 and market share of 64.1%) against -1.7 for US cotton. Table 3 below presents the elasticity of demand for Brazilian rubber under different scenarios for the elasticity of supply from other producers (ε) and elasticity of substitution between Brazilian rubber and other rubber grades (σ).

[25] Note that this refers to the elasticity of substitution between rubber from British Colonies and Brazil computed for 1885-1910.

<< Table 3 here >>

From Table 3, it is possible to infer that, except in the case in which rubber is considered a homogeneous commodity (equivalent to having 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 low as 0.8, which would suggest an elasticity of demand around -1.10.[26] For rubber, it is very unlikely that the elasticity of substitution was actually higher than 1.8[27], implying that the elasticity of demand for Brazilian rubber would have fallen within the range of 0.8-1.5. 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. This point will be further explored later on here.

5.3 Welfare Effect

Once having established that demand for Brazilian rubber was quite inelastic, it is possible to compute the welfare effect of the export tariff. However, for this, we also need to find an estimate of the elasticity of <u>supply</u> of Brazilian rubber. Regressing total Brazilian exports of rubber against different combinations of variables such as a

[26] However, using the same parameters as Irwin (2003), i.e., $\sigma = 3$ and $\varepsilon = 0.5$, rubber would be equally elastic: -1.7 for rubber against -1.7 for cotton.

[27] This belief is based on several other different specifications (and different time periods) estimated by the author and not reported here. The elasticity of substitution between Brazilian and British Colonial rubber was usually below 1.5.

constant, lagged prices (or current price), population and a time trend, gives an elasticity of supply well below 1, probably close to 0.25.[28]

Table 4 below shows the real welfare effect of the actual export tariff levied by the Brazilian government, 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 used here before). First the new counterfactual price (P_2) was computed from Equation 6, which additionally allows us to find the correspondent new counterfactual quantity of rubber exported from Brazil (Q_2). The next step was to calculate the consumer surplus extracted from foreign consumers (Equation 6) and the domestic deadweight loss (Equation 7). Assuming that the elasticity of Brazilian rubber supply (ε_{BRZ}) was 0.25, Annual Real Net Welfare generated by taxation was equivalent to £132,076 from 1870 to 1910, or 1.27% of regional GDP[29].

<< Table 4 here >>

5.4 Optimal Tariff and Counterfactual Welfare Effect

From Table 3, it is possible to compute the implicit optimal export tariff, which is just the reciprocal of the absolute value of the elasticites reported there. Even in the more extreme scenario in which rubber is considered a homogeneous product, optimal export tariff would have been as high as 31.5% and under more realistic assumptions (σ = 0.8-1.5), it could have reached 93.4% (with 72.3% as a lower bound). Remember that these tariffs would have been levied on top of an existing one which averaged 18.7% from 1870 to 1910.

<< Table 5 here >>

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[28] See Fernandes (2009).

[29] Santos (1980) provides 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.

It is also possible to compute the welfare effect, had the government increased the tariff up to the optimum level. The government could have generated an extra £351,270 on average in the period 1870-1910 as welfare gains for the region had it increased the tariff to the optimum level. This would have been equivalent to 3.38% of Amazonian GDP in the same period.

<< Table 6 here >>

In sum, the government could have increased the regional welfare by 4.7% but it generated only 1.33%. These effects are far from insignificant and show the possibility of higher national welfare via government intervention. But before we can understand why the government did not generate the best possible outcome, it is necessary to check if the results presented here are reasonably robust.

6 Robustness Check

In order to ensure that taxation can significantly increase regional welfare, some robustness checks are provided. First, we will see what happens with the welfare in some sub-samples, ruling out possible effects of some specific years. Secondly, we will change two parameters of our exercise, namely, the elasticity of supply of Brazilian rubber and the elasticity of substitution between Brazilian and British Colonial rubber. Thirdly, we will see what the welfare effects are if we split the database into Britain and the USA. Finally, we will check if the results still hold when we add data from French sources.[30]

[30] All these robustness checks can be reproduced by the reader through a welfare calculator, provided by the author upon request.

6.1 Sub-Samples: 20-Year Moving Windows

Here we will repeat the exercise as of above for several subsamples of 20 years each. From Figure 7 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).

<< Figure 7 here >>

Still assuming that the elasticity of Brazilian rubber supply (ε_{BRZ}) was 0.25, Real Net Welfare generated by taxation would increase from £50,848 on (annual) average in 1870-1889 (equal to 1.27% of regional GDP) to £263,889 on average in 1891-1910 (equivalent to 1.67% of regional GDP). Therefore, the government was generating a higher real net welfare over time because: a) the value of rubber trade was increasing over time and; b) rubber demand was becoming more inelastic. It is also possible to compute the welfare effect, had the government increased the tariff up to the optimum level. The government could have generated an extra £795,426 on average in the period 1891-1910 as welfare gains for the region, had it increased the tariff to the optimum level. This would have been equivalent to 5.1% of Amazonian GDP in the same period.

In sum, the estimations on 20-year moving windows show that the results were not driven by a biased selection of the sample. Any subsample generates the same result: the government generated a positive welfare effect via taxation but its intervention could have been even more beneficial for the region, had the export tax been set at the optimal level. As a percentage of GDP, the welfare effect was increasing due to the increasing importance of rubber in the regional economy. Indeed, in the last 20 years of the boom (1891-1910), the government could have generated a total welfare gain of 6.7% of the regional GDP per year at the expenses of rubber manufacturers and final consumers. Again, these results reinforce the idea that the exercise of market power may cause relevant effects in terms of GDP levels.

6.2 Changes in parameters

Another possibility that needs to be explored is the effect of arbitrarily chosen parameters on the results. There are two key parameters that may be potentially driving the outcomes here: the elasticity of supply for Brazilian rubber (ε_{BRZ}) and the elasticity of substitution (σ) between Brazilian and British Colonial rubber grades.

For instance, setting ε_{BRZ} = 1.00 (instead of 0.25 as initially assumed) increases the actual welfare of the export tariff to £372,087 during the 1870-1910 period. This was equivalent to 3.6% of the regional GDP in the same period. The additional welfare effect the government could have generated via optimal taxation was £641,660, or 6.07% of GDP during these years. As expected, the greater ability of Brazilian producers to change their supply according to demand impulses would allow more welfare to be generated via taxation.

Setting now σ = 3 (instead of 1.3 as originally assumed) would decrease the ability of the government to generate positive welfare effect via taxation as rubber buyers would more easily switch to other suppliers whenever Brazilian rubber price increased. The actual welfare generated would be £100,531 (or 0.97% of GDP) and the additional counterfactual welfare would reach only £208,415 (or 2.00% of GDP) during the rubber boom (1870-1910). However, despite the lower welfare effect, the qualitative result does not change.

6.3 Splitting the Database

If we estimate the system of equations for the British and American dataset separately, the elasticities of demand facing Brazilian exporters in the USA and Britain would be -1.18 and -1.43, respectively. From 1870 to 1910, the actual welfare effect of the export tariff would reach 0.61% of the regional GDP in the British dataset and 0.73% in the American dataset. However, once more, there was scope for more welfare to be generated: and 2.13% of GDP using American data and 1.50%, using British data. Note that these welfare results differ from the ones computed from the joint database, reflecting the fact that here, we are not discounting off the trade between Britain and the USA. Moreover, the elasticity in the joint database is not necessarily the weighted average of the elasticities computed from the systems with the two separate databases.

6.4 Adding French Data

The next robustness check embodies adding more data to the database. I collected similar data from French sources (*Tableau Général du Commerce et de la Navigation*, 1870-1910). These data were organized in the same way as the British and American datasets, converted to the same units and added up, discounting off the trade among these three countries. The problem here lays in the fact that France also possessed several colonies (mainly in Africa) that exported rubber in similar conditions as the British ones did to Britain. However, in order to keep it comparable with the previous results, French colonies will not be discriminated separately. We will stick with our organization of Brazil, British Colonies and Rest of the World. Looking at the period 1870-1910, it is possible to see that the welfare effect of taxation is basically the same as before: the export tariff now generates a positive effect of 1.32% of regional GDP against 1.27% in the merged British and American dataset. The additional welfare effect at the optimal level of taxation would have reached 3.43% of regional GDP against 3.38% in the merged British and American dataset. This result is very much expected as the USA and Britain can be taken as good representatives of the world rubber consumption. Even though several other countries consumed some significant quantities of rubber, they were often supplied by Britain via re-exports.

7 The Political Economy of Taxation

In the previous sections, it was shown that even under a high inelasticity of supply, the government could have captured 4.65% of Amazonian GDP per year as a monopoly rent during the rubber boom (1870-1910) since the burden of taxation would mostly be passed through to the consumers in Europe and in the USA. However, the government captured it only partially. It is important to understand why this was so.

First, as Irwin (2003, p. 87) highlighted, "this partial equilibrium framework is static and ignores several important dynamic issues" and thus the optimal export taxes computed here should be understood as upper bounds, because the demand elasticity is probably biased downwards and then the demand elasticity may have risen when the export tax was imposed. Secondly, the long-run price elasticity of rubber demand may have been high.[31] Thirdly, the government ability to tax was in fact constrained in three different levels: nationally, regionally and locally. At the national level, there was a latent threat that foreign countries (such as the USA and Britain) could have actually retaliated against a possible higher export tariff. This retaliation might have had small effects over the Brazilian Amazon but for the country as a whole the result could have been quite significant. At the national level Pará (and even more Amazonas) still occupied a subordinate position and were thus forced to put "national" interests before their own. They invariably had to bend to pressures stemming from the central government.

At the regional level, the political economy of taxation was quite intricate. During the Empire (1822-1889), provinces/states were usually forbidden to levy any export tax, even though they sometimes did levy taxes on foreign and interprovincial trade. With the advent of the Republic in 1889, export tariffs became a state prerogative whereas the import taxes as well as income taxes stayed in the hands of the Federal government. In this context, Amazonian states (Pará and Amazonas states) lacked

[31] Although the model here does not tell anything on this matter, it is possible to conjecture that the government and the agents did not probably think that this long-run elasticity was high. Until mid-1890s, they actually believed that rubber plantations would never succeed. This belief was based on the fact that some plantation attempts had unsuccessfully been made in Brazil: at first it was wrongly believed that rubber trees needed a marsh terrain to grow because most areas under production were flooded during six to seven months every year. They also believed that rubber trees took 16 years to mature, because that was the estimated average age of trees under production in the Brazilian Amazon. In Malaysia, rubber trees took usually some 6 years to mature. Therefore, Brazilian producers and the government did believe that rubber trees would never be domesticated. After the successful domestication of rubber trees in Kew Gardens and their transplantation to Malaysia, it was a matter of time for Brazilian producers to lose their market power. Therefore, from that point onwards, they had all the incentives to tax as much as possible while Brazilian market power still lasted.

coordination. The competition for rubber proceeds led the Amazonas state to legislate in 1878 a differential tax on rubber exports. The plan was to divert the trade from Belém (state of Pará) to Manaus (state of Amazonas) as rubber shipped directly from Manaus would pay a slightly lower duty than rubber exported from Belém. The gap between the two export tariffs was subsequently widened in 1885 to 5 percentage points, causing several export houses from Pará to open or expand their businesses in Manaus. This plan was supported by the establishment of a direct shipping line connecting Manaus to New York and Liverpool.[32] This competition between the two most important rubber producing states limited their ability to push up export tariffs. Any marginal increase in either export taxes could have triggered even more trade diversion, leading to a suboptimal outcome: due to a lack of coordination, both states ended up levying a much lower export tax than they optimally could. In a strange way, the state of Amazonas was pursuing a beggar-thy-neighbor policy.

Finally, at the local level, both states were constrained by pressure groups, especially the *Associação Comercial do Pará* (Pará Commercial Association). The ability of these pressure groups to lobby was due to their access to the government: the higher the access to the government, the lower the costs of changing (or devising) government policies. Lobbying here means an expenditure that forces the government to change its tax policy or a payment to an intermediary to influence the government. Having no access to the government in the model here means that the cost of lobbying (λ) is prohibitively high. The government tries to maximize its revenues and the lobbies to minimize their losses (in terms of taxes).

The model presented here differs from the seminal work of Grossman and Helpman (1994) on protection and lobbies. In that paper, the authors assume that politicians are selfish but take into account the welfare of voter well-being (as this decides their re-election). Interest groups, in turn, contribute to the government to influence a certain trade policy but they do not see the relationship between their contribution and the electoral result. All they care is the welfare of their members. In

[32] Weinstein (1983, pp. 195-196).

this model, the resultant structure of trade protection depends on the outcome of a competition for political favors. If everyone is represented by an interest group, the political equilibrium is Pareto efficient, as politicians benefit from competition among interest groups to extract the most in form of contributions. Here, there is a single interest group for whose welfare the government does not care at al: the government tries to maximize its own revenues, nothing else.[33]

In this setting, it is then important to understand the incentives of each player and how much money they would commit to enforce the best outcome for them. First, the exporters would spend money lobbying up to what they would lose were the tax imposed. In other words, exporters would pay as much as the producer surplus they would lose, equivalent to the grey (shaded) area, *L*, in Figure 8 below (it is implicitly assumed that once the exporters lobby, the government is always forced to lift off the tariff or, at least, compensate the exporters for their losses). Secondly, the government would commit up to the total revenues generated by the tax equivalent to the dotted area, *T*. The model assumes that the government is a selfish agent who seeks to maximize its own revenues.

<< Figure 8 here >>

The interaction between the government and the exporters can be analyzed with the help of Table 7 which shows the payoff matrix for this game. The government has two options: it either levies the tariff at the optimum level or it does not. The export houses can lobby against the tariff or simply accept it. As explained before, lobbying entails a cost (λ) that once incurred ensures that the government will change its tax policy (do not levy the tax) or at least compensate for the export houses' losses (*L*). In

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[33] However, the model here could be changed in order to fit, say, Grossman and Helpman (1995)'s framework. It would be possible to construct a model with two opposing lobbying groups, say export houses and intermediaries. Assume that export houses and intermediaries have opposing goals concerning the export tariff. Whereas the former would lobby against the tariff, the latter would support it, as they would supposedly be the main beneficiaries of the redistribution of rents via public goods. It is possible that export houses lobbying power could partly cancel off intermediaries' lobbying power, leading to a suboptimal outcome. Anyway, in all models applied to the Brazilian Amazon, market power needs to be formally introduced as it impacts the regional welfare gains from taxation.

this simple game the government earns nothing if it does not levy the tax and *T* otherwise. However, if the export houses decide to lobby against it, the government needs to compensate them with, for simplicity, exactly *L*. If the export houses do not lobby against the tax, it will earn *L* in case the government does not levy it and $-L$ otherwise. Moreover, whenever it does lobby, its earnings will be equal to $L - \lambda$. For the government, unless $T - L < 0$, it is always a dominant strategy to levy the tax regardless of the reaction of the export houses, especially because the high inelasticity for crude rubber will ensure that $T - L >> 0$. In turn, from the export houses point of view, it is a dominant strategy to lobby as long as $L - \lambda > -L \rightarrow 2L > \lambda$. The key parameter is thus λ: if the cost of lobbying is low enough, the equilibrium would be located in the upper right cell of Table 7 as the government will set the tariff at the optimum level and will compensate the export houses with at least *L*. Since in this game λ depends on the access to government, export houses need to find access to the government to ensure that their costs of lobbying are reasonable, guaranteeing their compensation for the losses incurred. This is only possible because the inelasticity of demand for crude rubber will ensure that the total welfare appropriated will be larger *post-tax*, allowing this *Pareto* efficient outcome.[34]

<< Table 7 here >>

A more interesting case though is the one in which the government can set a tariff that is below the optimum level in a context of high (but not prohibitive) cost of lobbying. In that case, it is possible that the government may find a tariff level T' (where $0 < T' < T$) whose associated loss in producer welfare (L') is lower than λ but whose income is higher than $T - L$. This means that the income accrued by the government with the lower tariff but no lobbying would be higher than the income of the optimum

[34] An interesting case would the one in which the export houses have perfect access to the government, or even better, the case in which export houses comprise (or are) the government. This would be equivalent to a case in which the cost of lobbying is zero ($\lambda = 0$). In this case, the government would still set the tariff at the optimum level so long as it agrees with a rebate to the export houses that is equal to the loss in producer welfare generated by the tariff.

tariff with lobbying. In this context, the maximization of government revenues would not necessarily coincide with the maximization of the total welfare. Indeed, it is possible to compare the revenues generated by the 18.7% (£756,679) against the difference between the areas T (£2,522,697) and L (£1,953,965) in Figure 8 above. The result suggest that the government may have generated a higher budgetary income by applying a lower tariff (18.7%) compared to the scenario in which it sets the tariff at the optimal level but compensates the exporters for their losses. In this context, this equilibrium was certainly sub-optimal for the Brazilian Amazon, but it may have been Pareto efficient: the government was maximizing its revenues and, if this is all the government cares, there was no way to increase the welfare without decreasing the government utility level.

8 Final Remarks

The paper showed that export taxes can be used to substantially increase domestic welfare. In his paper, Irwin uses antebellum US as the "quintessential example of a 'large' country that could improve its terms of trade and welfare through trade restrictions". His findings suggested that despite high American market share on cotton, a 50% export tax would have raised US welfare by a meager 0.3% of US GDP, or about 1% of the South's GDP.

The US South should not be regarded as the typical case as the cotton export ratio to GDP was quite low. That is exactly why the welfare impact of such a high export tariff ends up being so insignificant for the domestic GDP. For many other overspecialized smaller countries or regions, the welfare effect of a high export tariff would not be so insignificant, provided that they possessed some degree of market power. This was the case of the Brazilian Amazon from 1870 to 1910. This region possessed significant market power on rubber which remained unchallenged until 1910. Even though it is uncertain if and how much exporters profited from Brazilian market power, the government certainly increased its revenues at foreign buyers' expenses. By doing so, the domestic welfare also increased. By levying a tariff of 18.7%, the government increased domestic welfare by 1.3% of GDP during the period 1870-1910. However, had the government increased the tariff at the optimal level, the total welfare impact could have reached 4.7% of regional GDP in the same period. It was argued that the government was constrained at three levels to reach the maximum possible welfare nationally, regionally and locally. First, the government feared trade reprisals or retaliations. Secondly, competition among states for tax collections generated a suboptimal outcome in which everyone was extracting less rents than they actually could. Finally, in a context of lobbies, government maximization may have differed from regional maximization of welfare. Moreover, the welfare impact could have been much higher had the region not suffered from labor shortages. The paper showed that if the elasticity of supply of Brazilian rubber was equal to 1, nearly 10% of regional GDP could have been captured by the government through export taxes. However, the high inelasticity of supply played a double role: at the same time that it decreased the welfare effect of taxation, it prevented immiserizing growth from happening.[35] If supply was freely available, given that there was scope for the expansion of rubber production in the Amazon Valley, the increasing specialization of the regional economy in rubber should have resulted in less favorable terms of trade (as the imports for all other goods would have increased). There was no reason to expect *a priori* that the utility loss caused by less favorable trading terms would be smaller than the direct utility gain of a more abundant factor endowment. However, the terms of trade did not worsen due to shortage of laborers: even though high prices of rubber would have induced a high increase in rubber production, this mechanism was hampered due to the shortage of labor. No overproduction followed and thus no worsening of terms of trade happened. Consequently, there was no immiserizing growth in the Brazilian Amazon from 1870 to 1910.[36]

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[35] For immiserising growth, see for instance Bhagwati (1958), Johnson (1967) and Bhagwati, Panagariya and Srinivasan (1998).

[36] I need to thank prof. Jeffrey Williamson for suggesting me to look at immiserising growth in the Brazilian Amazon context.

Data Sources

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UK Parliamentary Papers – Annual Statements of Trade (1870-1911)
French Tableau Général du Commerce et de la Navigation (1870-1911)
India Rubber World, several issues.
India Rubber Trade, several issues.
Brazilian Government Document Digitization Project (Brazil: Provincial Presidential Reports):
http://www.crl.edu/content.asp?l1=5&l2=24&l3=45

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Appendix A: AIDS System for British and US data combined, 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

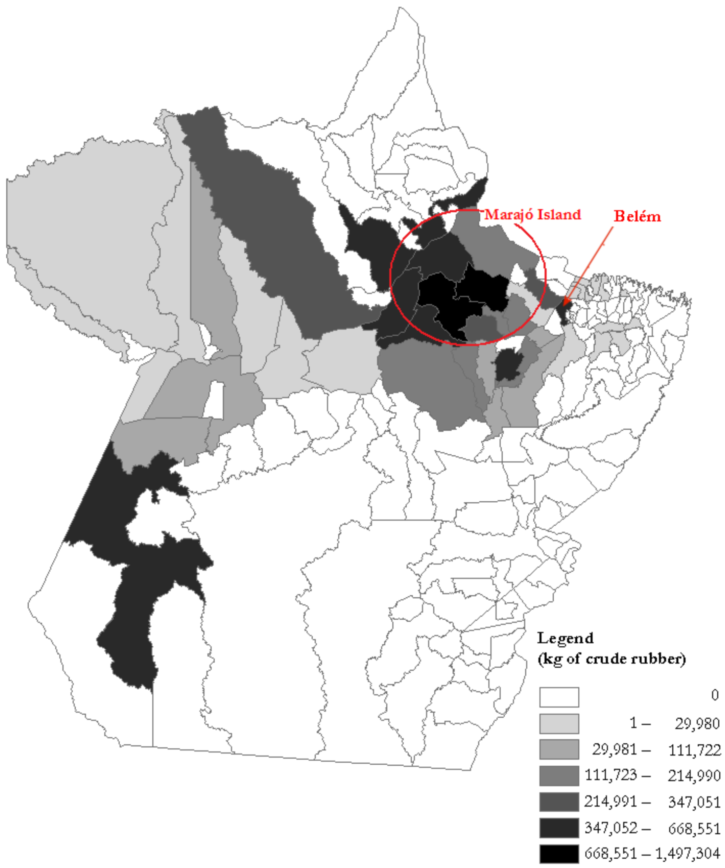
Equation: BRZ_MKT = C(10) + C(11)*LOG(BRZ_PRC) + C(12)
LOG(BRC_PRC) + C(100)(LOG(X)-LN_PRICE)
Observations: 41

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		

Figure 1: Geography of Crude Rubber Production in the Brazilian States of Pará and Amapá, 1897-1898



Source: Rubber Production by Cities, *British Diplomatic and Consular Reports, n. 2140 [Annual Series], Brazil: Report for the Year 1897 on the Trade of Para and District, 1898*. Note: I first found the geographical coordinates (latitudes and longitudes) of the cities or villages where production took place in 1897-8. Luckily, the cities/villages retained their old names and thus I was able to find their geographical coordinates from data gathered at the Instituto Brasileiro de Geografia e Estatística (IBGE) website (http://www.ibge.gov.br). I then matched their actual location with the political-administrative organisation of Pará State into municipalities as of 1998.

Figure 2 – Competitive Market & Government Taxation

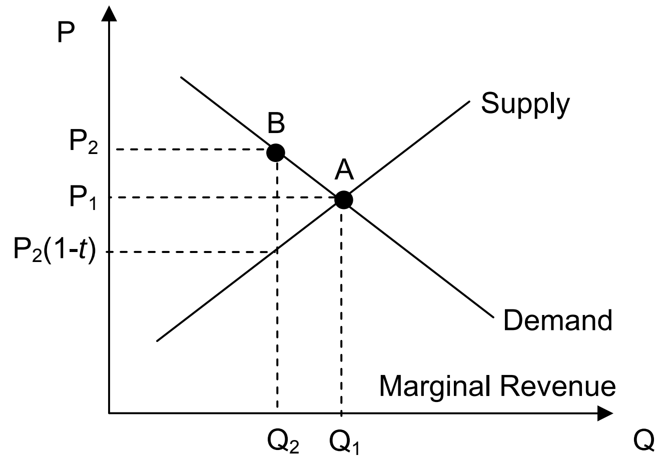


Figure 3 – Competitive and Monopoly Market Equilibria

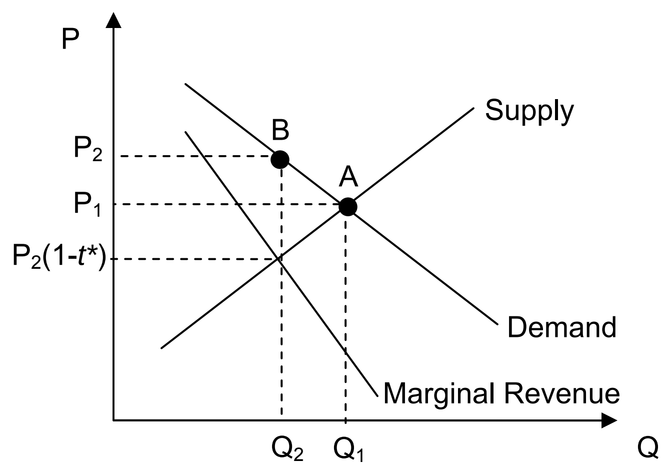
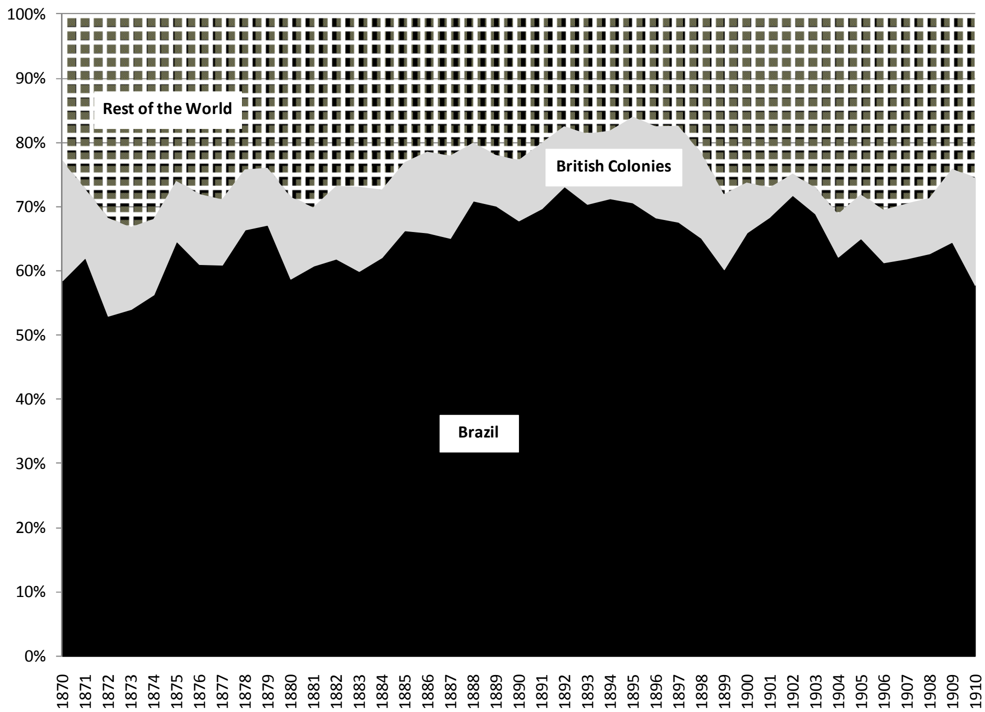
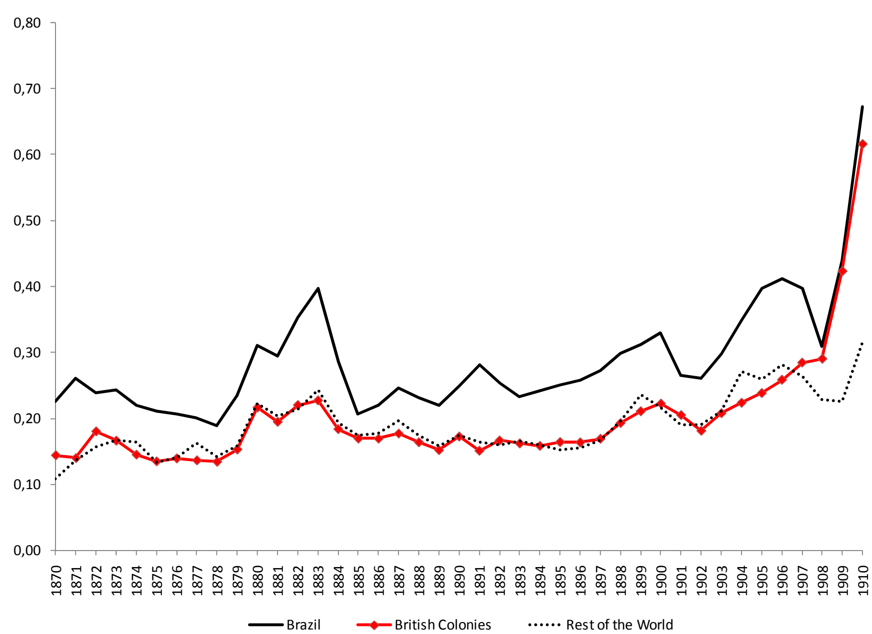


Figure 4 – Market Shares on Value of Rubber Exported into the USA and Britain 1870-1910



Source: UK Parliamentary Papers and Foreign Commerce and Navigation of the United States, several issues (1870-1910).

Figure 5 – Implicit Prices of rubber Imported into the USA and Britain (£ per kg) 1870-1910



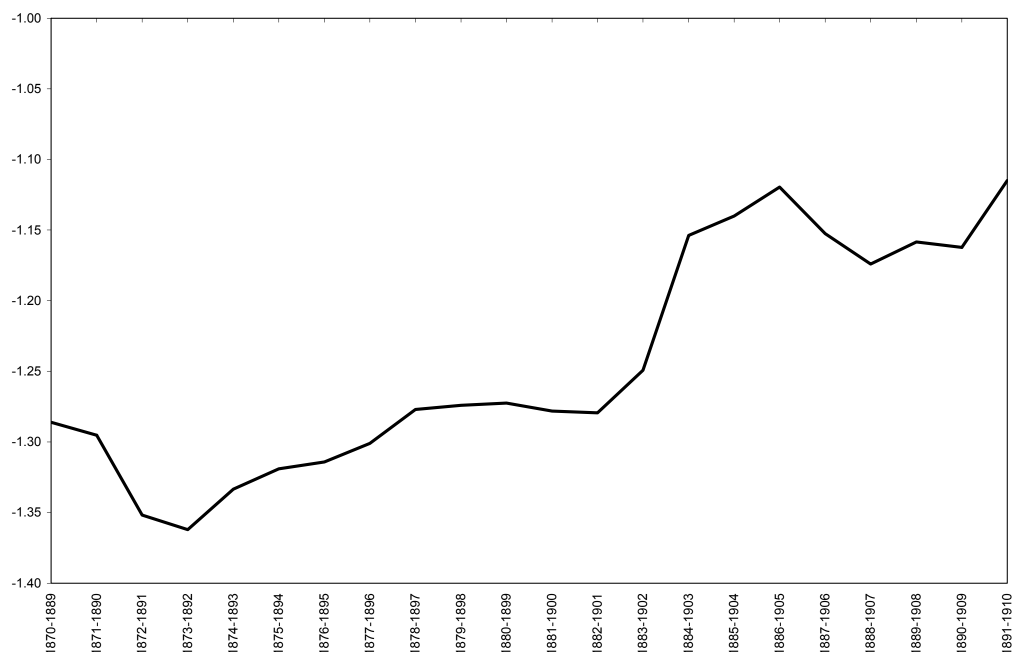
Source: UK Parliamentary Papers and Foreign Commerce and Navigation of the United States, several issues (1870-1910).

Figure 6 – *Ad Valorem* Export Tariff Levied by the Government, 1870-1910

Sources: Data were gathered from several *Provincial Presidential Reports*, *Relatório da Fazenda do Amazonas* (1918) and LeCointe (1922). See Fernandes (2009) for a more comprehensive dataset.

Figure 7 – Elasticity of Demand for Brazilian Rubber (20-year Moving Windows)

1870-1910



Note: It assumes a constant elasticity of foreign supply (ε) at 1.0 and an elasticity of substitution (σ) at 1.3. All estimates are statistically significant at 10% confidence level.

Figure 8 – Lobby Incentives

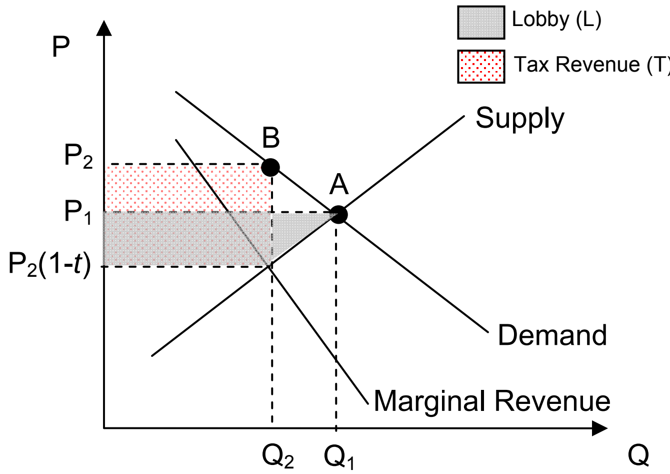


Table 1: Descriptive Statistics of Series Used, 1870-1910

	Unit	Average	Max	Min	Coeff. Variation
BRZ_QTY	kg	16.696.945	35.989.655	4.607.313	0,56
BRC_QTY	kg	3.680.938	11.376.831	1.450.236	0,57
REST_QTY	kg	9.751.898	33.812.362	3.537.810	0,71
BRZ_PRC	£ per kg	0,287	0,673	0,190	0,31
BRC_PRC	£ per kg	0,200	0,616	0,134	0,43
REST_PRC	£ per kg	0,191	0,315	0,109	0,24
BRZ_MKTSHR	%	64,5%	73,2%	53,0%	0,08
BRC_MKTSHR	%	10,6%	18,6%	3,3%	0,30
REST_MKTSHR	%	25,0%	33,1%	16,0%	0,18
EXPORT_TARIFF	%	20,6%	43,2%	9,4%	0,30

Note: BRZ = Brazil; BRC = British Colonies; REST = Rest of the World; QTY = Quantity; PRC = Price; MKTSHR = Market Share; and EXPORT_TARIFF = Export Tariff.

Table 2 – Implied Elasticites of Demand for Rubber, 1870-1910

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

Note: t-statistics below each estimate
Source: Data from Fernandes (2009)

Table 3 – Implied Elasticity of Export Demand for Brazilian Rubber under Different Scenarios

elasticity of substitution (σ)	Elasticity of Foreign Export Supply (ε)				
	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
1.50	-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
∞	-2.06	-2.34	-2.61	-2.89	-3.17

Note: table shows the output of equation 5, assuming Brazilian market share (S) = 64.1% and elasticity of demand for Brazilian rubber (η_{BRZ}) = $|1.3|$.
Source: Data from Fernandes (2009).

Table 4 – Annual Real Net Welfare of the Export Tariff

1870-1910

INPUTS	
P_1 (£ per kg)	0.287
Q_1 (in kg)	16,696,945
Brazilian Market Share (%)	64.1%
Actual Export Tariff (%)	18.7%
ELASTICITIES	
η	-1.321
η_{BRZ}	-1.313
WELFARE EFFECT	
P_2	0.279
Q_2	17,354,113
Consumer Surplus Extracted from Foreign Consumers	149,348
Deadweight Loss	-17,272
Net Economic Gain	132,076
Net Economic Gain (% GDP)	1.27%

Table 5 – Implicit Optimal Export Tariff

elasticity of substitution (σ)	Elasticity of Foreign Export Supply (ε)				
	0.00	0.50	1.00	1.50	2.00
0.50	120.3%	110.3%	106.4%	104.3%	103.0%
0.80	93.4%	91.6%	90.7%	90.2%	89.8%
1.00	84.4%	84.0%	83.7%	83.6%	83.5%
1.30	76.2%	76.2%	76.1%	76.1%	76.1%
1.50	72.5%	72.4%	72.4%	72.3%	72.3%
1.80	68.5%	68.1%	67.9%	67.8%	67.7%
3.00	60.5%	58.9%	57.7%	56.9%	56.3%
5.00	55.7%	52.8%	50.6%	49.0%	47.8%
∞	48.6%	42.8%	38.2%	34.5%	31.5%

Note: table shows the implicit optimal export tariff which was computed as the reciprocal of the absolute values of Figure 2. Therefore, it is also assumed here that Brazilian market share (S) was equal to 64.14% and the elasticity of demand for Brazilian rubber (η_{BRZ}) was equal to $|1.32|$.

Source: Data from Fernandes (2009).

Table 6 – Additional Counterfactual Welfare Effect of Optimal Export Tax

1870-1910

INPUTS	
P_1 (£ per kg)	0.287
Q_1 (in kg)	16,696,945
Brazilian Market Share (%)	64.1%
Total Optimum Export Tariff (%)	76.1%
ELASTICITIES	
η	-1.321
η_{BRZ}	-1.313
ADDITIONAL COUNTERFACTUAL WELFARE EFFECT	
P_2	0.322
Q_2	14,026,636
Consumer Surplus Extracted from Foreign Consumers	490,498
Deadweight Loss	-139,228
Net Economic Gain	351,270
Net Economic Gain (% GDP)	3.38%

Table 7 – Interaction Between Export Houses and state Government

		Government	
		Levy Export Tax	Do not Levy Export Tax
Export Houses	Lobby	(L - λ; T - L)	(L - λ ; 0)
	Do not Lobby	(- L ; T)	(L ; 0)

Source: Elaborated by me, based on the interactions specified in the text.