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The growth contribution of colonial Indian railways in comparative perspective

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Abstract

Railways were an important driver of global economic growth in the nineteenth and early twentieth centuries. Whilst 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 twentieth 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 that the aggregate growth impact of Indian railways was significant, increasing Indian gross domestic product (GDP) per capita by 13.5 per cent 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 with the latter, 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 the first era of globalization from 1860 to 1912, but they contributed less than in richer and more dynamic developing economies.

KEYWORDS
globalization, growth accounting, India, railways, social savings

JEL CLASSIFICATION
N7, O47, P52, R4

After their early construction in Britain, the new technology of railways spread across the world in the nineteenth century, and by the start of the First World War 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.[1] Whilst 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.[2]

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'.[3] The literature has documented that during the colonial era, Indian railways increased market integration, agricultural incomes, literacy, and to a lesser extent, urbanization.[4] Moreover, over time Indian railways became much more productive in delivering freight and passenger services.[5] However, a comprehensive accounting of their macro-impact has not been made.[6] Using data between 1860 and 1912, we offer the first estimate of railways' contribution to Indian macro-economic growth. We then compare railway impact in India with five large developing economies.

Our comparison set includes an African British colony (the Cape) and four Latin American independent countries (Argentina, Brazil, Mexico, and Uruguay). The time frame, 1860–1912, captures the development of the main rail network across these countries. Together with India, they accounted for 58 per cent 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.

However, there were important differences between the six countries, as seen in table 1. In terms of surface area, railway density was higher in Uruguay, India, Argentina, and Mexico and much lower in the Cape colony and Brazil, largely due to the presence of extensive unpopulated areas in those two countries. Argentina and Uruguay also stood out for their higher railway

[1] O'Rourke and Williamson, 'When did globalization begin?'; Jacks, Meissner and Novy, 'Trade costs'; Pascali, 'The wind of change'.

[2] There are some exceptions, as the macro-impact of railways has been studied in countries such as Brazil (Summerhill, *Order against progress*; idem, 'Big social savings'), Mexico (Coatsworth, 'Indispensable railroads'; idem, *Growth against development*), Argentina (Herranz-Loncán, 'El impacto directo'), Uruguay (Herranz-Loncán, 'The role of railways'), and the Cape colony (Herranz-Loncán and Fourie, 'For the public benefit?') among others.

[3] Kerr, *Engines of change*.

[4] See Collins, 'Labor mobility'; Andrabi and Kuehlwein, 'Railways'; Donaldson, 'Railways'; Chaudhary and Fenske, 'Railways'; and Fenkse, Kala, and Wei, 'Railways'.

[5] See Bogart and Chaudhary, 'Engines of growth'; eisdem, 'Railways'.

[6] Hurd's 'Railways', estimated the social savings on Indian freight traffic to be 1.2 billion rupees or 9% of national income in 1900. However, he offered no details on the assumptions and data used to arrive at that estimate. Derbyshire's 'Economic change' and *Railways' economic impact* make estimates of railways' growth impact on North India.

TABLE 1 Population, railway mileage, and GDP per capita of comparison countries in 1912

	Population (million)	Railway mileage (km)	Railway mileage per 1000 pop.	Railway mileage per 10 000 sq. km	GDP per capita *c.* 1860 in $2011	GDP per capita *c.* 1912 in $2011
India	303.4	53 887	0.18	132.37	$896	$1098
Argentina	7.4	32 212	4.37	113.89	$2160	$6223
Brazil	23.2	23 491	1.01	27.60	$752	$1042
Cape colony	2.6	3979	1.55	78.48	NA	NA
Mexico	15	20 447	1.36	103.74	$921	$2131
Uruguay	1.1	2522	2.20	135.24	$3000	$5176

Source: The data on population and railways mileage are for 1912, except for the Cape population (for 1911). Railway mileage comes from Mitchell, *International Historical Statistics*: *Africa*, and *International Historical Statistics*: *the Americas*, and population and GDP per capita data from the Maddison Project Database (version 2020; see Bolt and van Zanden, 'Maddison style estimates'), except for the Cape colony mileage and population, which come from Union of South Africa, *Official Year Book*, and Brazil GDP per capita in 1860, which has been calculated from its value in 1912 in the Maddison Project Database and its evolution according to Bacha et al., 'Secular stagnation?'. The 1860 GDP per capita for India is for 1861 (the nearest year with non-missing data).

mileage per capita, and in contrast, India had the lowest railway mileage per capita, reflecting its comparatively high population density.

These economies also differed in terms of gross domestic product (GDP) per capita growth, which was higher in Argentina, Mexico, and Uruguay than in the rest. According to the Maddison project data, India's per-capita income in 2011 USD increased by 23 per cent between 1860 and 1912 (from 896 to 1098), whereas the average for Mexico, Argentina, and Uruguay increased by 123 per cent (from 2027 to 4510). Brazil is perhaps the most similar to India in terms of 1860 GDP per capita and its lower income growth in this period.[7] 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, and their railways were largely under private ownership circa 1912.[8]

Our estimation draws on the growth accounting framework used to measure the impact of new technologies such as steam power, electricity, and information and communication technology.[9] 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.[10] Such an accounting framework is also ideal for cross-country comparisons[11] and enables us to answer our main

[7] 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 and complemented, in the case of Brazil in 1860, with Bacha et al., 'Secular stagnation?'. The Maddison 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., 'South Africa', show an even higher growth rate between 1861 and 1909 than in Argentina, Mexico, and Uruguay, whilst the international comparisons carried out in that paper would also point to a substantially higher level of GDP per capita than in India at the end of the railway era.

[8] Bogart, 'A global perspective'; Bignon et al., 'Big push'.

[9] Bakker et al., 'The sources of growth'; Byrne et al., 'Is the information technology revolution over?', Crafts and Woltjer, 'Growth accounting'.

[10] Crafts, 'Productivity growth'; idem, 'Steam'; Leunig, 'Time'; idem, 'Social savings'; Herranz-Loncán, 'Railroad impact'.

[11] See Herranz-Loncán, 'Transport technology'.

research questions: (1) how large was the contribution of railways to Indian GDP per capita growth? and (2) how did it compare with similar, non-industrialized 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 0.24 percentage points to annual income per capita growth in India from 1860 to 1912, which implies they increased GDP per capita by 13.53 per cent in 1912. In sensitivity tests we find that 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.[12] 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 per cent) and the Cape (0.37 per cent).

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 with past transport modes. The time savings were considerable in higher wage economies such as Argentina. Additionally, higher Indian railway fares relative to wages further reduced the total factor productivity (TFP) gains. Working in favour 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 with the other countries, where some earned negative profits.

To summarize, railways were the most important singular driver of economic growth in India between 1860 and 1913, accounting for more than 60 per cent of all per capita income growth in this period. Yet they made a smaller contribution to Indian economic growth compared with 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, such as 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 have reaped higher benefits from railways.

Our paper contributes to the growing literature that compares the historical performance of countries along different dimensions.[13] A large comparative project examines how GDP and GDP per capita evolved across modern-day countries.[14] 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

[12] The estimates for the comparison economies are our own calculations based on Coatsworth, 'Indispensable railroads'; Summerhill, 'Big social savings'; Herranz-Loncán, 'Transport technology'; and Herranz-Loncán and Fourie, 'For the public benefit?'.

[13] For example, Chaudhary et al., 'Big BRICs'; Prados de la Escosura, 'Augmented human development'.

[14] For example, see the Maddison Project summarized by Bolt and Van Zanden, 'Maddison style estimates'.

comparative evolution of productivity.[15] 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 nineteenth and twentieth 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.[16] In contrast, recent work highlights the divergence between India and Europe in the early modern period,[17] the low productivity of Indian agriculture,[18] and the central role of geography and unreliable water supply.[19] Railways have often appeared in these discussions as either an example of poor colonial investments[20] or a productive sector of the colonial economy.[21] 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 that estimate the impact of Indian railways on different outcomes.[22] The most related is Donaldson's, which estimates the effect of railways on trade costs, compared with alternatives such as roads or rivers, exploiting differences across districts unconnected to railways with connected districts.[23] He finds that railways increased real Indian agricultural incomes by 16 per cent from 1860 to 1930. Similar to Donaldson's structural trade model-based approach, our macro growth accounting methodology arrives at the same qualitative conclusion – railways increased Indian incomes. Our work also significantly expands on prior estimates of freight social savings for Indian railways by Hurd and for North India by Derbyshire.[24] 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 the First World War.

The rest of the paper is organized as follows. Section I provides a brief background on railways in India and the comparison economies. We describe the growth accounting methodology in section II. Section III describes each component of the growth contribution of railways for India. Section IV summarizes the comparative patterns on the different components, whilst section V compares the total growth contribution of railways in India and the other countries. Section VI concludes.

[15] Broadberry, *The productivity race*; Allen, 'Technology'; Bakker et al., 'The sources of growth'; Prados de la Escosura et al., 'Accounting for growth'.

[16] For a survey of works on colonialism and the Indian economy see Roy, 'Economic history'.

[17] Broadberry and Gupta, 'The early modern Great Divergence'.

[18] Broadberry and Gupta, 'The historical roots'; Ronnback and Theodoridis, 'Cotton cultivation'.

[19] Roy, *Monsoon economics*.

[20] Satya, 'British imperial railways'; Sweeney, *Financing India's imperial railway*.

[21] Bogart and Chaudhary, 'Engines of growth'; Chaudhary, 'Infrastructure – Railways'.

[22] See Mukherjee, 'Railways'; Hurd, 'A huge railway system'; Andrabi and Kuehlwein, 'Railways'; Chaudhary and Fenske, 'Railways'; Fenkse, Kala, and Wei, 'Railways',

[23] Donaldson, 'Railways'.

[24] Hurd, 'Railways'; Derbyshire, *Railways' economic impact*.

I | HISTORICAL BACKGROUND

By most accounts India's transportation sector was costly and unproductive at the beginning of the railway era.[25] 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 twentieth century, railways had spread to most parts of India as seen in figure 1, which shows 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 centres and newer towns that emerged along railway tracks.[26] However, outside of the links with Delhi there were fewer interior-to-interior connections, especially in central and southern India.

The construction and management of colonial railways involved private British companies, the colonial Government of India (GOI), and Indian Princely States.[27] In the first phase, until 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 per cent, 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.[28]

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.[29] 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 per cent 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

[25] Mukherjee, 'Railways'; Derbyshire, 'Economic change'.

[26] Derbyshire, *Railways' economic impact*.

[27] See Sanyal, *Development*, for a detailed overview of the regulatory history of Indian railways.

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

[29] Morris and Dudley, 'Selected railway statistics', p. 39.

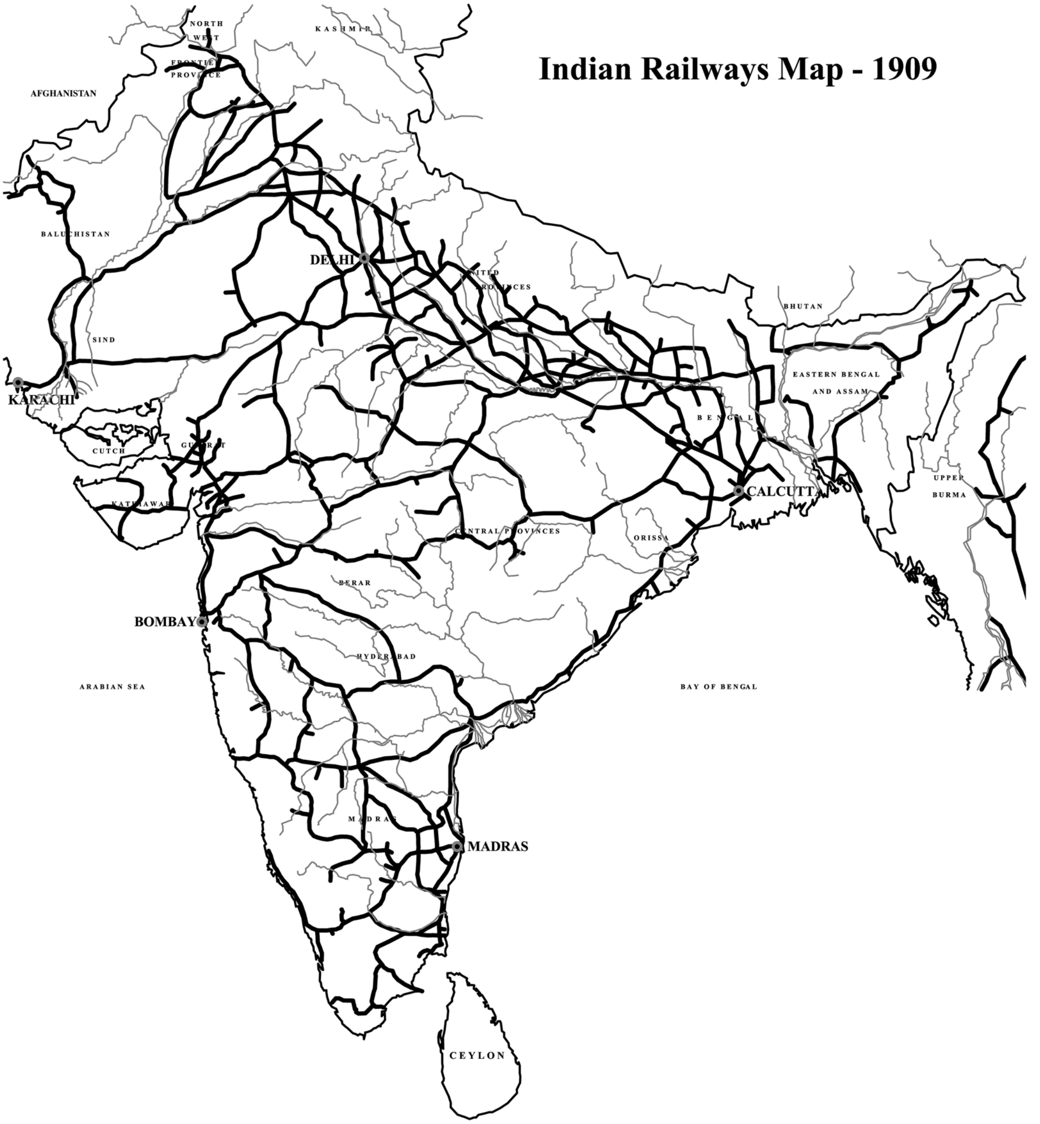

FIGURE 1 Railway map of India, 1909.

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, whilst at the same time having regard for progressive development of the economy.[30] Ghose also argued that the demand for freight was elastic to a degree, noting that traffic increased when freight rates fell. Christensen's analysis of cases where freight rates fell also suggests demand was elastic.[31]

There were three main passenger classes for railways in India. First class accounted for 0.6 per cent of passenger traffic in 1912, second for 5.9 per cent, and third for 93.5 per cent. Fares were

[30] Ghose, *Lectures*, p. 72.

[31] Christensen, 'The State'.

naturally highest for first class, which was targeted at high-ranking British and Indian officials. Fares for second class were meant for upper class Indians and lower-class Europeans and Eurasians.[32] The fare for third class, also the largest class, was much less. It was not targeted at those with the lowest income in India, as according to Ghose an agricultural labourer would have to spend two days of wages to travel 50 miles by train.[33] 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 twentieth 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. In 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, 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.

II | METHODOLOGY

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

$$\Delta(Y/L)/(Y/L) = s_K \Delta(K/L)/(K/L) + \Delta A/A \tag{1}$$

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 such as information and communication technology.[34] For railways this requires transforming expression (1) into:

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

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 sectors, and ϕ

[32] Kerr, *Engines of change*.

[33] Ghose, *Lectures*, p. 83.

[34] Crafts and Woltjer, 'Growth accounting'.

and γ are the shares of railways and other sectors' production value (or revenue) 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. In other words, the growth contribution comes from two sources: through embodiment in new capital and through conventional TFP growth. We discuss each below.

In the literature, the cumulative change in the TFP term, $\phi\,(\Delta A/A)_{RW}$, is approximated by the real income gains accruing to the users of railway freight and passenger services.[35] Those gains are measured by the change in consumer surplus, where the transport user is the consumer who benefits from introducing cheaper services.[36] With respect to freight, the demand for transport is derived from increased trade and convergence of prices across markets.[37] The demand for passenger services is derived from business and/or leisure travel. On the supply side, it is assumed there is a constant marginal cost of providing transport services, with and without railways.[38]

There are several steps in calculating the change in consumer surplus for freight and passenger services. The economic history literature generally starts with measuring the social savings of railways as a percentage of GDP, which is:

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

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.[39] 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. We discuss the weights for road and water transport in the next section.

It is useful to remark on the relationship between social savings and productivity growth in the transport sector spanning the era from 1850 to 1912. The latter 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 (ϕ in equation 2) gives an expression for 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 $(P_{1912}^{TR}/P_{1912}^{RW} - 1)$ captures the cost efficiency of railways relative to the predecessor technology. We emphasize both in our analysis.

[35] See Crafts, 'Steam'; Leunig, 'Social savings'.

[36] Metzer, *Some economic aspects*, pp. 3–26, formally shows how the gain in an economy's real income generated by a transport cost reduction brought about by railways is measured exactly by the Hicksian consumers' surplus of either the compensating or the equivalent-variation type. Also see Metzer, 'Railroads' and Jara-Díaz, 'On the relation', for graphical summaries.

[37] Jara-Díaz, 'On the relation', illustrates this with a perfectly competitive, spatially segmented two-market example, where the demand function for transport is the inverse of an excess demand function for the 'high-price' market minus the inverse of an excess supply function in the 'low-price' market. In this framework, if the excess demand was less elastic, then the demand for transport services would be less elastic too.

[38] Metzer, 'Railroads'.

[39] For foundational social savings work see Fogel, *Railroads* and Fishlow, *American railroads*.

Note that our social savings expression (3) departs from the logic of the original social savings estimates made by Fogel and Fishlow[40] because it uses the inflation-adjusted price of alternative transport just *before* the advent of railways *c.* 1850, for example, P^{TR}_{1850}/m_{1850}. Consistent with the growth accounting framework, we are interested in the contribution of railways compared with their predecessor technologies and infrastructure, not compared with 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.

We also extend the basic social savings framework to incorporate passenger time savings in the reference year *t*, defined as:

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

where the first term in parentheses is the difference in total hours travelled by the traditional mode and railways. $Travelhours^{TR}_t$ is equal to $Q^{RW}_t/Speed^{TR}$, where Q^{RW}_t are passenger km travelled by rail and $Speed^{TR}$ is the speed in km per hour for traditional transport, whilst $Travelhours^{RW}_t$ is equal to $Q^{RW}_t/Speed^{RW}$ 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.[41] 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.

The next step in estimating the change in consumer surplus is to adjust the social savings by accounting for price-elastic transport demand. As stated by Fogel,[42] if the elasticity of transport demand is allowed to be greater than zero, the rise in transport cost associated with the absence of railways would reduce the amount transported and hence also the diversion of resources from the economy to the transportation sector in the counterfactual. The implication is that the social savings are an upper bound on the added consumer surplus from railways. Like previous work,[43] we adjust the social savings using a formula which depends on the price elasticity and the ratio of railway to pre-railway transport prices.[44] In theory, with this adjustment, we approximate the change in consumer surplus for users, generated from introducing freight and passenger services, which is the cumulative TFP term.

Whilst this comprehensive social savings framework, including the passenger time saving, 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.[45] Whilst a strong assumption in some industrial economies, perfect competition could arguably apply in India and our comparison

[40] Ibid.

[41] Coatsworth, 'Indispensable railroads'; Summerhill, 'Big social savings'; Leunig, 'Time'.

[42] Fogel, 'Notes', p. 5.

[43] For example, Crafts, 'Productivity growth'.

[44] 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. If $\varepsilon = -1$, the ratio becomes $(\ln\varphi)/(\varphi - 1)$, see Fogel, 'Notes', pp. 10–1).

[45] See Metzer, *Some economic aspects*, and idem, 'Railroads', and Jara-Díaz, 'On the relation', for a detailed discussion of perfect competition and social savings.

economies, which relied heavily on exports of primary products. However, the transport sector itself has imperfect competition, which we address below.

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 such as schools.[46] 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 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. 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.[47] Other potential investments, such as 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.

The capital term has been included in several studies of railways, ranging from industrial economies, such as Britain,[48] to our comparison economies, where most railway capital was of foreign origin.[49] The rationale is similar. In the absence of railways, it is difficult to imagine an alternative undertaking which would have yielded similar returns and attracted a similar amount of capital from abroad, and therefore the total exclusion of the capital term from the calculation would yield an upward-biased picture of the size of the counterfactual economy.

The estimation of the capital term in equation (2) assumes the ratio of net railway revenues to GDP (s_{KRW}) is the output elasticity of capital in the railway industry. The growth of railway capital $\Delta(K_{RW}/L)/(K_{RW}/L)$ is approximated by the growth in railway mileage, although in the Indian case we adjust for different gauges, which were common in the country.

We also account for the possibility that railways earned profits, as this sector is characterized by imperfect competition and scale economies. Profits are defined as the difference between railway revenues and operating costs plus the user cost of railway capital. Profits are calculated in the reference year and divided by GDP. They are added to the consumer surplus accruing to users in the final assessment. This way, we add the transport producer surplus to the consumer surplus to provide a broader estimate of the total income gain.[50]

[46] For instance, the expansion of Indian railways has been credited with largely mitigating the effect of famines on mortality in twentieth-century colonial India. The 1943 Bengal famine was a war famine, different from the famines of the late nineteenth century (Roy, *How British rule*). That said, railways may have also contributed to higher mortality as people travelled in close quarters that lead to infectious disease epidemics, especially after large pilgrimages. Due to the complexity of incorporating and estimating spillovers, most of the social savings literature on railways does not quantify their effects. Whilst we recognize the effects of Indian railways may have extended to mortality and other socio-economic dimensions, we follow the literature and ignore such spillovers in the estimation.

[47] Bogart and Chaudhary, 'Railways'.

[48] See Crafts, 'Productivity growth'.

[49] See Bignon et al., 'Big push'; Herranz-Loncán and Fourie, 'For the public benefit'.

[50] McClelland, 'Social rates of return'.

III | GROWTH ACCOUNTING OF INDIAN RAILWAYS

As described in section II, 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 in which we are unable to measure or estimate a number, we relied on those used in our comparison economies. We refer the reader to the appendix for the necessary details on our assumptions and robustness checks.

The TFP for freight is captured by the additional consumer surplus derived from transporting freight on railways. To calculate this term, 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 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, Q_t^{RW}, of 25 160 million ton kms.

Drawing on Derbyshire,[51] 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 and Ramarao,[52] 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 per cent of river rates using Deloche's observations on the number of days it took to travel by river and sea between various Indian towns at different times of the year.[53] Appendix table 2 summarizes our estimates for road, river, and coastal freight rates around 1850.

We prefer to use historically informed estimates of freight rates over those estimated by Donaldson using variation in salt prices across North Indian districts for two main reasons.[54] First, his relative freight transport estimates do not use the majority of Indian districts bordering the coast, which are in the South. These estimates thus cannot be extrapolated to the relative coastal freight rate for all of India. Second, his estimated relative freight rates do not accord with historical observations that coastal shipping was always cheaper than road.[55] In contrast, he estimates the relative coast freight rate was higher than road or river.[56]

We convert the pre-railway transport rates to 1912 rupees using an average of the four regional consumer price indices developed jointly by Allen and Studer.[57] Their consumer price indexes

[51] Derbyshire, 'Economic change'; idem, *Railways' economic impact*.

[52] Mukherjee, 'Railways'; Ramarao, *Line*.

[53] Deloche, *Transport* (vols. I and II).

[54] Donaldson, 'Railways'.

[55] Derbyshire, *Railways' economic impact*.

[56] Apart from these two major reasons, his exercise draws on the years 1860–1930 to estimate relative freight rates that do not match our years of analysis and uses variation in salt prices. Grains and seeds accounted for the majority of traffic carried on Indian railways, and they often faced different freight rates on railways compared with salt. See app. for more details.

[57] Allen, 'India'; Studer, 'India'.

(CPIs) approximate the series of McAlpin,[58] as presented in appendix table 1. The inflation-adjusted freight rates for road, river, and coastal transport are presented in appendix table 2. For a later robustness check, we also report inflation-adjusted freight rates using observed freight costs from the 1870s.[59]

In the next step, we calculate the weights for traditional transport prices on the basis of 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. On the basis of the observations of the engineer Stephenson, reported in Ramarao,[60] and Bourne's report on river navigation,[61] approximately one-tenth to two-fifths of freight would have been transported by road for railways situated near navigable rivers. We use the higher estimate of two-fifths to avoid over-estimating the counter-factual river traffic for railways near rivers, though we present a robustness check using the one-tenth road estimate. For networks near the coast, and in the absence of detailed sources on coastal traffic, we also assume that two-fifths of railway traffic would have gone by road and three-fifths by the coast in the absence of railways. For the remaining railways, where road transport was the only alternative, we use Derbyshire's two-bullock cart freight rate for the six railway systems in North India, where according to Deloche, wheeled traffic was common.[62] The higher pack bullock rate is used for the remaining railway systems again on the basis of remarks by Deloche.[63] Appendix table 3 presents the estimated traffic shares across the alternative modes for the 17 major railway systems. On the basis of those calculations, we estimate that in the absence of railways, two-bullock carts would account for 20 per cent of traffic, pack bullocks 35 per cent of traffic, river 36 per cent, and coastal transport 9 per cent.[64] These figures imply an inflation-adjusted, weighted average pre-railway freight rate of 0.201 rupees per ton km (see appendix table 4). Thus, P^{TR}_{1912} is set to 0.201 in our baseline social saving estimation.

Using railway system-level data from Bogart and Chaudhary,[65] 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: −0.5 in Mexico,[66] −0.6 in Brazil,[67] −0.49 in Argentina,[68] and −0.77 in Uruguay.[69]

As presented in table 2, the social savings from railways are 4677 million rupees, which represents approximately 22.9 per cent of Indian GDP using Sivasubramonian's national income

[58] McAlpin, 'Price movements'.

[59] See Derbyshire, 'Economic change'.

[60] Ramarao, *Line*.

[61] Bourne, *Indian river navigation*.

[62] Derbyshire, *Railways' economic impact*; Deloche, *Transport*, vol. I, p. 261.

[63] Deloche, *Transport*, vol. I.

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

[65] Bogart and Chaudhary, 'Engines of growth'.

[66] Coatsworth, *Growth against development*.

[67] Summerhill, 'Big social savings'.

[68] W. R. Summerhill, 'Profit and productivity on Argentine railroads, 1857–913', unpublished research paper (2000).

[69] Herranz-Loncán, 'The role of railways'. In the case of the Cape colony there is not enough information to estimate the price elasticity of demand. Below we use an elasticity of −0.59, which is the average of the other five available estimates.

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)	4677.24
SS as % of GDP	22.9
Additional consumer surplus as a % of GDP	8.44

Sources: Authors' calculation based on Administration Reports on Railways and sources described in the text, such as Deloche, *Transport*, vols. I and II, and Derbyshire, 'Economic change'. For nominal Indian GDP, we use Sivasubramonian, 'Revised estimates', app. tab. 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 ε is the price elasticity of transport demand (with negative sign) and φ is the ratio between counterfactual and railway transport prices.

estimate of 20 434 million rupees.[70] 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 equalled 8.44 per cent of GDP. Thus, Indian railway freight transport generated very large gains in consumer surplus. We will discuss the implications for income growth later.

We subject our freight social savings calculation to many robustness checks, summarized in appendix table 6. First, we replaced the two-bullock freight rate with the four-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 per cent. Second, we assume that near navigable rivers, one-tenth of the rail traffic would have gone by road in the absence of railways, as compared with two-fifths in our baseline. Applying this one-tenth to road traffic reduces the additional consumer surplus to 7.48 per cent, not a huge difference. Third, we assume all road transport in India would have used two bullock carts. Here the additional consumer surplus in freight goes down more significantly to 5.82 per cent. However, based on Deloche's description of pre-rail roads,[71] we think it is unlikely two 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 per cent confidence interval for our preferred elasticity estimate, −0.6. The additional surplus then changes to 9.84 per cent and 7.28 per cent, 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 7.36 per cent, indicating only a marginal impact of selecting the 1850s in the baseline. Sixth, we use Donaldson's reported historical relative freight rates,[72] 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 two-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 per cent. 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.[73]

[70] Sivasubramonian, 'Revised estimates'.

[71] Deloche, *Transport*, Vol. I.

[72] Donaldson, 'Railways'.

[73] For example, in their analysis of US railroad market access, Donaldson and Hornbeck, 'Railroads', builds on Fogel, *Railroads*, and assume the wagon freight rates were 36.6 times more expensive than railroad 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 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 do 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 travellers described by Ramarao.[74] 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 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 for other economies, 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 and other sources give estimates of travel speeds using several pre-railway modes.[75] In the absence of data on passenger wages, we assumed third-class travellers earned the hourly wage of skilled workers, second-class travellers twice that amount, and first-class passengers, who 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. For the latter, this implies that their journeys were mainly made out of necessity, which is supported by Ghose's descriptions.[76] 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 395.62 million rupees and the time savings from greater speed amounted to 234.21 million rupees. All together the passenger savings represent 629.84 million rupees, or 3.08 per cent 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 per cent of GDP. The latter figure is probably a lower bound for the passenger savings.[77]

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 per cent of Indian GDP, in 1912. This is substantially lower than the social savings because of the −1 price

[74] Ramarao, *Line*.

[75] Ibid.

[76] Ghose, *Lectures*.

[77] 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 to pay 3.3 days' worth of wages to travel 10 km at half the pre-railway fare of the second class.

TABLE 3 Social savings of passenger transport, India (1912)

	1st class	2nd class	3rd class	Total
Savings in transport costs (million rupees)	72.81	491.44	−168.62	395.62
Savings in travel time (million rupees)	8.10	16.43	209.69	234.21
Total savings (million rupees)	80.91	507.87	41.07	629.84
Total savings as % of GDP	0.40	2.49	0.20	3.08
Consumer surplus (million rupees)	19.30	61.99	41.07	122.36
Consumer surplus as % of GDP	0.09	0.30	0.20	0.60

Sources: Authors' calculation based on Administration Reports on Railways and sources described in the text, such as Ramarao, *Line*. For nominal Indian GDP, we use Sivasubramonian, 'Revised estimates', app. tab. 1a, or 20 434 million rupees. As the price elasticity is −1 for first and second class, the ratio between the additional consumer surplus and the social savings is described by $(\ln\varphi)/(\varphi-1)$, where φ is the ratio between counterfactual and railway transport prices. For third class the price elasticity is 0 and so the ratio between consumer surplus and social savings is 1.

elasticity assumption. On the basis of 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 with freight. In our baseline, the additional surplus from rail freight services equalled 8.44 per cent of Indian GDP.

To calculate railway profits in India, we used total revenues and operating costs as reported in the 1912 Administration Report for Railways (pp. 3–4). For capital costs we used the book value of capital (4769 million rupees) multiplied by the yield on long-term government bonds (3.66 per cent) plus an amortization/depreciation rate (1.5 per cent).[78] This is similar to estimates for Brazil and Spain by Summerhill and Herranz-Loncán.[79] The calculations reveal that profits in Indian railways equaled 68.82 million rupees in 1912, which represented 0.34 per cent of Indian GDP. Thus, railway profits were close to the surplus from passenger services, but far less than surplus from freight.

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 (5 ft. 6 in.) and just under half was meter gauge (3 ft. 3 in.). The remaining parts were narrow gauge (2 ft. 6 in. and 2 ft.). We convert the number of railway km to standard gauge units using data on capital outlay per mile of standard, meter, and narrow gauge, provided in the 1913 Administration Report for Railways (p. 313). According to this information, the ratio of capital cost per mile for meter to standard gauge was 0.47, and for narrow to standard gauge was 0.28. The implied average annual growth rate of capital is 6.65 per cent from 1860 to 1912. 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.[80] This gives an average percentage of 1.08. We report the figures for the capital term in the comparative section below.

[78] The 1912 Administration Report for Railways (p. 1) gives the capital outlay. Bogart and Chaudhary, 'Railways' describes trends in GOI government bond yields and sources.

[79] Summerhill, *Order against progress*; Herranz-Loncán, 'Railroad impact'.

[80] 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 (£1 = 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 colony (1905)	Mexico (1910)	Uruguay (1912–3)
Social savings as % of GDP	22.9	20.6	18.8	12.0	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	1.9	3.6	2.9	5.6	2.6	1.4
Price elasticity of demand	−0.6	−0.49	−0.6	−0.59[b]	−0.5	−0.77
Additional consumer surplus as a % of GDP	8.44	11.61	8.97	8.16	11.48	2.17

Notes: (a) For Brazil, we use Summerhill, 'Big social savings', which is the main source of Herranz-Loncán, 'Transport technology' and gives more detailed information than the latter. He 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, *História*, whose growth over time is implausibly higher than in all other available indices. (b): not available (average of the other five economies).
Sources: Summerhill, 'Big social savings'; Herranz-Loncán, 'Transport technology'; Herranz-Loncán and Fourie, 'For the public benefit?'; and for India, tab. 2.

IV | COMPARISON OF SOCIAL SAVINGS, PROFITS, AND CAPITAL

Table 4 summarizes the freight social savings in India compared with 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 per cent 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 3–4 times higher. Railways thus generated big social savings in countries such as India with expensive pre-rail transport.

Unlike social savings, railway freight revenues as a share of GDP were relatively small in India, at 1.9 per cent, with Uruguay being the only economy with an even smaller share (1.4 per cent). Railways in Uruguay were lightly used on account of cheaper substitutes, such as rivers. Freight revenues ranged from a high of 5.6 per cent in the Cape to 2.6 per cent in Mexico among the other comparison countries. On this basis, Indian railways 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 per cent) and Mexico (11.5 per cent) and lowest in Uruguay (2.2 per cent). 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 consumer surplus 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 the First World War.

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

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	2.30	1.48	3.23	0.48	0.58
Total savings/GDP (%)	3.08	2.01	4.34	5.21	0.71	1.04
Additional consumer surplus/GDP (%)	0.60	1.85	1.96	2.79	0.40	0.60
Total Savings/GDP upper classes (%)	2.88	0.70	3.58	4.27	0.65	0.96
Total Savings/GDP lower classes (%)	0.20	1.31	0.77	0.95	0.06	0.08
Passenger revenues as % of GDP (upper classes)	0.11	0.81	0.50	0.97	0.27	0.39
Passenger revenues as % of GDP (lower classes)	0.83	0.61	0.47	1.91	0.38	0.22
Pre-railway fare/railway fare (upper classes)	25.83	1.39	7.66	5.00	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	10.90	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, 'Big social savings'; Herranz-Loncán, 'Transport technology'; Herranz-Loncán and Fourie, 'For the public benefit?'; and for India, tab. 3.

3.08 per cent 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 the 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, such as in Mexico and Uruguay. Additionally, 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.

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

TABLE 6 Comparison of railway profits

	India (1912)	Argentina (1913)	Brazil (1913)	Cape C. (1905)	Uruguay (1912–3)
Revenues (million LCU)	616.51	140.11	250.00	4.05	7.05
Operating costs (million LCU)	301.59	87.27	177.70	2.61	4.11
Capital costs (million LCU)	246.09	84.98	132.83	1.56	5.38
Total costs (million LCU)	547.69	172.26	310.53	4.17	9.49
Profits (million LCU)	68.82	−32.14	−60.53	-0.12	-2.45
Profits as a % of GDP	0.34	−1.29	−1.06	-0.28	-0.74

Note and source: LCU stands for local currency units. For India see text; for Argentina, Dirección General de Ferrocarriles, *Estadistica*; for Brazil, Summerhill, 'Big social savings'; for the Cape colony, Herranz-Loncán and Fourie, 'For the public benefit?'; and for Uruguay, Dirección General de Estadística, *Anuario Estadístico*, and Díaz Steinberg, 'Essays', p. 174. We have modified the Cape colony estimation to assume the same amortization rate as in the other economies. There are no data on profits for all Mexico railways, so they are omitted from this calculation.

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, which we are unable to do. However, it is likely that both factors played a role since the higher population density of India was related to its lower wages whilst the relatively high profits of Indian railways also suggest there was room to reduce fares.

Indian railways generated higher profits at 0.34 per cent of GDP in 1912 than railways in any of the other countries, as presented in table 6.[81] Indeed, India is the only country in this comparison set where railways generated profits, which is partially related to the cost of capital. Being a British colony, India's risk of default was very low, and therefore it borrowed at lower rates compared with 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.[82] 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.[83]

Finally, table 7 compares the Indian capital term (the product of the annual growth rate of railway km per capita and the ratio of net operating revenues to GDP) with the other countries.[84] 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

[81] It is not possible to obtain aggregate profit figures for the whole Mexican system; see Ortiz Hernán, 'Introducción', p. 28.

[82] Herranz-Loncán and Fourie, 'For the public benefit?'.

[83] For more discussion of the fiscal implications of Indian railways see Bogart and Chaudhary, 'Railways'.

[84] 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 colony (1905)	Mexico (1910)	Uruguay (1912–3)
Railway capital per capita yearly growth rate (%)	6.65	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, 'Transport technology' and Herranz-Loncán and Fourie, 'For the public benefit?'.

sector and their importance to total GDP, which was higher in the Cape and Argentina and less in India.

V | 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 percentage of 1912 GDP. Together the total encapsulates the TFP contribution of railways until 1912. Second, we convert the TFP contribution into an annual per cent increase, assuming railways started yielding productivity gains in 1860 for all countries.[85] For example, if railways increased TFP through profits and additional surplus by a combined amount of 10 per cent, their annual contribution to TFP from 1860 to 1912 would be 0.18 per cent. 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 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.

These calculations show that Indian railways added 0.24 percentage points to GDP per-capita growth per year between 1860 and 1912. Put differently, over this 52-year period, Indian railways increased GDP per capita by 13.5 per cent. 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. 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.

[85] 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.

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 (1912–3)
(1) TFP term: contribution to per capita income growth	0.17	0.22	0.18	0.20	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	0.24	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	0.63	4.06	1.63	1.05
(5) Railway contribution as % of GDP per capita growth	62.7	16.3	36.8	9.0	18.1	6.4

Notes: Annual GDP per capita growth figures are based on 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.

Sources: See text, tabs. 4–7. GDP per capita growth comes from the Maddison Project Database (see Bolt and Van Zanden, 'Maddison style estimates' for a summary), except for the Cape colony, which has been estimated from Magee et al., 'South Africa' and census figures, and Brazil before 1900, from Bacha et al., 'Secular stagnation?'.

What accounts for Indian railways' smaller contribution relative to Argentina and the Cape colony? As described in section IV, (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. Whilst 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 with 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 cent per year from *c*. 1860 to *c*. 1912, less than most of our comparison economies. Strikingly, railways accounted for 62.7 per cent of total growth in India, higher than Brazil (36.8 per cent), Mexico (18.1 per cent), Argentina (16.3 per cent), and the Cape colony (9 per cent). Generally, Indian railways accounted for a higher share of total growth up to the First World War than the other countries.[86]

VI | CONCLUSION

Indian railways played a big role in integrating markets and increasing agricultural income. However, their effect on the aggregate growth of the Indian economy has not been established. Using a

[86] It is important to stress that these measures are blind to distributional matters. However, the distribution of railway benefits might be as crucial as its size. Railways, for instance, might substantially contribute to increasing social or regional inequality. Moreover, a large proportion of benefits in peripheral economies might accrue to foreign agents, acting either as railway users or as owners of railway companies. For instance, if the commodities that are transported by the railways end up being exported, a certain share of railway gains will end up with foreign consumers, who will benefit from cheaper goods. Knowing these effects would require a much more detailed analysis of the railway business and the structure of traffic, which is unfortunately beyond the reach of the current research.

growth accounting approach, which builds on social savings, our paper estimates the growth contribution of Indian railways. We find that railways contributed 0.24 per cent 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. This could be due to lower wages in India or the higher presence of small-holding peasant agriculture leading perhaps to a smaller share of crops available for sale in markets. More research is needed to identify the specific factors driving the differential penetration rate of railways in India versus the more dynamic economies in Latin America. 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. Whilst 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, cheap fares allowed the poor of Europe to travel more, but in India people travelled for different reasons, with a significantly larger rural population that faced mobility barriers of caste and language.[87]

Working in favour 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 find total factor productivity of Indian railways in 1913 was higher than Argentina, for example.[88] 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, accounting for an exceedingly large share of Indian GDP per capita growth. However, taken in absolute terms (i.e. in percentage points of growth), the Indian railways' growth contribution was lower than in more dynamic and richer economies such as Argentina and the Cape colony.

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[87] Ghose, *Lectures*, p. 82.

[88] Bogart and Chaudhary, 'Engines of growth'.

DATA AVAILABILITY STATEMENT

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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