The Contribution of Railways to Economic Growth in Latin America before 1914: a Growth Accounting Approach

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Abstract

Railways are usually considered as one of the most important innovations that fostered the transition of Latin America to economic growth before 1914. The social saving estimates that are available for several Latin American countries seem to confirm that view. However, the interpretation of the results of the social saving literature is not straightforward, since the comparison among social savings calculated for different countries and years may be troublesome, and the actual meaning of the social saving estimates is not clear. This paper suggests an alternative approach to the economic impact of railways in Latin America. It presents estimates of the direct growth contribution of the railway technology in Argentina, Brazil, Mexico and Uruguay before 1914, which are calculated on the basis of the growth accounting methodology. The outcomes of the estimation indicate that railway effects on Uruguayan economic growth were very low. By contrast, in the other three cases under study (Argentina, Mexico and Brazil) the railways provided huge direct benefits. In Argentina and Mexico, these amounted to between one fifth and one quarter of the total income per capita growth of the period under analysis. By contrast, in the case of Brazil, the outcomes of the analysis indicate that the direct contribution of railways to growth would have been higher than the whole income per capita growth of the Brazilian economy before 1914. This unexpected result might suggest that the national level is not the most adequate scale to analyse the economic impact of network infrastructure in the case of large, geographically unequal and insufficiently integrated developing economies.

1. Introduction

Between the mid nineteenth century and the eve of the Great War, Latin America was one of the world regions with a faster economic growth. According to Maddison's figures, the economies of the area grew well above the world average in 1870-1913, and its growth rate was comparable that of the "Western Offshoots" (Table 1). To a large extent, that growth episode was a consequence of the expansion of exports of primary products during the first globalisation boom.

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Table 1. Growth rates during the first globalisation boom (1870-1913)
Percentage points per year

	GDP	GDP per capita
Latin America	**3.48**	**1.81**
Western Europe	2.10	1.32
Western Offshoots	3.92	1.81
Japan	2.44	1.48
Asia (excluding Japan)	0.94	0.38
Eastern Europe and former USSR	2.37	1.15
Africa	1.40	0.64
World	*2.11*	*1.30*

Source: Maddison (2001), p. 126.

In many Latin American economies the construction of railway networks was one of the most important bases of the economic expansion of 1870-1913. As in the rest of the world, Latin American railways had a huge influence on the reduction of domestic transport costs. In addition, in the case of Latin America, and opposite to what happened in the industrialised economies, which had already developed relatively efficient and competitive market structures at the advent of the railways, these were essential to create or to strengthen the links between previously fragmented local markets, and also between them and the world markets. In this regard, they had a much more "developmental" character in Latin America than in the core economies (Coatsworth, 1981, pp. 77-78).

Historians have often highlighted the importance of railways for Latin American development during the first globalisation. For instance, according to Summerhill (2003), "*the railroad conferred on Brazil benefits that probably exceeded, by far, those stemming from the other major changes in economic organization in this period*" (p. 96), and railways may be considered to have "*laid the groundwork for Brazil's transition to rapid economic growth after 1900*" (p. 1). In the case of Argentina, "[i]*n the aggregate, railroad technology accounted for an appreciable portion of the productivity growth enjoyed by the Argentine economy between 1890 and 1913. Railroads were certainly not the sole determinant of overall gains in productivity in the economy, but they were no doubt among the most important*".[2] And, in Mexico, the railways "*were one of the most powerful factors of transition to capitalism*".[3] In those countries, the railways not only generated large increases in aggregate productivity, thanks to the reduction in transport costs, but also encouraged market integration, labour

[2] Summerhill (2000), p. 5; see also Lewis (1983), p. 220.
[3] Kuntz Ficker (1999), p. 134; see also Kuntz Ficker (1995) and Dobado and Marrero (2005).

mobility, and the emergence of scale and agglomeration economies. In addition, they increased the economy's stock of exploitable natural resources, and stimulated the inflow of foreign capital and the growth of investment. In sum, in Summerhill's words, "*(…) it now seems unlikely that any other technological or institutional innovation was more important in the transition to economic growth in Latin America before 1930*" (Summerhill, 2006, p. 297).[4]

So far attempts to provide quantitative indicators of the economic impact of Latin American railways have been largely addressed to the estimation of the social savings, which measure the cost of transporting the railway output of one year by the best available alternative. Social savings may be considered therefore as an approach to the resource saving impact of the railway technology, and the high level of Latin American social saving estimates has usually been interpreted as a clear indicator of the large contribution of the railway technology to economic growth in the region (see Table 2).

Table 2. Available estimates of social savings of freight railway transport in several countries

	Year	Social savings/GNP or GDP (%)
US	1859	3.7
US	1890	4.7
England and Wales	1865	4.1
Russia	1907	4.5
France	1872	5.8
Spain	1878	4.4
Spain	1912	12.7
Colombia	*1927*	*3.37/7.86*
Brazil	*1913*	*18.0/38.0*
Mexico	*1910*	*24.9/38.5*
Argentina	*1913*	*26.0*

Sources: Fishlow (1965), pp. 37 and 52; Fogel (1964), p. 223; Hawke (1970), p. 196; Metzer (1977), p. 50; Caron (1983), p. 44; Herranz-Loncán (2008), p. 140; Summerhill (2003), p. 89; Coatsworth (1979), p. 952; Summerhill (2000), p. 31; and Ramírez (2001).

[4] Nonetheless, there is also a negative interpretation of the economic role of railways in the Latin American economies, associated to the *dependentista* literature. From this perspective, the railways should be blamed for having promoted and supported a purely extractive economic model, reinforcing the export orientation of the economies of the region and its dependence on foreign powers, and constituting therefore an obstacle to the emergence of a different development pattern, more oriented to sustained economic growth and industrialisation and to the expansion of internal markets. An example of this approach is Coatsworth (1981, p. 191), who indicates that the railways "*may be seen as foreclosing other* [development] *possibilities with very large effects over the longer period*", and points out that most of the benefits of the railway technology were finally channelled to the North-Atlantic economies through the repatriation of dividends and interest payments and the demand for industrial products. Despite their relevance, these issues are beyond the scope of this paper.

However, these social saving figures cannot be taken as unambiguous indicators of the relative contribution of railways to economic growth in each country, for two reasons. Firstly, a direct comparison among social saving estimates calculated for different years and with different methodologies in order to draw conclusions on the relative role that railways performed in each economy may be misleading (Leunig, 2010). For instance, since the social savings tend to increase over time, estimates for the third quarter of the nineteenth century would be hardly comparable with figures for 1914. Secondly, the actual economic meaning of the social saving, as is usually calculated, is not clear. As has been recently stressed by Leunig (2010), in the case of a "macro-invention" (such as the railways), "*for which price falls are dramatic, for which previous levels of quantity sold are relatively small, and for which price elasticity of demand proves to be high, then it is likely that the social savings estimates will be hugely out of line with the conventional, and correctly defined, measure used by economists to value the welfare effects of improvements to technology, namely the rise in consumer surplus.*"

In order to overcome these shortcomings, the growth accounting methodology, which is actually the most usual way to evaluate the economic growth implications of new technology over time, may constitute a more adequate approach to the contribution of railways to economic growth (Crafts, 2010). This paper uses the growth accounting framework to provide preliminary estimates of the contribution of railways to economic growth before 1914 in four of the main Latin American economies (Argentina, Brazil, Mexico and Uruguay), in order to obtain aggregate and comparable indicators of the direct impact of the railway technology on those economies during the period of export-led growth. To that purpose, next section offers a brief summary of the process of railway expansion in Latin America; Section 3 describes the growth accounting framework that has been used in this paper; Section 4 presents the available evidence on the growth contribution of railways in Latin America; and, finally, Section 5 concludes.

2. Railways in Latin America before 1914: an overview

By 1914 railways were present all over Latin America, although their development had been highly unequal among countries. The first railway line in the region was open in Cuba in 1837, only 12 years after the inauguration of the first British railway. Cuba would not be joined by any other Latin American economy until the

1850s, when railway construction started in Argentina, Brazil, Mexico, Peru, Colombia and Chile. By 1900, the railways were already present in all countries of the region.

Railway construction was especially intense in Argentina, Brazil and Mexico. These countries accounted, since the late 1880s, for approximately 75 percent of the whole Latin American railway mileage. However, in per capita terms, the Brazilian and Mexican networks fell behind the countries of the Southern Cone, Cuba and Costa Rica, as may be seen in Tables 3 and 4.

Table 3. Railway mileage in Latin America (1890-1912) (km)

	1890	*1900*	*1912*
Argentina	9,254	16,767	32,212
Brazil	9,973	15,316	23,491
Mexico	9,718	13,585	20,447
Chile	2,747	4,354	7,260
Cuba	1,731	1,960	3,803
Peru	1,599	1,800	3,276
Uruguay	983	1,730	2,522
Bolivia	209	972	1,284
Colombia	358	644	1,061
Venezuela	454	858	858
Guatemala	186	640	808
Costa Rica	241	388	619
Ecuador	92	92	587
Paraguay	240	240	373
Puerto Rico	18	223	354
Nicaragua	143	225	322
El Salvador	87	116	320
Dominican Republic	115	182	241
Honduras	96	96	170
Haiti	0	37	103
Panama			76
TOTAL	*38,244*	*60,225*	*100,187*

Source: Mitchell (2003).
Note: Panama is included within Colombia both in 1890 and in 1900.

Table 4. Railway mileage per capita in Latin America (1890-1912) (km per 10,000 pop)

	1890	*1900*	*1912*
Argentina	24.39	34.93	42.65
Uruguay	13.90	18.89	21.78
Chile	10.46	14.77	21.20
Costa Rica	10.46	12.64	16.51
Cuba	11.23	12.25	16.13
Mexico	8.25	10.41	14.22
Brazil	6.92	8.34	9.53
Peru	5.99	5.79	7.46
Guatemala	2.33	7.23	7.08
Bolivia	1.04	5.15	6.03
Paraguay	5.96	4.79	5.83
Nicaragua	3.61	4.86	5.67
Ecuador	0.81	0.71	3.81
Venezuela	2.03	3.90	3.31
Dominican Republic	2.60	3.03	3.14
El Salvador	1.29	1.45	3.13
Puerto Rico	0.21	2.33	3.05
Honduras	2.51	2.14	2.96
Colombia	0.89	1.53	2.09
Panama			1.78
Haiti	0	0.29	0.58
TOTAL	*7.33*	*9.94*	*12.94*

Sources: Mitchell (2003), Maddison (2001) and Banks' CNTS Archive.
Note: Panama is included within Colombia both in 1890 and in 1900.

Tables 3 and 4 may be taken as preliminary evidence of the different role that railways performed in the growth of each Latin American economy before 1914. In both tables, Argentina stands out as a special case, where railway expansion reached levels comparable to some European networks. Other group of economies in which relatively dense networks were constructed was made up by other Southern Cone countries (Uruguay and Chile), Cuba, Costa Rica, Mexico and, to some extent, Brazil and Peru. By contrast, in the rest of the continent railway development was extremely slow and railway systems were scarcely integrated, consisting mainly of a series of isolated lines that connected production areas with the main ports, and hardly affecting large shares of the territory of their countries. Actually, to some extent, the contribution of railways to the economic growth of each country might be expected to be proportional to the development of its railway network. In countries with relatively dense networks, railways would be important not only as a reinforcing factor for the export orientation of the economy, but also as an instrument of market integration, by its own or in combination with river and coastal navigation.

This paper focuses on the cases of Argentina, Brazil, Mexico and Uruguay (from now on, LA4), a sample of countries that, according to Maddison's database, accounted for 65 percent of Latin American GDP and 59 percent of the region's population by 1913. These countries are in the first ranks of Tables 3 and 4; they possessed 79 percent of the total Latin American mileage in 1912 and had, together with Chile, Costa Rica and Cuba, the highest mileage per capita in the region. Actually, with the exception of Brazil, they were among the rare cases where an integrated national railway network was built. *A priori*, therefore, they might be expected to be among those Latin American economies in which the railways had a higher growth impact. The next sections try to approach that impact through the application of growth accounting techniques.

3. The measurement of the contribution of railways to economic growth.

The most usual way to measure the global contribution of technological change to economic growth is the estimation of the so-called "Solow Residual", on the basis of a typical Cobb-Douglas production function and competitive assumptions. The "Solow residual" ($\Delta A/A$) was originally interpreted as the total factor productivity growth provided by new technology, and is estimated from the following expression:

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

where Y is total output, L is the total number of hours worked, K denotes the services provided by the capital stock, and s_K is the factor income share of capital.

Some recent research on the contribution of information and communication technologies (ICT) to economic growth has been based on a generalization of expression (1), which aims at incorporating the hypothesis of endogenous innovation and embodied technological change. Oliner and Sichel (2002), for instance, apply a disaggregated version of equation (1), in which different types of capital and different components of TFP growth are distinguished. This allows them to measure the growth impact of ICT, both through disembodied TFP growth and through the embodied capital-deepening effect of investment in ICT. Therefore, they transform expression (1) into:

$$\Delta(Y/L)/(Y/L)=s_{Ko}\Delta(K_o/L)/(K_o/L)+\gamma(\Delta A/A)_o+s_{KICT}\,\Delta(K_{ICT}/L)/(K_{ICT}/L)+\varphi\,(\Delta A/A)_{ICT} \qquad (2)$$

where K_{ICT} and K_o are the services provided by capital stock in ICT and in other sectors, respectively, A is the TFP level in the sector indicated by the subscript (ICT and other), s_{KICT} and s_{Ko} are the factor income shares of ICT capital and other capital, and φ and γ are the shares of ICT and other sectors' production in total output.

The contribution of a new technology to labor productivity growth may be approached by the sum of the last two terms of equation (2), which would approach, respectively, the "capital contribution" and the "TFP contribution" of the new technology. In fact, this would be a lower bound estimate of the real impact of the new technology, as there may be spillovers from the sector under consideration to the rest of the economy that would not be included in that estimate. Unfortunately, growth accounting studies usually fail to quantify indirect TFP spillovers, due to the measurement difficulties involved.[5]

When this methodology is applied to the study of non-leading economies, it is necessary to introduce an additional *caveat*. The use of the TFP growth rate in a specific sector as a measurement of the "TFP contribution" of that sector's new technology may be adequate for the analysis of advanced economies, in which new technologies are only introduced when they can provide their services at the same cost as the old technology that they replace. For instance, in the case of Britain, the railways were introduced when they could provide transport services at a similar unit cost to that of their competitors (mainly waterways and coastal navigation) and, therefore, the contribution of the railway technology to the aggregate British TFP growth (excluding spillovers) may be adequately approached by the growth of TFP in the railway sector.

By contrast, that procedure may be misleading in the case of peripheral countries, which acquire new technologies from the core economies. Peripheral countries might obtain higher TFP gains from a new technology than those measured by the TFP growth rate of the corresponding sector, for two reasons. On the one hand, the old sectors that the new technology was going to replace might be less efficient than in the core economies. On the other hand, peripheral countries might acquire the new technology when it had already been used and improved in the leading economies for a while. As a consequence, at the time of the introduction of the new technology, the difference between the unit cost of its services and the services provided by the old technology that it replaces might be very large. In a complete growth accounting assessment, the "TFP contribution" of a new technology should include that difference, and TFP growth in the new technology sector would therefore not provide a complete measure for that contribution.

[5] See Oliner and Sichel (2002), pp. 16-20, and Crafts (2004b), pp. 339-340.

This issue was already stressed in Herranz-Loncán (2006) for the case of the Spanish railways. Whereas, as has already been indicated, the first British railways had no great cost advantage over their main competitor (i.e. water transportation) when they were established, the first Spanish railway services were considerably cheaper than the alternative modes they displaced (mainly traditional overland transportation), and the difference between railway and traditional transport costs should be included in the contribution of the railways to TFP growth in the Spanish economy (and added up to the last term of expression 2). Similarly, an estimate of the whole TFP effects of Latin American railways should not only include TFP improvements within the railway sector itself (as in the British case) but also those TFP gains that were associated to the shift from old forms of transportation to the railways (as in the Spanish case).

In this context, instead of approaching the "TFP contribution" of railways in the LA4 countries through TFP growth in the railway sector, it may be estimated on the basis of the available social saving estimates, as those included in Table 2 above. Social savings are usually calculated as:

$$SS = (P_{ALT} - P_{RW}) \times Q_{RW} \quad (3)$$

where P_{RW} and P_{ALT} are, respectively, the price of railway and counterfactual (alternative) transport, and Q_{RW} is the railway transport output in the reference year. This expression is actually an upward biased estimate (due to the implicit assumption of a price-inelastic transport demand) of the equivalent variation consumer surplus provided by the railways which, if perfect competition in the rest of the economy is assumed, provides a general equilibrium measure of the entire direct real income gain obtained from reducing resource cost in transportation (Metzer, 1984; Jara-Díaz, 1986).

As has been stressed by Crafts, the price dual measure of TFP allows considering such gain in real income as equivalent to the TFP increase provided by the railways. According to the previous considerations, in a country like Britain, where railways were only introduced at the point where they could offer transport services at the same cost as water transportation, it should actually be equivalent to TFP gains in the railway sector itself (Crafts, 2004a, p. 6). By contrast, in Spain or in the LA4 economies, the total gain in real income (obtained from the social savings estimations) would not only reflect TFP growth in the railway sector but also those TFP gains associated with the shift from old forms of transportation to the railways. As a consequence, estimates of TFP increases based on the Spanish (or Latin American) social savings might be compared with the British figures based on the TFP growth rate in the railway sector, in order to analyze differences in the whole TFP growth impact of the railway system (including the substitution among different transport modes).[6] This comparison is carried out, in the cases of Spain and Britain, in Table 5, which presents the available estimates of the contribution of the railway technology to economic growth in those two countries as the sum of the two last terms of expression (2).

Table 5. Railways' Contribution to Growth in Britain and Spain before 1913

	Britain (1830-1850)	Britain (1850-1870)	Britain (1870-1910)	Spain (1850-1912)
a) Railway capital stock per capita growth	22.8	5.9	0.4	4.2
b) Railway profits share in national income	0.6	2.1	2.7	0.86
c) "Capital term" of the railway growth contribution (a x b) (percentage points per year)	*0.14*	*0.12*	*0.01*	*0.036*
d) Railway TFP growth	1.9	3.5	1.0	-
e) Railway share in national output	1.0	4.0	6.0	-
f) "TFP term" of the railway growth contribution (d x e) (percentage points per year)	*0.02*	*0.14*	*0.06*	*0.10 / 0.13* [a]
g) Total gain in real income from railway TFP growth / Income per capita increase since the beginning of the railway era (%)	-	-	-	*10.01/12.56* [b]
h) TFP Spillovers	*na*	*na*	*na*	*na*
i) Total railway contribution (c+f+h) (percentage points per year)	*0.16*	*0.26*	*0.07*	*0.14 / 0.17*
j) Railway contribution as % of GDP per capita growth	*14.97*	*18.85*	*8.51*	*13.64/16.19*

Sources: Own elaboration from Crafts (2004b) and Herranz-Loncán (2006) and (2008).
Note: (a) Calculated from row g and the income per capita growth rate in 1850-1912; (b) Calculated directly from the available social savings estimates; na: not available.

In both countries, the railway technology accounted on average for approximately 13-16 percent of GDP per capita growth in the six/eight decades before 1913. This is indeed a substantial contribution for a single sector. However, the similarity between the estimates for both countries critically depends on the inclusion of the resource saving effects of the shift from alternative transport modes to the railways in the Spanish case. If this shift were not considered, the direct economic impact of Spanish railways would just amount to approximately 5 to 6 percent of Spanish GDP per capita growth, i.e. less than half the contribution presented in Table 5. It is also interesting to see that, although the contribution of railways to Spanish economic

[6] Actually, although small, there was also some potential transport cost reduction in Britain from the substitution of the railways for alternative transport modes; see Hawke (1970). Therefore, an account of the growth contribution of the British railways such as that in Table 5, which is just based on the increase in TFP within the railway sector, would contain certain downward bias associated with the exclusion of those gains, which must be kept in mind in the comparison between the British and the Spanish or LA4 cases.

growth was sizeable, it was not significantly higher than the British equivalent figure. This contrasts with the traditional interpretation on this matter, based on the available social saving estimates, which considered that railways were more vital in a poor country like Spain, with fewer opportunities for water transport, than in a rich country like Britain, well endowed with waterways. As may be seen in row (b) of the table, that difference was largely overcome by the much higher importance of the railway sector in the British than in the Spanish economy. Next section applies this methodology to the estimation of contribution of the railway technology to productivity growth in the LA4 countries, in order to evaluate the role that railways performed in those countries during the first globalisation boom.

4. The contribution of railways to economic growth in the LA4 countries before 1914.

As has been described in the previous section, the contribution of railways to economic growth may be estimated as the sum of two terms. The first is the product of the growth rate of the railway capital stock per capita times the factor income share of railway capital (the "capital contribution"). The second is the TFP growth rate in the transport sector times the share of railway production in total output (the "TFP contribution"). As has been indicated, this second term may be measured directly, through the calculation of the direct real income gain obtained by the economy from reducing resource cost in transportation, on the basis of the social savings. The next two subsections are devoted to the estimation of those two terms in the LA4 countries before 1914.

4.1. The contribution of railways to economic growth: the capital term.

There are no available estimates of railway capital stock for the LA4 countries during the second half of the nineteenth century and the first few years of the twentieth century. Therefore, as is customary in this kind of exercises, I have assumed the evolution of railway capital to be similar to that of railway mileage. Table 6 shows the yearly growth rates of railway mileage per capita in the LA4 countries since the start of the "railway era" until the eve of World War I.[7]

[7] I do not include in the analysis the early years of operation of the railways, when only some very short stretches with very little traffic were open to the public. Therefore, I start my analysis, in the case of

Table 6. Growth rate of railway mileage per capita

Country	Period considered	Railway km per capita yearly growth rate (percent)
Argentina	1865-1913	6.36
Brazil	1864-1913	6.25
Mexico	1873-1910	8.61
Uruguay	1874-1913	3.91

Note: Growth rates are estimated by adjusting a log-trend to the mileage data.
Sources: Railway mileage comes from Mitchell (2003), except for Uruguay, for which it has been directly estimated from the country's statistical yearbooks. Population has been taken, for Mexico and Brazil, from the Maddison's database, for Uruguay, from Bértola (1998), and for Argentina, from Vázquez-Presedo (1971). Gaps between population data have been filled through geometric interpolation.

In order to estimate the capital term of the growth contribution of the railways in each country, those rates should be multiplied by the factor income shares of railway capital, i.e. the average ratios between railway net operating revenues and nominal GDP throughout the period under consideration. Table 7 presents estimates of the average ratios between net revenues and GDP in the LA4 countries. These figures must be taken with certain caution, especially in the cases of Mexico and Brazil, due both to the scarcity and bad quality of the statistics on railway operation and to the gaps and the relatively bad quality of the available nominal GDP figures.

Table 7. Average ratio between net railway revenues and nominal GDP in LA4 during the railway era

	Railway profit share in national income (net railway revenues/GDP, %)
Argentina (1865-1913)	1.81
Brazil (1864-1913)	0.81
Mexico (1873-1910)	0.91
Uruguay (1874-1913)	0.71

Sources and notes:

a) Argentina. Net revenue data from Dirección General de Ferrocarriles, *Estadística de los ferrocarriles en explotación* (1892-1913). Nominal GDP has been taken, for 1900 onwards, from the Oxlad database. For 1875-1900, I have driven backwards the Oxlad estimates on the basis of the evolution of real GDP, taken from Della Paolera, Taylor and Bózzoli (2003), and price indices, taken, for 1884-1900, from Della Paolera, Taylor and Bózzoli (2003), and, for 1875-1884, from Ferreres (2005). For 1865-75 I have estimated nominal GDP on the basis of Prados de la Escosura's (2009) assumption that real income per capita grew at a yearly rate of 0.8 percent, the evolution of population (Vázquez-Presedo, 1971) and the evolution of prices (Ferreres, 2005).

Argentina, in 1865 (when towns as Luján, Mercedes and Chascomús were already connected to Buenos Aires), in the case of Brazil, in 1864 (year of the connection of Rio de Janeiro with the *Vale do Paraíba* through the Dom Pedro II railway), in the case of Mexico, in 1873 (when the Mexico-Veracruz line was completed) and, in the case of Uruguay, in 1874 (when Montevideo was connected with Durazno). On the other hand, in the case of Mexico I end the analysis in 1910, to avoid the impact of the Mexican revolution and to adapt my research to the chronology of Coatsworth's social saving estimation (see below).

b) Brazil. In the absence of reliable estimates of net revenues of the whole Brazilian railway network, I have taken the ratios between net revenues and GDP in 1913 provided by Summerhill (2003) and have driven them backward on the basis of: i) the series of freight gross revenues of a sample of Brazilian railway lines estimated by Summerhill (2003), under the assumption that the operating ratio of the Brazilian railways was constant throughout the period under study and the lines of the sample represented a constant share of the total revenues of the network;[8] ii) the evolution of Brazilian nominal GDP. This has been taken, for 1900 onwards, from the Oxlad database, and, for the period before 1900 I have driven backwards the Oxlad estimates on the basis of Goldsmith (1986).

c) Mexico. Firstly, I have estimated the amount of net revenues in 1910 on the basis of the gross revenues of the network, taken from Coatsworth (1981, pp. 42-43), and the operating ratio of the *Ferrocarriles Nacionales*, which accounted for two thirds of the network in 1910, taken from Grunstein Dickter (1996), p. 202. Secondly, I have assumed the evolution of net revenues between 1873 and 1910 to be similar to that of the gross revenues of the network, available in Coatsworth (1981, pp. 42-43). This means that I assume, as in the case of Brazil, a constant operating ratio in the Mexican railway network. Nominal GDP data come, for 1900-1913, from Oxlad and, for 1895-1899, from *Estadísticas Históricas de México* (http://biblioteca.itam.mx/recursos/ehm.html). Before 1895, yearly real GDP figures have been obtained from Maddison (2001) through interpolation, and have been expressed in nominal terms, for 1885-95, on the basis of the evolution of an index of prices in Mexico City, taken from *Estadísticas Históricas de México*, and, for 1878-1885, on the basis of the index of export prices in Coatsworth (1981), p. 42. For 1873-1875 I have assumed that the growth rate of real and nominal GDP were the same.

d) Uruguay: for net railway revenues, see Herranz-Loncán (forthcoming, b). Nominal GDP is calculated on the basis of its level in 1955, taken from the official national accounts, and its previous evolution, as estimated by Bertino and Tajam (1999) and Bértola (1998).

The average ratios between net revenues and GDP in Table 7 clearly show the outstanding importance of the railway sector in Argentina, compared with the rest. Actually, the Argentinean ratio between net revenues and GDP was not very far away from the average British equivalent figures in 1850-1910 (2.52 percent). By contrast, those ratios seem to have been significantly lower in Brazil, Mexico and Uruguay, where they would have been much more similar to the equivalent Spanish figure in 1850-1912 (0.86 percent). This provides a first indication of the different importance of the railway sector in export-led growth episodes during the period, and the prominent position of Argentina in this regard, as is stressed below.

As a result of those calculations, the capital term of the yearly contribution of railways to growth in Brazil, Mexico and Uruguay would range between 0.03 and 0.08 percentage points of growth, whereas the capital term of the growth contribution of the

[8] It is difficult to know how far away these assumptions are from the real situation of the Brazilian railways, and they, therefore, may have introduced some biases in the final figures of unknown magnitude. The sample of lines analysed by Summerhill (2003) accounted for a relatively constant share of the Brazilian railway mileage only since the mid 1870s (around 55 percent). Before that date, however, they would represent approximately 80 percent of the total mileage of the network; see Summerhill (2003), pp. 66-67. If this change is accounted for in the estimation, it hardly affects the final estimates (the Brazilian figure in Table 7 would be 0.79 instead of 0.81). This correction, however, has not been applied to the calculation, because the lines excluded from Summerhill's sample and built after the mid 1870s may be assumed to have lower net revenues per km than the lines of the sample, which were among the most important of the Brazilian system.

Argentinean railways would have been much higher (0.12). With the exception of Argentina, the reported percentages are in line with the equivalent Spanish figure in 1850-1912 (0.036) and the British estimate for 1830-1910 (ca. 0.07). In this context, the relative advantage of Argentina was mainly associated to the large size of the railway sector relative to GDP (see Table 8).

Table 8. The contribution of railways to economic growth in LA4: the capital term

	(a) Railway km per capita yearly growth rate (percent)	(b) Railway profit share in national income (net railway revenues/GDP, percent)	(c) Railway contribution to economic growth: capital term (percentage points of growth) (a x b)
Argentina (1865-1913)	6.36	1.81	0.115
Brazil (1864-1913)	6.25	0.81	0.051
Mexico (1873-1910)	8.61	0.91	0.079
Uruguay (1874-1913)	3.91	0.71	0.028

Sourcess: see Table 6 and 7.

4.2. The contribution of railways to economic growth: the TFP term.

The estimation of the TFP term of the growth contribution of railways in the LA4 countries has been based on the corresponding social saving estimates. In the cases of Brazil and Mexico, those estimates are available in Summerhill (2003) and Coatsworth (1981). In the case of Argentina, Summerhill (2000) carried out a preliminary calculation, which only measured the social savings of freight railway transport, and which I have revised and enlarged to include passenger transport (see Herranz-Loncán, forthcoming, a). Finally, for Uruguay, I have recently produced complete (freight and passenger) social saving estimates for 1912-13 (see Herranz-Loncán, forthcoming, b).

The estimation of the TFP term of the contribution of the railway technology to GDP per capita growth requires the transformation of those (freight and passenger) social saving figures into estimates of the direct real income gain due to the railways in each country. In order to do this, the social savings must be expressed as additional consumer surplus (i.e. corrected by the elasticity of demand), and increased by the amount of “supernormal” profits of the railway companies, as in Herranz-Loncán

(2006). This is the objective of this subsection. Starting with freight transport, Table 9 shows the social savings of the railways in the LA4 countries by 1910/1913.[9]

Table 9. Social savings of freight railway transport in the LA4 countries in 1910/1913

	Argentina[a] (1913)	Brazil (1913)	Mexico[b] (1910)	Uruguay (1912-13)
a) Railway freight output (million ton-km)	8,985.4	1,697.3	3,456.1	305.81
b) Railway rate in pesos/milreis per ton-km (*in pounds*)	0.0101 (*0.0020*)	0.097 (*0.0023*)	0.023 (*0.0024*)	0.016 (*0.0033*)
c) Railway freight output (million pesos/milreis) (a x b)	90.64	165.32	79.53	4.74
d) Average alternative transport rate in pesos/milreis per ton-km (*in pounds*)	0.067 (*0.0130*)	1.388/0.727 (*0.0323/0.0169*)	0.241 (*0.0249*)	0.057 (*0.0121*)
e) Alternative transport output (million pesos/milreis) (a x d)	604.13	2,356.71/1,234.21	833.61	17.36
f) Railway rate/alternative transport rate (percent) (b / e)	6.67	7.01/13.39	9.54	3.66
g) Social savings (million pesos/milreis) (e – c)	*513.50*	*2,191.39/1,068.89*	*754.08*	*12.61*
i) As a percentage of GDP	*20,6*	*38.45/18.75*	*24.33*	*3.83*

Notes: (a) for Argentina, all monetary amounts are in gold pesos; (b) for Mexico, Coatsworth's data have been expressed in Mexican pesos of 1910.
Sources: For Mexico and Brazil, own elaboration from Coatsworth (1981) and Summerhill (2003). For Argentina, Herranz-Loncán (forthcoming, a) and, for Uruguay, Herranz-Loncán (forthcoming, b).

There are two reasons that explain the differences in relative size among the countries' social savings estimates in row (i). The first one is the different importance of the railway sector in each economy (as may be seen, for instance, in the different ratios between net railway revenues and GDP in Table 7 above). This factor substantially increases the potential size of the social savings in Argentina, as in the case of the capital term of the railways growth contribution. The second reason is the different ratio between the railway and the alternative transport rate in each country (row f of Table 9). This ratio is mainly determined by the respective assumptions on the railway transport share that would be transported by carts or pack animals in each counterfactual economy, since these were the most expensive alternative transport means. Unit transport costs were instead much lower in water freight transport.

In the case of Argentina, for instance, I have suggested a unit cost of road transport of 0.070 gold pesos per ton-km, much higher than both the railway average rate (0.010) and water transport rates through the River Paraná (0.008) (Herranz-Loncán, forthcoming, a). In the case of Uruguay in 1912-13 I have estimated the road

[9] Figures in Table 9 exclude the "hidden" or "indirect" costs of alternative transport means, due to the difficulty to measure them; see Coatsworth (1981), pp. 104-105, and Summerhill (2003), p. 61.

transport rate as 0.056 pesos per ton-km, and the railway and water transport rates as 0.016 and 0.006 pesos per ton-km, respectively (Herranz-Loncán, forthcoming, b). The cheapest of those three transport means was river or coastal navigation. In fact, the substitution of water transport for the railways in the counterfactual economy would not have meant any cost increase, but a saving of resources, and the use of the railways was only justified for the presence of hidden costs in water transport (which are not considered in these social saving estimations).

Regarding the hypothetical distribution of railway freight transport among different alternative transport means in each country's counterfactual economy, in the cases of Mexico and Brazil I have accepted Coatsworth's and Summerhill's assumption that, in the absence of railways, the whole railway freight transport would be carried by road. The lack of waterways or coastal navigation routes that ran parallel to the railway lines in those countries makes this assumption fully plausible. By contrast, the situation was completely different in Argentina and Uruguay, where a significant share of railway transport followed the same direction as the coastline or the navigable rivers. In my estimations I have assumed that, in the absence of railways, 13.1 percent of the Argentinean railway freight transport and 21 percent of the Uruguayan one would be transferred to river navigation. These percentages are the outcome of a rough estimation of the share of railway freight traffic that ran parallel or close to navigable rivers in those two countries.[10] These assumptions mean that the percentage of freight railway traffic that would be transferred to overland transport in the counterfactual economy would be 86.9 percent in Argentina and 79 percent in Uruguay, compared with 100 percent in Mexico and Brazil. To a large extent, these different percentages explain the different relative size of the social saving in each country.[11]

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[10] In the case of Argentina, this percentage is the sum of: i) the share of the Buenos Aires-Rosario company (whose main line ran parallel to the Paraná river) over total freight railway transport in 1907 (the last year for which this information is available, just before the merger of this company with the *Ferrocarril Central Argentino*), and ii) the freight transported by the companies of the Mesopotamia (the *Provincia de Santa Fe, Nordeste* and *Entre Ríos* companies), which ran to a large extent in the same directions as the Paraná and Uruguay rivers. That information has been obtained from Dirección General de Ferrocarriles, *Estadística de los ferrocarriles en explotación* (1907/1913). In the case of Uruguay, I have estimated the share of railway traffic stemming from areas close to the Uruguay River or the La Plata estuary; see Herranz-Loncán (forthcoming, b).

[11] In the case of Argentina and Uruguay, I have also considered the fact that, in the absence of railways, livestock transport would have been replaced by droving. Droving would account for 10.05 percent of total railway freight transport in the counterfactual economy in Argentina and 18.78 percent in Uruguay. This does not affect the reasoning since, although the prices or droving services were much lower per ton-km than carting rates, droving involved a high indirect cost associated to the livestock's weight loss

As a result of the combination of those two factors (the importance of the railway sector in the whole economy and the share of railway output transferred to road transport in the counterfactual economy), in the cases of Argentina, Brazil and Mexico the social savings figures are very high in terms of GDP. By contrast, the Uruguayan estimate is much lower than the rest.[12]

The next step of the estimation of the TFP term of the growth contribution of railways is the correction of the freight social saving figures according to the price elasticity of demand in each country, in order to obtain unbiased estimates of the additional consumer surplus of railway freight transport. This elasticity has been estimated as -0.5 in Mexico by Coatsworth (1981), and as -0.6 in Brazil and -0.49 in Argentina by Summerhill (2000, 2003). My own estimate for Uruguay is -0.77 (Herranz-Loncán, forthcoming, b). The estimates of additional consumer surplus of railway freight transport that result from applying those elasticities to the social saving figures reported in Table 9 are shown in Table 10.[13]

Table 10. Additional consumer surplus of railway freight transport in LA4 in 1910/13.

	Argentina (1913)	Brazil (1913)	Mexico (1910)	Uruguay (1912-13)
Social saving of railway freight transport (million pesos/milreis)	513.50	1,068.32/2,191.34	754.08	12.61
Price elasticity of demand	-0.49	-0.6	-0.5	-0.77
Additional consumer surplus of railway freight transport (million pesos/milreis)	289.89	510.31/783.05	355.91	7.18
As a % of GDP	*11.61*	*8.97/13.77*	*11.48*	*2.19*

Sources: for Argentina, Mexico and Brazil, own calculation on the basis of Coatsworth (1981), Summerhill (2000) and (2003) and Table 9; for Uruguay, Herranz-Loncán (forthcoming, b).

These figures must be increased by the additional consumer surplus of railway passenger transport. In the case of passengers, the additional consumer surplus should take into account not only the savings of costs in the transport activity itself but also the

during the journey. I have applied the Uruguayan droving rates to Argentina. On this subject, see Herranz-Loncán (forthcoming, b).

[12] Differences among countries in railway rates or alternative transport prices also introduce differences in the social saving estimates. For instance, railway rates were very high in Uruguay, and road transport prices seem to have been lower in Argentina and, specially, in Uruguay, than in the rest of LA4. Nevertheless, it is difficult to know to what extent those alternative transport rates are biased, due to the scarcity of information. As O'Brien (1983, p. 177) warned, this is one of the main drawbacks of social saving calculations.

[13] The ratio between the biased and unbiased estimates of additional consumer surplus is given by $[(\phi^{1+\varepsilon}-1)/(1+\varepsilon)(\phi-1)]$, where ε is the elasticity of transport demand and ϕ is the ratio between counterfactual and railway transport prices; see Fogel (1979), pp. 10-11.

time saved by individuals thanks to the replacement of traditional transport means by railways. This requires estimating the share of additional travelling time that would have to be deducted from the travellers' working time in the counterfactual economy, as well as the railway passengers' average hourly wage.

As in the case of freight, Coatsworth (1981) and Summerhill (2003) produced careful estimates of the social savings of railway passenger transport for Mexico and Brazil, respectively. These were based on the assumption that, in the absence of the railways, first class passengers would have used stagecoach transport, but second class passengers would have walked instead. Since my interest is the additional consumer surplus of passenger transport, and not the mere social savings, here I follow a different approach. Firstly, I estimate the social savings of railway passenger transport in both countries considering stagecoach transport as the counterfactual transport system for all passenger classes. And, secondly, I correct the social saving estimates according to the price elasticity of demand, but allowing for different elasticities in first and second class railway transport. More concretely, for first class passengers, I assume the price elasticity of transport demand to be approximately -1,[14] and, for second class passengers, I consider railway transport as a completely new good. This is equivalent to assume that the users of second class passenger transport would not have travelled at all at the price of the most comparable alternative transport system, i.e. stagecoach transport.[15] The result of this strategy is an alternative estimate of the social savings of passenger railway transport in those two countries, although fully based on the information provided by those authors.In the cases of Argentina and Uruguay, I have carried out a similar estimation although, as in the case of freight, I have assumed that, in the absence of the railways, certain share of the Argentinean and Uruguayan passenger transport would have been transferred to river navigation. I have estimated that percentage to be 16.8 percent in Argentina and 16.6 percent in Uruguay.[16] As for the savings in travel time, here I have assumed, as Coatsworth and Summerhill, that the lowest-income social groups did not use railway transport. Therefore, I value the travel time of second class travelers at the average hourly wage of industrial workers, and that of first class travelers at twice that amount. Finally, I also consider, as in the cases of Mexico and Brazil, that only about half of the time savings were savings in working

[14] See, for instance, Boyd and Walton (1972), pp. 247-250, and Metzer (1977), p. 73.
[15] See, for instance, Hausman (1994).
[16] Those percentages are calculated on the basis of the same assumptions as in the case of freight.

time and must therefore be included in the estimation of the additional consumer surplus.[17] The results of the estimation are shown in Table 11.

[17] The actual percentages of travel time that were considered working travel time by Coatsworth (1981) and Summerhill (2003) were 40 and 51.7 percent respectively. I have used the threshold of 50 percent for the four countries for the sake of homogeneity. However, using those authors' percentages instead has a minimum impact on the final results.

Table 11. Social savings of railway passenger transport in LA4 in 1910/13.

A) First-class passenger transport

	Argentina (1913)	Brazil (1913)	Mexico (1910)	Uruguay (1912-13)
a) Railway output (million passenger-km)	1,309.43	605.19	229.91	68.155
b) Railway rate in pesos/milreis per passenger-km (*in pounds*)	0.015 (*0.0031*)	0.047 (*0.0011*)	0.037 (*0.0038*)	0.019 (*0,0041*)
c) Railway output (million pesos/milreis) (a x b)	20.21	28.44	8.45	1.30
d) Unit value of working travel time in pesos/milreis per hour (*in pounds*)	0.452 (*0.090*)	0.891 (*0.0208*)	0.356 (*0.0367*)	0.409 (*0.0870*)
e) Railway passenger transport average speed (km p. h.)	39.4	39	40	34.4
f) Working travel time by railway (million hours) (50 percent of a at e km p. h.)	16.617	7.759	2.874	0.991
g) Value of the working travel time by railway (million pesos/milreis) (d x f)	7.503	6.913	1.023	0.405
h) Counterfactual water transport output (million passenger-km)	219.52	-	-	11.29
i) Counterfactual water transport rate in pesos/milreis per passenger-km (*in pounds*)	0.0057 (*0.0011)*	-	-	0.0048 (*0.0010*)
j) Counterfactual water transport output (million pesos/milreis) (h x i)	1.251	-	-	0.054
k) Water passenger transport average speed (km p. h.)	12	-	-	12
l) Working travel time by water transport (million hours) (50 percent of h at k p. h.)	9.147	-	-	0.0023
m) Value of the working travel time by water transport (million pesos/milreis) (d x l)	4.130	-	-	0.00093
n) Counterfactual road transport output (million passenger-km)	1,089.91	605.19	229.91	56.87
o) Counterfactual road transport rate in pesos/milreis per passenger-km) (*in pounds*)	0.0246 (*0.0049*)	0.360 (*0.0084*)	0.120 (*0.0123*)	0.0614 (*0.0131*)
p) Counterfactual road transport output (million pesos/milreis) (n x o)	22.812	217.87	27.609	3.494
q) Road passenger transport average speed (km p. h.)	17.25	13	15	6.5
r) Working travel time by road transport (million hours) (50 percent of n at q km p. h.)	31.592	23.277	7.664	4.374
s) Value of the working travel time by road transport (million pesos/milreis) (d x r)	14.264	20.738	2.728	1.789
t) Savings on transport costs (million pesos/milreis) (j + p – c)	7.855	189.43	19.156	2.248
u) Savings on travel time (million pesos/milreis) (m + s – g)	10.891	13.825	1.705	1.385
v) Total savings (million pesos/milreis) (t + u)	*18.746*	*203.25*	*20.861*	*3.633*
w) As a percentage of GDP	*0.75*	*3.57*	*0.67*	*2.60*

B) Second-class passenger transport.

	Argentina (1913)	Brazil (1913)	Mexico (1910)	Uruguay (1912-13)
a) Railway output (million passenger-km)	1,544.28	1,012.00	830.54	47.231
b) Railway rate in pesos/milreis per passenger-km (*in pounds*)	0.010 (*0.0020*)	0.027 (*0.0006*)	0.014 (*0.0015*)	0.016 (*0.0033*)
c) Railway output (million pesos/milreis) (a x b)	15.19	26.82	11.90	0.73
d) Unit value of working travel time in pesos/milreis per hour (*in pounds*)	0.226 (*0.0448*)	0.445 (*0.0104*)	0.178 (*0.0184*)	0.205 (*0.0435*)
e) Railway passenger transport average speed (km p. h.)	39.4	39	40	34.4
f) Working travel time by railway (million hours) (50 percent of a at e km p. h.)	19.598	12.974	10.382	0.687
g) Value of the working travel time by railway (million pesos/milreis) (d x f)	4.424	5.780	1.848	0.140
h) Counterfactual water transport output (million passenger-km)	258.90	-	-	7.82
i) Counterfactual water transport rate in pesos/milreis per passenger-km (*in pounds*)	0.0057 (*0.0011)*	-	-	0.0048 (*0.0010*)
j) Counterfactual water transport output (million pesos/milreis) (h x i)	1.476	-	-	0.038
k) Water passenger transport average speed (km p. h.)	12	-	-	12
l) Working travel time by water transport (million hours) (50 percent of h at k p. h.)	10.787	-	-	0.0016
m) Value of the working travel time by water transport (million pesos/milreis) (d x l)	2.435	-	-	0.00032
n) Counterfactual road transport output (million passenger-km)	1,285.39	1,012.00	830.54	39.41
o) Counterfactual road transport rate in pesos/milreis per passenger-km) (*in pounds*)	0.0246 (*0.0049*)	0.360 (*0.0084*)	0.120 (*0.0123*)	0.0614 (*0.0131*)
p) Counterfactual road transport output (million pesos/milreis) (n x o)	31.621	364.32	99.737	2.421
q) Road passenger transport average speed (km p. h.)	17.25	13	15	6.5
r) Working travel time by road transport (million hours) (50 percent of n at q km p. h.)	37.258	38.923	27.685	3.031
s) Value of the working travel time by road transport (million pesos/milreis) (d x r)	8.411	17.339	4.928	0.620
t) Savings on transport costs (million pesos/milreis) (j + p – c)	17.905	337.502	87.842	1.725
u) Savings on travel time (million pesos/milreis) (m + s – g)	6.422	11.559	3.080	0.480
v) Total savings (million pesos/milreis) (t + u)	*24.327*	*349.061*	*90.922*	*2.205*
w) As a percentage of GDP	*0.97*	*6.14*	*2.93*	*1.58*

Sources and notes: for Mexico and Brazil, own elaboration based on Coatsworth (1981) and Summerhill (2003); for Argentina and Uruguay, see Herranz-Loncán (forthcoming, a) and (forthcoming, b).

As may be seen in Table 12, when these figures are corrected according to the elasticity of demand, and under the assumptions described above, the additional consumer surplus of passenger railway transport becomes much lower, especially in the case of the second class, as a result of the assumption that this category of passenger transport was a completely new good. The resulting total additional consumer surplus for passenger transport is, therefore, much smaller than in the case of freight, which is consistent with the low importance that passenger transport had, according to Coatsworth (1981) and Summerhill (2003), in the direct benefits that Mexico and Brazil received from the railways. The only exception to that rule is Uruguay, due to the low size of the social saving of freight transport in that country.

Table 12. Additional consumer surplus of railway passenger transport in LA4 (corrected by the elasticity of demand)

	Argentina (1913)	Brazil (1913)	Mexico (1910)	Uruguay (1912-13)
a) First-class (million pesos/milreis)	16.65	68.55	12.25	2.31
b) Second-class (million pesos/milreis)	0.44	4.01	1.31	0.05
Total (a+b)	*17.09*	*72.57*	*13.56*	*2.36*
As a % of GDP	*0.68*	*1.28*	*0.44*	*1.69*

Sources: see text and Table 11.

The scarcity of adequate information prevents from including in the additional consumer surplus estimates other sorts of freight transport (essentially high-speed freight), which accounted for a non-negligible share of railway revenues.[18] Their absence would introduce certain downward bias in the additional consumer surplus figures. This bias, however, is probably small. Since, as in the case of second class passenger transport, most of that traffic should be considered as a completely new commodity, its contribution to the additional consumer surplus may be expected to be rather low.

Finally, in order to obtain a complete measure of the real income gain provided by the railways in each country, the estimates of the additional consumer surplus of freight and passenger transport should be corrected for the potential presence of supernormal profits in the railway system. Supernormal profits should be calculated as the difference between gross revenues and total expenditure, including capital costs.

[18] For instance, this kind of traffic accounted for 11.8 percent of the total revenues of the Brazilian railway companies in 1913 (percentage estimated from Summerhill, 2003), for 4.8 percent in the case of Argentina (estimated from Dirección General de Ferrocarriles, *Estadística de los ferrocarriles en explotación*, 1913), and 4.9 in Uruguay (see Herranz-Loncán, forthcoming, b).

The latter, in turn, may be calculated as a percentage of the value of the stock of railway capital, which should include both the amortisation rates and the opportunity cost of capital. This calculation, however, is far from easy, due to the accounting procedures that were followed at the time. On the one hand, operating costs often included some replacement and new investment expenditures, which were not, therefore, incorporated to the capital account. On the other hand, railway capital was rarely depreciated, leading to an overstatement of the capital stock figures.[19] In addition, in those countries, such as Argentina or Brazil, where railway subsidies mainly consisted on guaranteed returns upon investment, capital figures were often artificially inflated by the companies.[20] In this context, it is very difficult to obtain an accurate estimate of supernormal profits. Therefore, here I just compare the difference between the net returns of each system and the opportunity cost of capital, approached through yields to government bonds, in order to have a preliminary idea of their potential size.

By 1912-13, railway net operating returns were around 4 percent of total investment in Argentina, 3.6 percent in Brazil and 4 percent in Uruguay.[21] Given that the yields to government bonds were 4.88 percent in Argentina and 4.97 percent in Brazil at the time (Flandreau and Zumer, 2004), it seems likely that supernormal profits were actually negative in those railway systems, since net revenues would not have been sufficient to cover capital costs. However, those negative returns would be relatively small, specially compared with the additional consumer surplus of railway transport. For instance, in the case of Argentina and Brazil, if I take the yields on bonds as a proxy of the opportunity cost of capital and ignore amortization needs, that correction would amount to just 3-4.5 percent of the additional consumer surplus. Therefore, given the uncertainty on the real value of investment in those railway systems, I have decided to exclude this correction from the final figures.

[19] See Summerhill (2003), p. 169.

[20] This is the typical Averch-Johnson effect; see Averch and Johnson (1962). In the case of the *Ferrocarril Central Argentino*, López del Amo (1989), pp. 240-241, estimates that the company's accounts exaggerated investment figures by 57 percent between 1908 and 1930.

[21] Railway net returns come, in the case of Argentina, from Dirección General de Ferrocarriles, *Estadística de los ferrocarriles en explotación* (1913); in the case of Brazil, from Summerhill (2003); and, in the case of Uruguay, from Herranz-Loncán (forthcoming, b). In the case of Mexico, there are no available estimates of the total capital invested in the railway network and, therefore, it is not possible to calculate an average rate of return; see Ortiz Hernán (1996), p. 28. However, if the net revenues of the system by 1910 are combined with the estimate of 1,130 million pesos of foreign investment in Connolly (1997), p. 83, the resulting percentage is less than 3 percent. Therefore, the situation would not be very different to the other three countries.

Table 13 summarises the results of the estimation of the direct real income gain of railway transport in each country. These figures allow calculating the TFP term of the growth contribution of railways by expressing that income gain as a contribution to the yearly growth rate of the economy between the start of the railway era and the reference year of the estimation. Figures in the table clearly show that, from the viewpoint of the TFP component of the railway growth contribution, the LA4 countries may be divided in two groups. On the one hand, in Argentina, Brazil and Mexico the TFP term accounted for 0.23 to 0.49 percentage points of growth during the railway era, i.e. a much higher amount than in Britain or Spain. By contrast, in Uruguay, that contribution was only around 0.09 percent, and rather close therefore to the British or the Spanish equivalent figures.

Table 13. Direct real income gain from railway transport LA4 in 1910/1913

	Argentina (1913)	Brazil (1913)	Mexico (1910)	Uruguay (1912-13)
a) Freight transport additional consumer surplus (million pesos/milreis)	289.89	510.31/783.05	355.91	7.18
b) Passenger transport additional consumer surplus (million pesos/milreis)	17.09	72.57	13.56	2.36
c) *Total (a+b)*	*306.98*	*582.88/855.61*	*369.46*	*9.54*
d) *As a % of GDP of the year of reference*	*12.29*	*10.25/15.04*	*11.92*	*2.89*
e) *As a % of the income per capita increase since the beginning of the railway era*	*16.21*	*94.83/139.20*	*20.65*	*6.64*
f) TFP term of the railway growth contribution (percentage points per year)	*0.487*	*0.226 / 0.332*	*0.449*	*0.090*

Sources: see text.

4.3. Summary.

The figures presented in the previous subsections allow making a preliminary estimation of the contribution of railways to productivity growth in the LA4 countries before World War I, which is presented in Table 14.

Table 14. The contribution of railways to productivity growth in LA4 before 1914 (percentage points per year)

	Argentina (1865-1913)	Brazil (1864-1913)	Mexico (1873-1910)	Uruguay (1874-1913)
a) Railway capital stock per capita growth	6.36	6.25	8.61	3.91
b) Railway profits share in national income	1.81	0.81	0.91	0.71
c) Railway capital contribution (a x b)	*0.115*	*0.051*	*0.079*	*0.028*
d) TFP contribution	*0.487*	*0.226 / 0.332*	*0.449*	*0.090*
e) TFP Spillovers	*na*	*na*	*na*	*na*
f) Total railway contribution (c+d)	*0.602*	*0.277/0.383*	*0.528*	*0.118*
g) GDP per capita growth	3.00	0.24	2.17	1.35
h) Railway contribution as % of GDP growth (f/g)	*20.04*	*116.1/160.5*	*24.27*	*8.71*

na: not available.

Sources: GDP per capita growth rates are calculated, in the case of Argentina, from the estimates by Della Paolera, Taylor and Bózzoli (2003) (I assume a 0.8 percent yearly growth rate before 1875, following Prados de la Escosura, 2010); in the case of Brazil, from Goldsmith (1986) and, since 1900, Haddad (1978); in the case of Mexico, from the Maddison's database; and, in the case of Uruguay, from Bértola (1998). For other magnitudes, see text.

Figures in Table 14 clearly confirm the exceptional character of Uruguay within the LA4 sample. Despite the substantial effort made to endow the Uruguayan economy with one of the densest networks of the continent, the direct contribution of the railways to economic growth was much lower than in the rest of LA4 and also lower than in Britain and Spain, both in absolute and relative terms. Uruguay provides therefore an interesting counterexample of a Latin American country in which the construction of railways during the first globalization constituted a relative failure. This result is partially associated to the low level of the capital term, due to the relative slowdown of Uruguayan railway construction since the 1890s. However, the main reason for that outcome is the low size of railway output in Uruguay by 1913. As is indicated in Herranz-Loncán (forthcoming, b), there are several potential explanations for the underdevelopment of the Uruguayan railway sector: alternative water transport was available for many routes, the specialisation of the country in livestock production did not generate much transport output per km^2, and the small scale of the country increased the share of short distance journeys over total transport, reducing therefore the competitiveness of the railways over traditional overland transport means. In other words, and opposite to what happened in the other LA4 countries, the geography of Uruguay did not provide an adequate context for achieving all the potential benefits of the new technology.

By contrast, the size of the direct growth contribution of railways in Argentina, Brazil and Mexico is, by all means, impressive. In absolute terms, the railways provided between 0.3 and 0.6 percentage points of growth per year in each of those three countries, i.e. between two and four times the equivalent figure in Britain or Spain. Such an advantage was, once more, mainly associated to the TFP effect. The capital term, by contrast, only made a significant difference in Argentina, due to the large share that railways net revenues accounted for within national income by 1913.

The high level of the TFP terms in those countries had several origins. In the cases of Brazil and Mexico, its most important explanatory factor was the absence of alternatives to road transport in a counterfactual economy without railways. This generated a huge difference between the railway rates and the alternative transport costs, with a large effect in the estimated direct income gains. In the case of Argentina, the size of the TFP term may also be explained, once more, by the large share that railways accounted for in the economy, as well as by the high efficiency of the Argentinean railway system, which applied the lowest rates to freight transport in the LA4 sample. All those reasons together help to explain that Argentina, Mexico and Brazil obtained huge absolute benefits from railway construction during the first globalization period.

The last row of Table 14 reports the growth contribution of railways as a percentage of the actual rate of growth of income per capita in each country. As has been indicated, Uruguay also stands out by the low level of the growth contribution of their railways in relative terms: just 8.7 percent of the growth of income per capital, i.e. a much lower percentage than in Britain or Spain. By contrast, in Argentina and Mexico the railways were directly responsible for 20 to 25 of the growth of income per capita between the start of the railway era and 1910/1913. Those percentages are quite impressive for a single sector, and significantly higher than the Spanish or British equivalent figures. Moreover, it is necessary to recall that those percentages exclude the indirect effects of railways, due to the difficulty to quantify them. In this regard, it is plausible to assume that the TFP spillovers of the railways were more important in Latin America than in Europe, because, in the former, they allowed the exploitation of the natural resources of a large share of the territory, which would have remained idle without them (Summerhill, 2003, p. 78). This would be especially relevant in the Argentinean case, since the main export during the period under study, i.e. grain, was absolutely dependent on railway transport (Cortés Conde, 1979; Lewis, 1983, pp. 219-220; López, 2007, pp. 46-51). As long as economic growth was led by exports, the indirect impact of railways during the period might have been almost as important as the direct effect, and the advantage of Argentina over Spain or Britain would be even larger than the figures in Table 14 explain.

In this context, Brazil deserves a special comment. Although the contribution of railways was lower in that country than in Argentina and Mexico in terms of percentage points of growth, that contribution was actually higher than the total growth of the stagnated Brazilian economy during the decades prior to 1914. This might be taken as a confirmation of Summerhill's statement that: "*the railroad conferred on Brazil benefits that probably exceeded, by far, those stemming from the other major changes in economic organization in this period*" (Summerhill, 2003, p. 96). However, the ratio is too high to be believed, and this anomaly raises some questions on the accuracy of the analysis that has been carried out in this paper. In this regard, it is possible, of course, that the available estimates of Brazilian income per capita of the late nineteenth and early twentieth century underestimate the actual growth of the Brazilian economy, since there is still a large margin of improvement of the long term economic history series of the main Latin American economies. However, the ratios reported in Table 14 may also reflect the fact that, in some cases, the country level may not be the most adequate scale to carry out analyses of the growth impact of the railways. During the period under analysis, the Brazilian economy constituted a huge and hardly integrated economic space. The absence of integration was also visible in the railways, which, opposite to what happened in Argentina, Mexico or Uruguay, did not constitute a national network, but were divided in several sub-systems, only partially connected through coastal navigation. In this context, the stagnation of 1865-1913, as has been suggested by the historiography, was compatible with considerable changes in the economic geography of the country, with some regions growing at high rates and other areas sinking into a deep crisis. As might be expected, the most important of those systems were established in the more dynamic areas (Sao Paulo and Rio de Janeiro), whereas the rest of the country only had some scattered lines that did not constitute intertwined networks. It is arguable to what extent, in such an economy, measuring the impact of the railways at the national level is meaningful. Probably, carrying out the analysis at the regional level would provide indicators much more relevant for the understanding of the role of the railways in each economic space.[22]

5. Concluding remarks

Railways constituted one of the most important technological breakthroughs of the nineteenth century, leading to a substantial upward shift in national economies' production functions worldwide. In the case of Latin America, historians have often highlighted the importance of railways for economic growth during the first globalisation boom, and the social saving literature has given empirical support to the hypothesis that those Latin American countries that invested heavily in railways obtained higher benefits from them than the more developed economies of Europe or North America. In this context, this paper has provided estimates of the direct contribution of railways to productivity growth in Argentina, Brazil, Mexico and Uruguay, which were among those Latin American economies that built relatively dense networks during the first globalisation boom. The results of the estimation indicate, firstly, that the contribution of railways to growth varied substantially across Latin American countries. More precisely, in the case of Uruguay, the growth impact of railways was very low, lower actually than in some European countries, such as Britain and Spain. This unexpected result may be explained by the features of the Uruguayan geography and economic structure, and provides a clear counterexample to the hypothesis that railways had higher benefits in Latin America than in the core industrialised countries.

By contrast, in the other three countries under study (Argentina, Mexico and Brazil) the railways provided huge direct benefits that amounted, in the first two cases, to between one fifth and one quarter of the total income per capita growth of the period under analysis. Besides, those ratios should be increased by the indirect spillovers coming from the railway system. Specially in the case of new settlement countries, such as Argentina, these may be expected to have been also very high, compared with those received from the railways by those economies that were relatively well developed and integrated at the advent of the railways (such as the UK). Finally, the case of Brazil merits a special reference, since the outcome of the analysis carried out in this paper

[22] For instance, if the analysis of the impact of railways is applied to the economic area organised around Sao Paulo and Rio de Janeiro it would probably provide a lower ratio in row h and, in the case of the North-East regions, it would probably produce a much lower level of the percentage in row f.

would indicate that the direct contribution of railways to growth would be higher than the whole income per capita growth of the Brazilian economy before 1914. Keeping in mind the possible biases associated to the lack of precision of the available income figures, this unexpected result would also suggest that the national level may not be the most adequate scale to analyse the economic impact of network infrastructure in the case of large, geographically unequal and insufficiently integrated developing economies.

6. References

Averch, H. and Johnson, L. L. (1962), "Behavior of the Firm Under Regulatory Constraint", *American Economic Review*, 52, 5, pp. 1052-1069.

Bertino, M. and Tajam, H. (1999), *El PBI de Uruguay, 1900-1955*, Montevideo, Universidad de la República, Instituto de Economía.

Bértola, L. (1998), *El PBI de Uruguay 1870-1936 y otras estimaciones*, Montevideo, Universidad de la República, Facultad de Ciencias Sociales.

Boyd, J. H. and Walton, G. M. (1972), "The Social Savings from Nineteenth-Century Rail Passenger Services", *Explorations in Economic History*, 9, 3, pp. 233-254.

Caron, F. (1983), "France", in O'Brien, P. (ed.), *Railways and the Economic Growth of Western Europe*, London, McMillan, pp. 28-48.

Coatsworth, J. H. (1979), "Indispensable Railroads in a Backward Economy: The Case of Mexico", *Journal of Economic History*, 39, 4, pp. 939-960.

Coatsworth, J. H. (1981), *Growth against Development: The Economic Impact of Railroads in Porfirian Mexico*, DeKalb, Northern Illinois University Press.

Connolly, P. (1997), *El contratista de don Porfirio. Obras públicas, deuda y desarrollo regional*, Zamora, Colegio de Michoacán.

Cortés Conde, Roberto (1979), *El progreso argentino, 1880-1914*, Buenos Aires, Editorial Sudamericana.

Crafts, N. F. R. (2004a), "Social Savings as a Measure of the Contribution of a New Technology to Economic Growth", LSE, Department of Economic History Working Paper 06/04.

Crafts, N. F. R. (2004b), "Steam as a General Purpose Technology: A Growth Accounting Perspective", *Economic Journal*, 114, pp. 338-351.

Crafts, N. F. R. (2010), "The Contribution of New Technology to Economic Growth: Lessons from Economic History", *Revista de Historia Económica-Journal of Iberian and Latin American Economic History*, 28 (3), pp. 409-440.

Della Paolera, G.; Taylor, A. M. and Bózzoli, C. G. (2003), "Historical Statistics", in Della Paolera, G. and Taylor, A. M. (eds.), *A New Economic History of Argentina*, Cambridge, Cambridge University Press, pp. 376-385.

Dobado, R. and Marrero, G. A. (2005), "Corn Market Integration in Porfirian Mexico", *Journal of Economic History*, 65, 1, pp. 103-128.

Ferreres, O. (2005), *Dos siglos de economía argentina. Historia argentina en cifras*, Fundación Norte y Sur.

Fishlow, A. (1965), *American Railroads and the Transformation of the Ante-bellum Economy*, Cambridge (MA), Harvard University Press.

Flandreau, M. and Zumer, F. (2004), *The Making of Global Finance, 1880-1913*, Paris, OECD.
Fogel, R. W. (1964), *Railroads and American Economic Growth: Essays in Econometric History*, Baltimore.
Fogel, R. W. (1979), “Notes on the Social Saving Controversy,”, *Journal of Economic History*, 39, 1, pp. 1-54.
Goldsmith, R. (1986), *Brasil 1850-1984: desenvolvimento financeiro sob um século de inflação*, São Paulo, Harper & Row do Brasil.
Grunstein Dickter, A. (1996), “¿Competencia o monopolio? Regulación y desarrollo ferrocarrilero en México, 1885-1911”, in Kuntz Ficker, S. and Riguzzi, P. (eds.), *Ferrocarriles y vida económica en México (1850-1950). Del surgimiento tardío al decaimiento precoz*, México, El Colegio Mexiquense, pp. 167-221.
Haddad, C. (1978), *Crescimento do produto real no Brasil, 1900-1947*, Rio de Janeiro, FGV.
Hausman, J. A. (1994), “Valuation of New Goods under Perfect and Imperfect Competition”, NBER Working Paper 4970.
Hawke, G. R. (1970), *Railways and Economic Growth in England and Wales*, Oxford, Clarendon Press.
Herranz-Loncán, A. (2006), “Railroad Impact in Backward Economies: Spain, 1850-1913”, *Journal of Economic History*, 66, 4, pp. 853-881.
Herranz-Loncán, A. (2008), *Infraestructuras y crecimiento económico en España, 1850-1935*, Madrid, Fundación de los Ferrocarriles Españoles.
Herranz-Loncán, A. (forthcoming, a), “El impacto directo del ferrocarril sobre el crecimiento económico argentino durante la Primera Globalización”, *Revista de la Asociación Uruguaya de Historia Económica*.
Herranz-Loncán, A. (forthcoming, b), “The Role of Railways in Export-Led Growth: the Case of Uruguay, 1870-1913”, *Economic History of Developing Regions*.
Jara-Díaz, S. R. (1986), “On the Relation Between Users’ Benefits and the Economic Effects of Transportation Activities”, *Journal of Regional Science*, 26, 2, pp. 379-391.
Kuntz Ficker, S. (1995), “Mercado interno y vinculación con el exterior: el papel de los ferrocarriles en la economía del porfiriato”, *Historia Mexicana*, XLV, 1, pp. 39-66.
Kuntz Ficker, S. (1999), “Los ferrocarriles y la formación del espacio económico en México, 1880-1910”, in Kuntz Ficker, S. and Connolly, P. (coord.), *Ferrocarriles y Obras Públicas*, México, Instituto Mora, pp. 105-137.
Leunig, T. (2010), “Social Savings”, *Journal of Economic Surveys*, 24, 5, pp. 775-800.
Lewis, C. (1983), *British Railways in Argentina, 1857-1914*, London, Institute of Latin American Studies.
López, Mario Justo (2007), “La combinación de la acción nacional y provincial y la suma del capital privado y público en la construcción de las primeras líneas ferroviarias, 1857-1886”, in López, Mario Justo and Waddell, Jorge E. (comps.), *Nueva historia del ferrocarril en la Argentina. 150 años de política ferroviaria*, Buenos Aires, Lumiere.
López del Amo, F. (1989), *Ferrocarril, ideología y política ferroviaria en el proyecto liberal argentino (1852-1916)*, University of Barcelona, PhD Thesis.
Maddison, A. (2001), *The World Economy: A Millennial Perspective*, Paris, OECD.

Metzer, J. (1977), *Some Economic Aspects of Railroad Development in Tsarist Russia*, New York, Arno Press.

Metzer, J. (1984), "Railroads and the Efficiency of Internal Markets: Some Conceptual and Practical Considerations", *Economic Development and Cultural Change*, 33, 1, pp. 61-70.

Mitchell, B.R. (2003), *International Historical Statistics: The Americas, 1750-2000*, Houndmills, Palgrave.

O'Brien, P., (1983): "Transport and Economic Development in Europe, 1789-1914", in O'Brien, P. (ed.), *Railways and the Economic Growth of Western Europe*, London, McMillan, pp. 1-27.

Oliner, S. D. and Sichel, D. E. (2002), "Information Technology and Productivity: Where Are We Now and Where Are We Going", *Federal Reserve Bank of Atlanta Economic Review*, 87, 3, pp. 15-44.

Ortiz Hernán, S. (1996), "Introducción", in Kuntz Ficker, S. and Riguzzi, P. (eds.), *Ferrocarriles y vida económica en México (1850-1950). Del surgimiento tardío al decaimiento precoz*, México, El Colegio Mexiquense, pp. 15-30.

Prados de la Escosura, Leandro (2009), "Lost Decades? Economic Performance in Post-Independence Latin America", *Journal of Latin American Studies*, 41, pp. 279-307.

Ramírez, M. T. (2001), "Los ferrocarriles y su impacto sobre la economía colombiana", *Revista de Historia Económica*, 19, 1, pp. 81-122.

Summerhill, W. (2000), "Profit and Productivity on Argentine Railroads, 1857-1913", Los Angeles, UCLA, Department of History, UCLA (mimeo).

Summerhill, W. (2003), *Order Against Progress. Government, Foreign Investment, and Railroads in Brazil, 1854-1913*, Stanford, Stanford University Press.

Summerhill, William R. (2006), "The Development of Infrastructure", in Bulmer-Thomas, Victor; Coatsworth, John and Cortés Conde, Roberto (eds.), *The Cambridge Economic History of Latin America. Vol. 2: The Long Twentieth Century*, Cambridge, Cambridge University Press, pp. 293-326.

Vázquez-Presedo, V. (1971), *Estadísticas históricas argentinas (comparadas). Primera parte 1875-1914*, Buenos Aires, Ediciones Macchi.