Railroads and the Transformation of the Brazilian Economy[*]

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Brazil's per capita growth performance is one of the most impressive on record during the period 1900-1980. This stands in stark contrast to the Brazilian experience in the nineteenth century, when per capita growth in real product was virtually nil.[1] The pace of economic activity in Brazil underwent a profound acceleration around the turn of the century. The available figures for pre-1914 real product show a trend rate of growth of per capita GDP from 1870 to 1900 that is actually negative, while from 1901 to 1913 GDP per capita rose at a staggering annual rate of 7.2 per cent.[2] While indicators of aggregate output in Brazil remain wildly imperfect by even the most forgiving standards, independently derived estimates concur in revealing a traverse from a dismally poor growth path in the nineteenth century to a much improved course for most of the twentieth century.[3] The reasons for this turnaround are myriad;

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[1]Nathaniel Leff, Underdevelopment and Development in Brazil: Vol. I: Economic Structure and Change, 1822-1947 (London, 1982), presents estimates of growth rates for the nineteenth century.

[2]The series employed here is that of Cláudio Contador and Cláudio Haddad, "Produto real, moêda, e preços: a experiência Brasileira no período 1861-1970," Revista Brasileira de Estatística 36(1975): 407-440 (hereafter CH). Using AR1 estimation to regress the natural logarithm of per capita GDP on time yields the following parameter estimates:

for 1870-1900 $\ln (GDP/POP) = 26.4 - 0.011\ YEAR$
$(2.7) \quad (-2.3)$
$R^2 = 0.97 \quad D\text{-}W = 0.84 \quad F = 841$

For 1901-1913 $\ln (GDP/POP) = -131.3 + 0.072\ YEAR$
$(-11.7) \quad (12.1)$
$R^2 = 0.99 \quad D\text{-}W = 1.4 \quad F = 918$

These results give a rough idea of the fin-de-siécle shift detectable in the output estimates. For reasons noted below not too much can be made of either the precise timing or the degree of the shift given the derivation of the underlying data series.

[3]The absence of economic censuses hampers national income accounting for pre-1920 Brazil. Quantitative measures of nineteenth-century economic growth depend, as in Leff's case, on foreign prices and arbitrary assumptions about the income velocity of circulation, or, as in the cases of CH and Haddad (before 1920), purely on statistical extrapolations using principal components analysis; Leff, Underdevelopment and Development in Brazil; Contador and Haddad, "Produto real, moêda, e preços,"; Cláudio Haddad, Crescimento do Produto Real Brasileiro, 1900-1947 (Rio de Janeiro, 1978). The tenuous nature of the estimates by CH and Leff have led others to reject their use. See Albert Fishlow, "Conditionality and Willingness to Pay: Some Parallels from the 1890s," chap. in Barry Eichengreen and Peter Lindert, eds., The International Debt Crisis in Historical Perspective (Cambridge, MA, 1989), 105, n.23; and L.A.V. Catão, "The international transmission of long cycles between 'core' and 'periphery' economies: a case study of Brazil and Mexico, c. 1870-1940," Ph.D. diss., University of Cambridge, 1991. Leaving aside the even more precarious revisions to CH by Topik, and Goldsmith, the CH and Haddad estimates remain the only output series for pre-1920 Brazil; Steven Topik, "The Economic Role of the State in Liberal Regimes: Brazil

no single factor has been found culpable in perpetuating low rates of growth among relatively backward countries. Though various factors account for the Brazilian traverse in varying degrees, both contemporary and modern analysts suggest that the high cost of overland transport was an important obstacle to economic growth in nineteenth-century Brazil. Since many also stressed the role of transport improvements, in the form of railroads, in overcoming this obstacle, a focused inquiry into the direct economic impact of railroads in Brazil is warranted.

Historians and economists have long been interested in the economic consequences of the construction and operation of railroads in the nineteenth century. Early studies, including some on historically backward economies, have presented evidence showing that railroads did not have the profound direct economic impact implicit in the earlier, more anecdotal historiography.[4] More recently, economic historians studying countries that did not enjoy well developed pre-rail transport systems have identified relatively large direct benefits following from the establishment of railroads.[5] However, outside of research on Mexico and Spain, relatively little work has been done on transport modernization in economies where high pre-rail transport costs posed a significant obstacle to economic growth.

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and Mexico Compared, 1888-1910," chap. in Joseph L. Love and Nils Jacobsen, Guiding the Invisible Hand (New York, 1988), 129; Raymond W. Goldsmith, Brasil 1850-1984: Desenvolvimento Financeiro Sob Um Século de Inflação (São Paulo, 1986).

[4]The voluminous literature on the economic impact of railways defies complete citation. The more prominent case studies include those by Robert William Fogel, Railroads and American Economic Growth (Baltimore, 1964); Albert Fishlow, American Railroads and the Transformation of the Ante-bellum Economy (Cambridge, MA, 1965); Gary Hawke, Railways and Economic Growth in England and Wales (London, 1970); Jacob Metzer, Some Economic Aspects of Railroad Development in Tsarist Russia (New York, 1977); Jan de Vries, "Barges and capitalism: Passenger transportation in the Dutch economy, 1632-1839," A.A.G. Bijdragen, 21; John H. Coatsworth, Growth Against Development (Dekalb, 1980); and Antonio Gomez Mendoza, Ferrocarriles y cambio economico en España, 1855-1913 (Madrid, 1982). For overviews of the related literature see Patrick K. O'Brien, The New Economic History of the Railways (New York, 1977); and Robert William Fogel, "Notes on the Social Savings Controversy," JEH, 39. To the works cited by these authors should be added the contributions on Spain, Belgium, and France in Patrick K. O'Brien, ed., Railways and the Economic Development of Western Europe, 1830-1914 (New York, 1983).

[5]Coatsworth, "Indispensable Railroads in a Backward Economy: The Case of Mexico," JEH, 39; idem, Growth Against Development; Gomez Mendoza, Ferrocarriles y cambio economico en España.

This paper details the direct economic effects of railroads in Brazil by focusing on the resource savings that railroads afforded the economy through lower transport costs. The first section below briefly sketches the methodological approach employed in estimating the gains that railroads provided Brazil. By reducing transport costs railroads occasioned the extension, integration, and regional specialization of markets for agricultural commodities and manufactures followed from the reduced cost of transport, raising the level of output and income in the economy.

The measure of that difference is known as the direct social savings, which gauges the improvement in efficiency in the economy that is attributable to the introduction of the railroad. The social savings of railroads is defined as the difference between the actual cost of transporting goods and passengers in one year by rail, and the cost of shipping the same mix of goods and passengers over the same distances by an alternative means of transport in the absence of railroads. The magnitude of the social savings depends on two elements: declining unit transport charges, resulting from the shift to a more productive mode of transport; and the responsiveness of the economy to those reduced charges, as indicated by the actual volume of transport services produced. A counterfactual economy is not an observed state; it is purely fictive. And, in this case, it need not necessarily bear any relationship to how the economy might have looked if railroads had never been built. However, to one degree or another, counterfactuals are implied in virtually all statements of causation, international and inter temporal comparisons, and assertions of historical "importance" or "significance." The virtue in making the counterfactual explicit, and in attempting to operationalize its constituent parts, is its capacity to spur new inquiry and more tightly focused research. Nonetheless, for the purposes of historical analysis some counterfactuals make more sense than others.[6] The counterfactual

[6]A masterful discussion of the importance of reasonable counterfactuals in historical research, and their strengths and limitations, is Alexander Gerschenkron, "Some Methodological Problems in Economic History: Postscript," in Continuity in History and Other Essays (Cambridge, MA, 1968), 50-56.

specifications of the Brazilian economy that are explored in this paper draw their characteristics directly from the known features of that economy to derive measures of direct social savings.

The second section derives measures of passenger benefits. In Brazil, pre-rail passenger travel was largely by foot or on the backs of animals. The savings the economy enjoyed by having these passengers travel by rail depended on the value of the resources released by the shift to rail travel. The direct savings on travel fares, and the value of the passenger travel time saved, comprise these resources. In Brazil the resources released by the substitution of rail passenger services for traditional modes were limited. The volume of passenger service was low, since the average Brazilian traveled neither frequently nor for long distances. Moreover, walking and riding were largely free goods that required comparatively few scarce inputs. In other countries, the construction of passenger savings estimates found that an important component was the amount of time saved on the journey. In Brazil the value of that time was low because low labor productivity plagued the economy. The result was that while railroad passenger services no doubt improved the efficiency of labor markets by making laborers geographically more mobile, the likely magnitude of that gain was small.

The third section provides a range of estimates of the savings afforded Brazilians in hauling freight by rail. Railroad freight services prove to be of much greater importance than passenger services in Brazil. Large savings on the unit cost of freight transport give rise to large social savings only if a sufficient quantity of freight or passengers is moved. Because pre-rail freight transport costs were high, the construction and operation of railroads resulted in large unit savings on shipping freight. The response of the Brazilian economy to the lower cost of shipment involved an expansion of the margin of agricultural cultivation and the creation of new manufacturing activities. With the growth of the nation's rail system after 1854 the production of transportables, and the concomitant demand for transport, expanded significantly. As a result of the rise in output, and the large unit savings on shipment, the direct social savings had grown

quite large by the close of the century, perhaps accounting for as much one quarter of GDP.[7] Converting this "stock" measure of resource savings in 1913 into a flow reveals a high average social rate of return from the investment in railroads.

The fourth section discusses the significance of the link between railroads and the economy's output mix in the context of Brazilian historiography.[8] It turns out that these gains were not concentrated in the export sector, as one might expect. Rather the "internal" sector of the economy benefited disproportionately, due partly to rate policies, and partly to the supply response of domestic-use agriculture.

Measuring the impact of railroads in the Brazilian setting

The high cost of transportation was but one of many obstacles constraining economic growth in nineteenth-century Brazil. The three decades following Brazil's independence in 1822 saw little in the way of change. The key institutional features and broad contours of the economy continued unaltered, and in many respects the country remained virtually as it had been since the late eighteenth-century. The major commercial change of the era was the opening of Brazil's ports in 1808. While this obviously led to gains from international trade, those gains were likely smaller than believed. The demise of formal mercantilism served largely to legitimate and tax a burgeoning illegal commerce. New opportunities in the foreign sector did little to induce institutional innovations or alter prevailing practices and techniques in the largely

[7]Pre 1913 estimates of freight social savings for five benchmark years beginning in 1869 are presently under revision.

[8]Indirect benefits through "backward linkages," or the derived demand for railroad inputs, are not addressed in this paper. In Brazil those linkages were small, limited to foundries internal to the large rail lines' shops, the refitting of locomotives, and the fabrication of some rolling stock. Most rails, rolling stock, coal and even cross ties came from abroad. On some of the backward linkages in Brazil see Colin M. Lewis, "Railways and Industrialization: Argentina and Brazil, 1870-1929," chap. in Colin Lewis and Christopher Abel, eds. Latin America, Economic Imperialism, and the State (London, 1985).

agrarian economy. No structural change or acceleration in per capita growth ensued in the 40 years following the opening to international trade.[9]

In this context the high cost of transportation compounded the country's economic problems. That transport in Brazil was expensive may come as a bit of a surprise. Coastal transport was generally much less costly than overland transport, and was important both before and after the construction of railroads.[10] Moreover, a glance at the map reveals an extensive array of rivers in Brazil's interior. Indeed, with one of the largest river systems in the world one would expect that Brazilian internal waterways presented ample opportunities for cheap inland navigation, akin to the Mississippi and its tributaries in the U.S. It turns out that most of Brazil's rivers were useless for long-haul freight service.[11] Except for the Amazon and its tributaries, rivers were rarely used to carry large quantities of freight. Insalubrious tropical conditions and the absence of readily marketable commodities meant that little settlement occurred in the Amazon basin. The river's cheap transport potential was tremendously useful for shipping rubber, but few other productive activities ever arose in the region. Major rivers located in more important regions of settlement typically proved navigable only for short distances. The Rio São Francisco first opened to steam navigation in the 1860s, but through passage to the coast was blocked by steep falls at Joazeiro in the province of Bahia. The river and the region itself

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[9]On the impact of the opening of Brazil to foreign trade, see Stephen Haber and Herbert Klein, "The economic consequences of Brazilian independence," chap. in Haber, ed., How Latin America Fell Behind. On the slow pace of per capita income growth in the first half of the nineteenth century see Nathaniel Leff, Underdevelopment and Development in Brazil (London, 1982).

[10]Locomotives were a poor substitute for coastwise shipping, and as a result most rail lines ran from the coast to the interior, in an attempt to establish links to interior rivers and create a large internal transport network.

[11]In addition to the accounts of numerous travelers to Brazil, the relative dearth of opportunities for internal navigation and the poor navigability of Brazil's rivers is detailed in Brazil, Arquivo Nacional (hereafter AN), Codice 807, vol. 7, Francisco Keller, "Noções geográphicas e estatísticas sobre a Província do Paraná," 1867; Centro Industrial do Brasil, O Brasil: Suas riquezas naturaes, suas industrias, vol. III, Industria de Transportes, Industria Fabril (Rio de Janeiro, 1909), 116-137; Fred Hartt, Geology and Physical Geography of Brazil (Boston, 1870), 292. For a survey of the navigable portions of inland waterways see; Armando de Miranda Lima, et al., "Rios navegáveis do Brasil," in Instituto Histórico e Geográphico Brasileiro, Diccionário Histórico, Geográphico e Ethnográphico do Brasil (Rio de Janeiro, 1922),710-23; and João Lyra, Cifras e Notas (Rio de Janeiro, 1924), 66-71.

depended on connection by rail to the coast. Further to the south, in the heart of the coffee district in the provinces of Rio de Janeiro and São Paulo, the Paraiba river was passable only in stretches were rocks and rapids permitted shallow-draft boats to maneuver. It too could not be navigated all the way to the coast, and two of Brazil's earliest railroads were constructed in order to connect the Paraiba valley with the port city of Rio de Janeiro. Brazil's far south would prove to be a fertile agricultural hinterland, but there most of the rivers flowed the wrong direction, heading inward to the Paraná and the Rio de la Plata basin. In short, before the construction of railroads almost all but the most localized freight services in Brazil were overland, and for most of Brazil river transport was complementary to overland conveyance.[12]

Before the construction of railroads costliness, torpor, and brigandage characterized the state of overland transport in Brazil. The prevalence of highway robbery around Rio de Janeiro at the time of Independence caused contemporaries to complain that "soon the roads will become impassable."[13] In Brazil severe topography posed a major obstacle to rapid communications, commerce, and economic growth.[14] Except for occasionally successful local efforts to improve road conditions, internal improvements were largely non-existent before the 1850s. Port cities and their immediate coastal hinterlands were relatively isolated from the country's interior regions. In Brazil a steep coastal escarpment runs from the northeast of the country to the far

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[12] A detailed discussion of river and overland transport in pre-railroad Brazil is found in William R. Summerhill III, Order Against Progress: Government, Foreign Investment, and Railroads in Brazil, 1854-1913 (Stanford University Press, forthcoming), ch. 2.

[13]AN, Codice 807, vol. 7, Felisberto Ignácio Januario Cordeiro to Jose Bonifácio da Andrade e Silva, "Memória sobre a segurança das estradas infestadas de salteadores e ciganos," Inhauma, 1822.

[14]Unless otherwise noted the description of overland transport conditions and railroads in Brazil has been inferred from a large corpus of travel accounts by contemporaries, and from Manoel da Cunha Galvão, Notícia Sobre as Estradas de Ferro do Brasil (Rio de Janeiro, 1869); Francisco Picanço, Viação Ferrea do Brazil (Rio de Janeiro, 1884); Max Lyon, Note sur les Chemins de Fer du Bresil (Paris, 1885); Cyro Diocleciano Ribeiro Pessoa Junior, Estudo Descriptivo das Estradas de Ferro do Brazil (Rio de Janeiro, 1886); Chrockatt de Sá, Brazilian Railways, Their History, Legislation, and Development (Rio de Janeiro, 1893); U.S. Department of State, "Railways in Brazil," Consular Reports, vol. 63, no. 239, August 1900; São Paulo, Department of Agriculture, Commerce, and Public Works, Railroads in the State of São Paulo (São Paulo, 1903); Great Britain, "Report on the Railway Systems of Brazil," Diplomatic and Consular Reports, No. 617 Miscellaneous Series, 1904; V.A. de Paula Pessoa, Guia da Estrada de Ferro Central do Brasil (Rio de Janeiro, 1904); and Julian Smith Duncan, Public and Private Operation of Railways in Brazil (New York, 1932).

south, hindering the movement of people and freight between coast and interior. Wagon roads proved difficult to construct, and almost impossible to maintain. Tropical rains turned them to mud and cart traffic made them into impassable ruts. As a result, most freight in Brazil moved on the backs of mules. Most people traveled by foot or by mount, with the occasional fortunate few affording to travel by diligência (stagecoach) over stretches where roads were passable.

To estimate the impact of the shift from a relatively backward mode of transport to the more efficient one represented by railroads, I follow the social savings approach and apply it to the Brazilian economy for 1913. The rather strong assumptions implicit in such a comparative statics approach to measuring the benefits accruing to the economy from cheap transport (even when properly handled) give cause for concern that the full impact of the railroad is perhaps not properly measured..[15] In applied work the original Fogel and Fishlow formulations of direct social savings appear to be rather durable. The social savings model is not an exercise in partial equilibrium analysis, but rather provides a general-equilibrium type measure of the gains arising from cheap transport.[16] Metzer has shown that social savings conceptually includes all of the gains to the economy arising from the reduced cost of transportation, assuming that there are no

[15]An estimate of the direct social savings resulting from reduced-cost transport service is a comparative statics approximation to the dynamic impact of railway expansion in the economy. It turns out that such a model, in spite of its many simplifying assumptions, has proven to capture effectively the magnitude of a shift from a relatively inefficient mode of transport to a more efficient one. Comparative dynamic analysis applied to a multi-sector CGE model of the U.S. economy initially provided results that drastically altered earlier conclusions about the importance of railroads, by producing much larger measures of the gains from railroads than those obtained by earlier studies using direct social savings; see Jeffrey Williamson, Late Nineteenth-Century American Development: A General Equilibrium History (New York, 1974), 184-201. The magnitude of those results stem in part from the assumption that the economy can provide additional freight transport services at no additional cost. Once corrected for that inconsistency the magnitude of railroad benefits as measured by comparative dynamics declines to roughly the same level as obtained by comparative static social savings; see Charles Kahn, "The Use of Complicated Models as Explanations: a Re-examination of Williamson's Late 19th-Century America," Research in Economic History 11(1986):185-216.

[16]On this characterization, and the discussions of the interpretive difficulties involved in this measure see Metzer, Some Economic Aspects, 3-26; idem, "Railroads and the Efficiency of Internal Markets: Some Conceptual and Practical Considerations," Economic Development and Cultural Change 33(1984):61-70. Kahn, "Use of Complicated Models;" Coatsworth, "The Impact of Railroads on the Economic Development of Mexico, 1877-1910," Ph.d. diss, University of Wisconsin, 1972, 3; and Fishlow, American Railroads, ch. 2.

railroad-induced economies of scale in other activities.[17] The cost savings on transport is identically equal to the gain in GDP involved in moving from the non-rail counterfactual to the railroad-including economy.[18]

Direct savings on passenger services

The social saving from railroad passenger services was low in Brazil. The savings that railroads afforded the economy through passenger services has two components. The first is the travel fares saved, while the second is the savings on travel time. Fare savings were larger for first-class travelers, and nil for those traveling in second class. The value of working time saved by the railroad's greater speed was low. Unfortunately, relatively little information is available on the nature of passenger travel in pre-rail Brazil. Measuring the impact of rail passenger service necessarily involves imposing a number of assumptions. With respect to the non-rail travel fares, the relevant alternative modes of travel are taken to be diligência (stagecoach) for first-class travelers, and foot travel for second-class passengers. The high travel charges by rail, and even higher travel charges for non-rail alternatives, are taken to be prohibitively expensive for most Brazilians. This concords with anecdotal evidence from the nineteenth century. The manager of one of the largest lines in Brazil's northeast in the 1870s noted with some frustration the fact that passenger trains operated with a large number of vacancies yet the dirt roads alongside the tracks were full of people walking from town to town.[19] For those people even the train was too expensive.

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[17]See Metzer, Some Economic Aspects. In practice the ability of a social savings approach to approximate correctly these gains turns on the standard concerns of historians regarding the control of the direction and nature of biases, and the quality of information and data.

[18]See Fogel, "Notes on the Social Savings Controversy," and D. McCloskey's heuristic use of the railroad social savings argument in this regard in Applied Theory of Price (New York, 1982), 225-229.

[19]Relatorio da Estrada de Ferro Recife ao São Francisco (n.p., 1874).

Empirical studies of the market for passenger transport services has have found demand to be quite sensitive to changes in passenger fares.[20] In pre-1913 Brazil the overall demand for rail passenger services was likely price elastic. The demand for rail passenger services is separable into two components: the demand for basic transport, and a demand for luxury and comfort. Increases in the price of passenger transport typically lead to both a reduction in the level of demand and a shift to cheaper, less comfortable classes of travel. While the degree of such reductions and shifts in Brazil awaits econometric analysis of recently collected rail passenger data, we can infer from contemporaries that slight increases in the cost of travel in the nineteenth-century were sufficient to diminish demand and cause major shifts in the distribution of passengers. For example, the demand for passenger services declined noticeably after the imposition of a transit tax in 1880 on the Pernambuco rail lines and on Brazil's largest railroad, the government-owned Dom Pedro II. Those who did travel in the wake of the increase purchased lower class tickets, with "first class being nearly empty."[21]

As a result, the estimate of the savings on passenger fares embodies the assumption that, in the face of the higher fares that would have prevailed in the absence of railroads, many fewer people would have paid to travel. Following other students of passenger social savings, as well as various studies of modern passenger demand, the savings on direct charges for first-class passengers are computed assuming that the demand for first-class services was unit elastic.[22] Fare savings for second-class passengers are negative, since it is held that they would all walk, spending nothing on travel charges in the absence of railroads. Computing the savings on travel

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[20]H.J. Boyd and G. M. Walton, "The Social Saving from Nineteenth-century Rail Passenger Services," Explorations in Economic History, 9, 233-254; Gary Hawke, "Railway passenger traffic in 1865," chap. in Essays on a Mature Economy: Britain after 1840, D.N. McCloskey, ed. (London, 1971), 367-384.

[21]See the railway notices in Anglo-Brazilian Times, 24 January 1880.

[22]Boyd and Walton, "The Social Saving from Nineteenth-century Rail Passenger Services;" Clifford Winston, "Conceptual Developments in the Economics of Transportation: An Interpretive Survey," Journal of Economic Literature 23(1985):74; A.D. Owen and G.D.A. Phillips, "The Characteristics of Railway Passenger Demand," Journal of Transport Economics and Policy 21(September, 1987): 243.

time requires sorting out the productively employed passengers from those whose time had little or no value at all. Leisure travelers, children, the elderly, and persons who are not employed in the conventional sense do not find their time valued in national income accounting. As a result a money metric of time savings is appropriate only for those rail passengers who were in the labor force. The railroad passenger statistics provide no information on the number of children, workers, and the like. The best we can do is to assume that rail passengers were in the labor force in the same proportions as the Brazilian population. The amount of time saved by these "working" passengers further depends on the speed of the rail and non-rail modes of transport. Assigning values to the time saved by "working" passengers generally follows work on the value of passenger travel time in various modes of conveyance in the late twentieth century.[23] Here the value of time saved by "working" first-passengers is taken to be twice the wage in their respective employment sectors, while the value of the time saved by "working" second-class passengers is equal to the wage in their respective sectors.

The identity employed for computing passenger social savings in 1913 Brazil is:

$$DSS_{PAX} = \left[\left(\alpha w_A + \eta w_N \right) \left(\frac{2Q_1}{t_D} - \frac{2Q_1}{t_R} + \frac{Q_2}{t_F} - \frac{Q_2}{t_R} \right) \right] + \int_{P_{R1}}^{P_D} DP^{\varepsilon} dp - \left(Q_2 P_{R2} \right)$$

where:
α is the share of agricultural workers in the population
η is the share of non-agricultural workers in the population
w_A is the hourly wage equivalent in agriculture
w_N is the hourly wage equivalent in the "non-agricultural" sector
Q_1 is the quantity of first-class passenger kilometers of service produced by rail,
with $Q_1 = DP^{\varepsilon}$ and ε being the price elasticity of demand
Q_2 is the quantity of second-class passenger kilometers of service produced by rail
P_D is the passenger kilometer charge by diligence

[23]Winston, "Conceptual Developments," 77; Reuben Gronau, The Value of Time in Passenger Transportation: The Demand for Air Travel (New York, 1970).

P_{R1} is the first-class rail charge per passenger kilometer
P_{R2} is the second-class rail charge per passenger kilometer
t_R is the average speed by rail in kilometers per hour
t_D is the average speed by diligence
t_F is the average speed by foot

The first term (in brackets) is the value of the time saved by the higher speed of the railroad. The identity embodies the assumptions made above, namely that the savings on time was only for those travelers who were in the labor force; that the share of workers among all travelers was equal to the labor force participation rate; that "working" first-class passengers valued their time at twice the wage of their assigned sector of employment; and that "working" second-class passengers valued their time at the wage of their assigned sector. While this estimate constitutes a likely upper bound on the value of time saved by traveling on railroads, it does not capture other welfare enhancing gains that do not conventionally enter into GDP accounting, such as increased leisure time, comfort, safety, and the like.

The second expression is the savings on passenger fares. It assumes that the demand for first-class travel was unit elastic and that the demand for second-class travel was perfectly elastic. While not an extreme upper bound this measure is a plausible upper bound on the unit-cost savings of railroads, based on what is known about travel in nineteenth-century Brazil. Most, if not all, second-class passengers would have traveled by foot (or at best, by mount) in the absence of railroads, an activity that imposed little or no direct charge to them. It is not plausible that all first-class passengers would have traveled by diligence. While few would have walked, many, particularly men traveling alone (given the customs of the era), would have ridden on horseback or on mules.[24] Travel by mount is assumed here to require no additional time beyond

[24]Brazilian passenger trains typically included an animal car, not for livestock, but for the mounts of passengers who needed to travel locally or in the city upon their arrival.

that of travel by coach, but would have saved the travel fare for those who owned horses and mules.[25]

The sum of the savings on passenger charges and travel time is the direct social savings on passenger services. The actual values for the variables and parameters used in estimating passenger savings come from a number of sources. Data on the volume of passenger services for both classes comes directly from information reported by railroad companies, either to their shareholders or to the Brazilian government.[26] Direct observations of actual passenger charges by class exist only for the lines for which company reports are available. For 1913 this is limited to only four of fifty lines for which we have passenger-kilometer data. Instead of using the rates of only four lines for the entire rail sector the average charges for first- and second-class passenger services are estimated by assuming that the average revenue by class for all lines equaled marginal revenue by class. Estimating marginal revenue involves exploiting the following identity:

$$TR_{PAX} = R_1 + R_2$$

where TR is simply total passenger revenues, R_1 is first class passenger revenues, and R_2 is second class passenger revenues. However, R_1 equals P_1Q_1, and R_2 equals P_2Q_2. Since by design the revenue per passenger kilometer is the "mean price," marginal revenues for each class of service are equated to average revenues by substituting and taking partial derivatives:

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[25]This assumes that mount ownership was for local travel, or purposes other than long distance passenger travel. If people bought and maintained these animals solely for travel over distances then traveling by mount was not a "free" service at all; such an inconsistency makes the estimate of direct social savings here too high.

[26]Brazil, Ministério da Viação e Obras Publicas, Estatística das Estradas de Ferro da União, 1913 (Rio de Janeiro, 1915), and annual and semester company reports for the San Paulo Railway, Great Western of Brazil Railway, Leopoldina Railway, Central do Brasil (before 1889 the Estrada de Ferro Dom Pedro II), Companhia Paulista, Companhia Mogiana, and Companhia Sorocabana, located in various collections in Rio de Janeiro, São Paulo, and London.

$$\frac{\partial TR}{\partial Q_1} = P_1 \quad \text{and} \quad \frac{\partial TR}{\partial Q_2} = P_2$$

In practice the marginal revenue for each class of service results from a regression of total passenger revenues for 50 rail lines on first- and second-class passenger kilometers, in which the constant term is constrained to zero (t statistics are in parentheses):

$$TR_{PAX} = \underset{(3.3)}{.041Q_1} + \underset{(1.5)}{.012Q_2} \qquad R^2 = .93$$

The passenger social savings are computed using \$041 as the passenger kilometer rail cost, and \$012 is used for the second-class passenger kilometer cost.[27] For travel by diligence relatively little information is available, partly because of the paucity of surviving sources, and partly because of the scarcity of roads adequate for stage coaches. Advertised fares in 1865 for travel from the city of São Paulo to the port of Santos were 15\$000.[28] Converted to a passenger kilometer basis the charge was \$190 in milréis of 1865. Adjusted to 1913 levels using the Paasche variant of the Lobo price index gives a passenger kilometer charge of \$635.[29]

The savings on the time spent traveling are computed assuming that rail travelers participated in the labor force in the same proportion as the whole population. No direct labor force figures are available for 1913. The sectoral labor force shares used here are interpolated

[27]The unit of Brazilian currency was the milréis, written as 1\$000. In 1913 one Brazilian milréis was worth U.S. \$0.32 (thirty-two cents).

[28]This rate appeared in advertisements in the Correio Paulistano in the early months of 1865. Because it was the only advertised rate, and because it was that of a new stage coach line seeking passengers and a niche in a market that already had several suppliers, one suspects that it may be a bit low. In that case the unit savings on first-class passenger services on the railroad are overstated. This creates a bias in favor of finding large social savings. Even then the estimates prove to be low.

[29]The Lobo indices are composed of wholesale prices of eight commodities, largely agricultural. What I refer to as the Paasche variant employs 1919 weights derived from a cost-of-living survey for Rio de Janeiro city; Eulalia Lobo, et al., "Evolução dos preços e do padrão de vida no Rio de Janeiro, 1820-1930: resultados preliminares," Revista Brasileira de Economia 25 (1973): 235-265.

values from the censuses of 1900 and 1920.[30] The share of the population working in agriculture was 34.5%, while 17.2% worked in "non-agricultural" activities (manufacturing, mining, and services). Hence, slightly less than half of the total travelers are treated as "unproductive" in the context of measuring the time savings.

Wages in these sectors are not directly available for 1913. The agricultural wage employed here is a simple average of the daily wages of farm workers throughout Brazil in 1911.[31] In order to be consistent with the travel-time savings estimated in work on modern passenger transport it would be desirable to have a manufacturing wage from 1913 to use for the "non-agricultural" wage. However, no wage series for manufacturing yet exist for Brazil in this period, and we are forced to rely on a few observations of daily wages for cotton textile mill workers in 1895.[32] Both wages are converted to an hourly basis by assuming a twelve-hour work day, and are adjusted to 1913 levels by assuming that wages in both sectors moved together with the Lobo price index. The average daily wage for farm workers in 1911 was 1$609, while the wage for textile workers in 1895 was 3$000 per day. Adjusted to 1913 hourly levels, these give $141 per hour in farming and $306 per hour in industry.

The travel time required by non-rail first-class passengers is derived by assuming that the average speed of non-rail first-class travel equaled that of stagecoaches traveling between the cities of São Paulo and Santos. The length of the average first-class passenger rail journey was only 33.2 kilometers, and the speed implied by the advertised travel times by dilgencia from São Paulo to Santos was 13 kilometers per hour. Based on scattered observations of rail speeds, along with published trip schedules, 39 kilometers per hour is taken as the rail speed in 1913.

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[30]Drawn from the censuses of 1900 and 1920. Improved labor force estimates await revision of the labor force data in both censuses, each of which suffers from omissions.

[31]Drawn from Brazil, Ministerio da Agricultura, Directoria do Serviço de Inspecção e Fomento Agrícola, Aspectos da Economia Rural Brazileira (Rio de Janeiro, 1922).

[32]As reported in the textile census published in the Ministry of Public Works report for 1896 (Relatorio, Ministerio da Viação e Obras Publicas)

The time required then to complete the average first-class rail journey by stagecoach was less than three hours, while by rail this same trip was accomplished in less than one hour, leading to a time savings of 1.7 hours for the average first-class passenger journey.

For second-class rail passengers the time saved by rail was much greater. While the average second-class passenger rail trip was only 25.6 kilometers in 1913, it would take a good deal more time to travel that distance by foot. No information on the speed of foot travelers in Brazil has yet been located. Foot soldiers in the late twentieth century are expected to maintain a moderate road speed of around 5 kilometers per hour for lengthy (i.e. 30 kilometers or more) marches. Travelers in nineteenth-century Brazil would have likely moved more slowly than that, given travel conditions and the mix of people making the journey (children and elderly persons, for example, would maintain a slower speed than young adults). In order to avoid understating the amount of time saved by second-class rail passenger travel, 3 kilometers per hour serves as a best guess at foot travel velocity. At that walking speed the average second-class trip in 1913 would take 8.5 hours, which meant that taking the train saved 7.9 hours per passenger trip.

Table 1 presents the derivation of first-class passenger savings in 1913. The time saved by first-class working passengers came to 15.7 million working hours in 1913. When valued at twice the sectoral hourly wages the time savings was worth 6.1 million milréis. The fare savings on traveling by rail instead of diligence comes to 66.3 million milréis, for a total savings on first-class passenger service equal to 72.4 million milréis in 1913. Table 2 contains the derivation of the savings on second-class services. Savings on travel fares are negative, given the assumption that all second-class passengers would have walked or ridden in the absence of railroads. However, working passengers in second class saved 158.6 million person hours in 1913, worth some 31 million milréis.

Evaluating the importance of the savings afforded by rail passenger service requires an estimate of national income for 1913. The Contador and Haddad estimates of real product suffice for the analysis here, although using Haddad's alternate estimate would result in slightly

higher savings.[33] First-class railroad passenger services saved only about 1.3 percent of GDP in travel charges and working time in 1913. Second-class services saved a good deal less, at only one third of one percent of GDP in 1913. This result follows directly from the known features of the Brazilian economy that have been included in the model. The demand for passenger transport was elastic with respect to the price charged. At prices higher than those charged by rail, many fewer people would have traveled. The savings railroads provided on travel time were reasonably large in terms of hours per passenger journey. But that time was not worth very much, since Brazil was a relatively low productivity economy. Or, in the words of a commercial envoy who visited Brazil in the 1880s and discussed the torpor of travel in the pre-rail era, "The axiom 'Time is Money' did not yet embody a truth."[34] Given the classic trade off between "time and money," people often spent the former to economize on the latter. Many Brazilians had plenty of time but little money, and high-cost modes of conveyance were beyond their reach.

Direct gains from freight services

Estimating the direct savings from freight services is conceptually similar to the measure for passenger services, but with one simplifying elision. Railroads not only moved goods to market at lower cost with less risk of spoilage or loss en route. By rail, goods moved to markets a great deal more quickly than they did by mule or cart. Trips that previously had taken days were reduced to hours by rail. Mid-century comment placed the top speed of mule trains at 3 leagues (18.6 kilometers) a day. In other words, the average rail freight journey in 1913 (143 kilometers) would take eight days by mule, yet less than a day at most by rail.[35] Mule speeds in the mountainous interior, with its even more precarious trails and roads, were as slow as 1.5 or 2

[33]Haddad, Crescimento do Produto Real Brasileiro.

[34]C.F. Van Delden Laerne, Brazil and Java. Report on the Coffee-Culture in America, Asia and Africa (London, 1885), 191.

[35]see O Agricultor Brazileiro, vol. 1, no. 12, 1854.

leagues a day. And while rail lines were regularly washed out by torrential tropical rains, shippers were still less at risk of interruption and delay by rail than they had been when sending things to markets in carts or on the backs of mule. The net effect of this gain in speed, reliability, and improved coordination was that inventory requirements were reduced. The savings on reduced inventories amounted to the interest and depreciation charges that were avoided by not holding the goods on farm (or by having them pile up at the factory). Unfortunately, little information bearing on these inventory costs seems to have survived and the present analysis ignores the freight analog to passenger time savings.

The direct social savings on rail freight services are given by:

$$DSS_F = Q (P_M - P_R) - G$$

where:

Q is the level of freight services in ton kilometers produced by rail in 1913

P_M is the charge for one ton kilometer of freight service by a non-rail alternative

P_R is the charge for one ton kilometer of freight service by rail

G is the value of government profit guarantees paid in 1913

The quantity of freight services and the rail freight charge come from two sources. For federally-conceded lines total freight output and revenue figures are available in the railway inspectorate's 1913 statistical volume.[36] In the south of Brazil, namely in the state of São Paulo, a number of major railway companies operated several important lines that were not federally conceded, and thus partly escaped the government's reporting requirements. For the largest of these companies--the Companhia Paulista, Companhia Mogiana, and Companhia Sorocabana--their respective shareholder reports contain detailed information. The partial information on

[36] Estatistica das Estradas de Ferro da Uniao for 1913.

these lines presented in the inspectorate's statistical volume was replaced by the complete output and revenue figures from the company reports. In 1913 Brazilian railroads comprising a little more than two-thirds of the nation's total track carried more than 1.6 billion ton kilometers of freight, at a cost of 165.4 million milréis, or $097 per ton kilometer.

Before the construction of railroads this freight would have moved overland on the backs of mules or, where possible, by cart. These were precisely the modes of transport that were supplanted following the construction of railroads.[37] The cost of these pre-rail overland freight services was high. Table 4 presents various estimates of the cost of transporting freight in the immediate pre-rail era in various parts of Brazil. The lowest of the charges is that for the 273 kilometer journey from Rio Claro, an agricultural market in the interior of São Paulo, to the port of Santos.[38] Importantly, because the working hypothesis here is that freight savings were large, these rates are employed to bias downward the magnitude of those savings.

The absence of an index of transport costs suitable to adjust the 1864 freight charge complicates computing the unit savings on freight transport. Of the various price indices available for nineteenth-century Brazil none are particularly appropriate for the task at hand. Two are used here. The first is the Lobo Paasche index of agricultural commodity prices, as used above to calculate passenger social savings. Between 1864 and 1913 it exhibits a four-fold increase and may overstate the rise in the cost of transport.[39] The second is the index with the

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[37]Brazil's largest mule market collapsed in the years following the introduction of railroads in São Paulo. See Herbert Klein, "A Oferta de Muares no Brasil Central: O Mercado de Sorocaba, 1825-1880," Estudos Econômicos 19 (1989): 347-69.

[38]The rates on São Paulo roads are simple averages of twelve monthly spot observations of the charge to transport coffee, reported in the prices current sections of Correio Paulistano in 1864.

[39]It is unlikely that it overstates it by much, for two reasons. First, of Lobo's three weighting schemes, what I have labeled the Paasche index rises the least. Second, an index that Lobo created of the wages of common day labor in Rio de Janeiro indicates the same increase as the Paasche index. Since muleteers carried goods to the city, they would have been regularly updated on urban wages, and thus on the opportunity cost of their own time and work. Labor charges likely accounted for a large share of the cost in pre-rail overland transport. To the extent that rural-urban labor markets were integrated at all in this period, wages in the countryside would have risen at roughly the same pace as that of unskilled labor in the city.

broadest product coverage for Brazil begins in 1870, and is exten back into the 1860s by regressing it on the CPI for Rio de Janeiro.[40] This index slightly more than doubled between 1864 and 1913, and may well understate the rise in transport costs during the period.

Table 5 presents two calculations of the direct social savings on railroad freight services in 1913. Both calculations deduct from the gross benefits the payments made to railway companies as profit guarantees by the Brazilian government in 1913. These payments comprised capital costs not reflected in the rail revenues, and came to a little less than 37 million milréis in 1913.[41] Estimate A adjusts the 1864 São Paulo road rate by the Lobo Paasche index. By that measure railroads presented Brazil with a resource savings of 2.15 billion milréis in 1913, or some 38% of GDP. The second measure, estimate B, adjusts the non-rail freight charge by the extended wholesale price index. By that measure the social savings on freight services come to one billion milréis, or 18% of GDP.

In light of these estimates, several sources of bias in the comparative statics approach is of little concern in the Brazilian setting. The comparative dynamic approachto the railroad's impact showed that Fogel's upper bound measure did not capture the consequences of the railroad-induced increase in capital formation in the economy. To the extent that a similar process was at work in Brazil the direct social savings estimated here will thus be too small, by some unknown magnitude. Because of the large unit savings on freight services in Brazil the concern here is that those savings not be over estimated, and ignoring for the moment dynamic effects that were likely present works to offset even further that possibility.

These estimates of the direct gains arising from railroads in Brazil turn on the verisimilitude of three key assumptions. The first is that the prices charged for transport services

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[40]Luis A.V. Catao, "A new wholesale price index for Brazil during the period 1870-1913," Revista Brasileira de Economia 46(1992):519-533.

[41]Guarantee payments in Brazil and London taken from Brasil, Balanço da Receita e Despeza da República no Exercício de 1913 (Rio de Janeiro, 1924), table 135.

equal marginal costs. The assumption is important since it is the prices charged for transport services, rather than costs, that are typically employed in social savings analyses. For the non-rail alternative mode or transport (mules, or some combination of muleteering and cartage) the prices charged no doubt accurately reflect the costs of providing overland freight services. Because it was characterized by many suppliers and small scale of operation muleteering was very close to being a perfectly competitive industry. The pricing of railroad services is of greater concern. To the extent that the prices for rail services exceed costs then the magnitude of social savings will be underestimated. In the case of Brazil, where freight savings turn out to be relatively large, it is more important to insure that the prices of rail transport services used for the estimation are no less than cost. Fortunately we can be reasonably sure that using prices in lieu of costs introduces little or no bias in either direction into the analysis. Average revenues for rail freight service in 1913 exceed both average costs and a rudimentary estimate of marginal cost.[42] Estimates of the profitability of four major railroad companies in Brazil indicate that profits were neither supernormal nor below the riskless rate of return in the long term. Railway profits were intermittently low, especially in the impropitious environment of exchange depreciation in the 1890s. The railroads' earnings were in depreciated Brazilian paper, while many costs were fixed in pounds sterling. The falling exchange rate placed many companies in a very tight spot for a few years.[43] Overall, market rates of return (taking into account dividends

[42]The average revenue is taken as the unit freight charge (freight revenues divided by ton kilometer). The average cost figure contains both upward and downward biases. In the first instance, average cost is the total cost of all services (freight and passenger) divided by freight ton kilometers. However, interpretation of the cost figures for Brazilian railroads is rendered problematic since they include typically include replacement expenditures and new purchases of rolling stock, but not interest or dividends. Preliminary estimates of cost functions give marginal cost estimates below average freight and passenger revenues.

[43]Perhaps no other issue in Brazilian history has occasioned so much econometric analysis as has the determinants of the exchange rate. See Fishlow, "Conditionality and Willingness to Pay," 69; Eliana Cardoso, "The Exchange Rate in Nineteenth-Century Brazil: An Econometric Model," Journal of Development Studies 19(January 1983):170-78; Leff, Underdevelopment and Development, 111-113; Catao, "The international transmission of long cycles." For an alternative view (that of the "Campinas School") on the working of the exchange rate in Brazil see João Manoel Cardoso de Mello and Maria da Conceição Tavares, "The Capitalist Export Economy in Brazil, 1884-1930," chap. in Roberto Cortes Conde and Shane J. Hunt, eds. The Latin American Economies: Growth and the Export Sector 1880-1930 (New York, 1985), 100-102.

as well as capital gains and losses) for British-owned lines exceeded the return to relatively risk-free assets, such as Brazilian government bonds, only slightly, and occasionally fell below that level for short periods.[44] In the long run supernormal profits did not appear to have existed. Government regulation from the earliest days of the railway age in Brazil kept freight and passenger charges near cost. In return for rate regulation the Brazilian government guaranteed minimum dividend payments for many lines. While many of those lines were sufficiently successful that they did not need the guarantee, others did require payment from the government. Those payments comprise capital costs that are absent from the rail revenue data. Where appropriate below those costs, while small, are deducted to insure that the magnitude of the direct social savings is not overstated.

The second major assumption of the model--that railroads did not create an externality in the form of scale economies in transport-using industries--may not in fact hold for the Brazilian case. To the extent that Brazilian railroads departed from this condition, direct social savings miss part of the gains afforded by railroads. Nonetheless, the resulting bias is very slight in the context of the freight savings estimates. This possibility is considered in more detail below.

The third key assumption is that in the absence of railroads the same freight would have been carried over the same distances by the non-rail alternatives. To the extent that the quantity of freight services depended on the railroad's cheap transport, the estimates are clearly upper bounds on the true measure of freight social savings.[45] Since the unit cost savings on shipping freight are so great, forcing the "non-rail" counterfactual economy to operate with the 1913 levels of transport output guarantees that the social savings are very large. A separate counterfactual case may be specified, in which the economy is permitted to adjust its level of freight output in accordance with the sensitivity of the demand for freight services to changes in

[44]W.R. Summerhill, "The profitability of British-owned railways in Brazil, 1862-1914," paper presented to the annual meeting of the American Historical Association, San Francisco, January 1994.

[45]More precisely, they would approach a "least upper bound" measure, because of the attempts to bias the unit savings downward, and because of the excluded cost savings on insurance and inventory charges.

the unit price of those services. Indeed, the assumption that the demand for freight services in nineteenth-century Brazil was perfectly inelastic with respect to price and that all of the freight carried in 1913 would have been carried in the absence of railroads is unwarranted. Given the large change in the unit cost of transport, in Brazil's pre rail economy many fewer goods would have traveled to market. That is, it is very likely that in the absence of railroads the Brazilian economy would have had much-reduced margins of feasible agricultural cultivation. Crop choices at the level of the farm would differ, and specialization by region would have be limited to a greater degree. In manufacturing, the less efficient textile mills and iron forges would continue to operate with the natural protection afforded by transport costs. In short, the size of the social savings in Brazil would be smaller, since the diversion of resources from other sectors to transport would be less than in the case where the 1913 level of transport services were produced. Since actual margins of feasible cultivation and the like are functions of the cost of transporting those goods to market--that is, a function of the gap between the f.o.b. supply and c.i.f. demand curves, it is useful to estimate the degree to which the demand for freight services in the counterfactual economy might be reduced at higher transport charges, and then permit the level of that demand, and total output in the economy, to adjust accordingly.

Measuring the counterfactual 1913 level of GDP with a higher cost of transport but a smaller transport sector is accomplished by permitting the price elasticity of demand for freight services to take on values other than zero. How much smaller the social savings would be depends directly on how sensitive of the demand for freight service would be to the change in the cost of transport.[46] Such an adjustment is made here by directly inferring this sensitivity from the observable features of the actual demand for freight transport services in Brazil at the turn of the century. It turns out that although demand would not have been perfectly inelastic,

[46]More formally, because this sort of adjusted, or "lower bound" measure of direct social savings departs from the use of actual 1913 levels of freight service, additional assumptions are required in order to treat it as the consumers surplus in the market for freight transport services.

the demand for transport was indeed relatively inelastic. An observer of railroads in Brazil's northeast during the 1870s and 1880s held that if rail rates on sugar were halved the result would be roughly a forty-percent increase in the volume of sugar shipped. The arc elasticity of demand implicit in the particular figures offered was -0.85.[47] The elasticity of demand for the transport of sugar is itself a function of the elasticities of f.o.b. supply and c.i.f. demand for sugar in Brazil, and the share of the c.i.f. price of sugar accounted for by transport costs. Since these elasticities and proportions vary widely among different commodities, the evidence from one market alone is an insufficient basis for claiming that the demand for all freight services was inelastic. Fortunately evidence beyond the impressions of contemporaries discussing markets for a single good is available. Preliminary econometric analysis of information on the demand for freight services permits us to establish a plausible range of elasticities of demand.[48] Table 6 presents the results of this analysis. Here the price elasticiy of demand for freight services is estimated for four different specifications of the market for transport services, using annual time series data from 1898 to 1913.

In the first specification the demand for freight service (Q), in units of ton kilometers, is modeled as a function of the real unit freight charge (P), and real per capita income.[49] Using ordinary least squares (OLS) regression on a logarithmic transformation of the variables gives a price elasticity of demand with the correct sign, and of a plausible magnitude (-0.53). The second specification reported in the table includes a time trend as a proxy for productivity

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[47]Calculated from Henrique Augusto Milet, A Lavoura da Cana de Açucar (Recife, 1881) 47-61.

[48]There is of course no one true elasticity, but rather a whole range of elasticities, corresponding to the very short run to the very long run. The goal here is to bound the range of plausible values of the price elasticity of demand for freight services in the late nineteenth and early twentieth centuries.

[49]The output, price, and trackage data are for a sample of the fourteen largest lines in Brazil (based on freight ton kilometers) from 1898 to 1913. This sample included lines from all of Brazil's regions. They also operated under various ownership arrangements (federally owned, Brazilian private ownership, leased to foreigners, and owned outright by foreigners). Price is average freight revenue per ton kilometer of freight service. Since most rail inputs were imported, Leff's import price index is used for deflation of the rail charges. GDP per capita is that from CH, cited above.

change in railway operation, and yields an elasticity estimate that is lower in absolute value (-0.26). For all equations, t statistics are reported in parentheses, and the elasticity estimates are statistically significant.

Both of the specifications estimated with OLS take the price of freight services as exogenous. The third and fourth specifications treat price as endogenous, controlling for supply-side shifts as well as demand factors, and are estimated using the two stage least squares (2SLS) technique. In the third specification, the supply of rail freight service is modeled as a function of the unit price received by the rail lines for their service, and the length of track (T) in operation. The demand side remains the same as in the first specification. Since the price of rail freight service is endogenous in the system it is estimated as the instrumental variable in a reduced-form equation where trackage and per capita income are exogenous to the system. While the price elasticity of the structural demand equation is statistically significant, with the correct sign, the fit of the underlying reduced-form equation was not particularly good, making the final results somewhat suspect. In the fourth specification trackage is seen to have both supply and demand side effects, while the prices of key inputs--coal (P_C) and rails (P_R)--are included in the supply function.[50] The price elasticity of demand is again statistically significant, with the correct sign, but the fit of the reduced form equation was especially poor, and the price of coal in the supply function takes on the incorrect sign.

Given the rather crude the demand estimates the lower bound social savings in 1913 are calculated across the range of measured elasticities, along with unit elasticity, in table 7. While it turns out that the magnitude of the freight social savings is quite sensitive to varying assumptions about the price elasticity of demand for freight services, under the assumption of unit elastic demand the savings impressive, ranging from 5 to 7 percent of GDP in 1913. It is

[50]Indices of the prices of rails and coals were adapted from the historical statistics volumes for the U.S. and Britain. Rail prices were converted from dollars to milréis, then deflated using Leff's index of import prices. Coal prices were converted from shillings to milréis, then likewise deflated.

unlikely that any other single technological or institutional innovation offered such gains to the Brazilian economy. Direct comparison of the Brazilian results with those of other countries is most easily accomplished for the case of the ante-bellum US.[51] There Fishlow found an upper-bound direct social saving of around 10 percent of GDP in 1859. In 1913 Brazil (which was at a roughly comparable stage of development) the lower bound freight savings were almost that much.

In 1869 Brazil's rail sector still consisted of only six lines. Most of the gains that railroads brought the Brazilian economy would have come sometime after that, most likely following the railroad boom in the 1880s. Between 1885 and 1913 Brazil's GDP rose from some 1.53 million contos to 5.68 million contos de réis, at 1913 prices, an increase in output of 4.15 million contos. Over the same interval Brazil's population grew from 12.9 million persons to 23.7 million. The implied gain in productivity across the economy was thus 1.56 million contos. The lower bound "B" measure of social savings comes to nearly 25 percent of this productivity gain, and almost 10 percent of the total increase in GDP. The upper bound "B" measure of social savings accounts for more than three-fourths of the gain in productivity per capita, and more than nearly one-third of the total increase in output. Clearly, by dramatically reducing the cost of freight transport services, railroads played a key role in the growth of the Brazilian economy in the late nineteenth and early twentieth centuries.

While direct social savings suggest the magnitude of the contribution of the railroad to the economy, that measure does not show whether the economy received a good return on the investment it made in securing those benefits. That sort of assessment calls for a measure of the social rate of return, and a number of historians have converted the "stock" of railroad benefits to

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[51]This is because of the different specifications of what social savings comprise in each case; for an attempt to make such comparisons see P.K. O'Brien, "Transport and Economic Growth in Western Europe," 1830-1914, Journal of European Economic History 11(Fall 1982):347. For the present analysis the freight that Brazilian railroads actually hauled in 1913 is assumed to be carried by the mode of transport that prevailed at the time in São Paulo, which also enjoyed better overland transport conditions than much of Brazil. So the savings here are neither of the "Fishlovian" type, nor purely the "Fogelian," but rather a combination of the two, since in the hypothetical absence of the railroad they admit the possibility of an adjustment to better roads than much of Brazil actually in fact had.

"flows." Table 8 presents a similar exercise for Brazilian railroads in 1913.[52] Average social rates of return are computed using two of the lower bound direct freight savings estimates from table 7, summed with net rail revenues from that year.[53] The construction costs of the Brazilian rail lines whose freight services entered into the social savings estimate are used as the denominator in the calculation. While the resulting rates are based on downward-biased measures of freight benefits, they are still impressive, ranging from a 18% to 23% social return to the economy in 1913.

Average rates of return do not necessarily provide an effective measure of whether or not "too much" or "too little" had been invested in the rail sector.[54] Cost-benefit analysis in this form must be performed in terms of the marginal rate of return--the benefit of an additional dollar invested in the rail system. Marginal rates of return are rarely observable in practice, and unfortunately in the absence of estimates from a variety of activities the meaning of a particular value is unclear. The estimatation of the marginal social return to the Brazilian rail sector proceeds under the assumption that the rail sector enjoyed constant returns to scale, and that there was strict proportionality between the social and private output of the sector.[55] Thus the ratio of net earnings to gross earnings would be equal to the private output elasticity of capital invested in railroads, and that elasticity could then be used to derive the social productivity of the resources invested in railroads.

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[52] Disaggregated results for major Brazilian railroads, taking into consideration their operating histories up through 1913, are found in Summerhill, "Market Intevention in a Backward Economy: Railway Subsidy in Brazil, 1854-1913," Economic History Review, August, 1998.

[53]Construction costs derived on a line by line basis from information in the Estatisticas volumes. In the cases where the capital accounts for large lines are available in their respective company reports the cost of land has been removed. For the Paulista, Mogiana, and Sorocabana lines the data come from the outlays on road, rolling stock, and structures as presented in their respective balance sheets for 1913. One large line of 1300 km, and one small line of 35 km, did not present information on the cost of construction, and per kilometer construction costs were imputed for these lines using the average for all other lines.

[54]Peter McClelland, "Social Rates of Return on American Railroads in the Nineteenth Century," Economic History Review 2d ser., 25(1972): 471-88.

[55]Paul A. David, Technical Choice, Innovation and Economic Growth (Cambridge, UK, 1975), 307-314.

Table 8 shows that the marginal social rate of return of railroads in Brazil in 1913 was between 6.8% and 8.8% under the assumptions outlined here. Rates on private debt instruments and public bonds in 1913 Brazil were at or below these levels, and the marginal social rate of return was no doubt higher than similar measures for major manufacturing and agricultural activities in Brazil at the same time. It may well be the case that Brazil could have done better still with more railroads, and that the strategies pursued in regulating rail companies stifled needed investment. But the meaning of such a measure is unclear when considered in the context of other activities with which high social returns are habitually associated, such as the investment in public education--an activity for which the social return remains wholly unknown in 1913 Brazil.

Indirect gains and structural change

The first of the three major assumptions of the social savings model was that prices charged for freight and passenger services equal marginal costs. Characteristics of the pre-rail transport business, and competitive private rates of return to major railroad lines, sustain the assumption. The second major assumption of the model is that the reduction in the cost of transport brought about by railroads did not cause transport-using industries to enjoy economies of scale, or induce investments that altered the economy's stock of resources. If railroads did either, the additional benefits escape the social savings model, and the estimates presented above miss part of the contribution of railroads to the economy.[56] This section examines two ways in which railroads impacted industrial performance, first by possibly inducing scale economies, and second by raising manufacturing productivity through location and capital-vintage effects.

[56]A diagrammatic representation of how railroads could enable factories to take advantage of increasing returns to scale is found in Jeremy Atack, "Economies of Scale and Efficiency Gains in the Rise of the Factory in America, 1820-1900," chap. in Peter Kilby, ed., Quantity and Quiddity (Middletown, 1987), 322-326. However, that differs from railroad-induced scale economies. The former is precisely the effect captured with the social savings estimate.

Econometric work on the Brazilian cotton textile industry suggests that it enjoyed mildly increasing returns to scale. Denslow's estimates of production functions for the industry in 1905 yield scale coefficients ranging from 1.012 to 1.042.[57] Haber's more recent estimates using the Brazilian cotton textile census of 1915 likewise yield an elasticity of 1.042.[58] Estimates for 1907, reported below, reveal only constant returns to scale. The extent to which these economies of scale were external to the textile firms is still unknown, but what matters is the impact of scale economies, and for the purposes of the present analysis all of the scale economies are treated as if they were at the level of the industry, resulting from the reduction in transport costs that followed the construction of railroads.

The value of cotton textile production in Brazil in 1915 came to some 219.9 million milréis according to the textile census of 1915.[59] Assuming that textile output was the same in 1913 and adjusting to 1913 prices by the Lobo index puts output at 163.5 million milréis. The rail lines that specified the tonnage hauled by commodity in 1913 enumerated a total of 43.3 thousand tons of nationally produced textiles. Assuming further that the average length of haul for a ton of textiles was the same as the 1913 average length of haul for all commodities leads to an estimate of 5.7 million ton kilometers of freight service. Using the average rail freight charge ($092) and the higher mule rate (1$462) to compute unit savings implies a direct social saving of 7.8 million milréis on hauling domestically-produced textiles, which is equal to 4.8 percent of

[57]David Denslow, "As exportações e a origem do padrão de industrialização regional do Brasil," chap. in Dimensões do Desenvolvimento Brasileiro, eds. Werner Baer, et al. (Rio de Janeiro, 1978), 23-24.

[58]Unpublished estimates kindly made available to me by Professor Haber. These results are robust with respect to the form of the production function. The same elasticity of scale results from using either a Cobb-Douglas or a translog specification of the production function.

[59]An alternate measure of textile output for 1915 is 261.2 million milréis, found in Great Britain, Department of Overseas Trade, A Report on the General Economic and Financial Conditions of Brazil for the Year 1919 (London, 1920). That figure is suspect, and is likely based on a misreading of the census results by the British consul. The lower figure from HTC-B data is used here both because it is more reliable and because its interaction with the social savings estimate and the scale coefficient magnify the effect discussed in the text.

the value of textile output. In other words, absent railroads 4.8 percent of the resources deployed in textile production in 1913 would have to be diverted to shipping textiles, and textile output would be 95.2 percent of its actual 1913 level. Now if all of the scale economies of the textile industry were due to the reduction in transport costs made possible by railroads, then the reduction of scale in the textile industry in the absence of the railroad implies an additional loss of only 0.2 percent of textile output ($1 - 0.952^{1.042} = .05$; $0.05-0.048 = 0.002$). Thus, in the presence of railroad-induced scale economies, the "unmeasured" benefits to the textile industry would equal only 327 thousand milréis, a minuscule share of 1913 GDP. Should it turn out that scale economies in textiles were actually at the level of the firm then even this modest addition is grossly overstated. Scale effects in one industry clearly cannot be imputed to the economy as a whole, and further assessment of the potential bias of assuming no induced economies of scale awaits additional work on other industries and agriculture. However, it appears unlikely that the magnitude of any such scale effects will be large in relation to GDP or the direct social savings already estimated.

If railroads enabled manufacturing to improve the quantity or quality of its capital stock they might still have exercised an independent impact on industrial output, beyond the social savings. Railroad expansion extended the markets for products, influencing location and investment decisions, and inducing investment in new enterprise. In manufacturing a clear cut case is again given by the textile indusy. While in 1860s all textile firms were in coastal locations, by the 1880s the industry had spread to interior, especially in Minas Gerais and the interior of São Paulo, and continued expanding through the turn of the century. Industrial investment, as indicated by imports of machinery and capital goods, increased spectacularly in

the 1880s, and again after 1900, contracting precipitously during the generalized recession of the 1890s.[60]

Expansion of manufacturing, extension into upcountry, and more recent capital, can be seen in productivity differentials across these firms after the turn of the century. Taking output to be a function of inputs and a shift (productivity) parameter, the production function is given by:

$$Q = AK^{\alpha} L^{\beta}$$

Linearizing the function by taking logarithms and adding a variable for inland location of firms gives the functional form:

$$\ln Q = a + \alpha \ln K + \beta \ln L + \delta INLAND$$

where D is a dichotomous, or "dummy" variable, that equals 1 if the textile mill was located inland, and 0 if it was near the coast. Textile production figures provide data in inputs, output and location.[61] Statistical results (with t-stats in parentheses) were:

$$\ln Q = \underset{(6.405)}{4.174} + \underset{(6.582)}{0.722} \ln K + \underset{(4.395)}{0.372} \ln L + \underset{(2.885)}{0.337}\, INLAND$$

R-squared .812

F 246.7

N = 172

[60]Suzigan, Indústria Brasileira, 76-84; Versiani, Industrial Investment, 14-15.

[61] Output is expressed as value of production, capital is the value of machinery and structures reported by the firm, and labor equals the number of workers. Data, by firm, is reported in Brasil, suas Riquezas Naturais, suas Industrias, tomo 3, Industria de Transportes, Industria Fabril. The locations of the 172 textile firms for which complete data are available were plotted on contemporaneous maps found in Mello, Atlas do Brazil, to determine whether the firm was on the coast or inland. Any firm that did not locate within a locality on the coast, or on a waterway with obvious access to the sea, was recorded as "inland."

The elasticity of textile output with resepect to a firm's up-country status, which is a proxy for the firms age and capital vintage, is expressed by:

$$\varepsilon_{\delta} = (e^{\delta} - 1) = 0.4$$

Being inland raised a firm's output by 40 percent, on average. The result shows that newer firms, with more recent capital, and made possible by railroad expansion, were systematically more productive than the firms traditionally located near the coast.

Roughly half the textile output in 1907 came from these high productivity firms located upcountry from the coast. If those firms were to remain in existence in the absence of the railroad, but the lower levels of productivity typical of coastal firms with there older vintage of capital, the sector's output would decline by nearly 20 percent. If the same relationship held across all Brazilian manufacturing, the additional costs to the economy deprived of its railroads would come to some 2.6 percent of GDP beyond the social savings already estimated. The expansion of manufacturing inland from the coast is scarcely imaginable without railroads, and hence one of the dynamic consequences not captured by the social savings estimate is the increase in both the quantity, and quality, of manufacturing capital brought about by railroad development.

Railroads also had an impact on the character of economic activity and the structure of the economy. Latin American historiography in general, and Brazilian historiography in particular, has focused much attention on the presumed role of exports in late nineteenth-century economic growth. In this view railroads were important to the growth of the export economy because they opened up export producing hinterlands, increased Brazil's comparative advantage in producing coffee, and locked Brazil onto a path of virtual export monoculture. While most accounts are cautious enough to point out that railroads also played a role in the development of domestic markets, it is exports that loom large in discussions of Brazilian underdevelopment and economic "dependency."[62] The putative importance of exports in the output mix is taken to have a number of negative consequences for the character and pace of economic growth and social and political development.

For the nineteenth-century U.S., where exports comprised a small share of both rail freight and total output in the economy, trade has been described as a mere "handmaiden" to growth.[63] In Brazil exports were likely more important than that, but they declined in importance over time. In contrast to the established view, it turns out that there was little about Brazil's economic growth in the late nineteenth century that was export oriented or export led. Referring to the share of exports in rail freight and in total output makes it possible to gauge the relative importance of exports in the economy.[64] Brazilian railroads differed markedly from

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[62]For a few recent examples of historical surveys that underscore the importance of exports and their relationship with railroads see Emilia Viotti da Costa, The Brazilian Empire: Myths and Histories (Chicago, 1985), 152, 192; Warren Dean, "Economy," chap. in Brazil: Empire and Republic, Leslie Bethell, ed. (New York, 1988), 245-6. One of the most recent and strongest statements implicating railroads in dependency is E. Bradford Burns, A History of Brazil, 3d ed. (New York, 1992), passim.

[63]Irving Kravis, "The Role of Exports in Nineteenth-Century United States Growth," Economic Development and Cultural Change 20(1972):387-405.

[64]These are a couple of the measures suggested by Kravis, "Role of Exports."

those elsewhere in Latin American with respect to the sectoral distribution of their forward linkages and their impact on the final output mix. By way of contrast, in Mexico market conditions and railway transport rate policies worked to favor export-sector growth. While this was not the sole factor in altering the output mix of the economy, the results were still dramatic. In 1877 some 9.3% of Mexican output was export bound. By 1910 the share of exports in GDP had risen to 17.5%.[65]

Referring to the available railway operating statistics and macroeconomic series for Brazil reveals that the expansion of the nation's railroads was accompanied by a declining share of export sector freight, and a steady decline of the share of exports in GDP. Taking freight data reported by fifteen major lines in 1887 as indicative, and employing a grossly overstated measure of export freight, the share of export sector tonnage was no more than 60.4%.[66] Under the same assumption the share of export sector freight in total tonnage had declined to 30% by 1913. With respect to national income, the share of exports fluctuated between 18% and 26% between 1870 and 1913. It must be cautioned that the share of exports in GDP reported here may be too high; Leff makes a case for an export share no greater than 15% in this period. The rate of decline of the export share of GDP is estimated here with the AR1 maximum likelihood procedure.[67]

ln (exports/GDP) = 28.8 - .016 Year

[65]Clearly shifts in both supply and demand, along with the relevant elasticities, are at work as well. For the Mexican freight and GDP figures see Coatsworth, Growth Against Development, 130-4, and John H. Coatsworth, "The Decline of the Mexican Economy, 1800-1860," chap. in America Latina en la época de Simón Bolívar: La formación de las economías nacionales y los intereses económicos europeos, 1800-1850, Reinhard Liehr, ed., (Berlin, 1989). In 1885 on Mexico's most important railway less than 25% of freight was export bound. By 1910 more than 50% of the tonnage on that same line was export sector produce.

[66]This measure takes all enumerated agricultural staples on these lines--coffee, sugar, cotton, hides, rubber, mate, and even cereals--as exports. Information on the tonnage of commodities hauled by rail in 1887 is found in the report of the Ministry of Agriculture for that year.

[67]OLS estimation of the relationship gives the same rate of decline, but manifests slight positive autocorrelation. A Dickey-Fuller test confirms the absence of a unit root in the ln (Exports/GDP) series.

(10.3) (-10.7)

R2 = .73 F = 116 D.W. = 1.9

On average the share of exports in Brazilian GDP declined at an annual rate of more than one and one half percent from 1870 to 1913.[68] This result strongly suggests that the supply of domestic-use agricultural goods and manufactures grew at least as fast as production for export. It is true that Brazilian railroads were intended to foster export growth from their inception. But Brazilian railroads fomented growth even more effectively in the domestic-use sector of the economy. Standing assertions found in the historiography aside, the result is in fact unsurprising when one considers the role of transport in the pre-rail output mix. Before Brazil had railroads, only goods with high value-to-weight ratios--such as exportables--could bear the high cost of transport. With a reduction of the cost of shipment many more low-value goods, like beans, manioc flour, and rice, could afford the costs of conveyance. Given that much of the historiography has cast Brazil's presumed export orientation in a negative light, it is perhaps ironic that Brazil would have likely done better had it actually had the export-led growth claimed for it.[69]

Conclusions

This paper has examined the relationship between the low cost freight transport services provided by railroads and the question of Brazilian economic growth by estimating the direct social savings for 1913. The results suggest that Brazil, like other economies that had especially backward pre-rail transport systems, experienced significant gains from the construction and

[68]Brazilian GDP from CH, exports drawn from Summerhill, "Brazilian export sector."

[69]The relationship between the growth of exports and the growth of GDP for the world's most successful economies during 1870-1913 show that many enjoyed rising shares of exports in GDP, indicating the presence of "export-led growth." Indeed, Kravis' argument aside, even the US was an "export economy" in this period, insofar as the rate of growth of exports exceeded that of GDP; see Angus Maddison, Phases of Capitalist Development (Oxford, 1982), 44-60.

operation of railroads. One important implication of this result is that historically backward economies may well enjoy precisely the kind of "big push" from specific innovations that had for so long been hypothesized for the more advanced economies. This differs from Fishlow's conclusion that investments in social overhead capital could be expected to bring very limited gains to the developing world, since they seemed to offer relatively little for the ante-bellum US, and from Metzer's assessment of the Russian case, where he concluded that the direct social savings on railroads in that backward economy ware not very large.[70]

In contrast to the role of railroads in relatively more advanced economies, where passenger savings comprised an important share of the total benefits, in Brazil the gains came almost entirely on freight services. While passenger services were no doubt important to many people, making it possible for rail travelers to commute more easily, to travel longer distances to respond to work opportunities, and by reducing the psychic costs of separation from family and familiar surroundings, for the representative Brazilian the magnitude of those benefits was small. Freight services, however, accounted for a large amount of capital and labor being released from use in the overland transport of agricultural commodities and manufactures throughout Brazil. As a result, railroad expansion, though often desultory even when managed from the seat of national government, at least partly removed one important impediment to the process of economic growth: the high cost of moving goods overland. Railroads integrated and extended markets, expanded the feasible margin of agricultural cultivation, and improved product market efficiency. Railroads made it possible for Brazil's export producers to respond to rising demand

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[70]Fishlow, American Railroads, and Metzer, Some economic aspects. Metzer put direct social savings on freight services in Russia at a little less than 900 million rubles, or 4.57 percent of a rough estimate of Russian GNP in 1907. Using Gregory's more recent estimates of Russian net national product, that same measure rises to some 6.6 percent of NNP. If the demand for freight transport in Tsarist Russia was an inelastic as Metzer suggests, and his upper bound estimate is in fact close to the "true" magnitude of the gains resulting from the construction of railroads (meaning that it warrants no downward adjustment to reflect a reduction in the quantity of freight services given an increase in the relative price of transport), then the magnitude of his savings estimates appears a good deal more impressive in light of Gregory's NNP figure. See Paul R. Gregory, Russian National Income (Cambridge, UK, 1980).

overseas. But more importantly, railroads spurred per capita growth to an even greater extent by boosting the domestic sector of the economy. While Brazil remained a relatively poor country even with railroads, that state of affairs must be attributed to other obstacles to growth. By 1913 Brazil was already a good deal less poor than it had been four decades before, and was well on its way to one of the most impressive per capita growth performances of the twentieth century.

Table 1
Savings on first-class rail passenger services in 1913

Time Savings	
1. Passenger kilometers	589,832,898
2. Passenger kilometers by agricultural workers (34.5% of 1.)	203,492,350
3. Passenger kilometers by non-agricultural workers (17.2% of 1.)	101,451,258
4. Time required for agricultural workers to travel by stagecoach (at 13 kilometers per hour)	15,653,258 hours
5. Time required for non-agricultural workers to travel by stagecoach (at 13 kilometers per hour)	7,803,943 hours
6. Time required for agricultural workers to travel by rail (at 39 kilometers per hour)	5,217,753 hours
7. Time required for non-agricultural workers to travel by rail (at 39 kilometers per hour)	2,601,314 hours
8. Travel time savings for agricultural workers (4.-6.)	10,435,505 hours
9. Travel time savings for non-agricultural workers (5.-7.)	5,202,629 hours
10. Value of time saved in agriculture ($141 X 8.)	1,471,406$000
11. Value of time saved in non-agriculture ($306 X 9.)	1,592,004$000
12. Total first-class time savings (2 X (10. + 11.))	6,126,820$000

Rate differential

1. First-class rail passenger kilometers in 1913	589,832,898
2. Passenger kilometers at higher stagecoach price	38,083,699
3. First-class passenger rail revenues ($041 X 1.)	24,183,149$000
4. Savings on travel fares (given by: $\int_{P_{R1}}^{P_D} Q_1 dp$ where $Q_1 = DP^{\varepsilon}$, $\varepsilon = -1$)	66,263,107$000
5. Total savings on fares and time for first-class passengers (4. + 12.)	72,389,927$000

Table 2.
Savings on second-class rail passenger services in 1913

1. Second-class passenger kilometers	996,934,404
2. Passenger kilometers by agricultural workers (34.5% of 1.)	343,945,474
3. Passenger kilometers by non-agricultural workers (17.2% of 1.)	171,474,265
4. Time required for agricultural workers to travel by foot (at 3 kilometers per hour)	114,648,491 hours
5. Time required for non-agricultural workers to travel by foot (at 3 kilometers per hour)	57,158,088 hours
6. Time required for agricultural workers to travel by rail (at 39 kilometers per hour)	8,819,115 hours
7. Time required for non-agricultural workers to travel by rail (at 39 kilometers per hour)	4,396,776 hours
8. Travel time savings for agricultural workers (4.-6.)	105,829,376 hours
9. Travel time savings for non-agricultural workers (5.-7.)	52,761,312 hours
10. Value of time saved in agriculture ($141 X 8.)	14,921,942$000
11. Value of time saved in non-agriculture ($306 X 9.)	16,144,961$000
12. Total second-class time savings (10. + 11.)	31,066,903$000
13. Second-class rail passenger revenues ($012 X 1.)	11,963,321$000
14. Total second-class passenger savings (12. - 13.)	19,103,582$000

Table 4.

Overland freight rates in nineteenth-century Brazil

Year	Price per ton*km	1913 price	Location	Source
1854	$896	2$088	Rio de Janeiro	F
1856	$430	1$230	São Paulo (Rio Claro-Santos)	C
1864	$393	$832	São Paulo	D
1865	$675	2$256	Rio de Janeiro	A
1886	1$000	1$554	MG-Rio-São Paulo	B
1855	$540	1$148	Bahia	E
1883	$800	1$251	Minas Gerais	E
1869	$753	1$172	Parana	E
1864	$528	1$117	Pernambuco	E

Note: All current values adjusted to 1913 levels by the Rio wholesale price index. Sources: A, Relatório do Ministério da Agricultura, Commércio, e Obras Públicas, 1866 (Rio de Janeiro, 1866), annexo P, 47. B, Jose Alipio Goulart, Tropas e Tropeiros, 172. C, Warren Dean, Rio Claro, A Brazilian Plantation System, 1820-1920 (Stanford, 1976), 40. D Correio Paulistano, various issues, 1864; E, Summerhill, Order Against Progress; F O Agricultor Brazileiro, vol 1., no. 12, 1854

Table 5--Direct Social Savings on Railroad Freight Services, 1913

Estimate A	
1. Railroad freight output (in ton kilometers)	1,697,321,018 ton km
2. Railroad freight revenues (at $097 per ton kilometer)	165.4 million milréis
3. Cost of pre-rail shipment (at 1$388 per ton kilometer)	2,356.7 million milréis
4. Direct social savings (line 3 - line 2)	2,191.3 million milréis
5. Brazilian government profit guarantees	36.9 million milréis
6. Adjusted direct social savings (line 4 - line 5)	2,154.4 million milréis
Estimate B	
1. Railroad freight output (in ton kilometers)	1,697,321,018 ton km
2. Railroad freight revenues (at $097 per ton kilometer)	165.4 million milréis
3. Cost of pre-rail shipment (at $727 per ton kilometer)	1,234.2 million milréis
4. Direct social savings (line 3 - line 2)	1,068.8 million milréis
5. Brazilian government profit guarantees	36.9 million milréis
6. Adjusted direct social savings (line 4- line 5)	1,031.9 million milréis

Source: see text.

Table 6.
Alternative specifications of the demand for freight transport services in Brazil, 1898-1913

[I] $\ln Q_D = 10.5 - .53 \ln P + 2.31 \ln (Y/N)$
(6.7) (-2.9) (9.2)

$R^2 = 0.86$ F = 46.2 D.W. = 1.9

[II] $\ln Q_D = -85.3 - 0.26 \ln P + .41 \ln (Y/N) + .06$ Year
(-5.6) (-2.3) (1.3) (6.3)

$R^2 = .96$ F = 103.6 D.W. = 2.0

[III] $\ln Q_D = 11.7 - .86 \ln P + 2.3 \ln (Y/N)$
(7.5) (-3.6) (9.8)

$R^2 = .88$ F = 57.6 D.W. = 1.9

$\ln Q_S = 8.8 + .16 \ln P + 1.23 \ln T$
(9.6) (1.2) (19.7)

$R^2 = .97$ F = 228.7 D.W. = 1.9

[IV] $\ln Q_D = 9.4 - .14 \ln P + .91 \ln T + .66 \ln (Y/N)$
(9.1) (-.66) (4.9) (1.8)

$R^2 = .97$ F = 184 D.W. = 2.4

$\ln Q_S = 8.3 + .45 \ln P + .2 \ln P_C - .37 \ln P_R + 1.3 \ln T$
(7.1) (2.3) (1.3) (-1.9) (17.9)

$R^2 = .97$ F = 133 D.W. = 2.1

Note: for data sources and assumptions behind the different specifications, see text. The price elasticity of demand for freight transport service, ϕ, is given by:

$$\phi = \frac{\partial \ln Q_D}{\partial \ln P}$$

which is the parameter estimate of ln P in demand functions I and II, and of ln P in III and IV.

Table 7.
Sensitivity of social savings to alternative values of the price elasticity of demand for freight transport service in Brazil, 1913

ϕ	"A"-Lower bound social saving (milréis X 10^6)	"A" as share of GDP in 1913	"B"-Lower bound social saving (milréis X 10^6)	"B" as share of GDP in 1913
0	2,154	38%	1,032	18%
-0.25	1,360	24%	738	13%
-0.50	881	16%	536	9%
-0.75	587	10%	395	7%
-1.0	402	7%	296	5%
-1.5	206	4%	173	3%

Note: Elasticities range accross those derived from different specifications of the demand function for freight transport services between 1898 and 1913, as reported in Table 5 and described in the text. To calculate the lower-bound social savings (LBSS) on railroad freight services, freight output is related to the cost of transport by the demand function

$$Q_i = D(P_i)^{\phi}$$

where Q_i is the quantity of freight service demanded, in ton-kilometers, P_i the unit charge for freight service, ϕ is the own-price elasticity of demand for freight service, and D is a shift parameter (constant). The LBSS is derived by integrating the demand function with respect to the price of transport. There are two cases. For the first case, where $\phi \neq -1.0$,

$$LBSS = \int_{P_R}^{P_N} DP^{\phi}\, dp - G = D\left(\frac{P_N^{\phi+1} - P_R^{\phi+1}}{\phi + 1}\right) - G$$

where P_M is the charge for one ton kilometer of freight service by mule, adjusted to 1913 prices as reported in table 3, P_R is the charge for one ton kilometer of freight service by rail, and G is the value of government profit guarantees and subsidies paid to railroads in 1913. For the case where $\phi = -1.0$, the LBSS is given by:

$$LBSS = \int_{P_R}^{P_N} DP^{\phi}\, dp - G = D(\ln P_N - \ln P_R) - G$$

Table 8.
Average and Marginal Social Rates of Return to Railroad Capital, 1913
(for case of unit elastic demand for freight services)

(i) "Unappropriable" social benefits

(a) Estimate A 402.5 million milréis

(b) Estimate B 295 million milréis

(ii) total rail revenues 250 million milréis

(iii) net rail revenues 72.3 million milréis

(iv) total social benefit (social savings plus net rail revenues)

(a) 474.8 million milréis

(b) 367.8 million milréis

(v) Construction cost of Brazilian railroads as of 1913 2,053 billion milréis
(road, track, structures, rolling stock, furniture,
exclusive of land where possible)

(vi) Average social rate of return I (line iv(a)/line v) 23.1%

(vii) Average social rate of return II (line iv(b)/line v) 17.9%

(viii) Share of capital earngings in total rail revenue in 1913 0.381
[lines (iii)/(ii), above]

(ix) Marginal social rates of return, 1913
(product of line viii and lines vi and vii)

(a) 8.81%

(b) 6.82 %