# The Growth Contribution of Colonial Indian Railways in Comparative Perspective[*]

Dan Bogart[†]
Latika Chaudhary[‡]
Alfonso Herranz-Loncán[§]

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## Abstract

Railways were an important driver of global economic growth in the 19*th* and early 20*th* centuries. While their role is well documented in industrial economies, we know less about their macro-economic impact in developing countries. In this paper, we first estimate the aggregate growth impact of Indian railways, one of the largest networks in the world in the early 20th century. Then, we compare their impact in India to four emerging Latin American economies (Argentina, Brazil, Mexico and Uruguay) and the Cape Colony. Using growth accounting techniques common to the cross-country estimates, we argue the aggregate growth impact of Indian railways was significant, increasing Indian GDP per capita by 13.8% by 1912. We also find that the growth impact of Indian railways was similar to Brazil and Mexico, but smaller than Argentina and the Cape. Compared to the latter two, India had a smaller size of railway freight revenues in the economy and lower wages to fares leading to lower passenger time savings. Railways were the most important infrastructure driver of economic growth in India during first era of globalization from 1860 to 1912, but they contributed less than in richer and more dynamic developing economies.

*Keywords*: Globalization, Railways, Social Savings, India, Growth Accounting

*JEL Codes*: N7, O47, P52, R4

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[††] Professor, Department of Economics, UC Irvine, Email: dbogart@uci.edu.

[‡] Associate Professor, Department of Defense Management, Naval Postgraduate School, Email: lhartman@nps.edu.

[§] Professor, Department of Economic History, Institutions, Politics and World Economy, University of Barcelona, Email: alfonso.herranz@ub.edu.

# 1 Introduction

After their early construction in Britain, the new technology of railways spread across the world in the 19th century and by the start of World War I they were a key engine of economic growth. By lowering transport costs, reducing price dispersion, integrating markets, and extending frontiers, railways increased incomes in many parts of the world. Indeed, they were a fundamental driver of the first wave of globalization along with the steamship (O'Rourke and Williamson 2002, Jacks, Meissner and Novy 2010, Pascali 2017). While an extensive literature documents the effects of railways in individual countries, we know less about the magnitude of their macro-economic impact in less developed economies.[1]

We address this gap by studying the comparative macro-economic growth impact of railways in India. Railways were massively important to the Indian economy and have been described as 'engines of change' (Kerr 2007). The literature has documented that during the colonial era, Indian railways increased market integration, agricultural incomes, literacy, and to a smaller extent urbanization.[2] Moreover, over time Indian railways became much more productive in delivering freight and passenger services.[3] However, a comprehensive accounting of their macro-impact has not been made.[4] Using data between 1860 and 1912, we offer the first estimate of railways' contribution to Indian macro-economic growth. We then compare railways impact in India to five large developing economies.

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[1] There are some exceptions, as railways macro-impact has been studied in countries like Brazil (Summerhill 2003, 2005), Mexico (Coatsworth 1979, 1981), Argentina (Herranz-Loncán 2011a), Uruguay (Herranz-Loncán 2011b), and the Cape Colony (Herranz-Loncán and Fourie, 2018) among others.

[2] See Collins (1999), Andrabi and Kuehlwein (2010), Donaldson (2018), Chaudhary and Fenske (2023), and Fenkse, Kala and Wei (2023).

[3] See Bogart and Chaudhary (2013, 2015).

[4] Hurd (1983) estimated the social savings on Indian freight traffic to be 1.2 billion rupees or 9 % of national income in 1900. But, he offered no details on the assumptions and data used to arrive at that estimate. Derbyshire (1987, 2022) makes estimates of railways' growth impact on North India.

Our comparison set includes an African British colony (the Cape) and four Latin American independent countries (Argentina, Brazil, Mexico, and Uruguay). The time frame, 1860 to 1912, captures the development of the main rail network across these countries. Together with India, they accounted for 58 percent of the total railway length in Latin America, Asia, and Africa as of 1912. Like India, the comparison economies relied heavily on primary product exports and had relatively less developed manufacturing sectors.

Yet, there were important differences between the six countries, as seen in Table 1. Argentina, the Cape, and Uruguay had lower populations, higher rail density, and (in the case of Argentina and Uruguay) higher per capita income in 1860 than the rest. Along with Mexico, their subsequent GDP per capita growth was also higher. According to Maddison project data, India's per-capita income in 2011$ increased by 23% between 1860 and 1912 (from 896 to 1098), whereas the average of Mexico, Argentina and Uruguay increased by 123% (from 2027 to 4510).[5] Brazil is perhaps the most similar to India in terms of 1860 GDP per capita and its lower income growth in this period. Lastly, both India and the Cape were British colonies where most of the railway network was under public ownership by 1912. Unlike them, the four Latin American economies were independent republics where their railways were largely under private ownership circa 1912 (Bogart 2010, Bignon et al. 2015).

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[5] The income per capita data are taken from the Maddison Project Database (2020 version), reported in purchasing power parity (PPP) adjusted dollars at 2011 prices. This database does not report figures for the Cape but for the whole of South Africa. However, recent estimates of GDP per capita for the Cape Colony, available in Magee et al. (2016) would indicate an even higher growth rate between 1861 and 1909 than in Argentina, Mexico and Uruguay. The comparison with the two largest Australian colonies (Victoria and New South Wales) during that period presented in that paper would also indicate that the Cape reached GDP per capita levels around half of those of these two Australian colonies at the end of the railway era and therefore (given the Australian GDP pc levels by then) significantly higher than Indian ones.

**Table 1. Population, railway mileage and GDP per capita of comparison countries in 1912**

| | Population (million) | Railway mileage (km) | Railway mileage per 1,000 pop. | GDP per capita c1860 in $2011 | GDP per capita c1912 in $2011 |
|---|---|---|---|---|---|
| India | 303.4 | 53,887 | 0.18 | $896 | $1,098 |
| Argentina | 7.4 | 32,212 | 4.37 | $2,160 | $6,223 |
| Brazil | 23.2 | 23,491 | 1.01 | $991 | $1,042 |
| Cape Colony | 2.6 | 3,979 | 1.55 | na | na |
| Mexico | 15 | 20,447 | 1.36 | $921 | $2,131 |
| Uruguay | 1.1 | 2,522 | 2.2 | $3,000 | $5,176 |

*Sources*: The data on population and railways mileage are for 1912, except for the Cape population (for 1911). Railway mileage comes from Mitchell (2003a, 2003b), and population and GDP per capita data from Maddison Project Database (version 2020; see Bolt and van Zanden, 2020), except for the Cape Colony mileage and population, for which railway length and population come from Union of South Africa (2018). Specifically, GDP data for India are from Broadberry, Custodis and Gupta (2015), for Argentina, Bértola and Ocampo (2012), for Brazil, Barro and Ursúa (2008), for Mexico, Prados de la Escosura (2009) and Barro and Ursúa (2008), and for Uruguay, Bértola (2016). The 1860 GDP per capita for India is for 1861 (the nearest years with non-missing data).

Our estimation draws on the growth accounting framework used to measure the impact of new technologies like steam power, electricity, and information and communication technology (Bakker et al. 2019, Byrne et al. 2013, Crafts and Woltjer 2019). Most related to our work, growth accounting has been used to quantify the macro-economic impact of railways and the underlying channels, including freight cost savings, passenger fare savings, passenger time savings, railway profits, and capital accumulation (Crafts 2004a, 2004b, Leunig 2006, 2010, Herranz-Loncán 2006). Such an accounting framework is also ideal for cross-country comparisons (see Herranz-Loncán 2014) and enables us to answer our main research questions: (1) how large was the contribution of railways to Indian GDP per capita growth, and (2) how did it compare to similar economies in the world?

We find that railways made a very large contribution to income per capita growth in India. In our preferred estimates, railways contributed 0.25 percentage points to annual income per capita growth in India from 1860 to 1912, which implies they increased GDP per capita by

13.65% in 1912. In sensitivity tests we find the aggregate growth impact is only marginally reduced under plausible alternative assumptions. Most of the growth came from greater productivity in the transportation of freight and investment in railway capital. In comparison, the productivity gains from Indian passenger services, including the time savings from faster trains, were small.

We then compare our India estimate to those for Argentina, Brazil, Mexico, Uruguay, and the Cape Colony where previous studies have used a similar growth accounting framework.[6] These studies find that railways had a large impact in these economies, except for Uruguay. Railways contributed 0.23 percentage points to annual income per capita growth in Brazil and 0.29 percentage points in Mexico from 1860 to 1912, similar to India. The annual growth impact was significantly larger in Argentina (0.35%) and the Cape (0.37%).

Why was the growth contribution of Indian railways smaller than in Argentina and the Cape? Our decomposition exercise for freight finds Indian railway traffic and revenues as a share of GDP were smaller than in these countries. Such a modest ‘penetration’ of railways suggests that Indian workers and communities did not fully assimilate into the global economy after the arrival of railways. In a similar decomposition exercise for passengers, we find lower Indian wages reduced the time savings from faster railway speeds compared to past transport modes. The time savings were considerable in higher wage economies like Argentina. Additionally, higher Indian railway fares relative to wages further reduced the TFP gains. Working in the favor of Indian railways the pre-rail transport system was more inefficient, raising their growth impact overall. We also find that Indian railways were more profitable in 1912 compared to the other countries, where some earned negative profits.

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[6] The estimates for the comparison economies are our own calculations based on Coatsworth (1979), Summerhill (2005), Herranz-Loncán (2014), and Herranz-Loncán and Fourie (2018).

Summarizing, railways were the most important singular driver of economic growth in India between 1860 and 1913, accounting for over 60% of all per capita income growth in this period. Yet, they made a smaller contribution to Indian economic growth compared to some other countries because of India's higher population to rail density, relatively low wages, and smaller freight revenues. The latter may be related to India's relatively low route miles per capita, lower agricultural productivity, or some combination of the two. Income also seems to have been a factor. In initially richer countries, like Argentina where income per capita at the beginning of the rail era was more than twice as large as India, their more developed economies seem to reaped higher benefits from railways.

Our paper contributes to the growing literature that compares the historical performance of countries along different dimensions (e.g., Chaudhary et al. 2012, Prados de la Escosura 2021). A large comparative project examines how GDP and GDP per capita evolved across modern day countries (e.g., see the Maddison Project summarized by Bolt and Van Zanden 2020). One conclusion of that literature is that the difference in income between the richest and poorest economies did not narrow during the first globalization era, and widened for Asian economies. Another related literature focuses on the comparative evolution of productivity (Broadberry 1997, Allen 2012, Bakker et al. 2019, Prados de la Escosura et al. 2021) These studies argue for large differential rates of capital accumulation and TFP growth across economies, with long-run implications for income divergence. Given its size and colonial status, India features prominently in the literature as an example of a large economy whose growth stagnated relative to the developed countries in the 19th and 20th centuries. We contribute to this comparative perspective finding that railways were an important driver of absolute income per capita growth in India, though their relative contribution was smaller than in some other parts of the world.

Our results also speak to the literature on the evolution of the Indian economy. Past nationalist accounts point to colonialism as the root cause of the relative decline of the Indian economy.[7] In contrast, recent work highlights the divergence between India and Europe in the early modern period (Broadberry and Gupta 2006), the low productivity of Indian agriculture (Broadberry and Gupta 2010, Ronnback and Theodoridis 2022) and the central role of geography and unreliable water supply (Roy 2022). Railways have often appeared in these discussions as either an example of poor colonial investments (Satya 2020, Sweeny 2011) or a productive sector of the colonial economy (Bogart and Chaudhary 2013, Chaudhary 2023). Our results are unambiguous that Indian railways increased income per-capita growth in absolute terms. The Indian economy in 1912 would have been much smaller without railways.

Finally, our paper complements studies, which estimate the impact of Indian railways on different outcomes.[8] The most related is Donaldson (2018), which estimates the effect of railways on trade costs, compared with alternatives such as roads or rivers, and finds a significant impact of railways on Indian agricultural incomes. Our work also significantly expands on prior estimates of freight social savings for Indian railways by Hurd (1983) and for North India by Derbyshire (2022). Combining different estimates of the cost advantages of railways with the growth accounting framework, we find railways were a big driver of Indian income growth before World War I.

The rest of the paper is organized as follows. Section 2 provides a brief background on railways in India and the comparison economies. We describe the growth accounting methodology in Section 3. Section 4 describes each component of the growth contribution of railways for India. Section 5 summarizes the comparative patterns on the different components,

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[7] For a survey of works on colonialism and the Indian economy see Roy (2002).

[8] See Mukherjee (1980), Hurd (2007), Andrabi and Kuehlwein (2010), Chaudhary and Fenske (2023), Fenkse, Kala and Wei (2023),

while Section 6 compares the total growth contribution of railways in India and the other countries. Section 7 concludes.

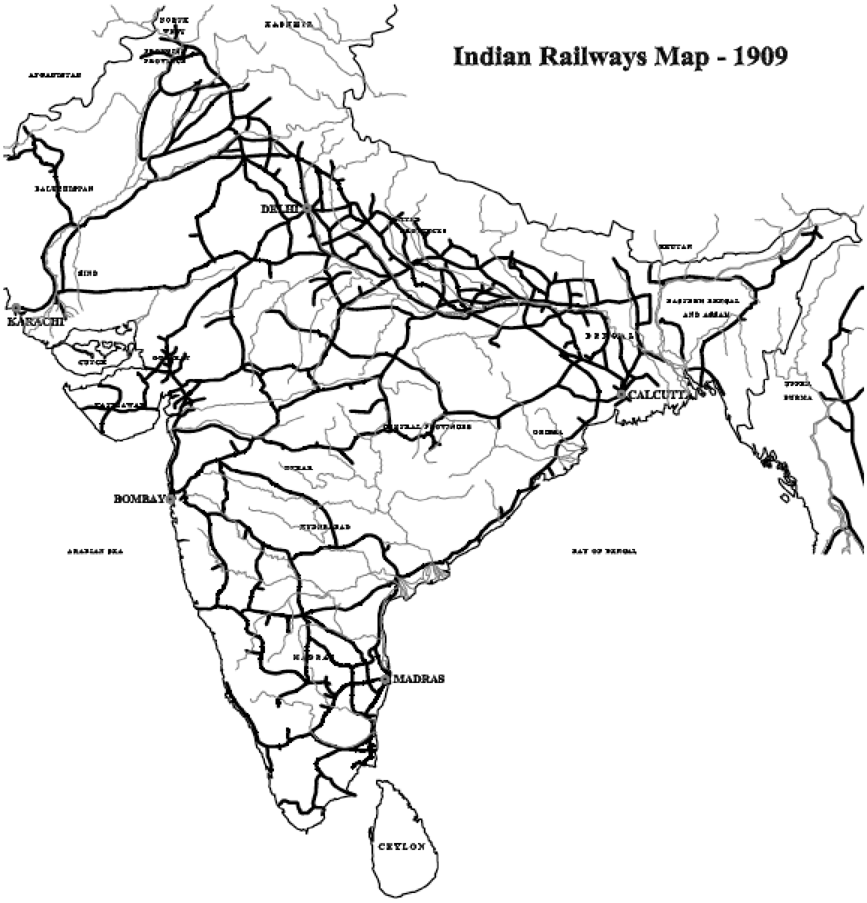
## 2 Historical background

By most accounts India's transportation sector was costly and unproductive at the beginning of the railway era (Mukherjee 1980, Derbyshire 1987). India had many rivers, but they were often not navigable or seasonal as in the case of the Ganga and the Indus. India also had a long coastline, but shipping was hampered by seasonality and changing winds. There was a road network, but quality roads were scarce as we discuss below.

The first rail 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. 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 20th century railways spread to most parts of India as seen in Figure 1, showing the network in 1909. The main lines connected the ports of Bombay, Calcutta, Madras, and Karachi and their hinterlands. A dense interior network was constructed between Delhi and Calcutta along the Ganga River, where railways served some long-standing population centers and newer towns that emerged along railway tracks (Derbyshire 2022). However, outside of the links with Delhi there were fewer interior-to-interior connections, especially in central and southern India.

**Figure 1. Railway map of India, 1909.**



The construction and management of colonial railways involved private British companies, the colonial Government of India (GOI), and Indian Princely States.[9] In the first phase up to 1869, private British companies constructed and managed trunk lines. They invested huge amounts of capital, aided by a public guarantee. In other words, the dividends of the private British railway companies were guaranteed to be 5%, shifting the risks to the GOI and effectively the Indian taxpayer. In the second phase, the GOI began constructing and managing railways in the 1870s. The third phase, beginning in the early 1880s, involved partnerships between the GOI as majority owner of the lines and private companies as operators. By 1912, there were 17 major railways systems of various organizational forms, most operating under majority ownership of the GOI.[10]

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[9] See Sanyal (1930) for a detailed overview of the regulatory history of Indian railways.

[10] Note we exclude Burma railways from the 17 major railways systems in India.

Freight services accounted for about two-thirds of Indian railway revenues in 1912. Agriculture was the largest traffic category and included grains (wheat and rice), oilseeds, pulses, cotton, tea, and jute (Morris and Dudley 1975, p. 39). As the largest source of Indian exports, they were the core of traffic between the hinterlands and the ports. The second largest traffic category was minerals, with coal being 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% of revenues between 1883 and 1912.

Indian freight rates were set by each railway system, subject to some regulation. Rates were applied to five general classes of goods plus two special rates for grains and coal. The GOI set a uniform maximum rate to prevent the exercise of monopoly power, and a minimum rate to prevent excessive competition. The relatively wide range between the max and min rates meant the operating systems had some leeway. Collusion was prevalent and even supported by the GOI. Ghose, a contemporary economist of Indian railways, argued that the primary objective of rating policy was to obtain an adequate net revenue, while at the same time having regard for progressive development of the economy (1927, p 72). Ghose also argued that the demand for freight was not inelastic, noting that traffic increased when freight rates fell. Christensen's (1982) analysis of cases where freight rates fell also suggests demand was non-inelastic.

There were three main passenger classes for railways in India. The first class accounted for 0.6% of passenger traffic in 1912, the second for 5.9% and the third class was 93.5%. Naturally fares were highest for the first class, which was targeted to high-ranking British and Indian officials. Fares for the second class were meant for upper class Indians and lower-class Europeans and Eurasians (Kerr 2007). The fare for the third, and largest class, was much less. It was not targeted to those with the lowest income in India, as according to Ghose an agricultural laborer would have to spend 2 days wages to travel 50 miles by train (1927, p. 83). Ghose also states that the primary reasons for travel were (1) business, (2) work, (3) pilgrimages, (4) marriage ceremonies, and (5) attending courts. Outside of business, the demand for these services was described as price inelastic.

The comparison economies shared important similarities with India. Brazil, Mexico, and Argentina also started building their railways very early, in the 1850s but, as with the latecomers, Uruguay and the Cape Colony, most of the construction took place in the 1880s and 1890s. In the four Latin American economies, railways were mostly private, but governments increased their involvement in the 20th century. Many railways were funded by British investors, although the participation of US capital was very important in Mexico and domestic capital remained significant in Brazil. By contrast, the Cape railways were built and managed by the colonial government. As in India, freight was the main source of revenue, and freight traffic was dominated by primary products, either for export or to supply domestic needs. Industrial commodities, though, were also a significant item, especially in the Cape Colony, and usually consisted of imports required to sustain development or luxury consumption. In all cases, the networks were designed to connect the interior with the main ports or, in the case of Mexico, the US border. As in the case of India, the alternative transport modes were generally under-developed, with the partial exception of water transport in Argentina and Uruguay. This explains the huge potential impact that railways were expected to have in most of these countries.

## 3 Methodology

The starting point for growth accounting is the following expression for increases in labor productivity:

$$\Delta(Y/L)/(Y/L) = s_K\,\Delta(K/L)/(K/L) + \Delta A/A \qquad (1)$$

where Δ is change over time, $Y$ is total output, $L$ is the total number of hours worked, $K$ denotes the services provided by the physical capital stock, $A$ is total factor productivity (TFP), and $s_K$ is the factor income share of physical capital. This expression has been used for estimating the growth contribution of specific technologies like ICT (Crafts and Woltjer 2021). For railways this requires transforming expression (1) into:

$$\Delta(Y/L)/(Y/L) = s_{KO}\,\Delta\,(K_O/L)/(K_O/L) + \gamma\,(\Delta A/A)_O + s_{KRW}\,\Delta\,(K_{RW}/L)/(K_{RW}/L) + \phi(\Delta A/A)_{RW} \qquad (2)$$

where $K_{RW}$ and $K_O$ are the services provided by the capital stock in railways and in other sectors, respectively, $A$ is the TFP level in the sector indicated by the subscript (railways and other), $s_{KRW}$ and $s_{KO}$ are the factor income shares of the capital invested in railways and other capital, and $\phi$ and $\gamma$ are the shares of railways and other sectors' production in total output. The growth contribution of railways is the sum of the last two terms of equation (2), the "capital term" and the "TFP term" respectively. We discuss each below.

As explained by Crafts (2004b) and Leunig (2010), The TFP term, $\phi\,(\Delta A/A)_{RW}$, is broadly equivalent to measuring the social savings of railways as a percentage of GDP, which is:

$$SS/GDP_t = (P_t^{TR} - P_t^{RW}) * (Q_t^{RW}/GDP_t) \qquad (3)$$

where $P_t^{RW}$ is the price of railway services in the reference year $t$, $Q_t^{RW}$ is the railway transport output in year $t$, and $P_t^{TR}$ is the price of the traditional or pre-railway transport services adjusted to the price level of reference year $t$. In our case, the reference year is 1912 and $P_{1912}^{TR}$ = $P_{1850}^{TR}/m_{1850}$, where $P_{1850}^{TR}$ is the weighted average price of road and water transport around 1850 when railways were being planned in India and $m_t$ the input price index for transport with base year equal to 1 in 1912. The weights for road and water transport will be discussed in the next section. To see the equivalence between TFP and social savings, note that productivity growth in the transport sector spanning the era from 1850 to 1912, can be written in its price dual form as (1/$P_{1912}^{RW}$ –$P_{1850}^{TR}/m_{1850}$)/($P_{1850}^{TR}/m_{1850}$), where the price of inputs in 1912 is normalized to 1. Substituting $P_{1912}^{TR}$ for $P_{1850}^{TR}/m_{1850}$ and rearranging terms gives the following expression for productivity growth: ($P_{1912}^{TR}/P_{1912}^{RW}$ –1). Multiplying productivity growth by the revenue share of railway transport in GDP ($\phi$ in equation 2) gives an expression for the TFP term as the social savings: [($P_{1912}^{RW}$ $*$ $Q_{1912}^{RW}$) / $GDP_{1912}$] * ($P_{1912}^{TR}/P_{1912}^{RW}$ –1), after factoring through $P_{1912}^{RW}$. The derivation reveals that the social savings has two components. The first is the share of railway revenues, ($P_{1912}^{RW}$ $*$ $Q_{1912}^{RW}$) / $GDP_{1912}$, which captures the penetration of railways in the economy by 1912. The second is the term ($P_{1912}^{TR}/P_{1912}^{RW}$ –1), which captures the relative cost efficiency of railways relative to the predecessor technology. We emphasize both in our analysis. We also make separate calculations for the social savings of freight and passengers services.

Note that expression (3) departs from the logic of the original social savings estimates made by Fogel (1964) and Fishlow (1965) because it uses the inflation adjusted price of alternative transport just *before* the advent of railways c.1850, e.g., $P_{1850}^{TR}/m_{1850}$. Consistent with the growth accounting framework, we are interested in the contribution of railways compared with their predecessor technologies and infrastructures, not compared to what alternative transport could have become, say through better roads or more canals. Therefore, we exclude productivity growth in road, river, and coastal transport after railways started in the 1850s. However, like previous works, we adjust the social savings down by relaxing the assumption of a price-inelastic transport demand. With the adjustment, we approximate the additional consumer surplus generated from introducing freight and passenger services.[11]

In addition to savings in transport rates, the TFP term should include passenger time savings in the reference year *t*, defined as:

$$TimeSavings_t = [(Travelhours_t^{TR} - Travelhours_t^{RW}) * (Valueoftime_t)]/GDP_t \qquad (4)$$

where the first term in parentheses is the difference in total hours travelled by traditional mode and railways. $Travelhours_t^{TR}$ is equal to $Q_t^{RW}/Speed^{TR}$, where $Q_t^{RW}$ are passenger km travelled by rail and $Speed^{TR}$ is the speed in km per hour for traditional transport, while $Travelhours_t^{RW}$ is equal to $Q_t^{RW}/Speed^{RW}$ where $Speed^{RW}$ is the speed in km per hour for railways. The second term within the brackets is the value of an hour of time, which we set at half the hourly wage of the passengers. Here we follow the standard practice that assumes that only about half of the time saved thanks to the railways was working time (Coatsworth, 1979; Summerhill, 2005, Leunig 2006). The final value of time savings in brackets [·] is divided by GDP in our reference year 1912, just like the savings from passenger and freight transport rates.

While this social savings framework offers an intuitive measure of the contribution of a new technology to income growth, two key assumptions underpin growth accounting and the associated social savings calculation. First, the estimation assumes perfect competition in the economy.[12] While a strong assumption in some industrial economies, perfect competition could arguably apply in India and our

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[11] The ratio between the additional consumer surplus and the social savings is given by $[(\varphi^{(\varepsilon+1)} - 1) / ((\varphi - 1) * (1 + \varepsilon))]$, 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).

[12] See Metzer (1984) and Jara-Díaz (1986) for a detailed discussion of perfect competition and social savings.

comparison economies, which relied heavily on exports of primary products. However, the transport sector itself is characterized by imperfect competition and scale economies. To address this concern, we add railway profits as a percentage of GDP to the TFP term. If there was monopoly power or misallocation in transport, it should be broadly captured in our profit measure. Second, the social savings calculation does not account for TFP spillovers from railways to other sectors, such as those associated with the commercialization of agriculture, the extension of finance, and the provision of complimentary public goods like schools. The evidence is that railways clearly generated spillovers, but there is no standard measure of estimating them in growth accounting. Moreover India and the comparison economies were all intensively exporting primary commodities, and thus spillovers from railways may have been of similar magnitude, which means ignoring them does not invalidate the comparative exercise.

The capital term $s_{KRW}\,\Delta\,(K_{RW}/L)/(K_{RW}/L)$ in equation (2) assumes that railway technology is 'embodied' in capital, and without railways this capital would not have been invested in another sector with the same return (Crafts 2004a, p. 7). In India, where most or all railway investment was of British origin, we think it is reasonable to assume the capital would not have been transferred to another sector within India in the absence of railways. Recall that investment in Indian railways was encouraged by significant dividend and interest guarantees (Bogart and Chaudhary 2015). Other potential investments, like canals or roads, did not have nearly the same political value to the GOI and thus we think it is unlikely they would have been encouraged by guarantees in the absence of railways. In sum, we assume that without railways India would not have received any of the British capital investment associated with railways, and we make a similar assumption for the comparison economies, where most railway capital was of foreign origin and there was arguably no alternative destination with comparable potential returns and risk for that capital.

Finally, the estimation of the capital term in equation (2) also assumes the ratio of net railway revenues to GDP ($s_{KRW}$) is a good proxy for the output elasticity of capital in the railway industry. While this assumption may seem too strict for a regulated sector, similar biases are present in all the countries under consideration, which reduces their impact on the comparative exercise. The growth of railway capital is approximated by the growth in railway mileage, although in the Indian case we adjust for different gauges, which were common in the country.

## 4 Growth accounting of Indian railways

As described in section 3, the growth contribution of railways includes four components: (1) TFP from freight traffic estimated as freight social savings, (2) TFP from passenger traffic estimated as passenger social savings, and including time savings, (3) railway profits added to TFP, and (4) the capital term. In this section, we briefly summarize the data and assumptions underlying the estimation for India. In cases where we are unable to measure or estimate a number, we relied on those used in our comparison economies. The reader is referred to the appendix for the necessary details on our assumptions and robustness checks.

### ***TFP term: freight transport***

The TFP for freight is captured by the additional consumer surplus derived from transporting freight on railways. To calculate the consumer surplus, we need estimates for the unit cost of railway transport and ton-km shipped by railways in 1912 (our reference year), the unit cost of traditional transport (a weighted average of road and water) around 1850 before railways were built, and the price elasticity of freight demand. The 1912 Report on the Administration of Indian Railways (pp. 4, 87) states that the average freight on all goods was 4.66 pies per ton mile. Using 192 pies to the rupee and 1.61 km to the mile, this implies a unit cost of railway transport equal to 0.0151 rupees per ton km, which we use as $\boldsymbol{P_t^{RW}}$ in our social savings calculation. The 1912 report also states (pp. 3-4, 65, 87) that 78.47 million tons of goods were shipped by rail and the average distance at which a ton was shipped was 199.15 miles. This implies a railway output, $\boldsymbol{Q_t^{RW}}$, of 25,160 million ton-kms.

Drawing on Derbyshire (1987, 2022), we use freight rates for road and river transport in the 1840s and 1850s. Road freight rates distinguish pack bullocks, two-bullock carts, and four bullock carts. We validate these estimates using other sources such as Mukherjee (1980) and Ramarao (1998), which reprints the engineer R. MacDonald Stephenson's 1844 'Report upon the Introduction of Railways into India' (see the Appendix). Since we are unaware of any source with direct observations on coastal freight rates, we assume coastal rates were 43% of river rates using Deloche's (1993a, 1993b) observations on the number of days it took to travel by river and sea between various Indian towns at different times of the year.

We convert the pre-railway transport rates to 1912 rupees using an average of the four regional consumer price indices developed jointly by Allen (2007) and Studer (2008). Their CPIs approximate the series of McAlpin (1983) as shown in Appendix Table 1. The reported and inflation adjusted freight rates for road, river, and coastal transport are shown in Appendix Table 2. For a later robustness check, we also report inflation adjusted freight rates from the 1870s.

In the next step, we calculate the weights for traditional transport prices based on an estimated share of how much rail traffic would have gone by road, river, or coast in the absence of railways. For example, if half of the traffic went by road and the rest by river we would give road and river prices each a weight of 0.5. We use proximity to the three main navigable rivers of India (Indus, Ganga, and Brahmaputra) and to the coast for each of the 17 major Indian railways. Based on observations of the engineer Stephenson, reported in Ramarao (1998), and Bourne's (1849) report on river navigation, approximately 1/10th to 2/5th of freight would have been transported by road for railways situated near navigable rivers. We use the higher estimate of 2/5th to avoid over-estimating the counter-factual river traffic for railways near rivers, though we present a robustness check using the 1/10th road estimate. In the absence of detailed sources on coastal traffic, we also assume that 2/5th of railway traffic would have gone by road and 3/5th by the coast in the absence of railways for networks near the coast. For the remaining railways, where road transport was the only alternative, we use Derbyshire's (2022) two bullock cart freight rate for the 6 railway systems in North India where according to Deloche (1993a, p. 261) wheeled traffic was common. The higher pack bullock rate is used for the remaining railway systems again based on remarks by Deloche (1993a). Appendix Table 3 shows the estimated traffic shares across the alternative modes for the 17 major railway systems. Based on those calculations, we estimate that in the absence of railways, 2-bullock carts would account for 20% of traffic, pack bullocks 35% of traffic, river 36%, and coastal transport 9%.[13] These figures imply an inflation adjusted, weighted average pre-railway freight rate of 0.201 rupees per ton-km (see Appendix Table 4). Thus, $\boldsymbol{P_{1912}^{TR}}$ is set to 0.201 in our baseline social saving estimation.

Using railway system-level data from Bogart and Chaudhary (2013), our preferred estimate for the price elasticity of freight demand in India is -0.6. The appendix details our estimates (Appendix Table 5) and justifies this elasticity estimate further. It is worth stating that our -0.6 elasticity estimate is similar to those reported for the comparison economies:

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[13] We assume the same distribution for all traffic, including those out of the 17 main systems

-0.5 in Mexico (Coatsworth 1981), -0.6 in Brazil (Summerhill 2005), -0.49 in Argentina (Summerhill 2000), and -0.77 in Uruguay (Herranz-Loncán 2011b).[14]

As shown in Table 2, the social savings from railways are 4,674 million rupees, which represents approximately 22.9% of Indian GDP using Sivasubramonian's (1997) national income estimate of 20,434 million rupees. The freight savings are clearly large, but the increase in consumer surplus is smaller due to the non-elastic demand for freight services. Our elasticity estimate (-0.6) implies that additional consumer surplus from railway freight services equaled 8.44% of GDP. Thus, Indian railway freight transport generated very large gains in surplus. Later we will discuss the implications for income growth.

**Table 2. Social Savings of Freight Railway Transport, India (1912)**

| | |
|---|---|
| Railway freight output (million ton-km) | 25,160 |
| Railway rate in rupees per ton-km | 0.015 |
| Pre-railway rate in rupees per ton-km | 0.201 |
| Social savings (million rupees) | 4,673.70 |
| SS as % of GDP | 22.9 |
| Additional consumer Surplus as a % of GDP | 8.44 |

Sources: Own calculation, based on Administration Reports on Railways and sources described in the text, like, Deloche (1993a, 1993b) and Derbyshire (1987). For nominal Indian GDP, we use Sivasubramonian's (1997) appendix Table 1a, or 20,434 million rupees. The ratio between the additional consumer surplus and the social savings is given by $[(\varphi\ (\varepsilon + 1) - 1) / ((\varphi - 1) * (1 + \varepsilon))]$, where $\varepsilon$ is the price elasticity of transport demand (with negative sign) and $\varphi$ is the ratio between counterfactual and railway transport prices.

We subject our freight social savings calculation to many robustness checks, summarized in Appendix Table 6. First, we replaced the 2-bullock freight rate with the 4-bullock cart rate to calculate an alternative weighted average pre-railway freight rate. Switching to this cheaper form of road transport implies the additional consumer surplus goes down slightly to 8.22%. Second, we assume that near navigable rivers 1/10th of the rail traffic would have gone by road in the absence of railways, as compared to 2/5th in our baseline.

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[14] In the case of the Cape Colony there is not enough information to estimate the price elasticity of demand. Thus below we use an elasticity of -0.6, which is the average of the other 5 available estimates.

Applying this 1/10th to road traffic reduces the additional consumer surplus to 7.44%, not a huge difference. Third, we assume all road transport in India would have used 2 bullock carts. Here the additional consumer surplus in freight goes down more significantly to 5.82%. However, based on Deloche's (1993a) description of pre-rail roads, we think it is unlikely 2 bullock carts were so widely used. Fourth, we assume a price elasticity of either -0.5 or -0.7, equal to the bounds of the 95% confidence interval for our preferred elasticity estimate, -0.6. The additional surplus then changes to 9.84 and 7.27% respectively. Given the uncertainty involved in the elasticity of demand estimation, one could argue the surplus additions are most likely to be within this range. Fifth, we use inflation adjusted road and river freight rates from the 1870s instead of the 1850s in the baseline. The additional surplus is now 7.35%, indicating only a marginal impact of selecting the 1850s in the baseline. Sixth, we use Donaldson's (2018) relative freight rates, where road, river, and coastal are 4.5, 3.0, and 2.25 times more expensive per unit of distance than railways, respectively. The major difference is for roads, where our baseline 2-bullock cart rate is 11.8 times more expensive than railways (see the Appendix for discussion) With Donaldson's freight rates, the additional surplus goes down to 3.26%. The latter can perhaps be viewed as a lower bound, but this calculation assumes Indian road transport was much more efficient than in other countries before railways, which seems unlikely.[15]

### ***TFP term: passenger transport***

The passenger social savings includes both income savings from lower fares and time savings from replacing slower traditional transport. The 1912 Administration Report for Railways gives railway passenger numbers, km carried, and average fares per km by first, second, intermediate, third, and seasonal/vendor classes (pp. 64, 87). For

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[15] For example, in the analysis of US railroad market access, Donaldson and Hornbeck (2016) build on Fogel (1964) and assume the wagon freight rates were 36.6 times more expensive than railroad transport.

comparability with other economies, which have two classes, we combine the intermediate with the second class and combine the seasonal with the third class. The last grouping is consistent with seasonal passengers paying similar fares as the third class on average. The intermediate class seems more appropriately grouped with second, but their numbers are small so it will not affect the results. Like the literature, we assume first and second-class  passengers would have used wheeled transport in the absence of railways, but third class passengers would have walked. The walking assumption is supported by the many foot travelers described in Ramarao (1998). We estimate inflation adjusted counterfactual fares of 0.58 rupees per passenger km for first class and 0.39 for second class. The appendix gives more details. It should be noted that pre-railway fares do not apply to the third class because we assume they walked in the absence of railways, which requires no fare. Of course, walking required more caloric intake and generated other disutility and costs for third class passengers which would be higher in the longer trips in the pre-rail counterfactual. However, like previous studies, we omit these extra costs, introducing a downward bias in our baseline passenger social savings estimates.

To measure time savings, we use data on travel speeds and passengers' hourly wages to value hours saved in travel. The 1912 Administration Report for Railways gives the average through speed of coaching trains (p. 445). Ramarao (1998) and other sources give estimates of travel speeds using several pre-railway modes. In the absence of data on passenger wages, we assumed third-class travelers earned the hourly wage of skilled workers, second-class travelers twice that amount, and first-class passengers, which were often British officials, earned at least the nominal wage of skilled workers in London. Similar to the comparison economies, we used -1 as the price elasticity of demand for first and second class passengers and a null elasticity for the third class, which implies that their journeys were mainly made out of necessity, which is supported by Ghose's

(1927) descriptions. Appendix Table 7 gives details on railway passenger numbers, distances, fares, and assumed wages by class in our baseline calculation.

Table 3 summarizes the total passenger savings of Indian railways in 1912. The monetary savings from lower railway fares amounted to 395.63 million rupees and the time savings from greater speed amounted to 234.2 million rupees. All together the passenger savings represent 629.8 million rupees or 3.09% of Indian GDP in 1912. As a robustness check, we also calculate the savings using a lower range of pre-railway fares for second and first-class passengers drawing from a different source. This reduces the total passenger savings to 2.35% of GDP. The latter figure is probably a lower bound for the passenger savings.[16]

**Table 3: Social Savings of Passenger Transport, India (1912)**

| | 1st class | 2nd class | 3rd class | Total |
|---|---|---|---|---|
| Savings transport costs (million rupees) | 72.81 | 491.44 | -168.62 | 395.63 |
| Savings travel time (million rupees) | 8.09 | 16.42 | 209.69 | 234.20 |
| Total savings (million rupees) | 80.9 | 507.86 | 41.07 | 629.83 |
| Total savings as % of GDP | 0.4 | 2.49 | 0.201 | 3.09 |
| Consumer surplus (million rupees) | 19.3 | 61.99 | 41.07 | 122.36 |
| Consumer surplus as % of GDP | 0.094 | 0.303 | 0.201 | 0.60 |

Sources: Own calculation, based on Administration Reports on Railways and sources described in the text, like, Ramarao (1998). For nominal Indian GDP, we use Sivasubramonian's (1997) appendix Table 1a, or 20,434 million rupees. The ratio between the additional consumer surplus and the social savings is described by formula in table 2.

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[16] Another robustness check assumes third class passengers paid half the pre-railway fare of the second class in the baseline. This raises the passenger social savings substantially to 25.41% of GDP. We view this scenario as unlikely in that third class passengers would need pay 3.3 days worth of wages to travel 10 km at half the pre-railway fare of the second class.

Next, we report the additional consumer surplus from passenger travel, after correcting for demand elasticity of the first and second class. In total it is 122.4 million rupees or 0.60% of Indian GDP in 1912. This is substantially lower than the social savings because of the unitary price elasticity, -1, assumption. Based on this estimate, it appears that the additional surplus from introducing railway passenger services contributed much less to the growth of the Indian economy by 1912 as compared to freight. In our baseline, the additional surplus from rail freight services equaled 8.44% of Indian GDP.

### *The TFP term: railway profits*

To calculate railway profits in India, we used total revenues and operating costs as reported in the 1912 Administration Report for Railways (p. 3-4). For capital costs we used the book value of capital (4,769 million rupees) multiplied by the yield on long-term government bonds (3.66%) plus an amortization/depreciation rate (1.5%).[17] This is similar to estimates for Brazil and Spain in Summerhill (2003) and Herranz-Loncán (2006). The calculations reveal that profits in Indian railways equal 68.82 million rupees in 1912, which represented 0.34% of Indian GDP. Thus, railway profits were close to the surplus from passenger services, but far less than surplus from freight.

### *The capital term*

For the capital term, we assume that the growth of railway capital is the same as the growth of railway mileage accounting for the multiplicity of gauges in India. 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 were narrow gauge (2ft. 6in. and 2ft.). We convert the number of railway km to standard gauge units, with one

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[17] The 1912 Administration Report for Railways (p.1) gives the capital outlay. Bogart and Chaudhary (2015) describe trends in GOI government bond yields and sources.

km of meter gauge and narrow gauge track representing 0.59 and 0.45 km of standard gauge track based on their relative width. The output elasticity of capital is estimated by the average percentage of railway net (operating) revenues in nominal GDP in 1860, 1872, 1882, 1891, 1901, and 1912.[18] This gives an average percent of 1.08. We report the figures for the capital term in the comparative section below.

## 5 Comparison of social savings, profits, and capital

Table 4 summarizes the freight social savings in India compared to the four Latin American countries and the Cape Colony. We also report ratios between pre-railway and railway freight rates and freight revenues as a percentage of GDP in each country. At 22.9% of GDP, Indian railways generated significant social savings in freight, second only to Mexico. In both countries, the alternative freight rate was more than 10 times higher than the railway freight rate, unlike in the Cape and Uruguay where it was only 3 to 4 times higher. Railways thus generated big social savings in countries like India with expensive pre-rail transport.

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[18] For India net revenues in 1860, 1872, and 1882 are taken from The Report to the Secretary of State for India in council on railways in India (1861, p. 11; 1873, p. 26, 1883, p. 51). For 1860 and 1872 the amount is given in British pounds and converted to Indian rupees at the exchange rate (one pound = 9.682 rupees). In 1891, 1901, and 1912 net revenues are from the Administration Report on railways in India (1892, p. 18; 1901 p. 105; 1912, p. 3).

**Table 4. Comparison of freight social savings and consumer surplus**

| | India (1912) | Argentina (1913) | Brazil (1913)[a] | Cape C. (1905) | Mexico (1910) | Uruguay (1912-13) |
|---|---|---|---|---|---|---|
| Social savings as % of GDP | 22.9 | 20.6 | 18.8 | 12 | 24.3 | 3.8 |
| Pre-railway freight rate/railway rate | 13.3 | 6.7 | 7.5 | 3.2 | 10.5 | 3.7 |
| Freight Railway Revenues as % of GDP | 1.8 | 3.6 | 2.9 | 5.6 | 2.6 | 1.4 |
| Price Elasticity of Demand | -0.6 | -0.49 | -0.6 | -0.6[b] | -0.5 | -0.77 |
| Additional consumer Surplus as a % of GDP | 8.44 | 11.6 | 9 | 8.1 | 11.5 | 2.2 |

Sources: Summerhill (2005); Herranz-Loncán (2014); Herranz-Loncán and Fourie (2018) and, for India, Table 2.

Notes: (a) For Brazil, Summerhill (2005) provides two alternative estimates based on the use of two different price indices; here we choose the results associated to his (B) estimate, since the other one, which gives much larger social saving estimates, is based on the use of the price index in Lobo (1978), whose growth over time is implausibly higher than in all other available indices. (b): not available (average of the other 5 economies).

Unlike social savings, railway freight revenues as a share of GDP were relatively small in India at 1.8% with Uruguay being the only economy with an even smaller share (1.4%). Railways in Uruguay were lightly used on account of cheaper substitutes, like rivers. Freight revenues ranged from a high of 5.6% in the Cape to 2.6% in Mexico among the other comparison countries. On this basis, Indian railways thus did not penetrate the economy as deeply as elsewhere, despite their higher productivity and lower cost than pre-rail transport.

The bottom panel of table 4 summarizes the comparative picture on additional consumer surplus in freight with the added surplus being highest in Argentina (11.6%) and Mexico (11.5%) and lowest in Uruguay (2.2%). India, Brazil, and the Cape Colony lie in the middle of the range. Although India was higher in freight social savings, additional consumer surplus is much less because of its average price elasticity of demand, which at -0.6 is higher in absolute terms than Argentina and Mexico. In general, a higher elasticity reduces the social savings derived from lower freight rates alone. India had the largest ratio of pre-rail to rail freight rates, which means its consumer surplus was most sensitive to correcting for non-inelastic demand. Nevertheless, outside of Uruguay, our calculations indicate that the freight social savings of Indian railways look comparable to other primary product exporting countries on the eve of World War I.

Table 5 summarizes the patterns on passenger social savings and surplus. The Cape Colony and Brazil generated the highest social savings in passenger transport. India was in the middle at 3.09% of GDP. In terms of additional consumer surplus from passenger transport, India, Mexico and Uruguay had much less than Argentina, Brazil, and the Cape Colony. It is helpful to distinguish social savings going to 'upper-class' passengers (first and second class in India, first in the other countries) versus 'lower-class' (third class in India and second in others). Generally, the additional consumer surplus is smaller when the social savings accrues to the upper-class passengers, who have a unitary elasticity of demand. Lower class travel is demand inelastic, by assumption, and thus the social savings is equal to the additional consumer surplus. Thus, it is relevant that most of India's passenger savings came from upper class, like in Mexico and Uruguay. Also in India the high upper-class savings are due to the large ratio between railway and pre-rail fares. As with freight, this means India's additional consumer surplus was most sensitive to the elastic demand of upper class passenger travel. In the case of Argentina and Uruguay their flatter topography and waterways offered cheaper opportunities for passenger travel before railways. Both the freight and passenger savings emphasize the inefficient state of passenger and freight transport in India before the arrival of railways.

**Table 5. Comparison of passenger social savings and consumer surplus**

| | India (1912) | Argentina (1913) | Brazil (1913) | Cape C. (1905) | Mexico (1910) | Uruguay (1912/13) |
|---|---|---|---|---|---|---|
| Savings in passenger transport costs/GDP (%) | 1.94 | -0.29 | 2.86 | 1.98 | 0.23 | 0.46 |
| Savings in travel time/GDP (%) | 1.15 | 2.3 | 1.48 | 3.23 | 0.48 | 0.58 |
| Total savings /GDP (%) | 3.09 | 2.01 | 4.34 | 5.21 | 0.71 | 1.04 |
| Additional consumer surplus/GDP (%) | 0.6 | 1.85 | 1.96 | 2.79 | 0.4 | 0.6 |
| Total Savings /GDP upper classes (%) | 2.88 | 0.7 | 3.58 | 4.27 | 0.65 | 0.96 |
| Total Savings /GDP lower classes (%) | 0.2 | 1.31 | 0.77 | 0.95 | 0.06 | 0.08 |
| Passenger revenues as % of GDP (upper classes) | 0.12 | 0.81 | 0.5 | 0.97 | 0.27 | 0.39 |
| Passenger revenues as % of GDP (lower classes) | 0.84 | 0.61 | 0.47 | 1.91 | 0.38 | 0.22 |
| Pre-railway fare/railway fare (upper classes) | 25.83 | 1.39 | 7.66 | 5 | 3.27 | 2.73 |
| Hourly wage/fare per km (upper classes) | 12.29 | 26.05 | 19.23 | 14.58 | 5.82 | 14.36 |
| Hourly wage/fare per km (lower classes) | 8.13 | 20.43 | 17.06 | 10.9 | 7.47 | 8.82 |

Sources: upper class means first and second class in India and first class in other economies. Lower class means third class in India and second class in other economies. For the figures, see Summerhhill (2005); Herranz-Loncán (2014); Herranz-Loncán and Fourie (2018) and, for India, Table 3.

Another finding is that India had a low social savings accruing to lower class passengers (see Table 5). Related to this, India also had lower time savings, which is where the gains to the lower class passengers came from. Lower Indian wages partly account for the lower time savings as shown in the bottom panel of Table 5. Wages relative to fares for both upper and lower class of travel were smaller in India than in Argentina, Brazil, and the Cape Colony. Mexico and Uruguay were similar to India in this regard. It is hard to say whether higher absolute fares or lower absolute wages are driving these patterns because we do not compare the absolute wages or fares across these countries. That would involve accounting for their differences in purchasing power that we are unable to do. Yet, it is likely that both factors played a role since the higher population density of India was related to its lower wages while the relatively high profits of Indian railways also suggest there was room to reduce fares.

Indian railways generated higher profits at 0.34% of GDP in 1912 than railways in any of the other countries as shown in Table 6.[19] Indeed, India is the only country in this comparison set where railways generated profits, which is partially related to the cost of capital. Like other British colonies, India was able to borrow at lower rates compared to countries in Latin America that faced a higher opportunity cost of capital. Yet, that is not the complete story because railways in the Cape colony had a lower opportunity cost of capital along with negative returns. Unlike India, railways in the Cape colony were considered an instrument for development with profit considerations playing a minor role in route placement (Herranz-Loncán and Fourie, 2018). Higher profits in India were partly due to the more commercial orientation of its network. It should be noted that the main beneficiary of higher railway profits was the colonial Government of India, as it was the majority owner by 1912. No other government in our comparison countries gained as much fiscally from railways.[20]

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[19] It is not possible to obtain aggregate figures for the whole Mexican system; see Ortiz Hernán (1996, p. 28).

[20] For more discussion of the fiscal implications of Indian railways see Bogart and Chaudhary (2015).

**Table 6. Comparison of railway profits**

| | India (1912) | Argentina (1913) | Brazil (1913) | Cape C. (1905) | Uruguay (1912-13) |
|---|---|---|---|---|---|
| Revenues (million LCU) | 616.51 | 140.11 | 250 | 4.05 | 7.05 |
| Operating costs (million LCU) | 301.59 | 87.27 | 177.7 | 2.61 | 4.11 |
| Capital costs (million LCU) | 246.09 | 84.98 | 132.83 | 1.56 | 4 |
| Total costs (million LCU) | 547.69 | 172.26 | 310.53 | 4.17 | 8.11 |
| Profits (million LCU) | 68.82 | -32.14 | -60.53 | -0.12 | -1.06 |
| Profits as a % of GDP | 0.34 | -1.29 | -1.06 | -0.28 | -0.32 |

Notes and sources: For India see text; for Argentina, Dirección General de Ferrocarriles (1913); for Brazil, Summerhill (2005); for the Cape Colony, Herranz-Loncán and Fourie (2018) and, for Uruguay, *Uruguayan Statistical Yearbooks* (1913-14) and Díaz Steinberg (2023, p. 174). We have modified the Cape Colony estimation to assume the same amortization rate as in the other economies. There is no data on profits for all Mexico railways, so they are omitted from this calculation.

Finally, Table 7 compares the Indian capital term (the product of the annual growth rate of railway km per-capita and the ratio of profits to GDP) to the other countries.[21] The third row gives the contribution in annual percentage points of GDP per capita growth as shown in the earlier accounting equation (2). India lies in the middle of the comparison set, higher than Brazil and Uruguay, but lower than the Cape Colony, Argentina, and Mexico. The factor income share of railway capital which was larger in Argentina and the Cape Colony largely drives these differences across countries. This share captures the degree of penetration of the railway sector and their importance to total GDP, which was higher in the Cape and Argentina and less in India.

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[21] For all the comparison countries, we approach the growth rate of railway capital through the evolution of rail mileage.

**Table 7. Comparison of the "capital term"**

| | India (1912) | Argentina (1913) | Brazil (1913) | Cape C. (1905) | Mexico (1910) | Uruguay (1912-13) |
|---|---|---|---|---|---|---|
| Railway capital per capita yearly growth rate, (%) | 6.83 | 6.36 | 6.25 | 4.44 | 8.61 | 3.91 |
| Average factor income share of railway capital, (%) | 1.08 | 1.81 | 0.81 | 3.84 | 0.91 | 0.71 |
| Railway capital contribution to annual yearly growth (%) | 0.07 | 0.12 | 0.05 | 0.17 | 0.08 | 0.03 |

Sources*:* for India see footnotes in text; for other countries, Herranz-Loncán (2014) and Herranz-Loncán and Fourie (2018).

## 6 Comparison of growth contribution

We now report the total growth contribution of Indian railways to GDP per capita growth between 1860 and 1912 and put this figure in a comparative perspective. Before discussing the patterns, we review the main steps involved in the calculation. The total contribution is the sum of the railway capital and TFP terms from equation (2), $s_{KRW}\,\Delta(K_{RW}/L)/(K_{RW}/L)+\phi(\Delta A/A)_{RW}$. First, we combine additional consumer surplus from freight and passenger services plus railway profits, all measured as a percent of 1912 GDP. Together the total encapsulates the TFP contribution of railways up to 1912. Second, we convert the TFP contribution into an annual percent increase, assuming railways started yielding productivity gains in 1860 for all countries.[22] For example, if railways increased TFP through profits and additional surplus by a combined amount of 10%, their annual contribution to TFP from 1860 to 1912 would be 0.18%. The TFP contribution in percentage points per year is reported in row 1 of table 8. In row 2 we report the capital term, measured as the annual contribution of capital in percentage points to GDP per capita growth. This figure is taken directly from table 7. Finally in

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[22] Railways were first opened in the mid-1850s for most countries we study, except the Cape in 1862 and Uruguay in 1869. We abstract from the last two starting later.

row 3, the sum of the TFP and capital terms generate the estimate of the total contribution of railways in annual percentage points per year.

**Table 8. Comparison of the growth contribution of railways in percentage points per year**

| | India (1912) | Argentina (1913) | Brazil (1913) | Cape C. (1905) | Mexico (1910) | Uruguay (1912-13) |
|---|---|---|---|---|---|---|
| (1) TFP term: contribution to per capita income growth | 0.17 | 0.22 | 0.18 | 0.2 | 0.22[a] | 0.04 |
| (2) Capital term: contribution to per capita income growth | 0.07 | 0.12 | 0.05 | 0.16 | 0.08 | 0.03 |
| (3) Total contribution | 0.25 | 0.34 | 0.23 | 0.37 | 0.29 | 0.07 |
| (4) Annual growth of GDP per capita c.1860 to c.1912 (%) | 0.39 | 2.06 | 0.1 | 4.06 | 1.63 | 1.05 |
| (5) Railway contribution as % of GDP per capita growth | 62.9 | 16.4 | 240.1 | 9.1 | 18.1 | 6.3 |

Sources: see text, Tables 4 to 7. GDP per capita growth comes from the Maddison Project Database (see Bolt and Van Zanden 2020 for a summary), except for the Cape Colony, which has been estimated from Magee et al. (2016) and census figures.

Notes: Annual GDP per capita growth figures are based growth from 1860 to 1912, except for the Cape Colony, from 1861 to 1909. (a) aggregate profits for Mexico are not available which introduces a bias in the estimates.

These calculations show that Indian railways added 0.25 percentage points to GDP per-capita growth per year between 1860 and 1912. Put differently, over this period of 52 years, Indian railways increased GDP per capita by 13.8%. This is a large impact by any standard. In comparative terms, railways contribution to Indian income growth was larger than in Uruguay, similar to Brazil and Mexico, and lower than in Argentina and the Cape Colony. This ranking is related to GDP per capita levels during the railway era. Argentina and the Cape Colony were richer than India, and their railway contribution was higher. Brazil and Mexico had more similar GDP per capita to India (at least in 1860), and railways had similar contributions in all. Uruguay is an exception because it was significantly richer than India, yet railways had a small contribution to income growth because of good pre-rail substitutes.

What accounts for Indian railways smaller contribution relative to Argentina and the Cape Colony? As described in Section 5, (1) Indian railway freight revenues as a share of GDP were relatively small and (2) passenger time savings from railways were lower than in Argentina and the Cape Colony because of lower wages to fares. Both these factors reduced the additional consumer surplus of Indian railways in relative terms. While railway profits were higher in India that in any of the comparison countries, they were not high enough to compensate for the relatively smaller gains in additional consumer surplus compared to Argentina or the Cape.

There is another comparative perspective that highlights the central role of railways for the Indian economy. In rows 4 and 5 of Table 8, we scale the annual growth contribution of railways to total GDP per capita growth. According to Maddison Project estimates reported in table 1, Indian GDP per capita increased at a rate of 0.39% per year from c.1860 to c.1912, less than most of our comparison economies. Strikingly railways accounted for 62.9% of total growth in India, higher than Argentina (16.4%), Mexico (18.1%) and the Cape Colony (9.1%). Brazil is an exceptional case as its growth rate is estimated to be quite low.[23] Generally, Indian railways accounted for a higher share of total growth up to World War I than the other countries.

## 7 Conclusion

Indian railways played a big role in integrating markets and increasing agricultural income. Yet, their effect on the aggregate growth of the Indian economy has not been established. Using a growth accounting approach, which builds on social savings, our

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[23] Maddison's figure show that the Brazilian economy declined in the decades before 1912. Since these figures are being revised by other scholars, we are cautious about drawing strong interpretations from the Maddison estimate of Brazilian GDP per capita in 1860-1912.

paper estimates the growth contribution of Indian railways. We find that railways contributed 0.25% per year to income per-capita growth, which made it the most important technological factor driving India's growth from 1860 to 1912.

We also compare India's experience with Argentina, Brazil, the Cape Colony, Mexico, and Uruguay, other primary exporting economies during the first era of globalization. Comparing our estimates for India with those of previous studies shows that railways had a large growth impact in most of these economies, but there were some differences. Railways' contribution to economic growth was much larger in India than Uruguay, similar to Brazil and Mexico, and smaller than Argentina and the Cape Colony. This tracks the ranking of GDP per capita for these countries during the railway era, apart from Uruguay (where the contribution of railways was relatively small). We also find that the railway impact in India and Brazil accounted for a much higher share of growth overall from 1860 to 1912. Broadly this difference reflects a lower rate of economic growth in these two economies.

Our calculations identify the channels by which railways impacted growth across our economies, especially India versus the rest. One factor was the penetration rate of railways, largely measured by freight and passenger revenues to GDP. Indian railways did not penetrate the Indian economy as much as elsewhere. More research is needed to understand why. Our comparative exercise also highlights the effect of low wages on time savings associated with railways. In Argentina and the Cape Colony, railways generated larger time savings because of their higher wages. India's large population and lower wages reduced the time savings. While some commentators have argued that higher fares in India curbed passenger travel, it is unclear whether lower fares would have substantially raised passenger social savings. As noted by Ghose (1927, p. 82) cheap fares allowed the poor of Europe to travel more, but in India people traveled for different reasons with a significantly larger rural population that faced mobility barriers of caste and language.

Working in favor of Indian railways were its low freight rates relative to pre-rail transport rates. Two factors played a role here. First, India's pre-railway transport was expensive and unproductive as evidenced by the wide-spread use of pack bullocks outside of north India. Second, Indian railways were relatively productive by international standards. Bogart and Chaudhary (2013) find total factor productivity of Indian railways in 1913 was higher than Argentina for example. High productivity is another reason why Indian railways generated higher profits in 1912.

Our bottom line is that railways were a key driver of economic growth in India before 1913, but they contributed less to economic growth than railways in more dynamic and richer economies like Argentina and the Cape Colony.

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# Online Appendix

## Indian railway freight social savings in 1912

Several sources are used to estimate the unit cost for alternative transport modes. Derbyshire (1987) gives road freight rates in the 1840s and 1850s for north India in pies per maund mile. In rupees per ton km, they are 0.220, 0.088, and 0.070 for pack bullocks, 2-bullock carts, and 4-bullock carts respectively. We convert to tons assuming 1 maund is 27.222 tons.[24] (for details see notes to Appendix table 2). Derbyshire's figures are consistent with other sources for carts. Mukherjee (1980) estimates that in Bengal the freight rate for 2-bullock carts averaged 0.096 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. Ramarao (1998), drawing on the engineer Stephenson, reports road freight rates in the mid-1840s based on documents of Bengali traders. The average freight rate per ton km in eight reported observations is 0.118 rupees per ton km.

Derbyshire (1987) also reports 0.022 rupees per ton km for downstream river traffic and 0.035 for upstream. In other sources, river freight rates are similar. Mukherjee (1980) cites a source which reports that on the Ganga rates were 0.03 rupees per ton km for downstream and 0.041 for upstream. The downstream rate is our benchmark as the rail traffic in export commodities going down to the ports can be assumed to have been substantially greater than upstream movements.

Note waterway rates include insurance for goods lost in transit. When insurance is not included, reported river freight rates are lower. For example, Mukherjee cites a

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[24] See Indian units of Measurement, https://en.dharmapedia.net/wiki/Indian_units_of_measurement

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 (1998, p. 12) that do not include insurance and average 0.017 rupees per ton km. Our baseline calculation uses river rates with insurance. It was common to take such insurance given the hazards of navigating Indian rivers. For instance, 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. The greater reliability of railways was part of its advantage over rivers.

To our knowledge, there are no direct observations on freight rates for coastal transport in the source materials. However, Deloche (1993b) gives figures on the number of days it took to travel by river and by sea between various towns at various times of the year. 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 provides 16 observations on travel times by river which yield an average of 30.1 km per day, and 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. This figure generally accords with most of the literature which finds coastal is a much cheaper form of waterborne transport, making use of the wind and sea currents.

We convert the c.1850 freight rates to 1912 prices which is needed to compare the inflation adjusted price of the traditional transport service with railways following equation (2). The most straightforward ‘inflation factor’ is the growth in consumer prices. We use Allen and Studer’s combined CPI using data from Allen (2007) and Studer (2008). They report CPIs for the four regions of India. McAlpin’s chapter in the Cambridge Economic History of India CEHI (1983) reports a national CPI from 1860 to 1912. These series suggest similar changes in prices from 1873 to 1910-12 (See Appendix Table 1). The crucial values for our calculation are the four-region average CPI in 1910-12 relative to the four-region average CPI in earlier periods. For example, prices rose by 87% between the 1840s & 50s, when Derbyshire's freight rates are measured, relative to 1912 when railway freight rates are observed.

**Appendix table 1: Consumer Price Indices for India 1840-1912**

| Year(s) | Allen-Studer, North | Allen-Studer, South | Allen-Studer, West | Allen-Studer, East | Allen-Studer, Average | CEHI |
|---|---|---|---|---|---|---|
| 1840-1859 | 86.66 | 93.68 | 84.91 | 84.78 | 87.51 | |
| 1873 | 100 | 100 | 100 | 100 | 100 | 100 |
| 1870-1875 | 97.33 | 112.15 | 101.7 | 92.33 | 100.88 | |
| 1898-1902 | 118.95 | 146.96 | 190.88 | 135.45 | 148.06 | |
| 1910-1912 | 132.06 | 181.59 | 193.19 | 148.45 | 163.82 | 174 |
| Ratio 1910-12 to 1840-59 | 1.52 | 1.94 | 2.28 | 1.75 | 1.87 | |
| Ratio 1910-12 to 1870-75 | 1.36 | 1.62 | 1.9 | 1.61 | 1.62 | |
| Ratio 1910-12 to 1898-1902 | 1.11 | 1.24 | 1.01 | 1.1 | 1.12 | |

*Source*: we use the Indian basket CPI in the 'Prices and Wages in India, 1595-1930' file made by Allen and Studer and made available through the Global Price and Income History Group. See Allen (2007) and Studer (2008) for more details. For CEHI see McAlpin (1983).

Appendix Table 2 summarizes our baseline figures for freight rates, the conversion to rupees per ton km, and the inflation adjustment to 1912 prices. Panel A reports Derbyshire (1987) freight rates in the 1840s and 50s converted to rupees per ton km. The next column shows how we inflate these to 1912 prices. Our preferred estimates in Panel A imply large unit cost differences from railways. Pack bullock rates were 29.4 times the freight rate of railways in 1912 and 2-bullock carts were 11.76 times the railway rate. Downstream river rates were 2.94 times as expensive as railways and coastal shipping rates were 1.26 times as expensive. The most striking is the high relative cost of road transport. It is not unreasonable considering that in their analysis of US railroads, Donaldson and Hornbeck (2016) build on Fogel and assume the wagon freight rates were 36.6 times more expensive than railroads. Our relative rates for pack bullocks and Indian railways are smaller although broadly similar.

**Appendix Table 2: Observed & inflation adjusted pre-rail freight rates**

| | As given (pies per maund mile) | Rupees per ton km | 1912 rupees per ton km | Ratio to railway freight rate |
|---|---|---|---|---|
| Panel A | | | | |
| *Road transport in 1840s & 50s (Derbyshire, 1987, 2022)* | | | | |
| Pack bullock | 2.5 | 0.220 | 0.412 | 29.41 |
| 2-bullock carts | 1 | 0.088 | 0.165 | 11.76 |
| 4-bullock carts | 0.8 | 0.070 | 0.132 | 9.41 |
| *River transport in 1840s & 50s (Derbyshire, 1987)* | | | | |
| Downstream | 0.25 | 0.022 | 0.041 | 2.94 |
| Upstream | 0.4 | 0.035 | 0.066 | 4.71 |
| *Coastal transport in 1840s & 50s (assumption)* | | | 0.018 | 1.26 |
| Panel B | | | | |
| *Road transport in 1870s (Derbyshire, 2022)* | | | | |
| Pack bullock | 2.5 | 0.220 | 0.357 | 25.48 |
| 2-bullock carts | 1 | 0.088 | 0.143 | 10.19 |
| 4-bullock carts | 0.8 | 0.070 | 0.114 | 8.15 |
| *Non-steam river transport 1870s (Derbyshire, 2022)* | | | | |
| Downstream | 0.15 | 0.013 | 0.021 | 1.53 |
| Upstream | 0.3 | 0.026 | 0.043 | 3.06 |
| *Coastal transport in 1870s (assumption)* | | | 0.009 | 0.65 |

Sources: Derbyshire (1987, 2022). To convert Derbyshire's pies per maund into rupees per ton km, we first divided the pies per maund by 192 to convert to rupees, then multiplied by 0.621 to convert miles to km, and finally multiplied by 27.222 to convert maunds to tons, assuming a maund was 37.324 kg. For the inflation of freight rates from 1840s & 50s to 1912 we multiply by 1.87 using the Indian consumer price from Allen and Studer reported in appendix table 1. For the inflation from 1870s to 1912 we multiply by 1.67 again using appendix table 1.

Panel B uses Derbyshire (2022) freight rates from the 1870s. Relative to Panel A notice that road transport stays constant and river transport rates decreases in nominal terms over the same period. These shifts are consistent with different trajectories of productivity growth in road and river transport. The introduction of steamboats would have pushed down river transport rates, even as input prices rose. Cart and bullock transport perhaps got marginally more productive, which is why their rates are stable. The rest of panel B shows the 1912 price adjusted road, river, and coastal freight rates and their ratio relative to railway freight rates. The panel B relative freight rates are lower than A for two reasons: (1) the inflation adjustment to 1912 prices is less and (2) road and river transport got cheaper in real terms from the 1840s & 50s to the 1870s due to productivity growth. We prefer to use the estimates in panel A as the growth accounting approach generally compares railways with its predecessor technology at the time railways were adopted, which is closer to the 1840s and 50s. This is especially so if we want to compare railways with the pre-steam technology.

It is important to discuss the two alternative freight rate estimates for India made by Donaldson (2018). The first are described by Donaldson as "observed historical relative freight rates" (p. 916). In these estimates, road, river, and coastal are 4.5, 3, and 2.25 times more expensive per unit of distance than railways, respectively. In panels A and B of Appendix Table 2 our relative figures are similar for river transport, somewhat different for coastal, but much different for roads. It appears that Donaldson is mainly using freight rates for 4 bullock carts, and likely in 1850 when they were 0.078 rupees per ton km. In our baseline, we prefer to use inflation adjusted freight rates which puts 4 bullock carts at 9.41 times the railway freight rate instead of 4.5. Also, we prefer to use pack bullocks or cart rates depending on the availability of good roads as discussed below. Yet for comparison, we use Donaldson's relative freight rates as a robustness check.

Donaldson's second estimate uses variation in salt prices across North Indian districts and over time to infer relative costs across different modes (p. 917). These imply road transport was even cheaper (2.3 times more expensive than rail), while coastal was much more expensive (6.18 times as expensive as rail). These second figures appear less suited to our analysis. Salt is not necessarily representative of all the products that were transported by rail. For instance, railways charged different freight rates for grain and coal than for salt. Moreover, it is not plausible that coastal transport was more expensive than road transport, as implied by the 6.18 coastal to rail rate ratio and the 2.3 road to rail ratio.

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 Indian railways systems, and aggregates to total railway traffic in 1912. The main navigable river systems in colonial India were the Indus, Ganga 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 Ganga River valley, where population was most dense. Among the 17 major railways systems, seven were close to one of the navigable rivers.[25]

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 mainly usable during the monsoon season. According to the railway engineer 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 it depended on the melting of snow in the Himalayas.

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

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 there was still significant road traffic in areas with navigable rivers. Stephenson stated that for the trade between Calcutta and Burdwan, a town on a tributary of the Ganga, three-fifths went by river and two-fifths went by road (Ramarao, p. 46). John Bourne's report on river navigation in 1849 stated that approximately one-tenth of tonnage between Calcutta and Mirzapore went by road (p. 50). Among those assumptions, we consider that 2/5th of the traffic would have gone by road in the absence of railways to avoid the risk of over-stating the amount of counter-factual river traffic for railways near rivers. Many railway lines diverted from navigable rivers and gained traffic that would have had to travel a significant distance by road. The most important example concerns coal traffic. By 1870 the Central Indian coal deposits were served by the East Indian railway, which had some track near the Ganga 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' (Bourne, 1849). 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. Nevertheless, we also present a robustness check using the lower 1/10th 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 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.[26] 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 'coastal' railways operated. As in the case of river transport, we assume that three-fifths of railway traffic would have gone by coast and two-fifths by road. We also present a robustness check assuming that 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.[27] In these and all other railway systems it is important to identify whether wheeled road traffic was available. Deloche's (1993a, p. 261) detailed study of roads and vehicles before railways suggests that wheeled traffic was widely available only in northern India, including Bengal and the Ganga river valley. For the rest of India, pack animals were the typical mode of road transport. Deloche's argument is supported by John Bourne (1849) 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.[28] The robustness of this assumption is checked in our analysis.

In Appendix Table 3, we summarize how traffic is allocated across alternative modes for the 17 major railways systems in the counter-factual. In the baseline, we

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[26] These were the Bengal Nagpur, Bhavnagar-Gondal, Madras and South Indian railways. We do not include any coastal traffic for the Bombay, Baroda and Central India railways because a majority of their mileage was inland and only a small proportion was coastal.

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

[28] The 2-bullock cart rate is assumed for the following systems: East Indian; Eastern Bengal; Oudh and Rohilkhand; Bengal and Northwestern; Bengal Nagpur; and Rohilkhand and Kumaon railways.

assume 3/5ths of rail traffic would have gone by river if a railway was near rivers and 3/5$^{ths}$ would have gone by coast if a railway was near the coast. These assumptions imply in the absence of railways 2-bullock carts would account for 20% of rail traffic, pack bullocks 35% of rail traffic, river 36%, and coastal transport 9%.[29]

**Appendix table 3: Share of traffic by alternate modes and railways--baseline**

| 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 | |

Notes: in the baseline, we assume 3/5ths went by river for railways near navigable rivers and 3/5ths went by coast for railways near coast.

The combination of inflation adjusted freight rates reported in Appendix Table 2 and counter-factual traffic shares by road, river, and coastal transport in Appendix Table 3 give the weighted average pre-railway freight rate used in our social savings calculation.

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[29] We assume the same distribution for traffic out of the 17 main systems, which accounted for less than 3% of the total in 1912.

The weighted average across all the modes is 0.201 rupees per ton km as shown in Appendix Table 4.

**Appendix table 4: Baseline traffic shares and counterfactual freight rates**

| Panel A: baseline | traffic share | Freight rate |
|---|---|---|
| Road, 2-bullock cart | 20.34% | 0.165 |
| Road, pack bullock | 34.86% | 0.412 |
| River | 36.04% | 0.041 |
| Coastal | 8.77% | 0.108 |
| Weighted Average | 100.01% | 0.201 |

Notes: For traffic shares see appendix table 3. For freight rates see appendix table 2.

The last step input into the social savings for freight is an estimate of the price elasticity of freight demand in India. We use railway system-level data from Bogart and Chaudhary (2013). The dataset includes operational data from 36 different railway systems from 1874 to 1912. Several smaller railway systems enter after 1874 and get merged with the larger 17 systems by 1912, including Burma Railways. Our dataset treats new railway systems as entrants to the panel and it incorporates exiting systems through mergers. We address the entry and attrition in the sample through different samples and specifications. Building on previous work, we know there was significant operational and demand heterogeneity across railways. Thus, our preferred estimate uses a two-way fixed effect estimator of log freight ton km on log freight rates plus controls. The specification for railway demand is the following where $\beta_1$ is the estimate for price elasticity:

$$Ln\ (freight\ ton\ km)_{it} = \beta_1 * ln\ (real\ freight\ rate)_{it} + \beta_2 * x_{it} + \delta_t + \alpha_i + e_{it} \quad (A.1)$$

Where *real freight rate* is the average charge in 1912 prices, based on freight revenues divided by freight ton km and our consumer price index. As controls, $x_{it}$ includes the natural log of track km for the system and in some specifications the log of goods train miles run for the system. These controls capture important organizational and demand features which evolved over time. Track miles capture the size of the system, which changes the number and composition of users, as do goods train miles run, since there are more potential railway users as additional goods trains are added and more shipments arrive at stations. We also add railway system fixed effects $\alpha_i$ and year fixed effects $\delta_t$ or a year time trend. The key assumption is that log freight rates are orthogonal to the error term after including our controls. This is plausible based on our reading of the annual Administration Report on Railways, which up to 1900 describes dozens of yearly changes in freight rates at the railway system level (see the regular Chapter VIII, Fares and Rates). Christensen (1982) discusses some cases where rates changed. For example, the decision by several railway systems to reduce their long-distance freight rates on grain following such a move by the Rajputana Malwa railway in 1884. In another case, the entry of the Bengal Nagpur railway in 1887 forced the East Indian Railway to reduce its freight rates on coal. These cases suggest there were quasi-random shocks to freight rates. However, freight rates are related to operational and demand factors, so our control variables are likely to be consequential for the estimates.

Appendix Table 5 reports the estimates of equation A.1. The first column includes log track miles as a control with a year time trend, but no railway system fixed effects. It suggests a price elasticity of -0.654. The estimated elasticity increases to -0.954 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 estimated elasticity increases to -1.125. This estimate is implausibly large, and we think one reason is the omission of goods train-miles run, an important demand feature of the railway system. In specification 4, we add ln (good train km) as an additional control, which yields an estimate of -0.631. This estimate is much more plausible as it is like our comparison economies. Specification 5 is the same as 4, except it restricts the sample to years after 1883, when there were fewer mergers, and the sample is more balanced. The estimated elasticity is a bit smaller at -0.597. Rounding the estimate from specification 5, we use 0.6 as our preferred elasticity.

**Appendix table 5: Price elasticity estimates for freight on Indian railways**

| | Dependent variable: Ln (Freight Ton Miles) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Ln (Freight Rate) | -0.654 | -0.959 | -1.125 | -0.631 | -0.597 |
| | [0.1245] | [0.115] | [0.110] | [0.051] | [0.051] |
| Ln (Miles) | 1.469 | 1.084 | 1.091 | 0.075 | 0.126 |
| | [0.029] | [0.061] | [0.059] | [0.051] | [0.051] |
| Ln (Train miles) | | | | 0.966 | 0.943 |
| | | | | [0.052] | 0.052 |
| Year | -0.008 | 0.013 | | | |
| | [0.003] | [0.003] | | | |
| Railway FE | No | Yes | Yes | Yes | Yes |
| Year FE | No | No | Yes | Yes | Yes |
| restrict sample to 1884-1912 | | | | | |
| Observations | 765 | 765 | 765 | 632 | 570 |

Notes: Robust standard errors in brackets

The counter-factual freight rate used in several robustness checks are shown in appendix table 6. These are discussed in the text.

## Appendix table 6: traffic shares, counterfactual freight rates, and consumer surplus in robustness checks

| replace 2 bullock with 4 bullock rate | traffic share | freight rate |
|---|---|---|
| Road, 4-bullock cart | 20.34% | 0.132 |
| Road, pack bullock | 34.86% | 0.412 |
| River | 36.04% | 0.041 |
| Coastal | 8.77% | 0.108 |
| Weighted average freight rate | | 0.195 |
| Additional consumer Surplus as a % of GDP | | 8.28 |
| replace with assumption that 1/0th of traffic went by river for railways near rivers | traffic share | freight rate |
| Road, 2-bullock cart | 7.69% | 0.165 |
| Road, pack bullock | 29.48% | 0.412 |
| River | 54.05% | 0.041 |
| Coastal | 8.76% | 0.108 |
| Weighted average freight rate | | 0.166 |
| Additional consumer Surplus as a % of GDP | | 7.48 |
| assume all roads were 2 bullock carts | traffic share | freight rate |
| Road, 2-bullock cart | 55.19% | 0.165 |
| Road, pack bullock | 0.00% | 0.412 |
| River | 36.04% | 0.041 |
| Coastal | 8.77% | 0.108 |
| Weighted average freight rate | | 0.115 |
| Additional consumer Surplus as a % of GDP | | 5.82 |
| Use inflation adjusted rates from the 1870s | traffic share | freight rate |
| Road, 2-bullock cart | 20.34% | 0.143 |
| Road, pack bullock | 34.86% | 0.357 |
| River | 36.04% | 0.021 |
| Coastal | 8.77% | 0.009 |
| Weighted average freight rate | | 0.162 |
| Additional consumer Surplus as a % of GDP | | 7.36 |
| replace with Donaldson's 'observed historical relative freight rates' | | |
| Road, 2-bullock cart | 20.34% | 0.068 |
| Road, pack bullock | 34.86% | 0.068 |
| River | 36.04% | 0.045 |
| Coastal | 8.77% | 0.034 |
| Weighted average freight rate | | 0.057 |
| Additional consumer Surplus as a % of GDP | | 3.26 |

## Indian railway passenger social savings in 1912

The passenger social savings includes both money savings from lower fares and time savings from replacing slower traditional transport. Measuring time savings require data on travel speeds and passengers' hourly wages. It also requires an assumption of the share of railway travel time that would have been devoted to working. We first define passengers, which in India are more differentiated than elsewhere. The 1912 Administrative report gives statistics for first, second, intermediate, third, and seasonal/vendor passengers. To simplify and make our analysis comparable with other economies, we combine second with intermediate and combine third with seasonal/vendor. Appendix Table 7, Panel A lists passenger numbers and distance carried by railway in 1912 (passenger kms) for our three categories.

**Appendix table 7: Inputs into passenger social savings for Indian railways**

| | 1st class | 2nd and intermediate class | 3rd class and season/vendor tickets |
|---|---|---|---|
| Panel A: Railway passenger numbers and distance in 1912 | | | |
| Number of passengers | 795,500 | 14,057,000 | 402,377,400 |
| Average km a passenger was carried | 171.53 | 92.00 | 57.74 |
| Passenger km (millions) | 136.45 | 1,293.27 | 23,235.24 |
| Inputs for money savings | | | |
| Railway fare (rupees per km) | 0.0461 | 0.0127 | 0.0073 |
| Pre-railway fare c.1850 (rupees per km) | 0.31 | 0.21 | 0 |
| Pre-railway fare, inflation adjusted to 1912 prices (rupees per km) | 0.5797 | 0.3927 | 0.0000 |
| Ratio pre-railway fare (inflation adjusted) to railway fare | 12.5752 | 30.9111 | NA |
| Inputs into time savings | | | |
| Railway speed in km per hour (rupees per km) | 36.48 | 36.48 | 36.48 |
| Pre-railway speed in km per hour | 6.44 | 4.12 | 3 |
| Ratio railway speed to pre-railway speed | 5.665 | 8.854 | 12.160 |
| Hourly wage in rupees | 0.928 | 0.118 | 0.059 |

Sources: See text and appendix for details on pre-railway fares, speeds, and hourly wages. See 1912 Administration Report for Railways p. 64 for passenger numbers by class, see p. 87 for distance carried and average fares by class, and see p. 445 for speeds of coaching trains (we calculate the weighted average across railway systems by passenger traffic). For the inflation of fares from 1840s & 50s to 1912 we multiply by 1.87 using the Indian consumer price from Allen and Studer reported in appendix table 1.

A common assumption in the literature is that first-classes passengers would have used coach transport in the absence of railways, but lower-class passengers would have walked instead. We follow a similar approach for India assuming third class passengers walked. The descriptions of contemporaries in Bengal published in 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. The assumption that the third class would have walked 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 travelers are documented in questionnaires sent to British officials in the 1830s and 40s (see 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, 1998 p. 91). These fares imply a passenger per km rate between 0.15 and 0.29 rupees using a distance of 680 km between Calcutta and Benares. They are lower than other observations for Bengal, which quote passenger travel by dak at 0.31 rupees per km and by palanquin at 0.21 to 0.23 rupees (Ramarao, 1998 p. 87, Bourne, 1849 p. 51). Drawing on this information we assume in the baseline that first class passengers paid the most expensive fares at 0.31 rupees per km and that second and intermediate-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 (index value of 1.87), the counterfactual fare is 0.58 rupees per passenger km for first class and 0.39 for second class. The railway fares for each class are reported in Appendix table 7, Panel B for comparison. It is noteworthy that dak rates were 12.5 times the first-class railway fare and palanquin rates were 31 times larger than second class railway fares. If we use the lower range of passenger fares for daks and palanquins between Calcutta and Benares (0.15 and 0.29 ca. 1850) then inflation adjusted fares are 0.2805 and 0.5423 rupees per passenger km. We use these as a robustness check.

The savings in travel time associated to much shorter passenger trips requires estimates of both 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 (calculation based on Administration Report 1913, p. 445). Prior to trains, Ramarao (1998 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, 4.12 km per hour by palkee, and 13.6 km by dak. Another source in Ramarao (1998 p. 87) puts the travel speed of palanquins at 3.86 km and daks at 6.44 km per hour. The dak travel time reported by the Military Board was perhaps based on night travel. Assuming a travel day of 20 hours for the dak in that source yields a more comparable speed of 7.15 km per hour. Drawing on these figures, we assume in the baseline that prior to railways the travel speed for second 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. The 3.57 walking speed does not account for breaks and is higher than assumed in our comparison economies, which assume 3 km per hour. Therefore, in our baseline we use 3 km per hour for third class. Appendix table 7 reports these speeds along with those for railways. Railway passenger trains were more than five and half times the speed of the fastest available form of transport before railways.

Our value of time estimates for India are more speculative given the limited source material. We assume third-class travelers were paid the hourly wage of skilled workers and second-class travelers 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 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 (2001) 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.

The final assumptions deal with the price elasticity of demand for passenger travel. In the case of first and second-class Indian transport, we choose -1 as is done for first classes in our comparison economies. The justification is that first and second-class travel contained a luxury element and perhaps elites would have turned to local entertainments had railways not existed. For the Indian third class, we adopt the common assumption of a null elasticity for the lowest class, which implies that their journeys were mainly made of necessity (see Herranz-Loncán 2014, Leunig 2006). While the assumptions on the price elasticity of demand are based on limited data, they are not implausible and are at least comparable to other economies.

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