

**PRODUCTIVITY IN THE PARAÍBA VALLEY: ASSESSING AGRICULTURAL
EFFICIENCY IN THE 19TH-CENTURY BRAZIL¹**

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ABSTRACT: Economic historians have long held that Brazil's productivity performance in the nineteenth century was poor. This paper provides actual estimates of the rate of productivity change in Brazilian agriculture from 1835 to 1885. It focuses on the coffee region, an area known to have enjoyed extensive growth but believed to have suffered intensive decline after mid century. Partial productivity measures suggest no trend in the productivity of slave labor, or any increase in the productivity of agricultural capital. However, contrary to the claims of earlier historians, appreciable increases in the productivity of agricultural land translated into rising total factor productivity. Improved productivity resulted from advances in transport, and mechanized coffee processing. Slave-based plantation agriculture in Brazil was compatible with productivity gains.

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Rising productivity, in the form of increases in output unexplained by increases in economic inputs, is one of the motor forces of economic growth, and as such continues to be of particular interest to economic historians. (Abramowitz and David, 1973; Rothenberg, 1992; Allen, 1992; Hoffman, 1996; Clark, 2002). The topic has largely escaped study in the case of Brazil, perhaps because it is widely held that there was little or no such productivity advance there before 1900. The coffee economy of Brazil's center south in particular has long been noted for its nineteenth-century expansion, but is presumed to have experienced little or no intensive growth, and perhaps even suffered decline. (Stein, 1985; Dean, 1976; Costa, 1982). To the extent there has been a divergence of views among interested scholars it has revolved around the nature and degree of extensive growth in the region. (See in contrast to Stein the treatments by Sweigart, 1980; and Slenes, 1986). Beyond the question of the regional coffee economy is the issue of economic performance more generally. Per capita economic growth in nineteenth-century Brazil is viewed as weak to non-existent. (Leff, 1972; Contador and Haddad, 1975). Yet this perspective is based on estimates that remain fundamentally conjectural, have endured thirty years without validation by primary sources, and have now become rather widely accepted and used in secondary works.

This paper has two main tasks. The first is to compile and present the evidence required to provide measures of partial and total factor productivity for agriculture in Brazil's Paraíba valley in the nineteenth century. The second task is to define and identify

the chief sources of productivity change. The argument of the paper runs in the following terms. Though the marginal product of slave labor and coffee capital fluctuated without trend from the 1830s and 1880s, the productivity of land in the plantation export economy increased. Total factor productivity rose as a result. Contrary to expectations, the expansion of Brazil's coffee economy was not merely extensive, but was intensive as well, precisely in the era when the historical literature has claimed that it was suffering from "decadence" and indeed incapable of vibrancy. The proximate sources of productivity growth are partitioned into "on-farm" and "off-farm" factors. The most prominent source of increases in off-farm "productivity" was transport cost reductions. Transportation in the region underwent major improvements after 1850, first in the form of turnpike wagon roads, followed soon thereafter by the arrival of the railroad. Transport conditions confronting the rural economy further improved as the real cost of freight shipment by rail declined, raising land values and implicit rents. On-farm sources of productivity gain likely stemmed from the increasing mechanization of coffee processing.

The paper proceeds in seven sections. The following section provides a brief overview of the Paraíba valley and Brazil's coffee economy, and identifies the areas from which original data sets are drawn. The next three sections provide quantitative measures of the cost of slave labor, agricultural capital, and farmland respectively, along with measures of partial productivity. The fifth section estimates total factor productivity, and its increase, on coffee plantations. The sixth section discusses particular features of this productivity growth, and the final section concludes.

1. Coffee Production and the Paraíba Valley: Conditions

The Paraíba valley, running from the north of the province of Rio de Janeiro to the eastern portion of the province of São Paulo, was the geographic heart of Brazil's first coffee boom. The cultivation of coffee in Brazil was first noted in the late eighteenth century, and by the early nineteenth century increasingly widespread coffee planting was underway in the country's center south region. Tropical latitudes, mountainous altitudes, and soil quality provided propitious natural conditions for the cultivation of the coffee bush. Rising demand overseas, the institution of slavery, and eventual transport improvements conjoined to allow Brazil's extant and emerging slave-owning elite to exploit these natural conditions for pecuniary gain.²

The measurement of partial and total factor productivity in Brazil's coffee-growing region draws on primary and secondary sources. While output prices and labor costs come from previously published studies, the price of land, value of coffee trees, and interest rates developed here come from original data sets assembled from archival evidence. In particular, evidence on the value of agricultural land and coffee groves is drawn from probate inventories on rural fazendas (plantations) in the two contiguous municípios (counties) of Vassouras and Paraíba do Sul. Figure 1 highlights the present-day boundaries of these two municípios. Municipal boundaries at the time differed somewhat, as the area of each of the counties was reduced by the creation of new counties over time.

Both counties are quite representative of the region, based on observable characteristics in the late nineteenth century. (Sweigart, 1980). The bulk of Brazil's coffee exports through the 1880s came from the Paraíba valley, and the region was the geographic heart of the country's first coffee boom.

As the nineteenth century progressed rising overseas demand contributed to the rapid expansion of Brazilian coffee production. Growing markets and incomes in Europe and the United States promised valuable outlets for Brazil's premier agricultural product. Supply conditions also favored expansion, and Brazil's share of the growing world coffee market climbed. Figure 2 provides an idea of the degree and pace of this growth (Fundação Instituto Brasileiro de Geografia e Estatística, 1990). Exporting just over 50 thousand metric tons of coffee in the mid 1830s, Brazil's production climbed to some 350 thousand metric tons by the early 1880s. Expansion proceeded at about 2.5 percent per year on average. Coffee prices, portrayed in Figure 3, were subject to fluctuation, but rose as well in the nineteenth century. The two separate series, one based on spot market prices in Rio de Janeiro, the other on the annual unit value of official coffee export figures, differ at several points after 1860 (Brazil, Ministério da Fazenda, 1906; Fundação Instituto Brasileiro de Geografia e Estatística, 1990). However, they are quite comparable and manifest a nearly identical trend over the period under consideration. For the purposes of this paper, the series of Rio market prices is employed.

² Once a disputed issue, the profitability of slavery in Brazil is no longer in doubt. See for

2. Slavery and Agricultural Labor.

Labor productivity on Rio de Janeiro coffee plantations varied over time, but did so without any general tendency. Labor productivity was, in effect, stagnant in the Paraíba valley. Coffee cultivation in nineteenth-century Brazil was a plantation activity and relied heavily on slave labor until final abolition in 1888. The expansion of Brazil's coffee economy before 1850 depended critically on a regular supply from abroad of newly enslaved Africans. Table 1 provides a sense of the volume of slave imports to Brazil in the last two decades of the slave trade. In 1850-51, British diplomatic pressure induced Brazil to finally abandon its dependence on the Atlantic slave trade. Despite the elimination of foreign slave imports, slaves continued to flow to the Paraíba valley, as they were bid away from owners in Brazil's northeast by the relatively high value of the marginal product of labor in the coffee groves (Slenes, 1980; Martins, 1980; Slenes, 1986). By 1878, Paraíba do Sul had nearly 19,000 slaves, and Vassouras had more than 21,000 (Rio de Janeiro(Province), 1879). Brazil's center south as a region had undergone an appreciable geographic concentration of slave holding since 1850. (Slenes, 1980). Since neither county hosted a large urban center, most of these slaves were rural. Figure 4 presents the prices of adult male slaves in Rio de Janeiro (drawn from records in Vassouras) and in the neighboring province of Minas Gerais, the southernmost portion of which bordered the northern edge of the Paraíba valley (Carvalho de Mello, 1984; Bergad, 1999). Nominal slave prices in these provinces, and indeed throughout Brazil's center south, rose in the

example, Mello, 1984; Mello, 1978; Denslow, 1975; Castro, 1973.

wake of the elimination of trans-Atlantic slave imports in 1850-51, and remained above pre-1850 levels until the very eve of abolition. (Dean, 1976; Slenes, 1980). Visual inspection reveals the same general pattern over time in Brazil's northeast (Andrade, 1988; Mattoso, et al., 1988; Barickman, 1991; Eisenberg, 1974). Yet in the coffee regions the real price of slaves did not remain as high as Figure 4 suggests. Figure 5 deflates the price of the average mineiro and fluminense slave by the price of coffee. Real prices ran up after 1850. For the coffee sector the peak slave price came around 1858. Real slave prices began to moderate after 1860 and into the 1870s, as the regional demand for slaves was met by the forced migration of slaves from the rest of Brazil. Slave prices dropped with the passage of the Free Birth Law in 1871, but fluctuated without trend through the 1870s and early 1880s (Conrad, 1972). Legislation freeing elderly slaves, debated in 1884 and passed in 1885, coincided with a downward slide of slave prices that was punctuated by final abolition.

Domestic markets enabled a vibrant internal trade in slaves that accommodated regional shifts in export prospects and production possibilities. There were also local rental markets in slaves for a wide variety of tasks, including agriculture. Carvalho de Mello's research on the economics of slave holding created a virtually complete time series on slave rental rates in Rio de Janeiro, drawn from advertisements in the leading daily commercial newspaper. The slave rental series for Rio de Janeiro is unmatched by any research on other regions of Brazil, and provides a unique opportunity to compare the actual costs of slave labor services with the net present value of slaves themselves. Figure

6 illustrates the hazards involved in attempting to use slave prices to indicate labor costs. It presents an index of the ratio of the slave hire rate to the price of a slave. From 1854 to around 1883 the ratio drifts only slightly upward, and slave prices serve as a reasonable proxy for the costs of slave labor. Before 1854 and after 1883 the ratio varies considerably. For this reason the rental series is the preferred measure of labor cost and productivity.

Figure 7, with a few interpolations, presents the nominal hire rates in index number form. It also deflates these rates by the price of coffee to create an index of real hire rates. The real rate index indicates the cost of labor confronted by coffee planters. The movement of the index over time indicates changes in the marginal product of labor. So long as the region's demand for slave labor could be met by imports, first from abroad and later from elsewhere in Brazil, labor's relative scarcity went unaltered. With no upward trend in the cost of hired slaves to planters, there was no enduring productivity increase in slave labor on coffee plantations.

3. The Credit Market and the Cost of Agricultural Capital

The productivity of agricultural capital on coffee plantations saw no enduring increases between 1835 and 1885. The key component of agricultural capital was the coffee bush itself. The value of coffee groves recorded in probate inventories dominates all other reported forms of capital. The marginal product of capital is indicated by the real unit cost of mature coffee trees. The unit cost of a coffee tree is taken here as its implicit

rental rate, given by the product of the value of the average coffee tree and the market rate of interest. The resulting figures fluctuated without trend through 1885.

Newly planted coffee groves did not yield their first harvest for at least four years, such that coffee cultivation posed an investment problem for the fazendeiro. Given that fazendas commonly had tens of thousands of trees, in orchards of varying ages, the planting and rearing of coffee trees was of considerable importance in determining plantation costs and output. The figures used here on the value of coffee trees derive from information on groves reported in nineteenth-century probate inventories. From 1850 onward, all of the trees are on estates in Paraíba do Sul.³ Due to issues of access to archival materials from before 1850, the estates used for information from 1835 through 1845 were all in the county of Vassouras.⁴ Virtually every agricultural property included among the probates specialized in the cultivation of coffee for export. Estate evaluators recorded the value of each coffee grove, and the number of trees comprising each grove. In some cases precise figures on the age of each grove appear in the enumerations. Less precise evidence indicating whether a particular grove was new, or old, appeared as frequently as did annotations of specific ages of the trees in the grove.

Table 2 provides three measures of the average value of coffee trees. The figures for 1855 are not yet complete and do not appear in the table. The first column is the

³ Probates for Paraíba do Sul are held in the historical section of the Arquivo Público Judiciário do Estado do Rio de Janeiro, in Rio de Janeiro, Brazil.

⁴ Probate inventories for Vassouras are held at the Centro de Documentação of the Fundação Universidade Severino Sombra, in Vassouras, Brazil.

average value of a coffee tree in the probates each year, irrespective of the tree's age. The second column deflates these values by the price of coffee. Nominal tree values increased gradually, while the real value fluctuated. However, both columns potentially suffer from problems of comparability over time, since neither controls for differences in the average age of the trees from period to period. The value of coffee trees varied considerably with their age. Correcting this potential problem requires adjusting the trees each year to a common basis to render their values comparable. Figure 8 presents the tree's age-price profile. The plot presents data for all probates from the period under study that reported the age of coffee groves, deflated by the price of coffee. The quadratic specification of the relationship between the real value per tree and its age provided a good fit, with an R2 of 0.826, and the following parameters:

$$V = 0.0247 \underset{(18.6)}{AGE} - 0.0009 \underset{(-12.6)}{AGE}^2$$

The estimated equation reveals that the typical coffee tree attained its maximum value at just under 14 years of age.

Adjustments to tree values for differing average tree ages for each year relies on such an equation for the nominal age-price relationship, along with a time trend. The third data column of Table 2 gives the resulting estimated nominal tree value. These differ from the actual nominal values in column one by more than twenty percent in every case, and reflect a general increase that is a result of the positive time trend parameter in the estimating equation. However, once these estimated values are converted to implicit

rental rates the difference they make for the final computation of total factor productivity is so slight as to matter very little.

Converting the value of a coffee tree to the rental cost of capital requires data on interest rates for each period. Table 3 presents figures on Brazilian interest rates, including newly available evidence on loan rates in the Paraíba valley. Until 1832, usury laws were in effect in Brazil such that recorded interest rates were capped. Effective interest rates cannot be determined until 1832, but thereafter were almost always specified in detail in loan contracts recorded in local notary offices. The first column of Table 3 reports discount rates in the Rio money market (Sweigart, 1980). These were systematically lower than the prevailing rates on loans to private individuals. The second and third columns report the rates on such loans. Credit market improvements, underwritten by government initiatives to expand bank financing to agriculture, reduced the cost of lending to a number of coffee planters below the averages reported here, though it is doubtful that the charges on those loans indicate the true opportunity costs of funds. The rates on mortgages in the western Paraíba valley come from mortgage registers eastern São Paulo, and encompass a variety of types of lenders (Marcondes, 1999). The Rio rates in the third column come from the loans recorded in Rio de Janeiro on urban and rural collateral, including plantations throughout the coffee zone (Ryan, in progress). The two loan rates are roughly comparable, and since the Rio loan time series reaches back to 1835 it is used to estimate the rental cost of agricultural capital.

Applying the loan rates to the tree values in Table 2 gave the rental series that, once deflated, revealed no significant trend in the cost of agricultural capital, irrespective of whether actual unit values were employed, or those from the estimating procedure described above. The productivity of the major component of coffee capital was constant through 1885.

4. Rural Land Values

Land values, more than the prices of the other two factors of production, suggests genuinely rising productivity in the coffee economy. Table 4 reports the unit value of land on coffee plantations, from 1835 through 1885, drawn from the same probate inventories used in the previous section. Evaluators reported not only the value of an estate's land, but also its dimensions, and occasionally the condition of particular plots within the plantation. One potential problem that emerges with the data is the different values assigned to plots of varying quality. Unused land was typically valued at appreciably greater levels than land under cultivation, and land that was already used and overgrown was valued less. If, for example, in a given year unused land appeared disproportionately in the probates it would bias the average land value upward. From 1870 onward, the information on land quality and characteristics reported in the probates permits adjustment to the unit land values, rendering them more uniform and comparable over time. The adjustments relied on OLS regression of the unit land values in a given year on dummy variables indicating its characteristics. Before 1870 the information on land quality was not sufficient for such

corrections.⁵ Table 4 reports unit land values (adjusted beginning in 1870 to prevent overstatement). As in the case of the slave hire rates and implied rental costs on coffee trees, the nominal land values are adjusted by an index of coffee prices. Two features in the table are apparent. First, there is a discontinuous and anomalous jump in 1845. Second, the general trend in both nominal and real land values is upward, suggesting rising implicit land rental costs. The probates in 1845 were scrutinized to rule out any special source of bias, and none was apparent. The first plans for a railroad in the region of Vassouras (which went unrealized) were in circulation at the time, which might serve to explain the early, transitory run up in the value of land. Nonetheless, it is not likely that the mere prospect of an eventual, unfunded railroad might so thoroughly valorize land in the eyes of estate evaluators, and the representativeness of the datum will only be confirmed as the annual time series of land values are created. In a procedure analogous to that employed to estimate the implicit capital costs, implicit land rents were derived using these values and the interest rates on Rio loans. The resulting index of implicit land rents, deflated by the price of coffee, confirm rising real values of land between 1835 and 1885. The productivity of land, unlike that of labor and capital, increased in Brazil's coffee zone, much to the benefit of the landowners.

⁵ That this created a bias appears unlikely. Stein's graph on the value of used and unused land in Vassouras suggests that the gap between the two is less pronounced before 1865 (Stein, 1985, p. 223).

5. Total Factor Productivity

Brazil's coffee economy enjoyed an appreciable degree of overall productivity advance between in the nineteenth century, though it was due entirely to the rising productivity of land. Total factor productivity is simply the ratio of output to inputs. It is measured here drawing on the "dual," and expressed as the ratio of input costs to output prices. Assuming that measurement error has not appreciably infected the component series, increases in the cost-price ratio indicate changes in technique, the organization of production, or other circumstances that permitted agriculture to enjoy increased output with no increase in conventional factor inputs.⁶

Though fazendas did not limit themselves solely to coffee cultivation, price series for other crops that occasionally appear in small quantities in the probate inventories, such as corn and beans, are not yet available for the region. In the calculation of total factor productivity, input prices are expressed in the nominal unit values reported in the preceding sections. The cost index is geometric average of the three input price indices, where the weights are the shares of each component in total production costs. Total factor productivity (TFP) in a given year is computed as:

$$A = \frac{w^a v^b r^f}{p}$$

⁶ Though well know, it bears repeating that this seemingly inexplicable quality of TFP and its growth led Abramowitz to ruefully label it an index of ignorance.

where w is the hire rate for slaves, v is the implicit land rent, r is the implicit rental rate on agricultural capital, the parameters are factor shares in total cost, and p is the price of coffee. All variables are expressed in index form, with 1850 values set to equal unity. In the absence of revenue and expenditure accounts from coffee fazendas, cost shares are not directly available. Here the shares are inferred, using production elasticities obtained from econometric analysis of output and inputs for a group of twenty-nine coffee fazendas in the Paraíba valley in 1883 (Laërne, 1885). Nine of the twenty-nine fazendas were located in the municipio of Cantagallo, just slightly east of Paraíba do Sul. Specifications of the production function that separated coffee trees from land as inputs gave results with poor statistical significance, and likely suffer from a degree of multicollinearity. Spacing between coffee trees was quite uniform, and measures of land under cultivation and trees in production were closely related. For the specification employed, the labor input, L , is taken as the number of field slaves; the area planted (K) as the composite capital-land input; and the 1883 coffee crop as output (Q). A Cobb-Douglas specification yielded:

$$\ln Q = 6.3 + 0.63 \ln L + 0.48 \ln K$$

(6.5) (2.6) (2.1)

with t statistics in parentheses, and R^2 of 0.61. The overall scale coefficient of 1.11 suggests modestly increasing returns to scale. Normalizing by the parameters by the scale elasticity gives a labor coefficient of 0.57, and a capital coefficient of 0.43. The relative

weights of land and trees are arbitrarily set to equal each other, so that the share of labor in the cost index is 0.57, while the shares of land and trees are .215 each.⁷

Applying these shares as weights to the indices derived in the previous sections yields the index of TFP. Two variants of the TFP are reported, one including the outlier land rent for 1845, and the other excluding it. Figures 9 and 10 present the two indices. The trend rate of productivity growth in Figure 9 is only slightly positive, since the high land rent for 1845 pulls the early part of the trend excessively upward. In Figure 10 the trend rate of growth is four-tenths of a percent per year. Figure 10 is preferred because of the doubtful representativeness of the outlier in Figure 9. In neither case do the results paint a portrait of decline or decadence, and the TFP index of Figure 10 indicates a degree of productivity increase comparable with TFP growth in even the relatively more advanced economies of the North Atlantic.

6. Features of Productivity Growth

No sources-of-growth analysis for the coffee economy can yet be performed, given the absence of information on changes in the stock of capital, land and labor. More generally however, productivity advance in the coffee sector is attributable to both on-farm and off-farm innovations. The most prominent of the off-farm innovations took the form of the introduction of steam locomotion applied to overland transport. Transport cost reductions appeared in higher farm gate prices, and higher land values. These necessarily

⁷These labor and non-labor shares are quite similar to those for the aggregate US economy

show up as a “cost” in the numerator of the TFP index. Their contribution to increasing land values, and rising TFP as measured in the preceding section, had little to do with any changes in organization or technology on the fazenda. Yet transport cost reductions contributed to overall productivity increase in the agricultural economy, by permitting specialization.

The first substantive improvement in transportation in the central Paraíba valley, beyond occasional attempts to open new local roads or repair old ones, came with the paved União e Indústria wagon road. The wagon road improved the valley’s links to standing transport routes down the mountains to the port of Rio de Janeiro. The road reduced the high freight costs of shipping by cart and mule over frequently impassable pathways. Transport costs were quickly further reduced with the expansion of the Dom Pedro II railroad through the valley. Figure 11 presents nominal and real freight unit revenues on the Dom Pedro II railroad, which linked the Paraíba valley to the port of Rio de Janeiro. The introduction of the railroad reduced the cost of overland shipment, and over time the cost of railroad freight shipment fell even further. The level of coffee freight charges was, in practice, higher than the average freight revenues, since the Brazilian government set freight rates so as to tax relatively high value-to-weight export goods (Summerhill, forthcoming). But the decline apparent in the average freight charge was applicable to coffee as well. Falling transport costs did not necessarily profoundly alter on-farm practices, but did improve productivity in the rural economy.

in the nineteenth century (Abramovitz and David, 1973).

Historians have provided few insights into what features of coffee fazendas *per se* might have led to higher levels of productivity over the century. Indeed, research findings from the last several decades stress the social and technical “routinism” of the slave-based coffee plantation, relative lack of innovation, disinterest in soil conservation, absence of fertilizers, and the conspicuous consumption of the planter class. One feature, however, does reveal room for on-plantation technological advance: the mechanical depulper, and related advances in processing coffee after it had been picked and before it was sent to market. Coffee processing required removal of the seed (the coffee “bean”) from the fruit once picked from the bush. Dehulling followed, as an interior shell was removed from the bean. Processing had in many fazendas been mechanized for some decades, as a large, water-powered machine (the *pilão*) functioned like a mortar and pestle. In the 1860s new machinery for depulping, winnowing, and sorting became more common, though as Stein pointed out for the case of Vassouras, the machines tended to operate alongside the traditional devices rather than supplant them completely. The probate inventories for Paraíba do Sul also indicate an increasing presence of machinery in the 1870s and 1880s. The new machines economized on coffee-processing labor requirements, raised the effective yields per tree over what they would have been, and in general increased the average quality of coffee produce, allowing it to fetch a higher price in the Rio market. The magnitude of these effects is not possible to gauge until the full array of evidence on agricultural machinery investment can be more fully fleshed out. But the direction of the effect of new machinery on agricultural productivity is little in doubt.

7. Conclusions.

This paper provided estimates of partial and total factor productivity in agriculture in the Paraíba valley. Indicators of partial productivity focused on three major inputs to coffee production: slave labor, coffee trees, and agricultural land. Under the most likely scenario total factor productivity in the slave-based coffee plantation economy grew slightly less than one-half of a percent per year between 1835 and 1885. All of that productivity growth stemmed from rising productivity of land and revealed in increasing land values. Agricultural productivity advance in this region of Brazil was modest yet appreciable. Indeed, it was very similar to the reported measures of TFP growth in the nineteenth-century U.S. economy, England's agricultural sector, and in the farmland of the Paris basin in the eighteenth century (Abramowitz and David, 1973; Clark 2002; Hoffman, 1996). That there was nothing particularly remarkable about the rate of TFP growth in the Paraíba valley is no doubt its most remarkable feature. Given that specialists have long discounted the prospects for productivity advance, the finding is a noteworthy one, for two reasons. First, in light of the historical literature, the finding underscores the centrality of microeconomic archival evidence, no matter what its potential pitfalls, for the study of rural history in Brazil, and in other areas of Latin America where economic censuses do not exist. Second, it provides original insight on Brazil's economic performance that takes a first step toward meaningful comparisons with the performance other countries and regions in the nineteenth century. The findings here are by no means the last word, but rather serve

as a prelude to a broader exploration of the topic, one that will have to draw on the abundant archival evidence to address the possibly very different experiences of Brazil's other major regions. Such investigations promise their own productive improvements to our understanding of Brazilian economic growth.

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FIGURE 1. COUNTIES OF VASSOURAS AND PARAIBA DO SUL, STATE OF RIO DE JANEIRO, BRAZIL, 2002.

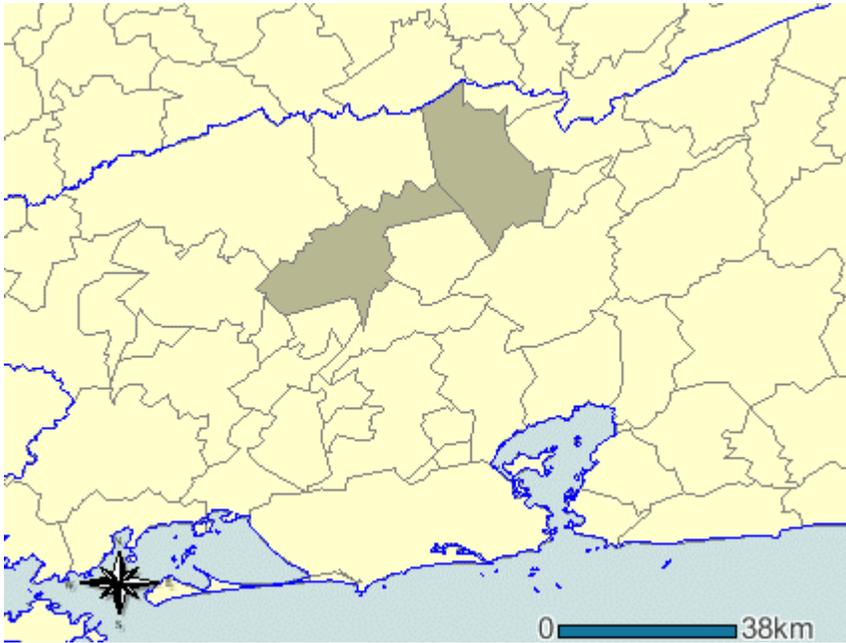


FIGURE 2. COFFEE EXPORTS FROM BRAZIL, 1821-1889

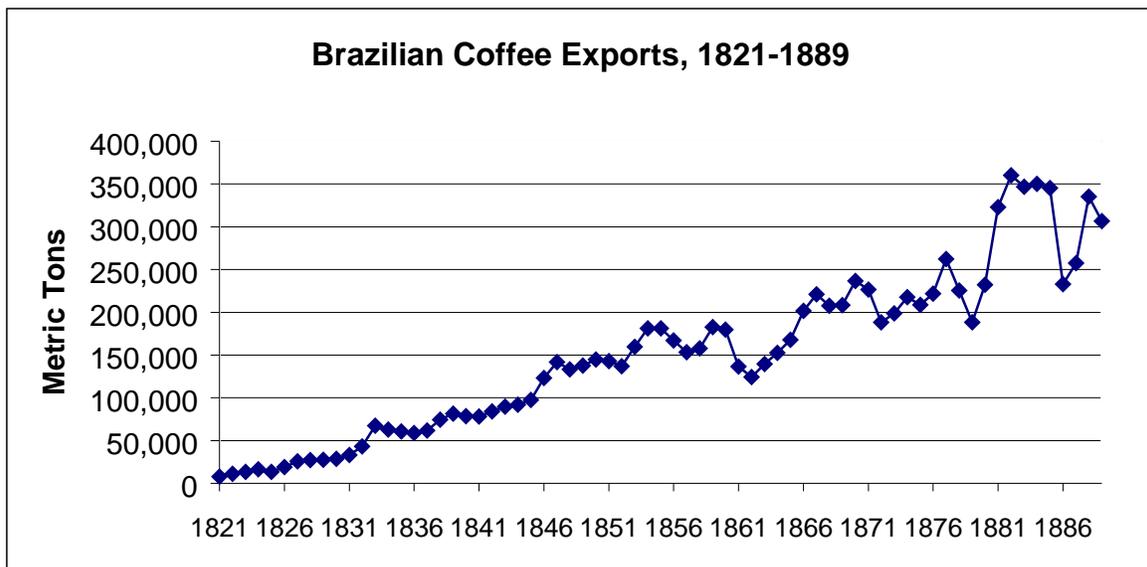


FIGURE 3. INDEX OF BRAZILIAN COFFEE PRICES, 1835-1888

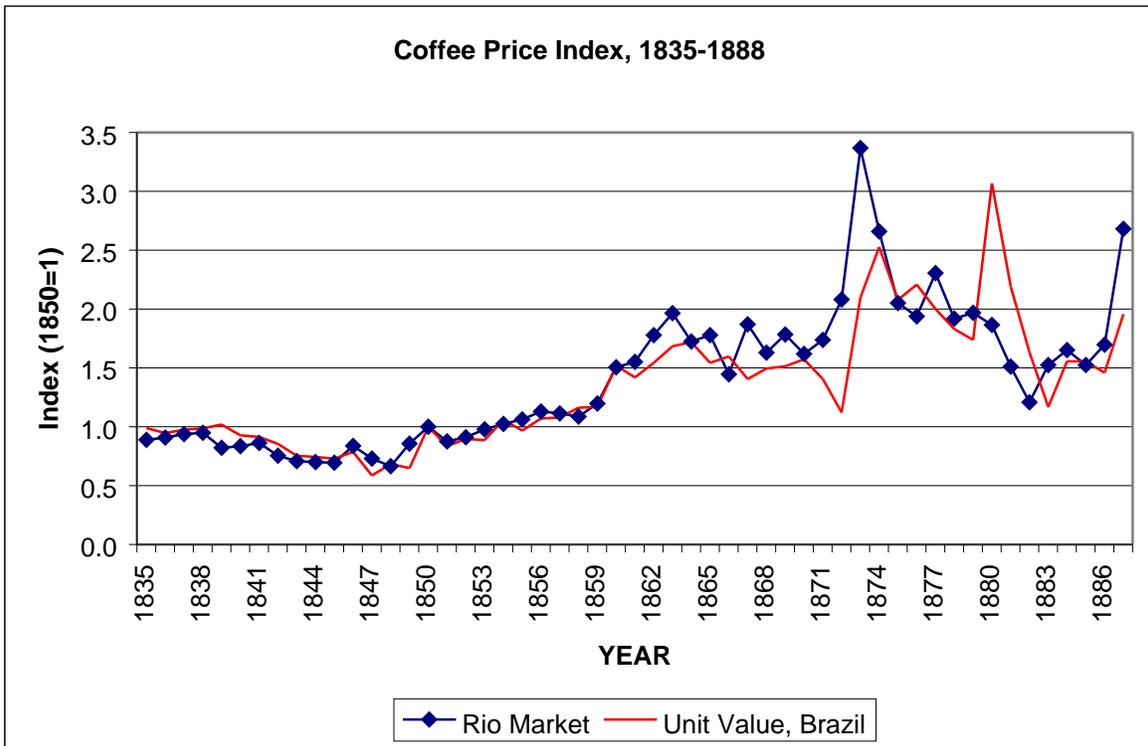


FIGURE 4. SLAVE PRICES, ADULT MALES, RIO DE JANEIRO AND MINAS GERAIS

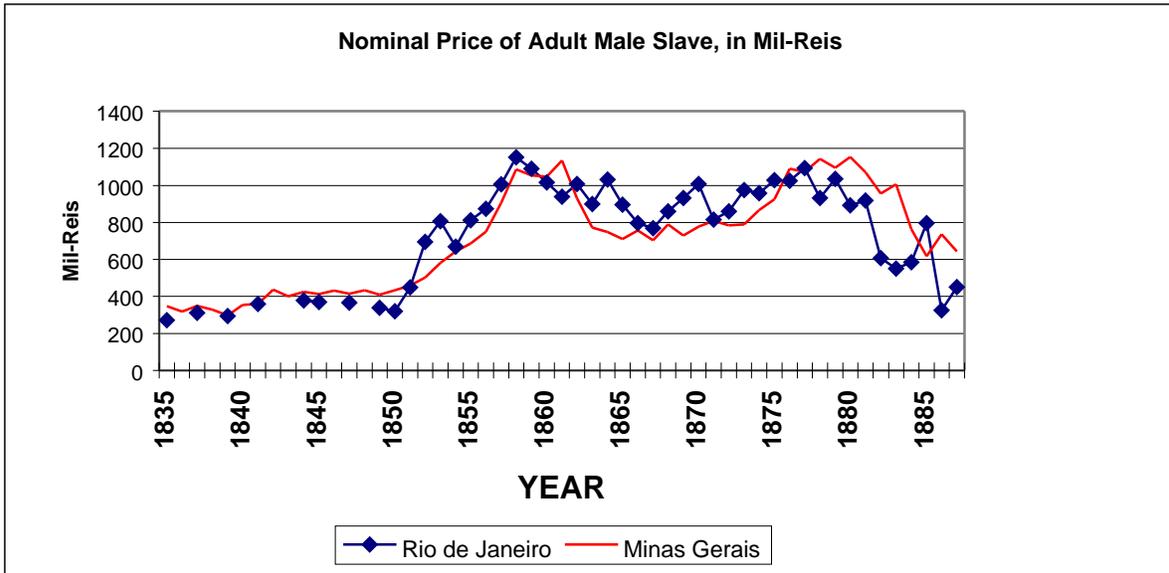


FIGURE 5. SLAVE PRICES DEFLATED BY PRICE OF COFFEE

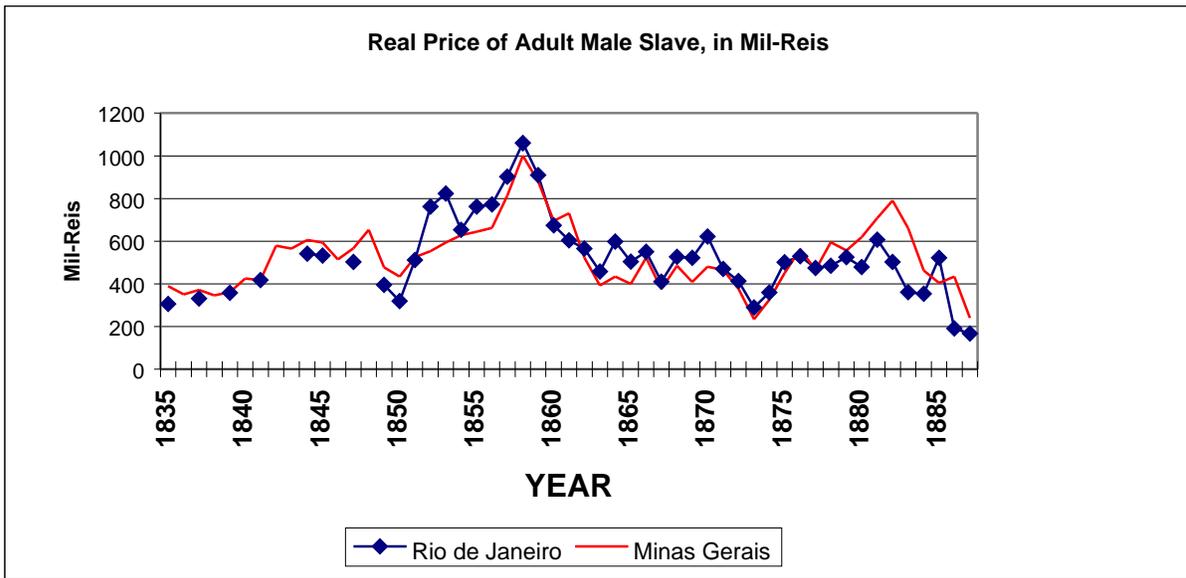


FIGURE 6. RATIO OF SLAVE RENTAL RATE TO SLAVE PRICE, RIO DE JANEIRO

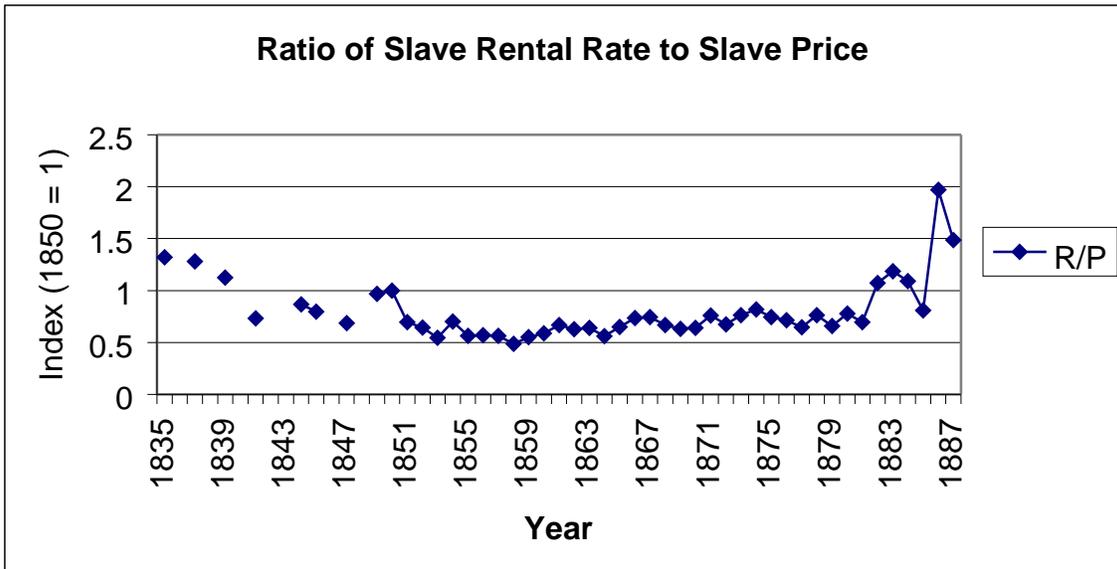


FIGURE 7. RENTAL RATES ON SLAVES IN RIO DE JANEIRO

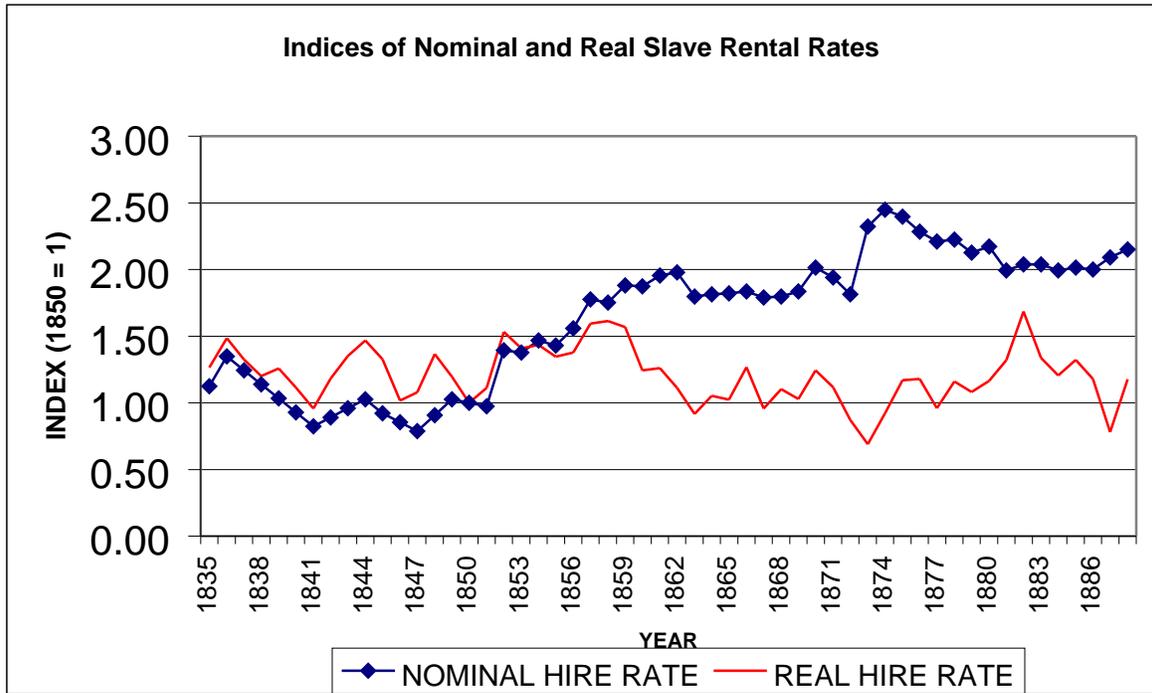


FIGURE 8. COFFEE TREE AGE-PRICE PROFILE

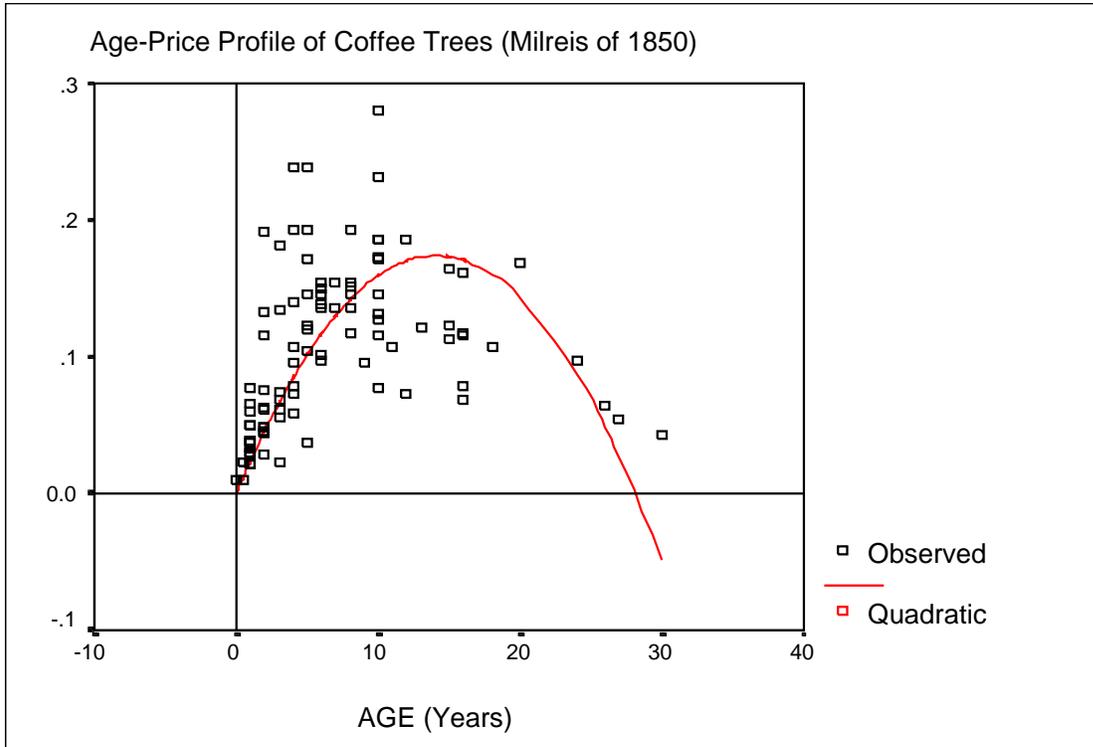


FIGURE 9. INDEX OF TOTAL FACTOR PRODUCTIVITY, "A" MEASURE

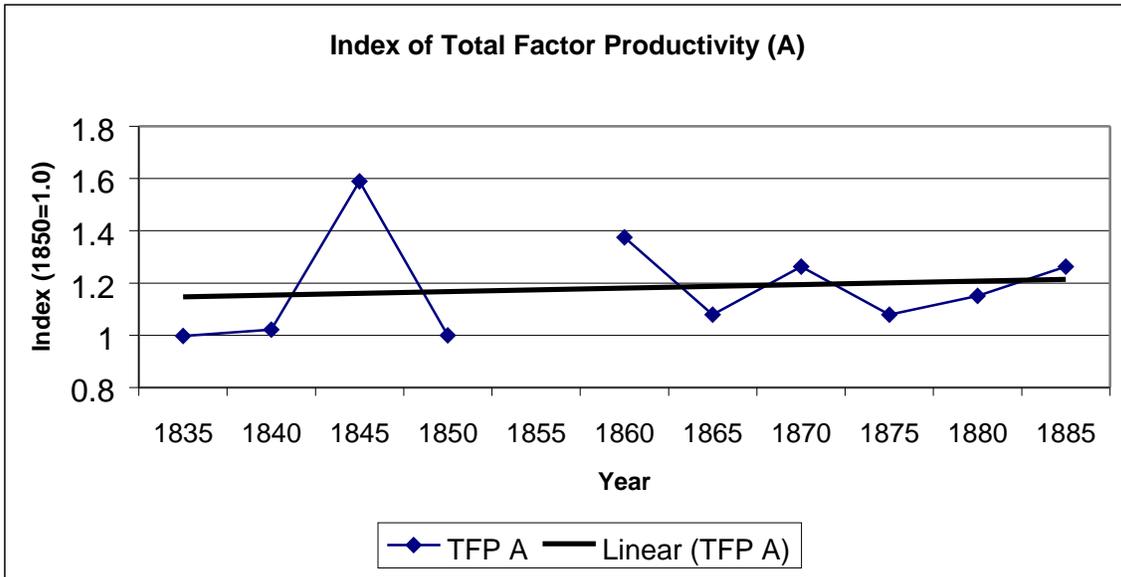


FIGURE 10. INDEX OF TOTAL FACTOR PRODUCTIVITY, "B" MEASURE

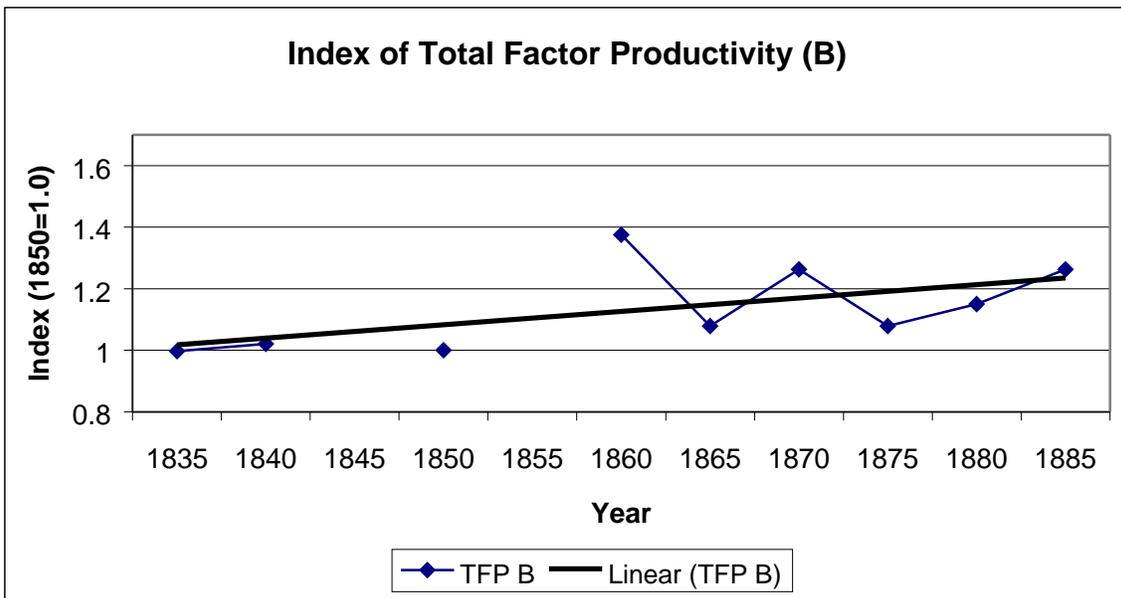


FIGURE 11. NOMINAL AND DEFLATED UNIT FREIGHT CHARGES, DOM PEDRO II RAILROAD, 1858-1888

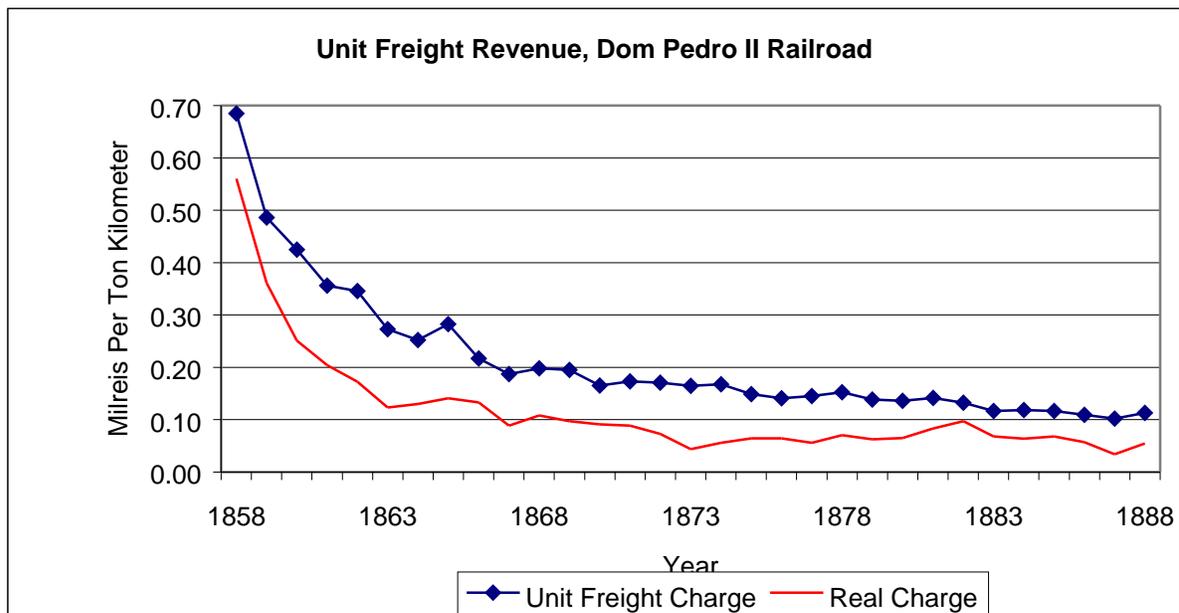


TABLE 1. IMPORTS OF ENSLAVED AFRICANS TO BRAZIL, 1831-1851

Year	Slaves	Year	Slaves
1831	138	1841	13,804
1832	116	1842	17,435
1833	1,233	1843	19,095
1834	749	1844	22,453
1835	745	1846	50,324
1836	4,966	1847	56,172
1837	35,209	1848	60,000
1838	40,256	1849	54,061
1839	42,182	1850	22,856
1840	20,796	1851	300

SOURCE: Leslie Bethell, *The Abolition of the Brazilian Slave Trade: Britain, Brazil and the Slave Trade Question, 1807-1869* (Cambridge, England: Cambridge University Press, 1970), 388-93, appendix)

TABLE 2. UNIT COFFEE TREE VALUE

YEAR	Tree Value	Tree Real Value	Estimated	N
			Nominal Tree Value	
1835	0.090	0.101	0.199	173,920
1840	0.160	0.192	0.208	371,538
1845	0.150	0.216	0.216	502,000
1850	0.180	0.180	0.224	159,640
1855	--	--	0.232	--
1860	0.180	0.120	0.240	186,400
1865	0.170	0.096	0.248	497,118
1870	0.200	0.124	0.257	335,250
1875	0.190	0.093	0.265	640,000
1880	0.210	0.113	0.273	931,766
1885	0.200	0.131	0.281	269,500

SOURCE: Probate inventories for Vassouras (1835-1845) and Paraiba do Sul (1850-1885).

NOTE: Value is expressed in milréis per tree. Real value derived by adjusting for price of coffee. Estimated nominal tree value is based on the parameters from a quadratic fitted to age-price data, and a time trend, evaluated at the value-maximizing age of the tree. N is the number of trees comprising the groves recorded in the probates.

TABLE 3. INTEREST RATES

YEAR	Rio Discount Rate	Western Paraiba Valley Mortgage Rates	Rio Loan Rates
1835			0.120
1840			0.146
1845			0.153
1850	0.075		0.145
1855	0.077		0.116
1860	0.09		0.149
1865	0.096	0.130	0.129
1870	0.077	0.135	0.117
1875	0.089	0.123	0.103
1880	0.075	0.108	0.107
1885	0.072	0.103	0.102

SOURCE: Discount rates for Rio money market from Sweigart, 1980. Rural mortgage rates for the western Paraiba Valley from Marcondes, 1999. Rio loan rates from Ryan, in progress.

NOTE: Discount rates are from published summary tables and purport to include all commercial bank discounting in Rio de Janeiro. Western Paraiba valley mortgage rates are from mortgage registries for two counties in eastern São Paulo. Rio loan rates are from all recorded loan contracts in the notary offices of Rio de Janeiro.

TABLE 4. UNIT LAND VALUE, IN MILRÉIS PER *ALQUERE*

YEAR	UNIT LAND VALUE	REAL UNIT LAND VALUE	N	Area
1835	50	56	9	1035
1840	34	41	14	841
1845	97	140	9	439
1850	57	57	9	481
1855	--	--	--	--
1860	200	133	18	966
1865	207	116	19	624
1870	229	141	14	523
1875	254	124	21	446
1880	257	138	33	836
1885	227	149	13	138

SOURCE: Probate inventories for Vassouras (1835-1845) and Paraiba do Sul (1850-1885).

NOTE: Value is expressed in milréis per *alquere*. One *alquere* is approximately 12 acres. Real value derived by adjusting for price of coffee. N is the number of separately recorded parcels of land. Area is the total area comprising the parcels, in *alqueres*.