CENTRE FOR ECONOMIC HISTORY
THE AUSTRALIAN NATIONAL UNIVERSITY
DISCUSSION PAPER SERIES

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DISCUSSION PAPER NO. 2015-03

FEBRUARY 2015

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The Growth Contribution of Colonial Indian Railways in Comparative Perspective*

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February 2015

Abstract

It is widely recognized that railways were one of the most important drivers of economic growth in the 19^{th} and 20^{th} century, but it is less recognized that railways had a different impact across countries. In this paper, we first estimate the growth impact of Indian railways, one of the largest networks in the world circa 1900. Then, we show railways made a smaller contribution to income per-capita growth in India compared to the most dynamic Latin American economies between 1860 and 1912. The smaller contribution in India is related to four factors: (1) the smaller size of railway freight revenues in the Indian economy, (2) the higher elasticity of demand for freight services, (3) lower wages, and (4) higher fares. Our results suggest large disruptive technologies such as railways and other communication technologies can generate huge resources savings, but may not have large growth impacts.

Keywords: Railways, Social Savings, ICT, India, Growth Accounting

JEL Codes: N7, O47, P52, R4

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*We thank seminar participants at UC Irvine and Yale's conference on New Research in South Asian Economic History. All errors are our own.

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1 Introduction

Advances in information and communications technology (ICT) have transformed economies around the world. Similar to cell phones and the internet of today, railways were the most important ICT of the 19^{th} century. Soon after the early construction of railways in Britain, steam powered railways spread from North-West Europe to Asia and Latin America beginning in the 1830s. In many countries railways were the engine of growth lowering transport costs, reducing price dispersion, integrating markets, extending frontiers and increasing incomes. But, the transformative and often disruptive impact of railways was not uniform across time and space. Some countries experienced a large economic bang, while in others the effects were more understated.

In this paper, we estimate the growth contribution of colonial Indian railways and compare it to the performance of railways in four large Latin American economies between the late 19^{th} and early 20^{th} century. The time frame captures the development of the rail network in these countries and ends just before World War 1. India offers a unique perspective because the existing evidence paints a mixed picture. On the one hand India fell behind other economies during the height of the 'railway era' from 1860 to 1912. India's per-capita income increased just 31% between 1870 and 1910 (from $533 to $697), whereas the Latin American average increased by 110% (from $742 to $1562).[1] Many scholars argue British colonial policies were the root cause of the decline (for example, Bagchi 1982). Such arguments specific to railways point to high fares, high freight rates and the construction of several unprofitable railways (Hurd 1983, 2007, Sweeney 2011). On the other hand Indian railways are thought to be a rare success story for the British Raj. Railways transformed India from many segmented markets separated by high transportation costs to an economy with local centers linked by rail to each other and the world. According to Donaldson (2012), railways raised agricultural incomes by 16% in districts with access to the network. And, Bogart and Chaudhary (2013) find that the growth and level of Indian railways' total factor productivity was large compared to both developed and developing economies by 1913. Comparing India to similar economies in Latin America can help shed light on this puzzle, and more generally the different effects of ICTs.

We choose Mexico, Argentina, Brazil and Uruguay (LA4) as the comparison set because like India these were large economies with extensive rail networks by 1912. LA4 accounted for 65 percent of Latin American GDP, 59 percent of the population and 79 percent of Latin American railway mileage. With the exception of Brazil, LA4 were among the few Latin

[1] The income per-capita data are from Maddison (2001), reported in 1990 purchasing power parity (PPP) adjusted dollars.

American countries to build integrated national railway networks. Similar to India, the LA4 economies heavily relied on primary exports in the 19^{th} century. But unlike India, their railways were mostly private, they were not colonies and had lower population density (and consequently higher wages) than India.

Our estimation is based on the growth accounting framework, which incorporates the social savings methodology. Social savings are the classic metric for evaluating the contribution of railways following seminal work by Fogel (1964) and Fishlow (1966). The social savings capture the value of lost resources had the quantity of railway traffic been transported at the prices of pre-railway transport in a benchmark year, say 1912. In a series of influential articles Crafts (2004a,b) extended social savings to a growth accounting framework. According to the basic growth accounting identity, income per-capita growth can be divided into increases in physical capital stock per-capita and "crude" total factor productivity growth (the so-called "Solow residual"). Crafts measured the contribution of railways to each one of the components by estimating a railway capital term representing the embodiment of railway technology in the capital stock, and a railway TFP term capturing the resource savings from lower transport costs. As Crafts shows, under competitive assumptions the TFP term is equivalent to the additional consumer surplus generated by railways, which in turn is the same as the social savings corrected by the elasticity of demand.

We extend the social savings methodology in several important ways. First, we decompose the savings for freight into two terms: (1) the share of railway freight revenues in GDP and (2) the ratio of pre-existing freight rates to railway rates. The share term can be called the "railway penetration effect" as it captures the degree to which individuals and firms used railway services. The ratio term can be called the "relative productivity effect" as it measures to what degree railways reduced freight rates relative to the alternative technology. Second, we decompose the savings from passengers into similar terms, and go further by decomposing the time cost of traveling, which depends on the hourly wage and the average speed of trains and alternatives. Third, we incorporate the profits of railways, which represent the part of TFP growth retained by railway companies and not transferred to users via lower fares. Quantifying the importance of the various components of the social savings provides an important step in explaining why a communication technology like railways had a large impact in one economy, and a smaller impact in another.

The main finding is that railways accounted for a large share of Indian GDP per capita growth, but they made a smaller growth contribution than railways in the most successful Latin American economies. Our preferred estimates show that Indian railways contributed 0.29 percentage points to annual income per-capita growth from the mid 19^{th} to the early

20^{th} century, larger than Uruguay (0.11%), similar to Brazil (0.31%), but less than Argentina (0.65%) and Mexico (0.53%). We perform several robustness checks and the same ranking of India's growth contribution carries through. One reaches a different conclusion regarding the contribution of railways as a share of total income per-capita growth. Railways account for 73% of all income per-capita growth in India, similar to Brazil at 62%. In contrast, railways account for a smaller share in Argentina (22%), Mexico (24%) and Uruguay (8%). In Argentina and Mexico the large savings provided by railways appear relatively small because income per-capita growth rates averaged 2.6% between the late 19^{th} and early 20^{th} century. India and Brazil were stagnant in the same period with income per-capita growth rates averaging only 0.5%.

What explains the differences across countries? The decomposition exercise for freight suggests Indian freight revenues were smaller as a share of GDP than most LA4, which lowers the social savings. But, pre-existing freight rates were much higher in India compared to railway rates, which increases the socials savings. We also find that India had a relatively elastic demand for freight services, and a higher elasticity lowers social savings because the latter must be adjusted down to estimate the additional consumer surplus. On net the relatively elastic demand for freight services in India combined with the smaller freight revenues contributed to lower consumer surplus from railways because these two factors more than compensate for the difference in freight rates between pre-existing and railway transport.

For passenger travel, the decomposition shows India had a relatively high penetration rate. Lower class passenger travel was huge in India by 1913. However, lower wages in India reduced the time cost of traveling and hence the social savings. Indian railway fares were also high compared to wages, which further lowered the social savings. Finally, we find that Indian railways were profitable in 1912 compared to Argentina and Mexico where railways earned zero or negative profits. Given the ownership structure of Indian railways, the profits largely went to the colonial Government and to some degree offset tax revenues on Indians.

Our paper contributes to the large literature on the economic impact of railways.[2] We offer a detailed analysis of the social savings from Indian railways before World War I. India is an important case because it had the largest railway system in the developing world in this period. Our results also speak to the literature on the Indian economy. In recent papers, scholars have studied the historical roots of the service sector (Broadberry and Gupta 2010), and the long-run adverse impact of direct colonial rule (Iyer 2010). We add to

[2] This literature began with the classic works by Fogel (1964) and Fishlow (1965). It has continued with studies by Coatsworth (1981), Summerhill (2000, 2003), Crafts (2004a), Leunig (2006), Herranz-Loncán (2006, 2011b, 2014), and Donaldson and Hornbeck (2013) among others.

this growing literature by studying one of the leading sectors of the economy. Our bottom line is that railways were the most important driver of economic growth in India before 1913. This is perhaps unsurprising because productivity growth in agriculture, the largest sector of the Indian economy was stagnant in this period (Broadberry and Gupta 2010). But, railways also contributed far less to Indian economic growth compared to other countries. Our decomposition exercises suggest India's economic structure is one reason. The more modest penetration of railways suggests that Indian workers and communities did not fully assimilate into the global economy when railways arrived. India's low wages were one key reason because they lowered the time savings of railways. There were also potential policy mistakes. Consistent with the extraordinary profits earned by Indian railways compared to LA4, fares and freight rates were high. Given the colonial Government's regulatory power on Indian railways, this would be a failure of colonial policy.

Finally, our results contribute to the literature on ICT. Researchers have found a large growth contribution from ICT in developed and developing countries (Roller and Waverman 2001, Aker and Mbiti 2010). The estimates presented here on railways are consistent with communications technologies playing a large and important role. That said, our findings suggest that where railways were not accompanied by other structural changes, they ended up accounting for an exceedingly large share of a small total per-capita growth rate.

The rest of the paper is organized as follows. Section 2 provides a brief background on Indian railways. We describe the social savings methodology in Section 3. Section 4 details the assumptions and calculations of the different components of the growth contribution. Section 5 puts Indian railways in a comparative perspective and Section 6 concludes.

2 Background on Indian Railways

By most accounts India's transportation sector was costly and unproductive at the beginning of the railway era. India had many rives, but they were often not navigable or seasonal as in the case of the Ganges and the Indus. India had a long coast line, but shipping was hampered by seasonality and changing winds. In terms of investments in roads and canals, India was clearly behind Western countries.

Railways changed India's transport sector dramatically. British mercantile firms were among the early advocates for railway construction in India (Thorner 1955). They argued railways would lower transport costs, allow access to raw Indian cotton and open Indian markets to British manufactured goods. The first passenger line measuring 32 km opened in 1853. The size of the network grew rapidly in the 1880s and 1890s with track km increasing from 15,000 in 1880 to 54,000 in 1913 (Bogart and Chaudhary 2015). Network expansion continued after 1913 when we end our analysis, but the pace of development slowed. Although economic motives spurred the initial wave of construction, political and development concerns became important beginning in the 1870s. Railways were built in part to mitigate the effects of famines, put down rebellions, and defend the frontier.

By the early 20^{th} century railways spread to most parts of India as seen in Figure 1 showing the network in 1909 (color coded for each railway system). The first passenger line connected the port of Bombay to the interior. Similar connections were soon made between the ports of Calcutta, Madras, and Karachi and their hinterlands. A dense interior network was constructed between Delhi and Calcutta along the Ganges River, where railways served long-standing population centers. However, outside of the links with Delhi there were few interior-to-interior connections. Much of central and southern India was distant from a railway.

The construction and management of colonial railways involved private British companies, the colonial Government of India (GOI), and Indian Princely States. In the first phase up to 1869, private British companies constructed and managed trunk lines under a public guarantee. Such guarantees for railway construction were common in the 19^{th} century. For example, railway companies in Brazil received guarantees of around 7%, large than the 5% in India. In the second phase, the GOI began constructing and managing railways in the 1870s. The third phase, beginning in the early 1880s, involved hybrid public-private partnerships between the GOI as majority owner of the line and private companies. In the fourth phase, starting in 1924, the GOI began taking over railway operations completing nationalization.[3]

The structure of the economy matched the flow of goods on the railways. The largest traffic category was agriculture (see Figure 2).[4] It included commodities like grain, oilseeds, pulses, cotton, tea, and jute. Agriculture, the largest source of Indian exports, was the core of traffic between the hinterlands and the ports. The second largest traffic category was minerals, with coal being by far the largest. Coal was shipped internally and was used by railways distant from mines, and to a lesser extent in manufacturing. Salt, another important commodity in internal trade, was also part of the mineral category. In comparison, traffic in manufactured goods was small averaging 5% between 1883 and 1912. Some of these goods were Indian made, but many were imports.

Several studies have looked at the economic impact of Indian railways. Early work by

[3]See Sanyal (1930) for a detailed overview of the regulatory history of Indian railways.
[4]The commodity data are from Morris and Dudley (1975, p. 39).

Hurd (1975) and McAlpin (1974) found less price dispersion and more price convergence in railway districts compared to non-railway districts and as railways expanded over time. These studies and those by Studer (2008) suggest a large impact of railways on market integration. By contrast, Andrabi and Kuehlwein (2010) argue against a large impact. They regress the price gap for wheat and rice between major Indian cities on an indicator variable for whether a railway connected the two cities in each year. Unlike the earlier studies, they focus on changes in price gaps before and after railways link a market pair. Their estimates imply that railways explain only 20 percent of the overall 60 percent decrease in price dispersion between the 1860s and 1900s. In a similar vein, Collins (1999) examines wages and finds limited evidence of convergence during the key decades of railway expansion.

Recently, Donaldson (2012) taking a theoretically grounded and rigorous empirical approach finds large effects of railways on trade costs and agricultural incomes. He exploits variation in salt prices, a better proxy for trade costs compared to wheat or rice prices used in other studies, because salt was produced in one district and transported to others. Using panel and IV regressions, he finds the arrival of railways increased agricultural incomes by 16% in a district-level analysis. Significantly for our paper, Donaldson estimates the degree to which railways reduced trade costs relative to carts and boats using differences in salt prices across districts.

Unlike these studies, we take a macro approach and estimate the impact of Indian railways by measuring their contribution to the increase in capital stock per-capita and TFP of the economy. The latter is based on an estimation of the social savings of railways. As is well known, the social savings compare the freight rates of railways with some alternative, like bullock carts, and use these figures to measure the income loss from shipping railway traffic with pre-railway transport technology. The main precedent of our work is Hurd (1983), who estimated the social savings on Indian freight traffic to be 1.2 billion rupees or 9 percent of national income in 1900. But, Hurd's calculation is not detailed. He does not specify the assumptions, sources or sample. We combine a social savings calculation with the recent methodology developed by Crafts (2004a) to estimate a precise impact of Indian railways by 1912 when most of the network was complete. We then compare the Indian experience to LA4 for which such estimates have already been compiled using the same methodology (Herranz-Loncán 2014). This exercise puts the Indian experience in a global perspective and offers a much needed macro view.

3 Methodology

The starting point to measure the growth contribution of a new technology is the usual Solow expression for increases in labor productivity:

$$\triangle(Y/L)/(Y/L) = s_k \triangle(K/L)/(K/L) + \triangle A/A \tag{1}$$

Where Y is total output, L is the total number of hours worked, K denotes the services provided by the physical stock, A is "crude" total factor productivity, and s_k is the factor income share of physical capital. This expression has been used in recent research as a basis for estimating the contribution of general purpose technologies to productivity growth by distinguishing between different types of capital and different components of TFP growth. For example, Oliner and Sichel (2002) measure the growth contribution of ICT, both through disembodied TFP growth and through the embodied capital-deepening effect of investment in those technologies by transforming expression (1) into:

$$\triangle(Y/L)/(Y/L) = s_{ko}\triangle(K_o/L)/(K_o/L)+\gamma(\triangle A/A)_o+s_{kict}\triangle(K_{ict}/L)/(K_{ict}/L)+\varphi(\triangle A/A)_{ict} \tag{2}$$

Where K_{ict} and K_o are the services provided by the capital stock in ICT and in other sectors, respectively, A is the TFP level in the sector indicated by the subscript (ICT and other), s_{kict} and s_o are the factor income shares of the capital invested in ICT and other capital, and φ and γ are the shares of ICT and other sectors' production in total output. The growth contribution of ICT is the sum of the last two terms of equation (2), which would approach, respectively, the "capital term" and the "TFP term" of that growth contribution.

In the case of peripheral economies, like India and Latin America, which import new technologies from core countries where they have been developed for some years, the TFP term has two components. First, TFP growth within the sector under consideration, and second, the increase in TFP associated with the substitution of that sector for the previous technology.

In this context (i.e., railways of peripheral economies), instead of approaching the TFP term of expression (2) through TFP growth in the railway sector over time, we can estimate TFP by comparing railway transport costs at the end of the period with the cost of domestic transportation just before the introduction of railways. This would be equivalent to measuring the social savings of railways as a percentage of GDP:

$$SS/GDP = (P_{TR} - P_{RW}) * (Q_{RW}/GDP) \tag{3}$$

where P_{RW} and P_{TR} are, respectively, the price of railway and pre-railway transport, and Q_{RW} is the railway transport output in the reference year. The social saving expression (3) is an upward-biased estimate of the equivalent valuation of consumer surplus provided by railways, due to the implicit assumption of a price-inelastic transport demand. If the social savings are corrected for the elasticity of demand and, assuming perfect competition in the rest of the economy, the elasticity adjusted social savings provides a general equilibrium measure of the entire direct income gains obtained from transport cost saving (Metzer 1984; Jara-Díaz 1986). The price dual measure of TFP allows considering such gains as equivalent to the contribution of railways to TFP growth.[5]

To see the equivalence between the TFP term and the social savings note that productivity growth in transport can be written in its dual form as $(1/P_{RW}–m/P_{TR})/(m/P_{TR})$, where m is the price of inputs in traditional transport relative to railways, whose input prices are normalized to 1. If one assumes that the prices of factor inputs rise with the general price level then m/P_{TR} is equivalent to the inverse of the inflation adjusted price of traditional transport, call it p_{TR}. Rearranging terms we get the following expression for productivity growth: $(p_{TR}/P_{RW}–1)$. Multiplying the price dual expression for productivity growth by the revenue share of railway transport in GDP gives an expression for the TFP term as the social savings: $[(P_{RW} * Q_{RW})/GDP](p_{TR}/P_{RW}–1)$ or $(p_{TR} - P_{RW}) * (Q_{RW}/GDP)$.

Our social savings calculation uses the inflation adjusted price of alternative transport just before the advent of railways (i.e., 1850). We are interested in the contribution of railways over their predecessor technologies, not the contribution of railways relative to what alternative transport could have become (as in Fogel 1964). Therefore we exclude productivity growth in road, river, and coastal transport after railways were adopted. Even if one thinks that productivity growth in pre-railway transport should be incorporated in the counter-factual it is likely to be small. We know that productivity growth in British road and inland water transport required investment in better roads and canals (Aldcroft and Freeman 1983, Bogart 2005). As of 1850 road and canal investment was not a top priority of British colonial officials, and it is unclear if that changed in the late 19^{th} century.[6] There was

[5]However, the potential presence of imperfect competition or scale economies in the transport-using sectors likely makes the social savings measure a lower bound estimate of the total income gain of railways. There are other potential TFP spillovers resulting from the commercialization of agriculture, the extension of finance, and the provision of complimentary public goods like schools. Our view is that spillovers existed but they were probably second-order compared to the direct resource savings from lower transport costs and faster speeds, especially in the Indian context where the qualitative evidence suggests there were limited spillovers to other sectors.

[6]Public investment in canal schemes did increase in the late 19^{th} and early 20^{th} century. But these schemes were about building new canals to harness the water of the Indus river and bring additional areas under cultivation in Punjab and Sind. There was limited investment in improving existing water transport

potential for productivity growth in sailing ships, but India had been exposed to European best practices for more than two centuries. By 1850 they had relatively good sailing ships.

The capital term is usually omitted in the literature on the growth effects of railways. Most studies make the assumption that the capital invested in railways would have been allocated to a different sector in the same country with a similar return (Crafts 2004a, p. 7). It is plausible that, in the absence of the railways, part of the resources invested in railway construction would have been devoted to improving irrigation. However, due to the foreign origin of most railway capital in both India and LA4, it is likely that at least part of these resources would not have been transferred to the Indian and Latin American economies. Therefore, in a complete counterfactual analysis of the economic impact of railways it is reasonable to include the growth in the capital stock per-capita associated with the railways as part of the sector's growth contribution.

As is shown in expression (2), we estimate the capital term as: $s_{kict}\Delta(K_{ict}/L)/(K_{ict}/L)$. This is based on the assumption of constant returns to scale in the production of railway services and perfect competition both in the railway industry and in the rest of the economy. This allows us to consider the ratio between net railway revenues and $GDP(s_{kict})$ as a good proxy for the output elasticity of capital in the railway industry. These assumptions may seem strict for a highly-regulated sector such as railways, but the magnitude of the associated biases is unclear. In the last section we estimate the size of profits in the railway sector and consider the implications in a comparative context.

4 Estimation for Indian Railways

In this section, we describe the estimation of the TFP term and the capital term in India between 1860 and 1912. We refer the reader to Herranz-Loncán (2014) for comparable calculations on Argentina, Mexico, Brazil, and Uruguay (LA4).

4.1 The TFP term: Freight

The TFP term consists of productivity growth in freight and passenger transport, both of which are measured through the consumer surplus added by railways. The first step in estimating the surplus from freight is to measure the cost of railway transport in 1912 and the cost of different transport modes around 1850 before railways were built in India. The second step is to allocate railway freight traffic in 1912 to the transport modes that would have been used in the absence of railways. The third step is to calculate the social savings

infrastructure.

using the cost of freight traffic in 1912 and the cost in the absence of railways. The fourth step transforms the social savings into additional consumer surplus by correcting for the elasticity of demand.

As is standard in the literature, we first estimate the cost of railway transport as the ratio of total freight revenues to total ton miles (the standard measure of freight output in railways i.e., the number of tons carried one mile). In our case, the ratio is the weighted average of freight revenues and ton miles of the 17 major railway systems operating in India.[7] The average freight rate was 0.014 rupees per ton km in 1912.[8] Next, we estimate pre-railway freight rates in the regions served by each of the 17 major railway systems. In these calculations we need to consider the availability of road, river and coastal transport and their freight rates c.1850 relative to railways in 1912. We begin by estimating the relative freight rates of each alternative mode.

One strategy would be to use Donaldson's (2012) calculations. He uses variation in salt prices across districts and over time to infer relative costs across different modes. His estimates imply that road transport was 7.88 times more expensive per unit of distance than railways, and river and coastal were 3.82 and 3.94 times more expensive than railways respectively. Although his estimates provide a benchmark, they are not well suited for a social savings calculation for two reasons. First, salt is less bulky to transport as compared to rice, wheat or other grains. This suggests railways probably charged different freight rates for salt than other commodities. Hence, salt is unlikely to be representative of the average charge.[9] Second, freight rates for the same commodity differed across railways. A before-after comparison of salt freight rates within the same railway à la Donaldson does not account for differences and changes in those differences in freight rates across railway systems.[10]

[7]These 17 railways jointly accounted for over 90% of the total mileage. Figure 1 shows the rail network by railway system. Apart from the larger railways, the map also shows the smaller 2 inch gauge railways that account for less than 10% of mileage and even less of the traffic. We exclude Burma railways in our calculations because the income data for India excludes Burma as well.

[8]Appendix table 1 shows the average rate for the 17 major railway systems and documents the calculation of the overall weighted average.

[9]For individual commodities we can only estimate the freight rates per ton as opposed to per ton km. The Railway Reports provide data on quantities and revenues by commodity, but they do not give the average distance hauled. For the most important freight classes in 1901 and 1903, we find salt paid a slightly lower railway freight rate than grain, oil seeds, and sugar but its freight rate was much less than coal and much more than cotton. The key question then is whether salt freight rates differed to the same degree on pre-railway transport. It is difficult to answer this question, but the data on pre-railway freight rates detailed below suggest that coal paid a similar freight rate to other commodities around 1850.

[10]For example, in 1899 the coefficient of variation for grain freight rates per ton mile was 0.22 and the coefficient of variation for coal freight rates per ton mile was 0.28. On general classes of good the coefficient of variation was around 0.11.

On account of these potential problems with using Donaldson's estimates, we use direct observations of road, river, and coastal freight rates before railways to estimate social savings. Derbyshire (1987) is an excellent reference and reports road freight rates in the 1840s and 1850s for north India for pack bullocks, 2-bullock carts, and 4-bullock carts. In rupees per ton km Derbyshire's estimates are 0.24, 0.097, and 0.078 for pack bullocks, 2-bullock carts, and 4-bullock carts respectively. Derbyshire's figures on road freight rates are consistent with other sources, especially for carts. Mukherjee (1980) estimates that in Bengal the freight rate for 2-bullock carts averaged 0.107 rupees per ton km in 1866. Mukherjee also cites two sources from the mid-19th century which put road freight rates between 3.05 and 4.5 British pence per ton mile. When converted into rupees per ton km, these figures represent 0.079 and 0.116 rupees per ton km. In another source, Ramarao (1998) published the letters and documents of traders in Bengal, who reported on road freight rates in the mid-1840s. The average freight rate per ton km in eight reported observations is 0.118 rupees per ton km. We therefore take Derbyshire's estimates of road freight rates as being representative of freight rates by pack bullock, 2-bullock carts, and 4-bullock carts throughout India in the 1840s and 50s.

The next step is to convert Derbyshire's rates to 1912 prices. Recall that our goal is to compare pre-railway costs with railway costs in 1912 prices. The most straightforward inflation factor for this period is the growth in consumer prices. We use the inflation factor between 1840-59 and 1912 reported in recent work by Allen (2007) and Studer (2008) to calculate nominal freight rates in 1912.[11] These estimates imply larger unit cost differences from railways compared to Donaldson's estimates. Pack bullock rates were 35 times the freight rate of railways and 4-bullock carts were 11 times the railway rate.

We draw on the same sources to estimate freight rates by river transport. Derbyshire (1987) reports 0.024 rupees per ton km for downstream traffic and 0.039 for upstream. In other sources, river freight rates are similar. Mukherjee (1980) cites a source which reports that downstream and upstream rates on the Ganges are 0.03 for downstream and 0.041 for upstream. Notably the previous water freight rates in Mukherjee include insurance for goods lost in transit. It was common to take such insurance given the hazards of navigating Indian rivers. Ramarao (1998 p. 12) cites a source stating that about 20% of the coal shipped by the Damodar river to Calcutta was typically lost, stolen, or washed away in transit. When insurance is not included, reported river freight rates are lower. For example, Mukherjee

[11] McAlpin's chapter in the Cambridge Economic History of India (1983) reports price series from 1860 to 1912. These series suggest similar changes in prices as reported in Allen (2007) and Studer (2008) where the two series overlap in years. We use the more recent price series because they go back to 1840 unlike the series reported in CEHI.

cites a source which states that freight rates by unimproved rivers were 0.5 pence per ton mile, which converts to 0.013 rupees per ton km. There are several downstream river freight rate observations in Ramarao that do not include insurance and average 0.017 rupees per ton km.

For the purposes of our social savings calculation we use river rates with insurance. Indian rivers were hazardous for shipping and without including insurance the costs of water transport are under-stated. For comparability with road rates we use Derbyshire's rates for river transport. One possibility is to average upstream and downstream rates, but it is more likely that downstream traffic was greater. Moreover, the coal traffic was downstream which is of special importance to the social savings. Therefore we chose the downstream rate of 0.024 rupees per ton km as our benchmark for water freight rates in the 1840s and 50s. When adjusted for inflation, the river freight rate in 1912 prices is 0.05 rupees per ton km. Measured relative to the railway rate in 1912, river transport in India was 3.57 times as expensive. This figure is quite similar to Donaldson's relative rate between river and rail.

We have been unable to find direct observations on freight rates for coastal transport in the source materials. However, there is data on the number of days it took to travel by river and by sea between various towns. The number of travel days would presumably influence labor costs and hence a comparison of travel days between river and coastal transport gives one estimate of the relative freight costs. Deloche (1994) gives figures on travel times in days at various times of year for coastal regions, and rivers. Using this source we have 16 observations on travel times by river which yield an average of 30.1 km per day. Deloche also gives 10 observations on travel time for coastal transport, which yield an average of 69.22 km per day. Drawing on this information we assume that the freight rate by coastal vessel was 42.8% (30.1/69.22) of the freight rate by river which amounts to 0.021 rupees per ton km in 1912 prices. This is probably an upper bound of the actual rate, since other differences, such as the larger scale of vessels in coastal than in river transport, may have reduced freight rates in the former. Table 1 summarizes the information on freight rates.

The next step in the freight social savings calculation is to identify how much rail traffic would have gone by road, river, or coast in the absence of railways. Our approach assesses the transport alternatives for each of the 17 major railways systems, and aggregates to total railway traffic in 1912. The main navigable river systems in colonial India were the Indus, Ganges and Brahmaputra. The major population centers were generally near rivers so many railways laid track nearby. For example, much of the East Indian railway followed the Ganges river valley where population was most dense. The Northwestern railway was similar in that it followed the more populated Indus river valley. Among the 17 major railways systems, seven were close to one of the navigable rivers.[12]

Proximity to a navigable river gave the possibility to river traffic but there were other constraints like seasonality and irregularity of water flow. The rivers were too dry for much of the year and only usable during the monsoon season. According to the railway engineer George Stephenson, "the great season for the transit of goods to and from northern India is from July to end of November, the navigation of the rivers during the other seven months of the year being so tedious and expensive" (Ramarao, p. 46). Observers also remarked that the water flow of rivers was inconsistent as they depended on the melting of snow in the Himalayas. In some cases, boats had to be hauled along mud and in other cases, the rivers were dangerous torrents.

The limitations of river transport meant that there was still a significant amount of road traffic in areas with navigable rivers. For Bengal there are some specific estimates of how much traffic went by road and by river prior to railways. Stephenson stated that for the trade between Calcutta and Burdwan, a town on a tributary of the Ganges, three-fifths went by river and two-fifths went by road (Ramarao, p. 46). John Bourne's report on Indian river navigation in 1849 stated that there were 1.06 million tons carried by the Ganges river between Calcutta and Mirzapore and 0.106 million tons carried by road (p. 50). Thus according to Bourne just under one-tenth of this trade went by road and just over nine-tenths went by river. Other records for Bengal support the contention that road traffic continued in areas with river transport.

Drawing on Stephenson and Bourne one assumption is that for railways near navigable rivers between $1/10^{th}$ and $2/5^{th}$ of the traffic would have gone by road in the absence of railways. We favor the higher $2/5^{th}$ assumption because there is a higher risk of over-stating the amount of counter-factual river traffic for railways near rivers. Many railways lines diverted from navigable rivers and gained traffic that would have had to travel a significant distance by road.[13] We also present a robustness check using the lower $1/10^{th}$ assumption for road traffic.

Coastal trade was widely available in India. Some railway systems in the Indian Peninsula followed the coast because population was most dense there. An example is the South Indian

[12] The railway systems near rivers were the East Indian, Northwestern, Eastern Bengal railway, Oudh and Rohilkhand, Bengal and Northwestern, and Assam Bengal.

[13] The most important example is the coal traffic. For example, by 1870 the Central Indian coal deposits were served by the East Indian railway, which had some track near the Ganges river but that portion of the track was at a greater distance from the coal deposits. The coal deposits in Central India are described in the 1840s as 'situated beyond reach of the great lines of navigation'. Therefore, based on the geography of India's coal deposits it is likely that more than 1/10th of the East Indian's coal traffic in 1912 would have had to be shipped by road instead of river.

railway which had much of its track mileage along the southeastern coast near the city of Madras. In total 4 of the 17 major railways systems were close to the coastline.[14] Like river transport, coastal transport was also seasonal. The winds generally blew south in the winter and north in the summer. Thus depending on the direction of trade and time of year, coastal shipping could be more expensive. Unfortunately it is very difficult to work out how much traffic would have been shipped by coast and by road in the areas where the South Indian and similar 'coastal' railways operated. For lack of better information we again assume that three-fifths of railway traffic would have gone by coast and two-fifths by road. That said, we present a robustness check assuming that only 10 percent of the traffic went by road similar to Bourne's assessments for river versus road traffic.

For the remaining railways road transport was the only alternative to railways.[15] In these and all previous railway systems it is important to identify whether wheeled road traffic was available. Deloche's (1993, p. 261) exhaustive study of roads and road vehicles before railways suggests that wheeled traffic was widely available only in northern India, including Bengal and the Ganges river valley. For the rest of India pack animals were the typical mode of road transport. Deloche's argument is supported by John Bourne who states that camels were the most notable mode of transport in the northwest (pp. 24 and 67). Drawing on these sources, we assume that Derbyshire's two bullock cart freight rate applies to the 6 railway systems in northern India and the higher pack bullock freight rate applies to the rest.[16]

We summarize our assumption on the share of traffic allocated to road, river, and coastal transport by railway system in table 2. Pack bullocks account for 35% of traffic, river 36%, 2-bullock carts 20%, and coastal transport 9% in the counter-factual. The allocation of traffic is important as freight rates differ significantly across modes of freight traffic. Table 3 shows the weighted average freight rate (rupees per ton km) in the counterfactual using the proportion of traffic allocated to each alternate traffic mode as the weights. We present estimates using both Donaldson's costing for pre-railway and railway transport and the alternative costing we developed using direct observations. Compared to Donaldson, the direct observations suggest road traffic was more expensive and coastal traffic less. Given the distribution of traffic to these modes, the counter-factual average freight rate without

[14] The railways systems near the coast were Bengal Nagpur, Bhavnagar-Gondal, Madras and South Indian railway. We did not include any coastal traffic for Bombay, Baroda and Central India because a majority of their mileage was in-land and only a small proportion was coastal.

[15] Railways without rivers or coasts nearby are the Bombay, Baroda and Central India; Great Indian Peninsula; Rajputana Malwa; Nizam; Udaipur Chitoor; Rohilkhand and Kumaon, and Jodhpor-Bikaneer.

[16] The 2-bullock cart rate is assumed for East Indian; Eastern Bengal; Oudh and Rohilkhand; Bengal and Northwestern; Bengal Nagpur; and Rohilkhand and Kumaon.

railways turns out to be significantly higher under direct observations. While it is difficult to say which is more accurate, we prefer using the direct observation freight rate because trade costs do not necessarily translate into freight costs. Donaldson's rates are not estimated on the basis of pre-railway information but from 1870-1930. Moreover, they could be sensitive to differences in freight rates between salt and other commodities. Finally, the studies on Latin America also employ the same methods to estimate the freight rate for alternative transport.

The final step for freight is to estimate the price elasticity of demand and adjust the consumer surplus accordingly. Without this adjustment the calculation assumes traffic levels would have been the same without railways even though freight rates, fares, and travel times are much higher. In other words, it assumes a perfectly inelastic demand. As this is implausible a correction needs to be made using an estimate for the price elasticity of demand. The estimates for price elasticity of freight are -0.5 in Mexico (Coatsworth 1981), -0.6 in Brazil (Summerhill 2000), -0.49 in Argentina (Summerhill 2003), and -0.77 in Uruguay (Herranz-Loncán 2011b). Most of these estimates come from regressions of railway freight traffic on freight rates and controls. We apply a similar method for India, but with the added advantage of using railway-level data from 1880 to 1912 rather than aggregate data for the whole system, as in other cases. The standard specification for railway demand is the following where β_1 is the estimate for price elasticity:

$$ln(freight-ton-miles)_{it} = \beta_1 * ln(real-freightrate/ton-mile)_{it} + \beta_2 * ln(railway-miles)_{it} + \beta_3 Year_t + \epsilon_{it}$$

Table 4 reports the estimates of the demand equation using the individual railway-level data. The data series are summarized in Bogart and Chaudhary (2013) and are drawn from annual Railway Reports published by the Government of India. The first column is the most parsimonious and suggests a very large price elasticity of -0.95. This decreases to -0.73 when we include railway fixed effects. In specification 3 we control for both railway and year FE, which allow for more flexibility over a simple trend. The estimate increases to -0.84. In the final specification, we add railway density (train miles run divided by track miles) as an additional control resulting in an estimate of -0.66. Since other studies do not include density in their elasticity estimation, we use the estimate of -0.84 from specification 3 in our main analysis and present robustness checks using the lower -0.66 estimate.

Equipped with a price elasticity estimate, we use a standard formula for transforming the social savings into additional consumer surplus.[17] Table 5 summarizes the calculations of

[17] The ratio between the additional consumer surplus and the social savings is given by $[(\phi^{(\varepsilon+1)} - 1)/((\phi - 1) * (1 + \varepsilon))]$, where ε is the price elasticity of transport demand (with negative sign) and φ is the ratio between counterfactual and railway transport prices; see Fogel (1979, pp. 10-11).

social savings and the additional consumer surplus in freight. We find large social savings in freight on the order of 27% of GDP in 1912. After accounting for elasticity, the social savings translate into 1,216 million rupees of consumer surplus, which is 6% of GDP. Consumer surplus from freight is lower than the social savings because of the large difference between the price of alternative transport and railways, and the large price elasticity. If we use the estimate for the lower elasticity of demand (-0.66), the additional consumer surplus increases to 8% of GDP.

4.2 The TFP term: Passenger

Like freight, the additional consumer surplus from passenger transport is estimated from social savings and then corrected for an elastic demand. The social savings in passenger transport includes money savings from lower fares and time savings from replacing slower traditional transport. The time savings require data on travel speeds and passengers' hourly wages. It also requires an assumption of the share of railway traveling time that would have been devoted to working. As before we begin with the cost of passenger transport using railways in 1912 and then proceed to alternatives that would have been used in the absence of railways.

In India there were four passenger classes for railways. The first class accounted for 0.6% of passenger traffic in 1912, the second and third together accounted for 5.9% and the fourth for 93.5%. Naturally fares were highest for the first class at 0.046 rupees per passenger km. The second and third were similar and averaged 0.016 rupees. The fare for the fourth was less at 0.007 rupees. The first class was targeted to high ranking British officials. The second and third classes were meant for upper class Indians and lower class Europeans and Eurasians (Kerr 2007). The identity of the fourth class is more difficult to establish but it is likely to have been middle class Indians rather than laborers. As we shall see below the fare was quite large even relative to skilled wages.

In the literature there is often an assumption that upper class passengers would have used stagecoach transport in the absence of railways, but all lower class passengers would have walked. We follow a similar approach for India and assume the first, second, and third classes would have used wheeled vehicles in the absence of railways. The descriptions of contemporaries in Bengal published by Ramarao (1998) indicate that wealthy Indians and British officials travelled in coaches known as daks. Some also travelled in a vehicle known as a palkeen or palanquin, notable for relying on human instead of animal power. Lastly, some travelers used the bullock carts transporting goods. Our other assumption is that the fourth class would have walked in the absence of railways. This is supported by reports of the large number of foot travelers in India. For example, on the Annabad bridge during the year 1837-38 it was noted that there were 435,242 foot travelers compared to 19,869 horses and 9,314 carts (Ramarao, p. 90).

The pre-railway fares for different travel types are documented for Bengal based on questionnaires sent to British officials in the 1830s and 40s on passenger travel and are published in Ramarao (1998). One question asked "What is the expense of the journey by land from Calcutta to Benares to the natives of various classes; for instance, the wealthy native traveler of moderate means and lastly to the poor description of pilgrims. . . ?" The respondent stated that it would be "from 150 to 200 rupees with twelve bearers. In a gharry will cost 100 rupees and if in a palanquin 125 rupees besides 25 rupees for a banghey to carry eatables" (Ramarao, p. 91). These fares turn out to yield a passenger per km between 0.15 and 0.29 rupees using a distance of 680km between Calcutta and Benares. They are lower than other observations for Bengal which quote passenger travel by dak at 0.31 rupees per passenger km and by palanquin at 0.23 rupees and 0.21 rupees (Ramarao, p. 87, Bourne, p. 51). Drawing on this information we assume that the first class passengers paid the most expensive fares at 0.31 rupees and that second and third class passengers paid the palanquin rate at 0.21 rupees. After converting these fares into 1912 prices using the same consumer price index as for freight, the counterfactual fare is 0.64 rupees per passenger km for first class and 0.43 for second and third classes. It is noteworthy that dak rates were 14 times the first class railway fare and palanquin rates were 36 times larger than second and third class railway fares.

The difference in fares does not apply to the fourth class because we assume they walk in the absence of railways, which requires no fare. The zero fare assumption for the 'lower class' passenger is common in the literature and so we retain it here for comparison with Latin America. However, it is not entirely satisfactory as walking consumes calories which require income. Bourne (p. 51) estimates that the expense of traveling by foot in India including time and subsistence was 0.533 pence per passenger mile or 0.028 rupees per passenger km in 1912 prices. In an extension we use this figure as the "walking cost" for the fourth class, even though it conflates time costs which are dealt with separately.

The savings from time require estimates of average travel speeds with and without railways and the value of passenger's travel time. The speed of passenger trains in India was between 27 and 51 km per hour; the average across Indian railway systems weighted by passenger traffic was 36.48 km per hour (Great Britain 1913, p. 445). Prior to trains, speeds were obviously much slower, but by how much? Ramarao (p. 87) published the Military Board's Report on the time occupied between Calcutta and Benares in travel. The Board states that it took 18 to 20 days by foot, 15 to 18 days by palkee (palanquin), and 4.5 to 5 days by dak. Assuming a 10 hour travel day and given that the distance between the two cities is around 680 km, this would imply a travel speed of 3.57 km per hour by foot and 4.12 km per hour by palkee. Another source also implies that the hourly travel speed of palanquins was 3.86 km per hour (Ramarao p. 87). The Military Board's reported travel time for the dak was low compared to others and it is likely that it included night travel. Assuming a travel day of 20 hours for the dak yields a speed of 7.15 km per hour. Another source in Ramarao (p. 87) puts the travel speed of daks at 4 miles per hour or 6.44 km per hour. Drawing on these figures, we assume that prior to railways the travel speed for fourth class passengers was 3.57 km per hour which is the estimate for walking. The speed for second and third class was 4.12 km per hour corresponding to the palanquin, and the speed for first class was 6.44 km per hour corresponding to the dak. By comparison passenger trains were more than five and half times the speed of the fastest available form of transport before railways.

For the value of time we assume fourth-class travelers were paid the hourly wage of skilled workers and that of second and third-class travelers at twice that amount. The hourly wage of skilled workers is estimated to be 0.059 rupees per hour. It is based on monthly wages in all regions of India reported in Allen (2007) and assuming 26 days in a month and 10 hours per day worked on average. Doubling this wage would give second and third class passengers an hourly wage of 0.118 rupees. First class incomes or wages are known with less certainty, but assuming they were high ranking British officials they should have received at least the nominal wage of skilled workers in London. According to Allen's data London building craftsman earned 100 grams of silver a day, which translates into 9.27 rupees. Assuming a 10 hour day would imply that first class passengers earned an hourly wage of at least 0.928 rupees. This figure is not unreasonable as it is around eight times the wage of the second and third class and 16 times that of the fourth class. Finally, as is customary in the literature, we assume that only half of the time savings would have been spent working and earning a wage. Leisure is priced at zero and thus only half the value of the time savings is included in the social savings.

The final assumption is related to the price elasticity of demand for passenger travel. In the case of first or upper class transport, the standard assumption is that the demand elasticity is -1. The justification is that upper class travel contained a luxury element and that elites would have turned to local activities for entertainment had railways not existed. By contrast, in the case of the second or lower class, the common assumption is a null elasticity, which implies that their journeys were mainly made out of necessity (see Herranz-

Loncán 2014, Leunig 2006). We adopt these assumptions for India and assume a demand elasticity of -1 for first, second, and third class passenger travel and zero elasticity for fourth class travel.

Table 6 summarizes the calculations for passenger social savings and the additional consumer surplus. We show the money and time savings separately and combined. India's passenger social savings hinge on whether we include walking costs or not. Without walking costs the social savings is 3.39% of GDP, which rises to 6.43% of GDP if we include walking costs. We think it is reasonable to include walking costs because otherwise the social savings from fourth class travel is essentially zero, which seems implausible. Similar to freight, we adjust the passenger social savings to consumer surplus using the price elasticity of demand. The consumer surplus from passenger travel is again lower than the social savings mainly because of the high price elasticity for second and third class passengers. In total the additional consumer surplus is 3.51% of GDP. Compared to the freight estimate of 6%, railway passenger travel generated lower social savings and consumer surplus in India.

4.3 The TFP term: Railway Profits

Railway profits are a part of the resource savings absorbed by producers. Hence, profits should be included in the contribution of railways to total income growth. Profits equal total revenues minus total costs. In our context, total costs had two components: (1) operational costs which included fuel, labor, and materials for maintenance and (2) capital costs, which were the payments to investors in railway track, locomotives, and vehicles. We use the total revenues and operating costs for all Indian railways as reported in Great Britain (1913, p. 3-4). For capital costs we use the book value of capital multiplied by the sum of the rate of return on capital in the economy and an amortization rate. The yield on long-term government bonds provides a reasonable rate of return on capital, 3.66% in 1912. We use a amortization rate of 1.5%, which is similar to that used for Brazil and Spain in Summerhill (2003) and Herranz-Loncán (2006). In 1912, railway officials estimated the book value of capital to be 1,606 million rupees (Great Britain, p. 3). Multiplying this book value by 0.0516 gives an estimate of the capital costs.

The calculations suggest Indian profits in railways equal 74.91 million rupees in 1912, which represented 0.37% of Indian GDP. Thus, profits were of reasonable size in India and made another contribution to income growth. The main recipient of railway profits was the GOI. India's revenue statistics indicate that its profits from GOI-owned and subsidized railways amounted to 6% of total Government of India tax revenues (Administrative Report Indian Railways 1912, p. 2, Statistical Abstract Relating to British India 1914-16, p. 47).

Interestingly, railway profits were larger in India than in LA4 as shown in Appendix Table 2.[18] For example, railways in Argentina and Mexico had negative profits in 1913. In particular, Argentina's low profits were on account of the high opportunity cost of capital around 5%. India's colonial status in contrast lowered the cost of capital.

4.4 The Capital Term

Apart from TFP, the other item in the modified growth accounting equation is capital. In the literature, it is common to assume that the growth of railway capital is similar to that of railway mileage because data on the value of the railway capital stock is unavailable for many countries including some in Latin America. To ensure comparability with LA4, we estimate the growth of railway capital in India using the growth of railway mileage. But, India had a multiplicity of gauges that adds a wrinkle to the calculation. Approximately half of the network in 1912 was on the 'standard' gauge (5ft. 6 in.) and just under half was meter gauge (3ft. 3in.). The remaining parts of the network were narrow gauge (2ft. 6in. and 2ft.). We include in the estimates an adjustment for differences in gauge by weighting miles according to their width, with 5ft. 6in. being the base mile. The result is to convert the number of railway kilometers to standard gauge units, with one km of meter gauge and narrow gauge track representing 0.59 and 0.45 km of standard gauge track based on their relative width.

Similar to the literature, we arrive at the contribution of railway capital to per-capita income growth in three steps. First, we calculate the growth rate of railway km per-capita between 1860 and 1912. Weighing the miles by gauge width gives us a rate of 6.8% per year. Second, we calculate the average ratio of railway profits (net operating revenues) and nominal GDP every ten years approximately in 1860, 1872, 1882, 1891, 1901, and 1912. Nominal GDP is available for a few years before 1900 so the early GDP figures must be read with caution.[19] This gives an average ratio of 1.08. Third, we multiple the annual growth rate of railway km per-capita with the ratio of profits to GDP to arrive at the contribution of railway capital.

5 Growth Contribution in Comparative Perspective

We are now ready to estimate the growth contribution of Indian railways to GDP per-capita between 1860 and 1912. In table 7, we report the estimates for India and LA4,

[18] We present comparative statistics for India, Argentina and Mexico for 1913 using the Comparative Railway Statistics published by the Bureau of Railway Economics (1916).

[19] The GDP estimates come from Sivasubramonian (1997) after 1899 and Heston (1983) before.

our comparison set of countries. We report two estimates for India. The first estimate is what we regard as the best estimate of the growth contribution of railways because it includes railway profits in the TFP term and accounts for walking costs in the estimates for passenger savings and surplus. One could also view this as the most favorable estimate of the surplus generated by Indian railways because profits increase the TFP term and walking costs increase passenger social savings of railways. The second estimate excludes profits and walking costs to make the Indian calculation comparable to LA4 that do not include profits or walking costs (Herranz-Loncán, 2014).[20]

We first focus on the TFP term, which represents the annual increase in GDP per-capita due to greater consumer surplus from railway freight and passenger transport, and due to greater railway profits. To calculate the contribution of the TFP term to per-capita income growth between 1860 and 1912, we first estimate the ratio of absolute TFP per-capita to the difference in income per-capita between 1860 (the beginning of the railway era) and 1912. Then we multiple this ratio with the annual growth rate of income per-capita, which yields the annual contribution of TFP in percentages reported below the time period in table 7. The best-case estimates for TFP suggest Indian railways added 0.21% to GDP per-capita per year. When compared to LA4 the Indian TFP term is larger than in Uruguay, comparable to Brazil, and smaller than in Mexico and Argentina.

Apart from Uruguay, the comparative TFP gains correspond closely to the growth differences between India and LA4.[21] Argentine and Mexican GDP per-capita between 1860 and 1910 was higher than India, while Brazilian GDP per-capita growth was comparable. Similarly, the TFP contribution in Argentina and Mexico was twice the contribution in India. In Brazil the TFP contribution was similar to India. In terms of productivity gains Indian railways look moderately successful when compared to railways in similar developing countries. The estimates for India excluding profits and walking costs are smaller, but they do not materially change the conclusions. In this case, India is closer to Uruguay than to Brazil, but still smaller than Argentina or Mexico.

Adding the TFP term to the capital term generates a total contribution of 0.29% per year for Indian railways. This is a sizable effect compared to GDP per-capita growth. According to Maddison's estimates Indian GDP per-capita increased at a relatively slow rate of 0.39% per year from 1860 to 1912. Strikingly railways accounted for 73% of this total growth. It is no wonder that railways have been credited with having a large impact

[20]There are two estimates for Brazil in the literature. We use the smaller estimate, which is based on a more plausible estimate of the cost of living increase in Brazil.

[21]Railways had a small bang in Uruguay because of the low output of railways and the limited advantage they conferred over alternate means of transport.

on the Indian economy. Since capital only accounts for 20% of railway contribution, the patterns on total growth contribution are similar to those for the TFP term. Indian railways increased income per-capita at a similar annual rate as in Brazil, but made less than half the contribution of railways in Argentina. Compared to Mexico, Indian railways also look less impressive contributing less than two-thirds as much to income per-capita growth. Only when compared to Uruguay did Indian railways have a bigger impact on growth.

Scaling the contribution of railways by total GDP per-capita growth offers another perspective. Here Indian railways account for a larger portion of the total GDP per-capita growth than in LA4. One reason is that Latin American economies grew more rapidly than India, especially Argentina and Mexico with average growth rates of 2.6% per year. The one exception is Brazil which shared a similar growth rate to India and where railways account for a comparable share of total GDP per-capita growth.

We dig deeper into the differences by decomposing freight and passenger social savings in table 8. The top panel focuses on freight. The social savings in freight were relatively large in India at 27% of 1912 GDP. India was similar to Mexico, larger than Argentina and Brazil, and significantly larger than Uruguay. What accounts for the difference? In rows 3 and 4, we decompose the social savings into two terms: (1) the ratio of the alternative fare and the railway fare minus 1 and (2) railway revenues as a percentage of 1912 GDP. These two terms multiplied together equal the social savings. Indian railways generated large social savings in freight because of the high ratio between alternative and railway freight rates. The alternative freight rate was 16 times larger in India compared to railway freight rates. In Mexico it was only 10 times larger and much less in Argentina and Brazil. The high ratio in India was a function of both low productivity of pre-railway transport and the relatively high productivity of its railways.[22] The second component of social savings is the share of railway revenues in GDP. In India, this figure was low, which lowered the social savings. Indian freight revenues were 1.7% of GDP compared to 3.6% in Argentina and 2.9% in Brazil. This suggests Indian railways did not penetrate the economy as deeply as elsewhere.

After we account for the price elasticity of demand, the additional consumer surplus from freight is 6% of GDP in India (row 2, table 8). The estimated surplus from railways is much larger in Argentina, Brazil and Mexico because they had less elastic demand. Demand elasticity in LA4 averaged just under -0.6. If we use the smaller estimate of elasticity (-0.66) found in table 4, consumer surplus from freight savings rises to 7.9%. One takeaway is that

[22]In Bogart and Chaudhary (2013) we provide evidence documenting the high productivity of Indian railways compared to other sectors in India and other railways around the world.

economic structure as reflected in elasticity of demand was significant in determining the effects of railways.

In the bottom panel we focus on passenger social savings. We do not report the additional consumer surplus here because we assumed India had the same elasticity as LA4. Thus, there is no variation coming from estimates of elasticity. If we exclude walking costs, the majority of India's social surplus in passenger transport comes from upper-class passengers, again similar to Brazil.[23] Focusing on the lower-class, India has the smallest social savings of passenger railway transport at 0.002% of GDP. Here the penetration effect was not the problem. Lower class passenger revenues were 0.81 percent of GDP in India and are higher than in LA4. One factor that lowered the time savings was the relatively slow speed of passenger trains in India compared to the alternative. The other factor was the relatively high passenger fares in India compared to lower class wages. The ratio is reported at the bottom of table 8. Notice that in Argentina the ratio of lower class fares to wages is much lower and as a result the social savings from passenger travel was much larger in Argentina than India.

We subject our calculations for India to a variety of robustness checks. We summarize a few key ones here. First, we replaced the 2-bullock freight rate with the 4-bullock cart rate to calculate the average freight rate for pre-railway transport. Switching to this marginally cheaper rate had no significant impact on the estimates. Additional consumer surplus in freight went down to 9.37% compared to 9.46%, and the TFP term contribution remained the same at 0.21% per year. Second, we assumed as suggested by Bourne (1849) that in the absence of railways 90% of the traffic would have been transported over water (river or coast) as compared to the 60% used in our calculation. Applying this alternate counterfactual distribution of freight transport between land and water reduces the total consumer surplus from 9.46% of GDP to 8.75%, and the TFP contribution goes to 0.20. Again this is not a huge different and can perhaps be viewed as a lower bound of the TFP contribution. Third and finally, we used the lower end of the fare range noted in the historical sources for 1^{st}, and 2^{nd} plus 3^{rd} class travel. This had no significant impact on the total consumer surplus or TFP contribution.

[23] Upper-class in India includes 1^{st}, 2^{nd} and 3^{rd} class, and 1^{st} class in LA4. Lower-class includes 4^{th}class in India and 2^{nd} class in LA4. LA4 had fewer classes of service compared to India.

6 Conclusion

Colonial Indian railways provide an interesting case to examine the growth contribution of ICTs. Several studies have documented large effects of railways on the colonial Indian economy. However, such conclusions sit uncomfortably with the fact that India fell behind other economies in the height of the 'railway era' from 1860 to 1912. This paper takes a macro approach and evaluates the growth contribution of Indian railways in a comparative context. It examines whether Indian railways made a larger or smaller contribution to income per-capita growth than did railways in Argentina, Brazil, Mexico, and Uruguay. We find that Indian railways contributed 0.29% per year to income per-capita growth, which is less than the 0.527% to 0.648% annual contribution of railways in Argentina and Mexico.

Our decomposition calculations show that the smaller growth contribution in India is related to four factors: (1) the smaller size of railway freight revenues in the Indian economy, (2) the more highly elastic demand for freight services, (3) lower wages, and (4) and higher fares. Smaller freight revenues suggest that Indian railways did not penetrate the Indian economy as much as elsewhere. More research is needed to understand why. The highly elastic demand for railway freight is also puzzling. It could be linked to the commodities India exported, like cotton. Or it might have to do with the expansion of cultivation following the spread of railways.

The other two factors are related to passenger transport. The role of lower wages in influencing social savings has been under-appreciated to date. Time savings were one of the main benefits of railways in developed countries like Britain (Leunig 2006). Of course, the value of time rises with wages and India's economy around 1912 had the lowest wages of any major economy outside of China. The last factor, India's high passenger fares could be considered a policy failure. India might have increased passenger traffic by lowering fares. The result would have been a larger social savings. Whether such a policy would have worked in India is worthy of future research. Railway commentators such as Ghose (1927, p. 82) were skeptical. Ghose remarked that cheap travel allowed the poor of Europe to travel more, but in India the causes of travel were different and its population was too rural.

Finally, Indian railways had low freight rates relative to pre-existing rates. There were two factors at work here. First, India's pre-railway transport was unproductive. Perhaps the best indicator is the wide-spread use of pack bullocks. In Britain, packhorses largely disappeared in the 18^{th} century, and were replaced by wagons and carts. In mid-19^{th} century India bullock carts had displaced pack bullocks only in the regions near Bengal. Second, Indian railways were relatively productive. A cross-country comparison of total factor productivity in 1913 put Indian railways ahead of Argentina (Bogart and Chaudhary 2013). Railway freight transport appears to be one of the most productive sectors in India by international standards. The high productivity is one reason why Indian railways were so profitable in 1912. Our bottom line is that railways were the most important driver of economic growth in India before 1913, but they contributed less to Indian (and also Brazilian) economic growth than railways in more dynamic economies like Argentina. The results parallel the findings in the ICT literature that communications technologies contribute less to per capita income growth in less developed economies, but they account for a larger share of total per capita growth.

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Figure 1: Railway Map of India, 1909

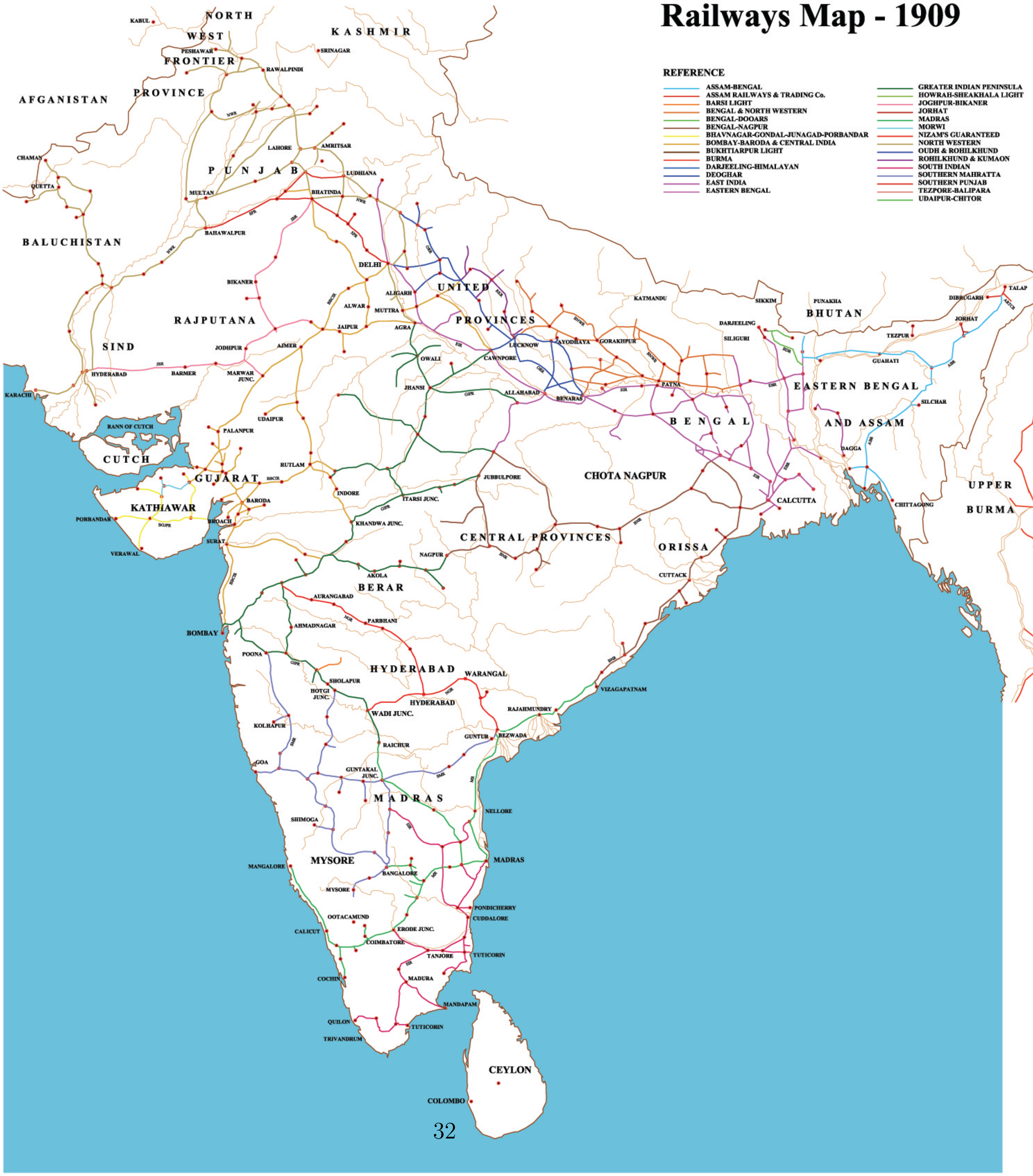

Figure 2: Taffic Categories on Indian Railways, 1883-1912

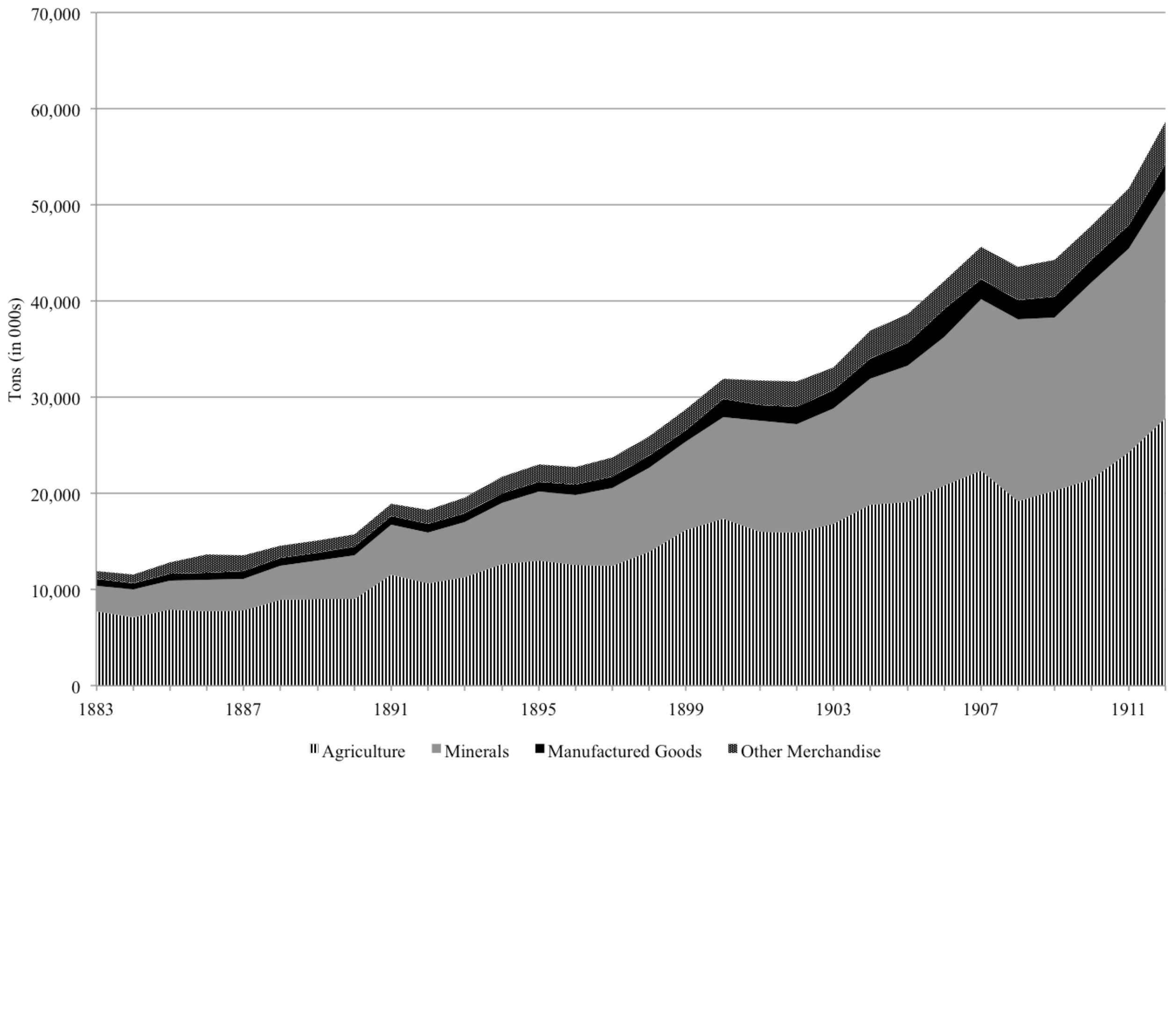

Table 1: Observed Freight Rates

	As Given (pies per maund mile)	Rupees per ton km	1912 Rupees per ton km	Ratio to Railway Freight Rate
Road Transport (Derbyshire, 1987)				
Pack Bullock	2.5	0.243	0.499	35.65
2-Bullock Carts	1	0.097	0.200	14.26
4-Bullock Carts	0.8	0.078	0.160	11.41
River Transport (Derbyshire, 1987)				
Downstream	0.25	0.024	0.050	3.56
Upstream	0.4	0.039	0.080	5.70
Coastal Transport (Assumption)			0.021	1.53

Sources: Derbyshire (1987). To convert Derbyshire's pies per maund into rupees per ton km, we first divided the pies per maund by 192 to convert o rupees, then multiplied by 0.621 to convert miles to km, and finally multiplied by 30 to convert maunds to tons. We used the Price Index reported in Allen (2007) and Studer (2008) to convert the nominal figures from the 1850s to 1912 freight rates.

Table 2: **Share of Traffic by Alternate Modes and Railways**

Railway System	2-bullock cart	Pack bullock	River	Coastal	Ton km (000s)
Near Navigable Rivers					
Assam Bengal	0	0.4	0.6	0	195
Bengal and Northwestern	0.4	0	0.6	0	627
Eastern Bengal	0.4	0	0.6	0	960
East Indian	0.4	0	0.6	0	8,804
Northwestern	0	0.4	0.6	0	4,528
Oudh and Rohilkhand	0.4	0	0.6	0	721
No Navigable Rivers					
Bengal Nagpur	0.4	0	0	0.6	2,029
Bhavnagar-Gondal	0	0.4	0	0.6	47
Bombay, Baroda, and Central India	0	1	0	0	1,224
Great Indian Peninsula	0	1	0	0	3,728
Jodhpor-Bikaneer	0	1	0	0	206
Madras	0	0.4	0	0.6	1,187
Nizam	0	1	0	0	324
South Indian	0	0.4	0	0.6	589
Rajputana Malwa	0	1	0	0	1,087
Rohilkand Kumaon	1	0	0	0	105
Udaipur Chittor	0	1	0	0	3
India (weighted average)	0.20	0.35	0.36	0.09	

Sources: See text and Figure 1 for details. The data on ton-km is from Great Britain (1913).

Table 3: Railway Freight Traffic in the Counterfactual

	Rail Traffic 1912	Freight Rates (rupees/ton-km)	
		Donaldson	Direct Observation
Road, 2-bullock cart	20.34%	0.11	0.20
Road, pack bullock	34.86%	0.11	0.50
River	36.04%	0.05	0.05
Coastal	8.77%	0.06	0.02
Weighted Average		0.08	0.23

Sources: See tables 1 and 2.

Table 4: Price Elasticity Estimates for Freight on Indian Railways

	Dependent Variable: Ln (Freight Ton Miles)			
	(1)	(2)	(3)	(4)
Ln(Freight Rate)	-0.9489**	-0.7298***	-0.8384***	-0.6578***
	[0.3890]	[0.1828]	[0.1960]	[0.1580]
Ln(Miles)	1.5246***	0.9655***	0.9690***	1.1128***
	[0.1109]	[0.0855]	[0.0874]	[0.0678]
Density (Train miles/Total Miles)				0.0003***
				[0.0001]
Year	-0.0153**	0.0175***		
	[0.0059]	[0.0055]		
Railway FE	No	Yes	Yes	Yes
Year FE	No	No	Yes	Yes
Observations	569	569	569	568

*** $p<0.01$, ** $p<0.05$, * $p<0.1$ Robust standard errors clustered at the railway-level in brackets. The unit of analysis is railway-system*year from 1880 to 1912. See Bogart and Chaudhary (2013) for details on the construction of the railway-level panel.

Table 5: Social Savings of Freight Railway Transport in India

	Direct Observation	Direct Observation
Railway freight output (million ton-km)	24,611	24,611
Railway rate in rupees per ton-km	0.014	0.014
Pre-railway rate in rupees per ton-km	0.23	0.23
Social savings (million rupees)	5,430	5,430
SS as % of GDP	26.57	26.57
Price Elasticity of Demand	-0.66	-0.84
Consumer Surplus (million rupees)	1,617	1,216
As a % of GDP	7.91	5.95

Sources: We use Sivasubramoniam's (1997) estimate for 1912 nominal GDP and Great Britain (1913) for 1912 railway freight output.

Table 6: Passenger Social Savings for Indian Railways

	1st class	2nd and 3rd class	4th class	4th class, walking cost
Passenger km (millions)	142.40	1,400.30	22,191.21	22,191.21
Railway Fare (rupees per km)	0.046	0.016	0.007	0.007
Pre-railway Fare	0.64	0.43	0	0.028
Railway km/hr	36.48	36.48	36.48	36.48
Pre-railway km/hr	6.44	4.12	3.57	3.57
Hourly wage (rupees)	0.928	0.118	0.059	0.059
Price Elasticity of Demand	-1	-1	0	0
Savings transport costs (million rupees)	84.22	582.74	-165.11	456.24
Savings time costs (million rupees)	8.45	17.79	165.43	165.43
Total savings (million rupees)	92.67	600.53	0.31	621.67
Total savings as % of GDP	0.45	2.94	0.002	3.04
Consumer surplus (million rupees)	19.2	76.6	0.31	621.7
Consumer surplus as % of GDP	0.09	0.38	0.002	3.04

Sources: See Ramarao (1998) and text for details on pre-railway fares. See Great Britain (1913) for passenger km, railway fares and railway speed. We use the wage reported in Allen (2007) and Sivasubramoniam's (1997) estimate for 1912 nominal GDP.

Table 7: India and Latin America

	India best estimate	India most similar to LA4	Argentina	Brazil	Mexico	Uruguay
Total Consumer Surplus (million rupees/pesos/milreis)	1,934	1,312	336	622	368	9
As a % of GDP c. 1913	9.46	6.42	13.46	10.93	11.88	2.78
Railway Profits (million rupees)	74.91	0	0	0	0	0
As a % of GDP c. 1913	0.37	0	0	0	0	0
Time Period for Growth	1860-1912	1860-1912	1865-1913	1864-1913	1873-1910	1874-1913
TFP term: Contribution to per-capita income growth (% per year)	0.21	0.14	0.53	0.26	0.45	0.09
Railway Capital: Contribution to per-capita income growth (% per year)	0.074	0.074	0.115	0.051	0.079	0.028
Total Railway Contribution (% per year)	0.29	0.21	0.65	0.31	0.53	0.11
Annual growth rate of GDP per-capita (% per year)	0.39	0.39	3	0.5	2.17	1.35
Railway Contribution as % of GDP growth	73.4	54.6	21.6	61.6	24.3	8.4

Sources: Herranz-Loncán (2014) for LA4, and tables 5-6 for India.

Table 8: Decomposition of Freight and Passenger Social Savings

	India	Argentina	Brazil	Mexico	Uruguay
Freight					
Social Savings as a % of GDP	26.6	20.6	18.8	24.3	3.8
Additional CS as % of GDP	5.95	11.61	8.97	11.48	2.19
(Pre-railway freight rate/railway rate)-1	16.01	5.66	6.47	9.48	2.66
Freight Railway Revenues as % of GDP	1.7	3.6	2.9	2.6	1.4
Passenger					
Upper-class SS as % of GDP	3.39	0.70	3.58	0.65	2.27
Lower-class SS as % of GDP (no walking costs)	0.00	1.31	0.77	0.06	0.18
Passenger, Lower-class					
Passenger Railway Revenues as % of GDP	0.81	0.61	0.47	0.40	0.53
Railway Time Savings as % of GDP	0.81	1.92	1.25	0.46	0.70
(Railway KMPH/Pre Railway KMPH)-1	9.28	12.13	12.00	12.33	10.46
Fare/Hourly wage	0.13	0.05	0.06	0.13	0.12

Sources: Herranz-Loncán (2014) for LA4, and tables 5-6 for India.

Appendix Table 1: Average Freight Rates across the Major Railway Systems, 1912

Railway system	Ton km (millions)	Average freight rate (rupees per ton km)
East Indian	8,804	0.0081
Bengal Nagpur	2,029	0.0123
Northwestern	4,528	0.0151
Oud and Rohilkand	721	0.0153
Assam Bengal	195	0.0161
Great Indian Peninsula	3,728	0.0163
Bengal and Northwestern	627	0.0174
Rajputana Malwa	1,087	0.0182
Bombay Baroda, and Central India	1,224	0.0185
Rohilkand Kuman	105	0.0185
Eastern Bengal	960	0.0194
Madras	1,187	0.0200
Jodhpor-Bikaneer	206	0.0208
Nizam	324	0.0218
South Indian	589	0.0224
Bhavnagar-Gondal	47	0.0304
Udaipur Chittor	3	0.0512

Source: Great Britain (1913).

Appendix Table 2: Railway Profits in India and LA4

	India, 1913-14	Argentina, 1913	Mexico, 1913
Revenues (million dollars)	206.27	134.92	28.6
Operating costs (million dollars)	106.83	84.69	18.07
Capital Costs (million dollars)	58.78	53.51	23.83
Total Costs (million dollars)	165.61	138.2	41.89
Profits (million dollars)	40.66	-3.28	-13.29
Profits (million rupees/pesos/M. dollars)	125.34	-3.4	-26.66
Profits as a % of GDP	0.61	-0.14	-0.89

Source: Comparative Railway Statistics United States and Foreign Countries, 1913 (Bureau of Railway Economics, 1916, pp. 21-22, 46, 50).