FACULTAD DE CIENCIAS ECONÓMICAS Y DE ADMINISTRACIÓN

DEPARTAMENTO DE ECONOMÍA

UNIVERSIDAD DE LA REPÚBLICA URUGUAY

Do all tracks lead to Montevideo?

Expansion of Railways and their impact on regional productive development in Uruguay between 1870 and 1952.

Matías Santiago Sena Sarmiento

Programa de Maestría en Economía de la Facultad de Ciencias Económicas y de Administración

Universidad de la República

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Tesis de Maestría presentada al Programa de Maestría en Economía de la Facultad de Ciencias Económicas y de Administración, Universidad de la República, como parte de los requisitos para la obtención del título de Magíster en Economía.

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Matías Santiago Sena Sarmiento*

Abstract

This thesis investigates whether the expansion of Uruguay's railway network caused sustained improvements in regional economic performance and reduced regional inequality during the period of railway expansion, consolidation, and institutional transition (1870–1952). The period spans the expansion and consolidation of the agro-export model (c. 1870–1920s) and the early decades of import-substitution industrialisation (c. 1930–1952), alongside a major institutional shift in railway governance from private concessions to increasing state intervention and eventual nationalisation in 1948, with the subsequent creation of a State monopoly company in railways in 1952.

I assemble a novel department-by-year dataset from railway company annual reports and state railway accounts, recovering investment flows and network characteristics. To measure multidimensional railway endowment, I construct a composite Railway Infrastructure Index. Demand-side connectivity is captured through a market-access measure based on minimum travel times across the evolving transport network. Because regional GDP per capita is observed only in benchmark years, I recover annual outcomes using modern spatiotemporal imputation to build a consistent panel for econometric analysis.

The empirical strategy estimates the effect of railway exposure on (i) departmental GDP per capita levels and (ii) departmental GDP per capita relative to Montevideo (a convergence measure in a highly monocentric economy). Identification combines two-way fixed effects, a heterogeneous spatial Durbin framework to model spillovers, and an instrumental-variables strategy based on least-cost paths to address endogenous network placement.

Results show that railway expansion raised average regional income in an economically meaningful way, with sustained effects over time and remaining robust to alternative definitions of market access, including monocentric access-to-Montevideo measures. By contrast, the evidence that railways systematically reduced regional inequality is weaker and more method-dependent: convergence effects, when present, are concentrated in a specific phase (1870–1887) rather than persistent across the full period. A central conclusion is heterogeneity, railways produced clear local winners and losers, suggesting that network design and initial conditions shaped the distribution of gains even when average development effects were positive.

JEL Classification: N76, N96, R40.

Keywords: Railways; Market Access; Regional Development; Spatial Spillovers; Least-Cost-Path; Regional Inequality; Uruguay

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Contents

“ (...) una estación de trenes, toda para mi. Mi tío abuelo (...) dirigía una estación de tren. Podría usar el telegráfo, dar entrada y salida a los trenes con un silbato, grave y hondo (...), podría cambiar las vías (...), podría expender los billetes que se distinguían por sus brillantes colores y ayudaría a embarcar a las ovejas y a los corderos en los enormes vagones de carga.”[1] (Peri Rossi, 2020, p. 8-9).

1 Introduction

Research on the expansion of railway networks and their role in economic transformation has a long tradition in economic history and development economics. From the classic work of Fogel (1964), which formalised the notion of *social savings* as a way to quantify the welfare contribution of rail transport, to more recent contributions that emphasize market access and spatial reallocation mechanisms, a broad view in the literature is that railways can reshape regional economies by lowering generalised transport costs, integrating markets and altering the incentives that guide the location of production. Yet, the magnitude and even the sign of these effects need not be uniform across space or time, because the same infrastructure investment may generate localised gains in some areas and displacement or concentration in others, depending on initial conditions and the structure of the network (Crescenzi and Rodríguez-Pose, 2012; Krugman, 1991b).

A major challenge in this literature is that the direction of causality between infrastructure and economic performance is not obvious. Regions that grow faster may attract infrastructure investment (or political support for it), whereas infrastructure may itself stimulate growth through lower trade costs and broader market access. This endogeneity problem is one reason why empirical evidence has been mixed and context-dependent. On the one hand, classic arguments link public investment (especially in transport) to productivity and growth (Aschauer, 1989). On the other hand, accessibility changes can reinforce center–periphery dynamics and exacerbate inequality if benefits accrue disproportionately to already-advantaged regions (Crescenzi and Rodríguez-Pose, 2012; Krugman, 1991b). Understanding whether infrastructure expansion promotes broad-based growth or instead strengthens spatial concentration therefore requires (i) careful measurement of infrastructure exposure and reachability, (ii) a regional perspective, and (iii) empirical strategies that take endogeneity and spatial spillovers seriously.

Uruguay offers an especially informative setting for studying these issues. During the period analysed here, railways were the dominant land transport technology: between the decline of stagecoach posts in the 1870s and the diffusion of trucks and automobiles in the 1920s, rail was effectively the backbone of domestic passenger and freight transport, excluding river navigation. At the same time, Uruguay combined (i) a comparatively dense railway network for its size, so dense that some authors characterize it as *overdimensioned*, where it even happened to be, barring from Argentina, Latin America most dense network, both by area and per capita (Herranz-Loncán, 2014), with (ii) a highly monocentric economic geography, where Montevideo has historically concentrated economic activity and political power. This spatial structure is reflected in large and persistent regional gaps: Montevideo’s per capita income has been estimated to exceed that of the rest of the country by roughly 50% (Travieso,

[1]Translation: (...) a train station, all for me. My great uncle (...) ran a train station. I could use the telegraph, signal trains in and out with a deep, low whistle (...), switch tracks (...), issue brightly coloured tickets and help load the sheep and lambs onto the enormous freight cars.

2017), and historical reconstructions of regional output show a marked predominance of the capital in the appropriation of national income (Martínez-Galarraga et al., 2020). These features imply that the same railway network can plausibly be interpreted both as an integrative technology and as an instrument that may have reinforced a radial, hub-oriented spatial equilibrium.

Uruguay is informative not only because railways were central to domestic transport, but also because it combines three features that make it a critical setting for studying infrastructure, spatial reallocation, and long-run development.

First, Uruguay entered the First Globalisation period with comparatively high income and human-development levels by regional standards (Bértola et al., 2024a). Together with Argentina, as Herranz-Loncán (2014) mentions, it is often characterised as one of Latin America's pre-1913 high-income cases. This would imply state capacity, market depth, and factor endowments that are atypically favorable for infrastructure-led transformation.

Second, despite this early advantage and its reputation as the "Switzerland of America", Uruguay experienced a prolonged episode of relative decline over the twentieth century, falling behind the international income frontier and becoming a well-known case of long-run underperformance (Fleitas et al., 2013; Oddone, 2010; Oddone and Cal, 2008; Rama, 1991). This makes the railway era consequential: if railways helped lock in a hub-oriented spatial equilibrium, their effects may persist beyond the construction phase and help interpret subsequent divergence.

Third, Uruguay's strongly monocentric structure and its geography, which separated the country in two, combined with its early communications system, which drew clearly three regions, up until the advent of the railway provide a clean environment to study the distributional consequences of transport-cost reductions (Barrán and Nahum, 1971; Herranz-Loncán and Travieso, 2023). In such a setting, rail access can both integrate markets and amplify center-periphery forces through a radial hub-and-spoke network. Heterogeneity and spillovers are therefore first-order empirical objects rather than secondary complications.

Historical empirical research on railways has typically examined their effects on economic activity and investment incentives, their role in reducing trade costs and integrating markets, and their broader consequences for inequality, population dynamics, and local economic structure. Against this backdrop, the contributions of this study are threefold. First, it provides a long-run perspective on the railway debate in Uruguay by extending the scope of existing work, largely centered on the private-investment era (Díaz, 2014; Herranz-Loncan, 2011; Travieso, 2017), and by explicitly regionalising the analysis. Whereas previous research often treats Uruguay as a single unit, or, when regionalised, focuses on a specific benchmark year, this study traces the evolution of railway exposure and outcomes across departments over an extended horizon. Second, it creates a novel dataset of railway infrastructure based on primary sources, spanning the period of increased use and investment, from 1870 to 1952. Third, it estimates the impact of railways on economic activity in a way that speaks directly to both the Uruguay-specific evidence (Díaz, 2014; Herranz-Loncan, 2011; Travieso, 2017) and the debate of international literature on the role of railways in the economy and inequality (Berger and Enflo, 2017; Bogart et al., 2022; Ciccarelli et al., 2021; Esteban-Oliver, 2023; Ficker, 2015; Soto, 2015). In the Uruguayan case, the key novelty lies in combining a long-run timeframe with a regional approach, and, specifically engaging with the aforementioned European literature on transport infrastructure and spatial disparities (Berger and Enflo, 2017; Bogart et al., 2022; Esteban-Oliver, 2023), this study examines the effects of rail expansion on regional inequality, measuring the convergence toward the country's richest region. To the best of my knowledge, this is the first attempt to quantify this convergence-based inequality channel for Uruguay.

This thesis assesses the association between railway expansion and regional economic performance in Uruguay from 1870 to 1952, a period that spans two widely recognised development models in the Uruguayan economic history: the expansion, peak, and crisis of the agro-export model (roughly 1870–1920s) and the subsequent import substitution industrialisation (ISI) golden period (roughly 1930–1960) (Bértola, 2008; Oddone, 2010; Oddone and Cal, 2008). Railway policy also evolved sharply over these decades: early expansion was largely driven by private concessions, later followed by growing state intervention, and ultimately by full nationalisation and the creation of A.F.E. in 1952. These institutional shifts motivate an explicitly historical approach that allows the infrastructure-growth relationship to vary through phases of network development and governance regimes.

Empirically, the thesis assembles and harmonizes new historical data and turns conceptual objects from economic geography into measurable proxies. It (i) constructs a department-by-year investment and infrastructure database using annual reports of railway companies and state rail accounts; (ii) builds a composite Railway Infrastructure Index (RII) using TOPSIS to capture multiple dimensions of railway endowment; (iii) measures market access using minimum network travel times; and (iv) extends sparse benchmarks of regional GDP per capita into an annual panel using modern spatiotemporal imputation methods.

The econometric analysis combines two-way fixed effects models, a heterogeneous spatial Durbin framework (to capture spillovers and heterogeneous responses across departments), and an instrumental-variables strategy based on least-cost paths to address endogenous railway placement.

Guided by the aforementioned elements, the thesis addresses two research questions. First: *What was the relationship between railway expansion and regional economic performance?* This question is evaluated using two outcome definitions: (i) departmental GDP per capita levels, and (ii) departmental GDP per capita *relative to Montevideo*, which captures the catch-up (convergence) dimension central in a monocentric country. Second: *Were railways a driver of the reduction of regional inequality, and what role did the railway laws play in which the State selected routes?* This question follows the idea that network design is not only an economic object but also a political choice with distributional consequences that potentially shape the spatial allocation of growth opportunities.

The evidence suggests that railways were an important driver of regional economic performance, while their distributional consequences were weaker and more method-dependent.

At the aggregate level, the evidence for *local development* is clear. When y is departmental GDP per capita (at $t+5$), the estimated global (total) marginal effect of railway infrastructure is positive and economically meaningful. In the spatial (HSDM) specification, the implied elasticity decreases from about 0.078 in 1870 to 0.025 by 1952, which is statistically not different from zero after 1910 (90% credible intervals).

In the instrumental-variable aggregation (2SLS), the elasticity is close to zero in 1870 (0.004) but becomes strongly positive by 1952 (0.148), statistically different from zero after 1900. Correcting for endogenous railway placement therefore does not overturn the conclusion that railway expansion increased average regional income. It also serves to identify a continuing effect, as periods with results different from zero occur at different times for the two estimation methods.

By contrast, the evidence for the *regional inequality hypothesis* is more subtle. When the outcome is GDP per capita relative to Montevideo, the IV-based estimates are essentially null at the national level, while the HSDM results suggest episodic convergence effects concentrated in a specific period, from 1870 to 1887. In other words, railway expansion appears to have contributed weakly positively to convergence relative to Montevideo, up until the north and the south of the country were connected, primarily when spatial interactions are explicitly modeled, and especially in a period of network extension, particularly in the south.

A central message of the thesis is heterogeneity. Department-level estimates reveal both winners and losers, consistent with spatial reallocation mechanisms emphasised in the New Economic Geography literature. Across methods and outcome definitions, a relatively robust pattern is that southern departments tend to fare better, while a border-connected department, Artigas, also shows positive effects, which suggests that the gains from railway expansion depended on local conditions and network position. By contrast, Lavalleja (and Tacuarembó in some cases) mostly emerges as the clearest loser, consistent with an alleyway interpretation in which the department served as a transit corridor for network traffic without internalising proportional local gains.

Finally, these conclusions are robust to redefining market access in a monocentric way. Replacing standard market access with an access-to-Montevideo measure yields qualitatively similar patterns: railway infrastructure stays strongly positive for departmental GDP per capita, while relative-to-Montevideo effects remain weaker and heterogeneous.

The remainder of the thesis is organised as follows. Section 2 presents a historical overview of the network's development and Uruguay's conditions. Section 3 presents the relevant literature and empirical research on the effect railways. Section 4 presents the conceptual framework and reviews the relevant literature on infrastructure, market access, regional development, as well as the theoretical model. Section 5 lays out the main hypotheses. Section 6 describes the data construction (including the investment database, the RII, and market access) and details the empirical strategy (TWFE, spatial models, and 2SLS). Section 7 presents the descriptive evidence on network evolution, the main empirical results, and robustness checks. The final section concludes and discusses implications for historical interpretation and for the broader debate on infrastructure and regional inequality.

2 Historical Overview

In this section I seek to describe the stages and motives of the railway process in Uruguay. I will also lay down the research questions and briefly present the relevant legislagion in this period.

Railway construction in Uruguay served multiple purposes, and the historical literature emphasizes that these purposes were not always aligned with a narrow view of railways as feeders of rural production. Barrán and Nahum (1971) argue that expansion was closely linked to *entrepôt* activity[2] and produced a largely radial network. In their interpretation, the growth of Rio Grande do Sul increased the strategic value of connecting Montevideo's port to Brazil, positioning the railway as an instrument for trade across the Plata region. They therefore stress that the early network was shaped by intra-regional commerce and by the incentives created by financial concessions, rather than being designed primarily to collect domestic agricultural output.

Barrán and Nahum (1971) also place the railway boom in the political context of *Militarismo*[3] (1872–1890), especially under Máximo Santos (1882–1886) and Máximo Tajes (1886–1890). During these administrations, many of the lines that would later define the national network were planned and built as part of a broader effort to extend state authority over a territorially fragmented country. The 1886 bridge that connected the north and south of the country by rail is one concrete expression of that objective. It is worth noting that both regions are separated by the Río Negro, a wide body of water that disconnected the regions for most of the year until the bridge was constructed. They also emphasise a military function: railways increased the government's capacity to move troops rapidly and to respond to both internal conflict and external threats in a period of political instability; which, as a matter of fact, would prove decisive in the 1904 Civil War. From this perspective, rail expansion reflected strategic priorities that were not reducible to the immediate needs of agriculture, ranching, or rural colonisation.

Subsequent studies, however, underscore that railways also interacted with changing rural production. Millot and Bertino (1996) highlight the sheep boom and the fencing of fields as developments that increased the volume and regularity of marketed output and raised the value of rail transport for producers. While they agree with Barrán and Nahum (1971) that the network reinforced the primacy of Montevideo, they dispute a strong separation between railways and the rural economy. In their account, livestock entrepreneurs themselves viewed rail access as an important infrastructure.

A similar emphasis appears in Baracchini (1978), who describes the railway's economic rationale as twofold: moving national production toward the port and supplying the domestic market with imported goods. Consistent with this reading, Herranz-Loncán and Travieso (2023) note that a route initially conceived to link the north with Brazil and the Uruguay River was incorporated into the broader system by 1890 and connected to Montevideo. Overall, the purposes of railway construction in Uruguay are best understood as the outcome of an interaction between financial incentives, political strategy, and evolving economic demands.

2.1 Initial railway expansion under private (mostly foreign) investment (1869–1915)

Uruguay's railways developed within a concession system that predated rail construction, but rail projects became the most consequential use of that instrument. Unlike the stagecoach-post system, whose routes largely followed private initiatives, railways were debated from the outset as a tool of

[2] Activity that considered its port as a storage point and hub to export goods to their final destination.
[3] A period of military dictatorship.

territorial integration and state strategy, and were progressively shaped through specific legislation (Baracchini, 1978).

The first railway proposal (1860) sought to connect Montevideo with Villa Unión[4], but it was rejected on the grounds that it did not meaningfully reduce long-distance travel costs. The first concession was approved in 1866 for a line between Montevideo and Durazno, creating the Ferrocarril Central del Uruguay (Baracchini, 1978). The company opened its first section (Montevideo–Las Piedras) in 1869. Financial disputes between the firm and the government delayed the extension to Canelones until 1872 (42 km). To resolve its financing constraints, the company turned to Baring Brothers and, in 1876, it was sold to British capital and reorganised as The Central Uruguay Railway Ltd. (Baracchini, 1978).

Two additional early developments were important. First, a western branch of the Ferrocarril Central reached San José in 1876. Second, the Ferrocarril Noroeste, connecting Salto to Cuareim (roughly 500 km north of Montevideo), completed works begun in 1872 and opened in 1878. Despite the number of concessions granted between 1869 and 1884, early construction progressed slowly: by 1882, only 414 km of line were in service (Baracchini, 1978; Millot and Bertino, 1996). A particularity of this network is that early expansion was concentrated in the Montevideo–Durazno and Salto–Cuareim corridors, two disconnected sections of the country, clearly serving different interests.

Evidence that planning often ran ahead of demand is visible even around Montevideo. Stations at Sayago, Colón[5], and La Paz[6] were built in 1869 on the Montevideo–Las Piedras section[7]. Sayago and La Paz, in particular, developed as hamlets around the stations, well before they became densely populated, and the former to be incorporated into Montevideo as a neighborhood.

A first turning point in railway policy came with the 1884 Railway Law, which adopted a layout proposed by the Comisión de Ingenieros (created in 1872) to define a scheme of "public interest" for railway development. The commission initially implied a suspension of new concessions until the projected map was completed; however, delays led to a renewed round of liberal concession granting between 1874 and the promulgation of the law (Baracchini, 1978).

The 1884 framework marked an explicit effort to treat railways as a strategic instrument, both to coordinate routes and to extend state influence. It was modified in 1886 to add branches and to contemplate a special layout if a Montevideo–Colonia line were built by the government (Baracchini, 1978). A third and especially influential reform followed in 1889. The 1889 Railway Law proposed the creation of the port of Colonia and the Ferrocarril Central del Interior, intended to connect Colonia with Brazil without passing through Montevideo. In the legislative debate, Minister Herrera y Obes articulated a strategic view in which railway expansion was not a consequence of accumulated wealth but an instrument to create it; accordingly, the state should undertake lines even when immediate profitability was low if they promoted the development of peripheral regions (Millot and Bertino, 1996).

[4]Today the Unión neighborhood, an urban zone within the city.

[5]Then Villa Colón.

[6]Then Independencia.

[7]Sayago would not exist as a hamlet until 1873, La Paz until 1872; Villa Colón already existed, albeit with a small population.

State intervention in Uruguay's railways became more explicit with the Railway Law of 1884, which marked a turning point in the policy regime. Barrán and Nahum (1971) emphasises that, before 1884, liberal ideas in the political elite constrained regulation and encouraged a concession model with limited state oversight. The 1884 law rested on the principle that railways were a state concession, which legitimised government control over key aspects of their operation. At the same time, intervention was cautious: legislators sought to avoid discouraging foreign (particularly British) investment (Barrán and Nahum, 1971). The law also established that, once concession periods expired, lines could revert to the state, opening the door to eventual expropriation.

Underlying this shift was an explicitly distributional concern. If railways could stimulate development in some regions while bypassing others, then route choice and operating conditions had public-interest implications. In that view, leaving decisions entirely to concessionary firms risked aligning network development with private profitability rather than broader territorial objectives.

Contemporary debates illustrate these changing attitudes. Figures such as Julio Herrera y Obes argued that, if private companies could profit from railways, the state could also do so, while critics such as Juan Zorrilla de San Martín raised doubts about the efficiency of public management. Barrán and Nahum (1971) interprets this debate as part of the emergence of a more autonomous political class oriented toward economic independence, laying the foundations for the interventionist trajectory that characterised much of Uruguay's twentieth century.

This in particular motivates one of the research questions in this thesis. To what extent did state railway legislation[8] and route selection contribute to changes in regional inequality? Building on Martí-Henneberg (2017), this question treats network design as a policy choice with distributional implications. Given Uruguay's strongly monocentric economic geography, I measure regional inequality as departmental catch-up relative to Montevideo.

These legislative initiatives coincided with the railway boom of 1884–1892, during which roughly 1,200 km of track were built and the network advanced toward connecting Uruguay's 19 departmental capitals, a key feature for this thesis. The 1890 Baring crisis, however, temporarily halted expansion and frustrated plans such as the Ferrocarril Central del Interior, which was never opened (Millot and Bertino, 1996).

In the early twentieth century, renewed attempts were made to advance strategic extensions. The Pan-American Trans-continental Railway Co. began works on a line from Durazno to Trinidad, but financial constraints and the outbreak of the First World War prevented the company from securing financing. The government ultimately took over the project in 1915, creating the Administración de Ferrocarriles y Tranvías del Estado (F.T.E.) (Coombs, 2025).

By the late nineteenth century, the principal operating companies that would remain active until 1948 had consolidated (e.g., Midland; Central Uruguay Railway; Eastern and Western Extensions; Northeastern and Northwestern of Uruguay). Some smaller firms had short lives and were absorbed, for example, Hygueritas was taken over by the Central Uruguay Railway in 1886. A milestone in territorial integration was the opening of the bridge over the Río Negro in 1886, which provided the first

[8]See Appendix D.

land connection between the south and north of the country and facilitated expansion toward Rivera and Brazil. Figure 16 (Appendix D) summarises the layouts proposed in the three Railway Laws.

After the late-nineteenth-century boom, a second wave of expansion occurred between 1901 and 1916, adding about 940 km of line and consolidating the connection of every departmental capital to Montevideo (Millot and Bertino, 1996).

2.2 Increasing State Intervention (1916–1947)

In favour of state interventionism, the political balance shifted further with the 1888 law, which Barrán and Nahum (1971) links to growing nationalist interventionism. The reform responded both to the limited scope of the 1884 arrangements and to concerns about tariff regulation and the market power of British operators. The 1888 law authorised the state not only to build railways but also to operate them, a provision absent from the earlier framework, and this would not happen until 1915 with the purchase of The Pan-American Trans-continental Railway Co. More broadly, it reflected increasing confidence in domestic administrative capacity and a stronger rejection of dependence on foreign capital (Barrán and Nahum, 1971). It is noteworthy that José Batlle y Ordoñez took a firm stance against foreign capital in general, as evidenced by his aversion to it when the creation of a state monopoly in the insurance sector was discussed in 1908 (Vanger, 1983). Given that his ideology shaped Uruguay in the 20th century it is clear why his second presidency ended with the creation of a State-owned company in railways and its sucessors to had a fierce fight against the tariffs imposed by the British companies in order to undermine the operators to buy them at barter prices (Nahum, 2005).

Between 1916 and 1940, a further 460 km were added to the network. This later expansion was solely state-led, through the F.T.E., and reflected the Herrera y Obes strategy of serving regions that private operators were unlikely to cover because of low short-run profitability.

During this period, the State and British companies engaged in ongoing conflicts over tariffs, reflecting the State's increasing interventionism in the railway sector. When the State saw itself unable to legally lower tariffs, it expanded its influence as much as possible, building road routes for vehicles in parallel with the railways between 1925 and 1930 to force British companies to lower their tariffs. In fact, in 1928, a Law was enacted to facilitate the expansion of routes, which had progressed slowly since 1905, when the first Law was passed. This led to the almost agreement to sell the railway system to the State at the beginning of the 1930s, which failed only due to the Peso devaluation, being the first instance in which British companies decided to de-capitalise the system (Baracchini, 1978; Nahum, 2005).

Owing to this, from the 1910s onward, railways faced growing competition from automobiles, buses, and trucks. British operators attempted (without success) to influence road planning to limit competitive pressure (Bertino et al., 2015). As aforementioned, tensions between the State and British firms deepened after a tariff dispute that began in 1918; British accounts interpreted tariff policy as an attempt to render operations unprofitable and force sales at low prices. Conflict intensified in the 1930s, contributing to a halt in private investment and leaving the state with deteriorating track and rolling stock (Nahum, 2005).

As shown in Figure 8, the interwar period saw the system extend to Colonia and strengthen connections to Río Negro, a key area for the meatpacking industry. The network also expanded to the east, adding a second connection to Brazil via Río Branco alongside the existing link at Rivera. By this point, the railway had reached its maximum geographical extent, reinforcing its role in territorial integration.

2.3 Statisation and creation of a State-Owned Company (1948–1952)

In 1948, the Uruguayan government negotiated the purchase of the British railway companies as part of the settlement of the United Kingdom's wartime debt to Uruguay. Nahum (2005) notes that the British companies themselves expected the sale, given their limited access to capital by the 1940s. Nationalisation transformed the private system into the Administración del Ferrocarril Central del Uruguay, which operated until 1952. In that year, a law merged it with the F.T.E., creating the Administración de Ferrocarriles del Estado (A.F.E.) (Bertino et al., 2015).

Overall, the railway network was central to Uruguay's economic and territorial integration: it connected the 19 departmental capitals and established strategic links with Brazil. Yet the system also faced persistent profitability constraints and, over time, increasing competition from road transport. In a monocentric country with high urban primacy, firms often pursued low-cost construction, few bridges and tunnels and a relatively circuitous layout, which limited the extent to which railways could exploit dense intermediate markets (Herranz-Loncán and Travieso, 2023). This history underscores how public policy and private interests jointly shaped a network that transformed Uruguay's territorial and economic geography.

2.4 Regional productive development

Here, I intend to make clear what is it known until now about the regional productive development in Uruguay, considering the role the railways could have played in shaping it.

In fact, this motivates another research question. What was the relationship between railway expansion and regional productive development? To answer this I study this relationship for Uruguay's departments over 1870–1952, allowing the association to vary across the three described phases of the railway system's evolution. To summarise multidimensional railway endowment, I also construct a composite index of railway infrastructure.

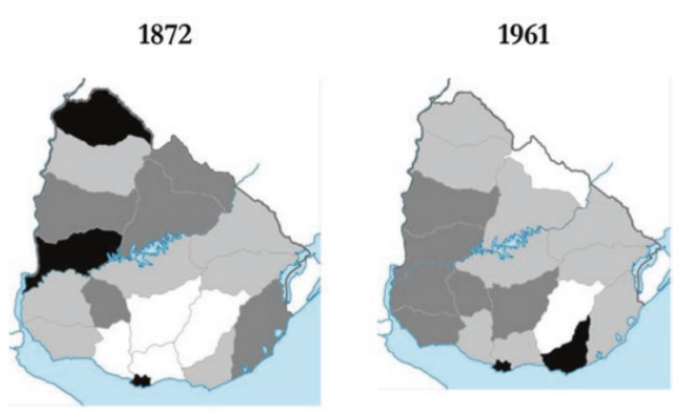


Figure 1: Departmental GDP per capita maps for 1872 and 1961. Colours represent the following: Black "High income", Dark grey "Middle high income", Grey "Middle low income", White "Low income".

Source: Taken from Martínez-Galarraga et al. (2020).

Figures 1 and 2 illustrate the national and regional context of Uruguay between 1872 and 1963, highlighting significant changes in departmental income distribution. Montevideo consistently demonstrates strong productive development and maintains its dominant national position. Other departments, however, display notable variation: some improve their relative wealth distribution, while others regress compared to the national average. These patterns reflect a complex process of regional economic transformation shaped by historical, political, and economic factors influencing Uruguay's development trajectory.

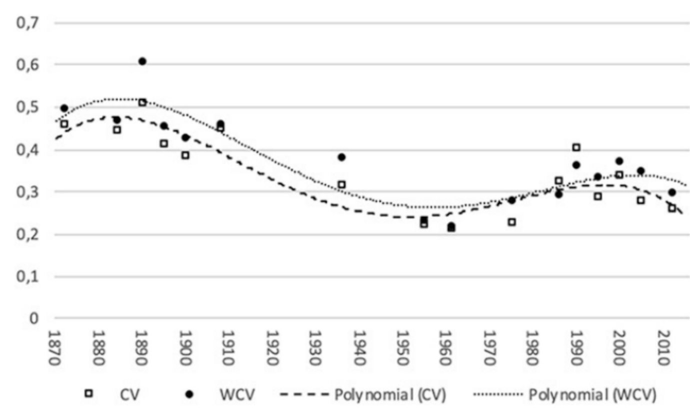


Figure 2: Regional Inequality in Uruguay measured by the coefficient of variation.
Source: Taken from Martínez-Galarraga et al. (2020).

Figure 2 further demonstrates changes in departmental income distribution from 1872 to 1961 and documents a substantial reduction in regional inequality, as measured by the coefficient of variation (CV). Notably, from 1880s onward, the CV declined by approximately 20 points, indicating a trend toward a more equitable spatial distribution of production across regions.

This evidence underscores that the period under study coincides with a marked reduction in regional inequality and a more egalitarian income distribution. A key analytical question is the extent to which railway expansion and development contributed to economic integration and the reduction of regional disparities. Examining the relationship between railway infrastructure and economic redistribution provides important insights into the structural role of transport networks in shaping Uruguay's social and economic development.

3 The Economic Impact of Railways

In general, historical empirical studies of railways have sought to measure their impact on economic activity, the effect of promoting or hindering investment, the capacity to bring markets closer together, reduce inequality, and shape both population dynamics and local economies.

A foundational reference in the economic history of railways is Fogel (1964), who introduced *social savings* as a way to quantify the welfare contribution of rail transport. The basic idea is counterfactual: social savings measure how much national income (or GDP) would have been lower in a given period if railways had not existed and traffic had been carried by the least-cost available alternative. This approach has shaped a large empirical literature that evaluates railways primarily through their effects on market integration, productivity, and aggregate growth.

For Latin America, the evidence highlights both the potential gains from rail connectivity and the importance of state capacity and policy design. For Argentina, Lenz (2005) links railway expansion to state consolidation, agricultural expansion, and improved connectivity of territories affected by conflict. As well, during that period, from 1880 to 1902, similar to what occurred in Uruguay, a railway boom took place. To serve the objectives laid above, the State granted lands to facilitate expansion, which proved more useful than the concessions given (Regalsky and Salerno, 2015).

For Brazil, Summerhill (2003) emphasises how railway development interacted with policy choices that favoured the internal market. However, as Lamounier (2015) shows, other authors hold the idea that railways were not by design trying to promote the internal market in substitution of exports, but mostly it was a failure of the companies in a context of regional political interests, which made the network as dense and connected as it was. On the other hand, while initially promoting industrialisation to build the network, as Brazil had the necessary workforce, once the system was mature enough, this process stopped and focused only on the materials needed to maintain the railway, such as in workshops.

A particular case in Latin America for its tardiness maturity in the network was Colombia. Particularly, Primmer (2020) shows that restrictions on foreign investment contributed to the underdevelopment of the railway system in Colombia's Santander department, limiting early market access and hindering subsequent development. More broadly, in Colombia, railways served to expand the strength of economic centres, in an unequal expansion initially limited to each region's capacity to raise the necessary capital; this shaped future regional integration and identity. And, while in other parts of Latin America which granted concessions over construction which granted the expansion and tariffs allowing certain sectors to thrive, the initial system of debt bonds which the State issued, caused the unintended consequence of speculative investment over construction, being that and the troubling political times the main reasons why the boom in this country was delayed to the 1920s-1930s (Correa, 2015).

Particularly for Mexico, as in Uruguay, the railway grew slowly at first and accelerated once a period of authoritarian rule began around the 1880s. As in Europe, railways in Mexico advantaged regions with access to the system and drove the growth of the mining industry. The most positive effect on the Mexican economy was the provision of a safe and stable means of transport, as passenger services could better exploit it, as the economy was not prepared for what the railway had to offer. As in Brazil, to promote certain sectors of the economy, the State had to impose different tariffs, demonstrating the extent to which governments went to leverage the railways (Ficker, 2015).

In Chile, favourable conditions for the mining of metals pressured the government to invest with the private sector in infrastructure from 1873 to the end of the Pacific War in 1883, in order to favour exporters with liberal concessions, causing different Companies to have incompatible networks. In 1884, the Government created a State company with the aim of connecting and promoting certain sectors of the economy. So much so that the impact of railways in the manufacturing sector came solely from the State, as it laid the network from the centre to the south of the country, the State, at least in those decades, promoted industrialisation by expanding the railways (Soto, 2015).

Taken together, these studies suggest that railway investments can generate large gains, as well as have the capacity to promote certain sectors, but the distribution and persistence of those gains depend on institutional and political conditions. The railways, as well, had the unintended consequence of increasing inequality in regions without access, prompting some countries to expand the railways to ensure provision and limit the capacity of this means of transport to exacerbate inequality.

Recent studies on Europe reinforces the idea that railway effects are heterogeneous across space and mediated by local capacities. Ciccarelli et al. (2021) study Italy over 1863–1914 and focus on regional impacts on manufacturing. Using region-level data on manufacturing value added and railway expansion, and estimating heterogeneous effects with Augmented Mean Groups (AMG), they find that the growth effects of railways were stronger in northern Italy than in central and southern regions. They also report that returns to railway investment materialised only gradually and were larger where institutions were stronger.

Other evidence from around Europe sought to link the effect of the railways on local population dynamics. In Spain during the Bourbon era, around 1860 to 1930, railways had a positive impact on regions that gained access to the network, and this impact was greater in more favourable settings. It reinforced hierarchies and promoted spatial inequality, resulting in an unequal distribution of the population across the country (Esteban-Oliver, 2023). In the case of England and Wales, from 1851 to 1891, it was found that having a railway station by 1851 caused higher population growth in the period and shifted the occupational structure of males; they also found, as in the Spanish case, that railways reinforced the existing hierarchies and contributed to deepen spatial divergence (Bogart et al., 2022). Lastly, in the case of Sweden, from 1870 to the present day, the population grew rapidly in the short term in areas where towns gained access to the railway network during the first wave of expansion, from 1855 to 1870. It was also noted that town growth was mainly reflecting the relocation of economic activity from non-connected nearby towns, deepening spatial inequality, and supporting evidence that the impact of transport infrastructure is dampened in the aggregate due to displacement effects (Berger and Enflo, 2017). Altogether, this evidences the railways' capacity to shape population dynamics, with growth in towns that gained access, and the importance they contribute to spatial inequality.

For Uruguay, the literature is smaller but provides key inputs for this thesis. Díaz (2014) compares private and social profitability of railway investment and evaluates when subsidies were justified. Travieso (2017) uses station-level transport information around 1910 to study patterns of production and shows that railways were not regionally neutral: geography and access to cheaper transport interacted to favor some areas over others. Herranz-Loncan (2011) evaluates railway benefits through the lens of social savings and argues that, while railways supported integration in an export-oriented economy, measured gains were smaller than in other Latin American cases, partly because maritime transport already provided an alternative for passenger and freight mobility.

Beyond their economic role, railways in Uruguay were also framed as a political and strategic instrument. Millot and Bertino (1996) notes that the state and dominant elites associated rail construction with modernisation and national integration, including the ability to mobilise troops in a context of recurrent internal conflict. Barrán and Nahum (1971) further argues that government guarantees to construction companies shaped the network's layout, contributing to lines that were longer and more circuitous than a purely efficiency-oriented design would imply. This combination of economic, political, and strategic motives is central to interpreting both the expansion of the network and its potentially unequal regional effects.

The contributions of this study are threefold. First, it offers a long-run perspective on the railway debate in Uruguay by extending the scope of existing research, which has largely focused on the private-investment era, and by explicitly regionalising the analysis. Whereas prior work typically treats Uruguay as a single unit, or, when regionalised, concentrates on a specific benchmark year, this study traces the evolution of railway exposure and outcomes across departments over an extended horizon. Second, it estimates the impact of railways on economic activity in a way that speaks directly to both the evidence corresponding to European cases and the Uruguay-specific evidence. In the Uruguayan case, the main novelty lies precisely in combining a long-run timeframe with a regional approach. Third, engaging with the European literature on transport infrastructure and spatial disparities, it examines the effects of rail expansion on regional inequality, measured through convergence toward the country's richest region. To the best of my knowledge, this is the first attempt to quantify this convergence-based inequality channel for Uruguay.

4 Conceptual Framework

Economic growth is a central theme in economic history and development economics. In the neoclassical tradition, growth in output per capita is explained by capital accumulation, labor input[9], improvements in factor quality (typically human capital), and total factor productivity. In this framework, capital and labor are treated as substitutable inputs, in contrast to classical views that stressed complementarities (Kaldor, 1961). Consistent with this perspective, GDP per capita (or its growth rate) is the standard empirical proxy for economic performance.

Early neoclassical models, such as Solow (1956), treat technological progress as exogenous. Endogenous-growth approaches, developed by Lucas (1988) and Romer (1990), instead emphasise mechanisms through which investment in human capital and knowledge production can generate lasting growth. For the purposes of this thesis, the key implication is that education and related capability-building processes are not merely correlates of development but potential drivers of it.

Transport infrastructure is one channel through which these growth mechanisms can operate in space. By reducing transport costs and improving connectivity, infrastructure can expand effective market size and alter the profitability of locating production across regions (Krugman, 1991b).

I use the term *infrastructure* to refer to the stock of physical systems that support economic activity, including roads, railways, ports and airports, utilities, and water and sanitation networks (Aschauer, 1989). While definitions vary, the common element in the literature is that infrastructure can affect both productivity and welfare by enabling exchange, mobility, and access to basic services (Baldwin and Dixon, 2008).

[9] In standard models, long-run growth cannot be sustained by factor accumulation alone because of diminishing returns.

4.1 Infrastructure: causal relations, channels and mechanisms

A first relationship of interest links infrastructure, investment, and growth through transport costs and market access. In the New Economic Geography tradition, improved infrastructure lowers trade and commuting costs, increases access to external markets, and can raise productivity by allowing firms to exploit scale economies (Krugman, 1991b). These mechanisms are particularly relevant for a network technology such as railways, where the economic payoff depends on how lines connect production areas to consumption centers.

At the same time, the spatial effects of infrastructure need not be uniformly beneficial. When connectivity improves unevenly, accessibility gains may concentrate activity in already-advantaged locations and reinforce center–periphery dynamics, as theory and some examples in Europe showcase (Alvarez-Palau et al., 2021; Crescenzi and Rodríguez-Pose, 2012; Krugman, 1991b). In this case, better-connected regions capture a larger share of the benefits of integration, while less-connected regions face increasing difficulties in attracting investment and participating in national markets.

A second set of mechanisms concerns the broader development effects of infrastructure and the possibility that network expansion changes the distribution of opportunities. Infrastructure can raise welfare not only through productivity and market access, but also by facilitating access to basic services. In particular, Agénor and Moreno-Dodson (2006) argues that infrastructure supports human-capital accumulation by improving access to education and health, which can translate into higher long-run growth.

From a territorial-development perspective, infrastructure also matters because it shapes interactions among local agents and the circulation of people, goods, and ideas. Vázquez-Barquero and Rodríguez-Cohard (2018) emphasises the role of infrastructure as part of a local system that enables coordination and learning. Similarly, Crescenzi and Rodríguez-Pose (2012) highlights that transport infrastructure can foster innovation and knowledge diffusion by reducing the frictions that limit mobility and exchange.

The historical perspective and evidence on the role of infrastructure and its measurement were well reviewed by Herranz-Loncán (2008). First, the study from the point of view of the companies' profits was a relevant perspective, and also one that often deemed the effect of railways as negative, having the downside of studying a sector that was characterised by being highly subsidised due to the nature of the investment, so private profits are a weak indicator.

This led to estimations of social savings becoming a better alternative, measuring the additional cost of transporting the railway output on the least-cost alternative, which comes with two pitfalls. First, social savings estimates do not account for the indirect effects of railways, which could be positive. Fogel (1964) noted that it was not intended to use as a contribution to economic growth, but rather as a measure of the indispensability of railways to growth. The second limitation is that it does not indicates what is the yield of the realised investments, as it could be the case that the railways contribute to high gains to the economy but the resources invested were so great that the economic impact is negative.

An alternative that emerged was to measure the railway investment yield and estimate how much of the total productivity growth in the economy was attributable to the railway system. This had the problem that, while originally accounting for the indirect impacts was not possible, Herranz-Loncán (2008) mentions that there was no methodology that could really account for the indirect measures associated with new investments. In this methodology, the capital stock can be divided between the public and private sectors, and this method was the first to use it. Herranz-Loncán (2008) concluded after doing his economic history review that there is no easy empirical solution nor one that is generally accepted. It is method-dependent, and each result must be interpreted cautiously, as must the methods used. A recent method has surged due to this and adds to the debate, but is not the dominant method in the literature as well. This is measuring the railway infrastructure effect on population dynamics rather than on an indicator of economic activity, such as in papers like Berger and Enflo (2017), Bogart et al. (2022), and Esteban-Oliver (2023).

When relating railway expansion to regional economic performance, it is therefore important to account for other location-specific determinants of productivity that may be correlated with infrastructure placement. Three controls are particularly relevant in the Uruguayan case: natural resources, education, and population.

Differences in land quality affect the productivity of agriculture and the pattern of regional specialisation. As Metzemakers and Louw (2005) notes, land is inherently heterogeneous because of its location-specific characteristics. In Uruguay, Travieso (2017) (following the classification in Marchesi and Durán (1969)) documents substantial variation in soil types across departments. Basalt soils, for instance, are relatively unsuitable for crop agriculture, while other areas are more favorable for cereals and higher-return activities. These endowments can shape both baseline income levels and the returns to improved market access. A particularity of Uruguay, while having different kind of soils, which can definitely shape who the railway serve, is that is does not have treacherous terrains, as neither has impenetrable forests, nor steep mountains or impassable jungles, as other countries of South America has, like Brazil or Colombia.

Education is a key component of human capital and a plausible driver of regional differences in growth. Kuznets (1973) stresses that sustained modern growth and technological change are difficult to achieve in contexts of widespread illiteracy. At the same time, education can generate externalities, for example by supporting innovation adoption and mitigating diminishing returns to physical capital (Obradović, 2009). From a historical perspective, Cappelli et al. (2023) for the 19th and 20th century and Hanushek and Woessmann (2020) for the 20th century each do literature reviews about empirical evidence on the effect of education on economic growth and development and they find a mild to positive link between education (or human capital) and the outcome, this shows important differences that were education was making on those centuries that needs to be accounted for.

Population size and density affect market size and the scope for agglomeration. Locations with higher density can sustain larger local markets and facilitate scale economies. Classic location theory emphasises that firms have incentives to concentrate where demand is dense and transport costs are lower (Hotteling, 1929). Empirically, Yegorov (2009) argues that low-density regions may fail to realise their growth potential even when endowed with natural resources, because sparse settlement limits the formation of integrated markets.

Even though the country gained its independence in 1828 and its first constitution in 1830, the concept of Uruguay was not well distributed across the territory, national identity and cohesion was difficult due to the lack of communications systems, three regions, with different autonomy, surged due to this. Montevideo region, which we can associate with the south of the country, the litoral, more connected to Argentina, and the north, connected with Brazil, which even had an early railway concession disconnected from the south solely to provide commerce with the northern country as presented before. Due to this, we cannot speak of a unified nation nor population until 1870 with the modernisation of the State, and even more, until communications improved, with the expansion of the railways and telegraph to the north of the country in 1886, 50 years after the creation of the country (Barrán and Nahum, 1967; Moraes et al., 2025).

I make the assumption of a unified nation throughout the entire period when I make aggregated estimations, or when I use comparative Montevideo-related outcomes to simplify the analysis, so this warrants the definition of the Uruguayan population made.

At least since the time of the Empires, from the late 18th century onward, and continuing after the country's independence, the north had stronger connections with the Portuguese, although informal, which also involved smuggling; the ties were strong. This continued after Brazil's secession from Portugal and Uruguay's subsequent independence, in which the real border seemed to lie more in the Rio Negro than in the actual frontier between the countries (De Souza Rangel and Zanotti, 1990; Moraes and Dávila, 2017). This is enlightening because it comes to show how the north responded due to the lack of connection to the south and also to understand how the border economy played in this particular region. It also explains why the first planned railway in the north sought to connect to Brazil rather than to Montevideo.

4.2 Conceptual mechanism: CES demand, iceberg trade costs[10], and market access

This section provides a brief economic-geography interpretation of how railway expansion can affect regional economic performance. The purpose is not to estimate a full structural model, but to discipline the empirical objects used later, in particular, railway-induced changes in generalised trade costs and their implications for market access, real income, and the spatial distribution of activity (Fujita et al., 1999; Krugman, 1991b; Redding and Turner, 2015). For a more intuitive, non-technical discussion of why trade costs are central in shaping spatial patterns, see Krugman (1991a).

To order ideas, consider a set of regions $i \in \{1, \ldots, 19\}$ (Uruguayan departments) and two sectors. A homogeneous good (A) is produced under constant returns and is chosen as numeraire (its price is normalised to one). A differentiated tradable sector (M) features increasing returns and monopolistic competition, as in the canonical economic-geography framework (Fujita et al., 1999; Krugman, 1991b). A representative consumer in region i has Cobb–Douglas preferences over the homogeneous

[10] As Krugman (1998) explains, iceberg trade costs get their name from the assumption that a fraction of any good shipped melts away in transit, incorporating transport costs into the good.

good and a CES aggregate of differentiated varieties,

$$U_i \;=\; C_{Ai}^{1-\mu}\, C_{Mi}^{\mu}, \qquad \mu \in (0,1), \tag{1}$$

where the manufacturing composite is

$$C_{Mi} \;=\; \left(\int_{\omega \in \Omega} q_i(\omega)^{\frac{\sigma-1}{\sigma}} \, d\omega \right)^{\frac{\sigma}{\sigma-1}}, \qquad \sigma > 1. \tag{2}$$

These preferences imply standard CES demand for each variety and an associated manufacturing price index P_i (Dixit and Stiglitz, 1977).

The link to railways operates through the costs of reaching markets. Trade across regions is subject to iceberg trade costs: shipping one unit of a variety from origin j to destination i requires sending $\tau_{ij,t} \geq 1$ units, where $\tau_{ij,t}$ depends on the transport technology and, in this thesis, on the effective road–rail network at time t. The delivered price in i of a variety produced in j is therefore

$$p_{ij,t}(\omega) \;=\; \tau_{ij,t}\, p_{j,t}(\omega). \tag{3}$$

The manufacturing price index in region i can then be written as

$$P_{i,t} \;=\; \left(\int_{\omega \in \Omega} p_{i,t}(\omega)^{1-\sigma} \, d\omega \right)^{\frac{1}{1-\sigma}} \;\approx\; \left(\sum_{j=1}^{N} n_{j,t} \left(\tau_{ij,t}\, p_{j,t} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \tag{4}$$

where $n_{j,t}$ denotes the number (mass) of varieties produced in region j and consumed in i.[11] Equation (4) delivers the basic cost-of-living implication used throughout the thesis: holding factory-gate prices fixed, a reduction in $\tau_{ij,t}$ lowers $P_{i,t}$ by making more varieties effectively "closer". Railway expansion can therefore raise welfare and real income via a price-index channel.

On the production side, each firm in the differentiated sector produces one variety under increasing returns,

$$\ell \;=\; f + a\, x, \tag{5}$$

where $f > 0$ is a fixed labor cost, $a > 0$ is a marginal labor requirement, and x is output. Under monopolistic competition with CES demand, optimal pricing implies a constant markup over marginal cost,

$$p_{j,t} \;=\; \frac{\sigma}{\sigma - 1}\, a\, w_{j,t}, \tag{6}$$

where $w_{j,t}$ is the local nominal wage (or, more generally, the local unit cost of production). Given (6), the value of shipments from a producer in j to market i can be written as

$$X_{ij,t} \;\propto\; \mu\, E_{i,t} \left(\frac{\tau_{ij,t}\, p_{j,t}}{P_{i,t}} \right)^{1-\sigma}, \tag{7}$$

where $E_{i,t}$ is total expenditure in market i. Summing over destinations, a firm's profitability and the attractiveness of locating production in j increase with a demand-weighted measure of proximity to

[11] The second expression uses a discrete approximation in which each region produces a set of symmetric varieties, meaning the varieties use the same technology and have the same factory gate cost.

large markets discounted by trade costs (Fujita et al., 1999; Krugman, 1991b). This is the motivation for market-access objects that aggregate market size through the transport network (Donaldson and Hornbeck, 2016; Redding and Turner, 2015; Redding and Venables, 2004).

With Cobb–Douglas preferences and the homogeneous good chosen as numeraire ($p_A = 1$), the exact cost-of-living term entering the expenditure function is proportional to $P_{i,t}^{\mu}$. Hence, the corresponding indirect utility is

$$V_{i,t} = (1-\mu)^{1-\mu}\mu^{\mu}\,\frac{Y_{i,t}}{P_{i,t}^{\mu}}, \tag{8}$$

where $w_{i,t}$ denotes nominal income (equivalently, total expenditure in equilibrium). For empirical interpretation, it is convenient to define the welfare-equivalent real-income index

$$\text{Real Income}_{i,t} \;\equiv\; \frac{Y_{i,t}}{P_{i,t}^{\mu}}, \tag{9}$$

which is proportional to indirect utility, with a proportionality factor common across regions and time when μ is fixed.

In this framework, railway expansion can affect development outcomes (such as GDP per capita) through two complementary mechanisms:

1. improvements in the transport network reduce trade costs $\tau_{ij,t}$, thereby lowering $P_{i,t}$ in (4) and raising real income in (9);
2. by changing effective access to demand as in (7), lower trade costs affect firms' location incentives and, in spatial equilibrium, can shift production, employment, and nominal wages $w_{i,t}$ across regions.

These implications motivate the primary empirical question of the thesis: whether railway expansion increased regional economic performance in levels.

To connect the mechanism to an empirical exposure object, a standard market access concept consistent with (7) is

$$MA_{i,t} \;=\; \sum_{j=1}^{N} E_{j,t}\,\tau_{ij,t}^{1-\sigma}, \tag{10}$$

or related variants that differ in functional form and in whether additional equilibrium terms are included (Donaldson and Hornbeck, 2016; Redding and Turner, 2015; Redding and Venables, 2004). It is worth noting that $E_{j,t}$ denotes total expenditure in market j, and that this equation considers each market separately. In a monocentric economy where a dominant center (Montevideo) represents a large share of domestic demand and acts as a gateway, an informative special case focuses on access to that center,

$$MA_{i,t}^{\text{MVD}} \;=\; E_{\text{MVD},t}\,\tau_{i,\text{MVD},t}^{1-\sigma}. \tag{11}$$

To link generalised travel time to iceberg trade costs in a reduced-form way, a convenient specification is to model trade costs as a smooth, increasing function of travel time ($TT_{ij,t}$),

$$\tau_{ij,t} \;=\; \exp(\kappa\, TT_{ij,t})\,, \qquad \kappa > 0, \tag{12}$$

so that more distant markets receive progressively less weight in (10)–(11).

Within this mapping, the railway infrastructure index (RII) is interpreted as a department-level measure of railway endowment and hub-oriented network position. Empirically, $RII_{i,t}$ is constructed via TOPSIS from multiple indicators of railway exposure: depreciated investment, number of stations, kilometers of track built in the department, and geodesic distance to Montevideo (capturing baseline centrality in a radial system). Conceptually, higher $RII_{i,t}$ should be associated with lower generalised transport costs faced by department i, by improving effective travel times along the transport network.

A parsimonious way to express this is to let the trade-cost term be a function of generalised travel time, and let travel time depend on rail exposure:

$$\tau_{ij,t} \;=\; \exp\bigl(\kappa\, TT_{ij,t}\bigr), \qquad \kappa > 0, \tag{13}$$

$$TT_{ij,t} \;=\; TT_{ij,t}(RII_{i,t}, RII_{j,t}), \qquad \frac{\partial TT_{ij,t}}{\partial RII_{i,t}} < 0,\; \frac{\partial TT_{ij,t}}{\partial RII_{j,t}} < 0. \tag{14}$$

In a monocentric setting, a particularly informative implication concerns access to the dominant center: improvements in $RII_{i,t}$ should reduce $TT_{i,\mathrm{MVD},t}$ (and thus $\tau_{i,\mathrm{MVD},t}$), even if the magnitude of bilateral effects differs across destinations. Under this mapping, market access becomes the composite object that translates rail exposure and the transport network into economically relevant accessibility,

$$MA_{i,t} \;=\; \sum_{j=1}^{N} E_{j,t}\, \tau_{ij,t}^{1-\sigma}. \tag{15}$$

A key implication is that the same amount of rail exposure (as captured by $RII_{i,t}$) need not generate the same development effect across departments, because its impact depends on how much it translates into effective access to economically large destinations. Define market-access weights,

$$s_{ij,t} \;\equiv\; \frac{E_{j,t}\, \tau_{ij,t}^{1-\sigma}}{MA_{i,t}}, \qquad \sum_{j=1}^{N} s_{ij,t} \;=\; 1. \tag{16}$$

so that differentiating market access with respect to rail exposure yields

$$\frac{\partial \ln MA_{i,t}}{\partial RII_{i,t}} \;=\; (1-\sigma) \sum_{j=1}^{N} s_{ij,t}\, \frac{\partial \ln \tau_{ij,t}}{\partial RII_{i,t}}. \tag{17}$$

Expression (17) clarifies interpretation: the change in $MA_{i,t}$ induced by a marginal increase in rail exposure is a weighted average of how exposure changes trade costs to each destination, with weights $s_{ij,t}$ proportional to destination economic mass and discounted by trade costs. Consequently, for a given improvement in $RII_{i,t}$, departments whose effective costs fall more sharply toward large markets, and especially toward the dominant center, experience a larger increase in market access and, through the spatial-equilibrium logic above, a larger potential increase in development outcomes.

This also makes precise the role of a Montevideo-only market access measure,

$$MA_{i,t}^{\mathrm{MVD}} \;=\; E_{\mathrm{MVD},t}\, \tau_{i,\mathrm{MVD},t}^{1-\sigma}. \tag{18}$$

since in a monocentric setting the growth and distributional consequences of rail exposure can be especially sensitive to how $RII_{i,t}$ changes $\tau_{i,\text{MVD},t}$. Intuitively, departments whose rail improvements disproportionately reduce generalised costs to Montevideo experience larger gains in access, which can translate into stronger level effects and potentially into convergence, depending on whether agglomeration forces shift activity toward or away from the center. In this sense, $RII_{i,t}$ should be associated with lower generalised transport costs faced by department i, by combining (i) railway endowment (investment, stations, and track kilometers) that can reduce effective travel times, and (ii) baseline hub centrality (geodesic proximity to Montevideo) that shapes the level of generalised transport frictions in a radial system.

Even if railway expansion increases average regional performance, its implications for spatial inequality are not mechanically determined. In core–periphery environments, reductions in trade costs can generate either convergence or divergence depending on agglomeration forces and the strength of market-size effects (Fujita et al., 1999; Krugman, 1991b). This motivates a secondary outcome focusing on catch-up relative to Montevideo:

$$\ln\left(\frac{\text{GDPpc}_{i,t}}{\text{GDPpc}_{\text{MVD}}}\right), \tag{19}$$

which directly captures whether departments converge to or diverge from the dominant center over time.

The spatial-equilibrium intuition above treats reductions in generalised trade costs as the primitive force linking railway expansion to regional development. In practice, however, transport networks are not allocated mechanically: their spatial distribution reflects deliberate choices shaped by fiscal constraints, lobbying, and state objectives. Railway investment may respond to expected economic returns, but also to political incentives and distributional conflicts: regions with greater political influence, stronger lobbying capacity, or strategic value may receive earlier or denser connections. This is a general point in the evaluation of transport infrastructure and motivates caution when interpreting reduced-form correlations (Cadot et al., 1999; Felbermayr and Tarasov, 2022; Knight, 2002; Redding and Turner, 2015). In the Uruguayan case, historical evidence indicates that the State actively shaped railway provision through subsidies and profit guarantees to attract private (often foreign) investment (Bertino et al., 2015). Moreover, in export-led Latin American settings, railway design often reflected a political economy linking export-producing areas to ports, mediated by foreign capital and domestic elites (Travieso, 2017). These considerations imply that observed railway exposure (and thus RII and MA) may be correlated with unobserved determinants of long-run development, motivating the IV-LCP approach introduced below.

Beyond goods-market integration, railways can also alter the effective reach of the state and the spatial distribution of political influence. By lowering travel times, railways may facilitate monitoring, administrative presence, and the provision of public goods in peripheral areas, amplifying development effects through institutional channels (Cermeño et al., 2022). Conversely, if policy choices and complementary investments are disproportionately concentrated around the dominant center, railways can reinforce hub advantages and contribute to persistent spatial inequality. In this thesis, these political-economy mechanisms are treated as plausible channels that complement the market-access mechanism highlighted by the spatial-equilibrium framework, while also reinforcing the need for an identification strategy that addresses non-random network placement.

Taken together, the conceptual block implies that railway expansion affects regional outcomes through (i) a cost-of-living channel (lower $P_{i,t}$) and (ii) an access-to-demand channel (higher $MA_{i,t}$), and that the payoff to rail exposure can be larger where reachable markets are economically larger. The empirical strategy therefore uses $RII_{i,t}$ as a proxy for railway exposure and network position, $MA_{i,t}$ as a proxy for demand-weighted accessibility computed from minimum travel times, and an interaction term $\ln(RII_{i,t}) \times \ln(MA_{i,t})$ to allow the marginal railway effect to vary with accessibility.

5 Hypotheses

Given the aforementioned research questions, I make the following hypotheses.

For the question related to the relationship between the railway expansion and regional productive development, the following hypothesis is presented:

H_1) The relationship between railways and regional economic performance, measured as departmental GDP per capita, was positive and significant; however, it was heterogeneous in the territory and different between periods.

Furthermore, for the question on the effect of the railway on regional inequality the hypothesis is as follows:

H_2) As connectivity progressed, the railways allowed the reduction of regional inequality in Uruguay. Furthermore, the State planning, which began with the first Railway Law of 1884, allowed to maintain the reduction of inequality connecting the railways to locations in which the private sector would not invest.

This is consistent with the work of Martí-Henneberg (2017), which shows that, in Europe, inequality was lower when States focused not only on reaching cities and densely populated locations in their countries after 1870, but also on serving remote and less populated areas. Also, this will test whether the idea of Minister Herrera y Obes, reflected in the 1888 Law on the purpose the railway should pursue, was realised, and, if so, this can be known as some kind of "Herrera y Obes hypothesis".

6 Methodology

6.1 Data

6.1.1 Variables

To operationalise notions of railway infrastructure, it is necessary to create a composite indicator variable. While previous research used network density or capital stock as a proxy for the effect of railways, my main objective is to measure the effect of the infrastructure, ad as so, network density or capital stock alone, while a key part of infrastructure are not the only things affecting it. For this I take advantage of multiple sources to create an index which combines railway density, distance between stations (also understood as accessibility to the network), depreciated investment (i.e. capital stock, which also can be understood as quality) and the geodesic distance to Montevideo (this is, the centrality of the network).

To create a composite index, several options were considered. It should be noted that a decision was made here. I wanted a comprehensible index that could be easily understood as a variable between 0 and 1, with 0 representing the worst possible infrastructure and 1 the best possible infrastructure. First, I could have done a manual index, which is combining all the inputs and assigning them manual weights and then normalising it in order to get a 0 to 1 index, but that would have been subjective and difficult to justify the weights that each component deserved in such an index, and relying solely on this and not in other component coud be dangerous. Then, I consider creating it using Principal Components Analysis (PCA) was thought but discarded due to the difficulty of interpreting such method and translating it to an index which could be easily understood as stated before. A third method, used in management studies on decisions, is the Technique for Order of Preference by Similarity to The Ideal Solution (TOPSIS) is a comprehensible and informative index that can combine multiple criteria to find the ideal solution. This is why 0 is the worst possible outcome and 1 the best, after combining all the data, as explained below. It is necessary to establish that, with respect to PCA, it has the disadvantage of requiring the choice of weights, which in this case were set to give greater weight to the quality and density parts. In contrast to a purely manual index, it allows the computation of an ideal solution, so after choosing the weights, the index automatically combines to find the result, as explained below.

The main source for railway inputs is the set of annual reports produced by private railway companies operating in Uruguay between 1869 and 1948. These reports provide year-by-year information on capital expenditure and related items, which I use to build department-level measures of railway investment. For the post-1948 period, I complement these materials with the annual reports of the three state operators, from 1948 to 1951 both Administración del Ferrocarril Central del Uruguay and Administración de Ferrocarriles y Tranvías del Estado, which managed two different sections of the network. And for 1952, the newly created Administración de Ferrocarriles del Estado (A.F.E.), which consolidated the Annual Reports of both previous companies.

To measure network endowment more broadly, I combine the Statistical Yearbooks of the República Oriental del Uruguay with A.F.E. reports (notably the 1955 and 1961 reports), as well as an excellent recent recopilation by Seijas Giménez (2024a,b), to construct department-level series on railway stations, which includes its exact geographical location and year of opening.

For economic outcomes, I use the regional gross value added (GVA) series reconstructed by Martínez-Galarraga et al. (2020), available for the benchmark years 1872, 1884, 1890, 1895, 1900, 1908, 1936, 1955, 1961, 1975, 1986, 1990, 1995, 2000, 2005, and 2012. The analysis in this thesis focuses on 1872–1961. To obtain an annual panel, I impute missing years using a machine-learning approach described in Section 6.1.2.

I also assemble controls that capture broader territorial conditions. For human capital and development inputs, such as education, phone coverage, sanitary conditions, participation in banking, and mechanisation. It is worth noting that each of these variables is constructed by recollecting data from different sources within each department and the meaning varies, for education and mechanisation the value of the variable is relative to the national average, being this 1. In the case of banking, the variable is the department's share of banking participation, which adds up to 1. The case of sanitary conditions and road infrastructure is the most particular, as they have their own meanings: sanitary conditions are the share of child mortality within a specific department, and road infrastructure is the number of roads built per km^2.

These variables come from a project in progress of department-level series compiled by Rodríguez Miranda and Willebald[12], which covers 1900–1960, the final goal of that project is to retrieve information further than 1900. Given the nature of the variables' values, I assume that prior to 1900, no changes were made, and the value at 1900 by department is the same as that from 1870 to 1899. The caveat is that the variables with their own meaning can be the most difficult to treat here, so this is a hard assumption. However, as they are the control variables, I proceed with the said strategy.

For geographic and climatic endowments (e.g., rainfall and soil quality), I use the department-level estimates provided by Castro Scavone (2023), available for 1870, 1884, 1890, 1908, 1916, 1924, 1937, 1943, 1951, 1956, 1966, 1970, 1980, 1990, 2000, and 2008. As well I merge it with year by year data from the Global Climate Monitor[13] project, which has monthly and yearly data by department from 1901 to 2025. Owing to the fact that data for all years does not exist I take 20 year average windows (from 1870) which comprenhends all the period of study.

Table 1: Data*

Variable	Meaning	Source
y_{it}	Regional value added per capita by department (2005 $U)	Martínez-Galarraga et al. (2020)
$rail_i$	Kilometers of railway track by department	Statistical Yearbooks (R.O.U.) and company reports
$DistMdeo_i$	Distance from the department to Montevideo	
$rugosidad_i$	Department ruggedness (from elevation maps)	Instituto Geográfico Militar
$inversion_i$	Railway investment (1914 British pounds)	Company annual reports
$estaciones_i$	Railway stations by department	Statistical Yearbooks (R.O.U.) and A.F.E. reports
$distestaciones_i$	Distance between railway stations within a department	Statistical Yearbooks (R.O.U.) and A.F.E. reports
$Pluviosidad_i$	Average annual rainfall (mm)	Castro Scavone (2023)
$Calidad_i$	Potential productive capacity of soils in a department	Castro Scavone (2023)
$Educacion_i$	Education** by department	Willebald and Rodríguez Miranda (2020)*****
$Poblacion_i$	Population by department	Willebald and Rodríguez Miranda (2020)*****
$Coberturatelefonica_i$	Phone coverage in the department	Willebald and Rodríguez Miranda (2020)*****
$Bancoscada100000$	Banks per 100,000 inhabitants by department	Willebald and Rodríguez Miranda (2020)*****
$Partipbancapublica_i$	Participation in public banking*** by department	Willebald and Rodríguez Miranda (2020)*****
$Prodtrabprimario_i$	Primary sector productivity**** by department	Willebald and Rodríguez Miranda (2020)*****

* Main analysis sample: 1870–1952.
** Education coverage measured as: $\frac{Primaryschoolenrolment+1.4\times Secondaryschoolenrolment}{Childrenpopulation(5to19)}$.
*** Share of public banking by department, it sums to 1.
**** Productivity calculated as: $\frac{PrimarySectorVA}{Ruralworkforce}$.
***** CSIC I+D Project 2020 "Patrones de desarrollo regional en Uruguay en perspectiva de largo plazo (siglos XX y XXI)". Academic director: Henry Willebald.

[12] CSIC I+D Project 2020 "Patrones de desarrollo regional en Uruguay en perspectiva de largo plazo (siglos XX y XXI)". Academic director: Henry Willebald.
[13] https://kerdoc.cica.es/

6.1.2 Creation of the Investment Database

I build the investment database by extending the approach in Díaz (2014). Relative to that study, I (i) extend the coverage from 1914 through 1952, (ii) incorporate investment undertaken by state operators, and (iii) allocate investment to departments whenever the underlying sources allow.

Company annual reports typically contain a section on *capital expended*. In many cases, reported capital outlays are broken down either by station or by department. When the breakdown is available, I aggregate the relevant lines to obtain the investment undertaken by each company in each department-year. When the reports do not provide a department allocation (e.g., telegraph lines or rolling-stock purchases), I allocate the expenditure across the departments served by the company in proportion to the kilometers of track operated in each department. Appendix B reproduces a representative page.

Following Díaz (2014) and Herranz-Loncan (2011), I convert nominal capital outlays into a depreciated investment measure using a 1.7% annual depreciation rate. As will be described next, I then use TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) to combine railway investment with other dimensions of railway endowment, stations by department, network density, and geodesic distance to Montevideo, into a composite index.

As mentioned before, $RII_{i,t}$ (Railway Infrastructure Index) is constructed using TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), which aggregates multiple railway-infrastructure attributes into a single closeness-to-ideal score (Hwang and Yoon, 1981; Pandey et al., 2023). Railway infrastructure is treated as a multidimensional object summarised by four criteria: (i) railway capital stock at 1914 investment prices (S), (ii) network density in km of track per km^2 (D), (iii) local accessibility (I), measured as the distance between stations within a department (inverted so higher values indicate greater accessibility), and (iv) centrality (P) (defined so that higher values indicate greater centrality, proxied by inverse distance to Montevideo).

Let $X_{it}^{(k)}$ denote the raw value of criterion $k \in \{S, D, I, P\}$ for department i in year t. To ensure comparability over time, each criterion is mapped to the unit interval using a global max–min transformation:

$$x_{it}^{(k)} = \frac{X_{it}^{(k)} - \min_{j,\tau} X_{j\tau}^{(k)}}{\max_{j,\tau} X_{j\tau}^{(k)} - \min_{j,\tau} X_{j\tau}^{(k)}}, \qquad k \in \{S, D, I, P\}. \tag{20}$$

This normalisation places all criteria on a common $[0, 1]$ scale, where larger values indicate better infrastructure outcomes by construction.

TOPSIS requires criterion weights. Let $\mathbf{w} = (w_S, w_D, w_I, w_P)$ with $\sum_k w_k = 1$. In the baseline specification, weights are set based on the importance of each dimension on how the service works on quality and connectivity. In particular the bigger dimension will be the capital stock, as it encases the capital effort behind the network build-out, upgrading and maintenance capacity, key components on quality. Followed by network density, as it captures the territorial coverage of the network within a department, reflecting on how well connected a department is. After this it goes accessibility, as it tries to measure the capacity of local communities to access the railways and its positive spillovers, as well as how many communities or stations the railway serve given its size. As this can also be captured by the previous dimension, and also because the railways in Uruguay served mainly to transport goods its weight was reduced. Last the position of the department was put in this index considering the particularities of Uruguay, as being a monocentric economy, as well as the relevance of the department considering the gravitational point, it is a positional quality of the infrastructure, due to this it was given a low weight.

Therefore the weights used were as follows:

$$\mathbf{w} = (0.45,\ 0.30,\ 0.175,\ 0.075). \tag{21}$$

A practical issue is that criteria such as centrality may be non-zero even when there is no railway presence in the department. To impose that the index equals zero in the absence of infrastructure, define a gate:

$$\text{Gate}_{it} = \mathbf{1}\{\text{stations}_{it} > 0\}. \tag{22}$$

Given the global max–min scaling, the (empirical) ideal and anti-ideal bundles satisfy

$$x_k^* = \max_{i,t} x_{it}^{(k)} = 1, \qquad x_k^- = \min_{i,t} x_{it}^{(k)} = 0, \qquad k \in \{S, D, I, P\}. \tag{23}$$

Distances to the ideal and anti-ideal are computed using a weighted Euclidean metric:

$$d_{it}^+ = \left[\sum_k w_k \left(x_{it}^{(k)} - x_k^*\right)^2\right]^{1/2}, \tag{24}$$

$$d_{it}^- = \left[\sum_k w_k \left(x_{it}^{(k)} - x_k^-\right)^2\right]^{1/2}. \tag{25}$$

The TOPSIS closeness coefficient is then

$$C_{it} = \frac{d_{it}^-}{d_{it}^+ + d_{it}^-}, \qquad 0 \le C_{it} \le 1, \tag{26}$$

and the baseline railway infrastructure index is defined as

$$RII_{it}^{\text{baseline}} = \begin{cases} C_{it}, & \text{if Gate}_{it} = 1, \\ 0, & \text{if Gate}_{it} = 0. \end{cases} \tag{27}$$

Larger values indicate closer proximity to the ideal infrastructure bundle. By construction, $RII_{it} = 1$ is attained only if a department simultaneously reaches the ideal value in all criteria; otherwise, the index remains strictly below one.

Finally, because many reports use the pre-decimal British currency system, in current value, I transform them into 1914 British Pounds using the implicit investment deflators for the Uruguayan economy taken from Bértola et al. (2024b). I convert amounts reported in pounds, shillings, and pence using the standard equivalences (£1 = 20 shillings; 1 shilling = 12 pence) before rounding and aggregation.

As Figure 3 depicts, it is consistent with the periods of major investment and then of decapitalisation of the network. The Figure depicts the different patterns of network evolution, as well as which departments were responsible for each of the booms.

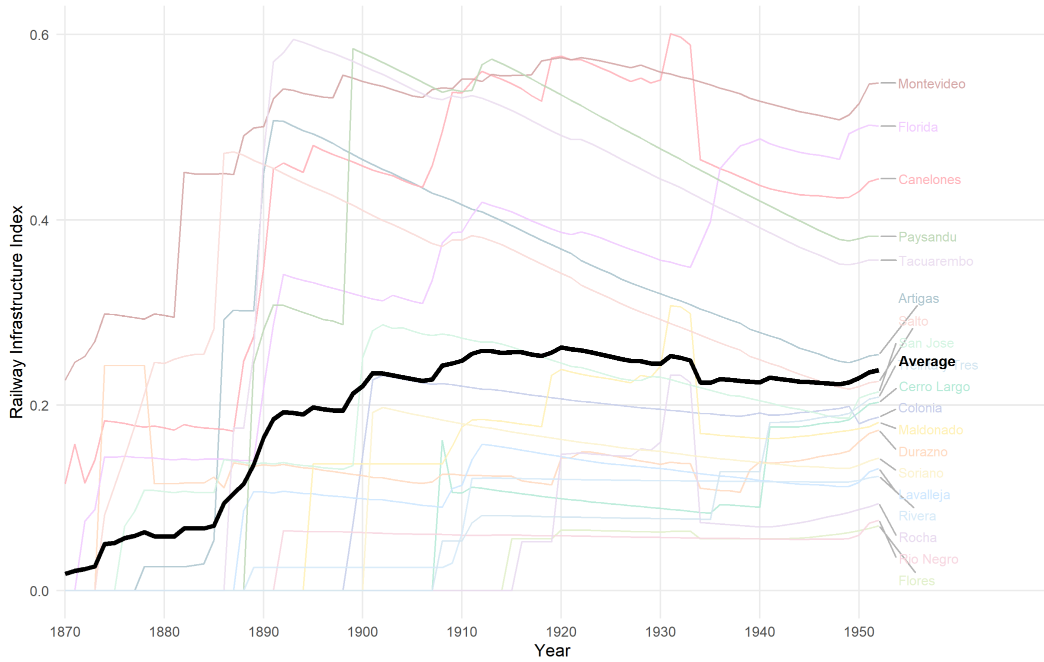


Figure 3: Evolution of the Railway Infrastructure Index by department with national average in black. Source: Own estimations.

6.1.3 Amplifying Regional GDP data

The regional GVA series in Martínez-Galarraga et al. (2020) is available only for a limited set of benchmark years. To construct an annual department-level panel for 1870–2023 (to comprehend our period of study), I impute the missing observations using a spatiotemporal imputation model.

Specifically, I implement PriSTI (Spatiotemporal Imputation with Enhanced Prior Modeling), introduced by Liu et al. (2023). PriSTI is a conditional diffusion-based imputation framework that exploits two sources of structure that are natural in this setting: (i) spatial dependence across departments, represented by an adjacency matrix, and (ii) temporal dependence within each department's series. The tensor formulation also allows the inclusion of auxiliary time-varying covariates (e.g., national aggregates, sectoral series, and population), which can help discipline the imputation when benchmark data are sparse.

At the same time, and in order to obtain a credible GDP per capita, given how sensitive this is to the population of departments, the decision was to update population estimates given certain benchmarks (population census of 1860, 1908, 1963, 1975, 1985, 1996, 2004, 2011 and 2023) using a Piecewise Cubic Hermite Interpolating Polynomial with an algorithm provided by Carlson and Fritsch (1989). This method was used as it has the capacity to do smooth joins between benchmarks, are shape-preserving and there is no local overshoot, an advantage over standard cubic splines or linear interpolation methods.

Relative to linear interpolation, the advantage of this approach is that it can accommodate nonlinear dynamics and spatial correlations in the data-generating process (Liu et al., 2023). At the same time, the scarcity of benchmark observations implies that imputed series should be interpreted with caution. I therefore document the implementation choices, inputs, and validation checks in Appendix A.

6.2 Empirical Strategy

6.2.1 Empirical strategy: From spatial equilibrium intuition to reduced-form estimation

The economic-geography block above highlights transport costs as the primitive: railway expansion changes generalised trade costs $\tau_{ij,t}$ (equivalently generalised travel times $TT_{ij,t}$), which in turn shape (i) the local price index and real income and (ii) firms' access to demand and location incentives (Donaldson and Hornbeck, 2016; Fujita et al., 1999; Krugman, 1991b; Redding and Turner, 2015; Redding and Venables, 2004). This thesis does not estimate a full structural model or recover parameters such as μ, σ, or κ. Instead, it uses reduced-form panel specifications that relate observed regional outcomes to empirical proxies for (a) railway exposure / network endowment and (b) demand-weighted accessibility, in a way that is consistent with the mechanism emphasised by the model.

A key object in the conceptual block is market access, $MA_{i,t} = \sum_j E_{j,t}\tau_{ij,t}^{1-\sigma}$, where $\tau_{ij,t}$ is a decreasing function of effective travel time. Empirically, I operationalise these objects with (i) a railway infrastructure index $RII_{i,t}$ and (ii) market access $MA_{i,t}$ constructed from minimum network travel times. Because the framework allows heterogeneous returns to infrastructure depending on the size of reachable markets, I also estimate specifications in which the marginal effect of $RII_{i,t}$ varies with $MA_{i,t}$ via an interaction term. Two additional empirical issues motivate the set of estimators used in the thesis. First, railway expansion may generate spatial spillovers across neighboring departments. Second, railway placement is plausibly endogenous to expected economic returns and political incentives.

To address these concerns, I estimate two-way fixed effects (TWFE) reduced-form models, a spatial Durbin model specification (HSDM) that allows for spatial feedback, and an IV strategy based on least-cost paths (LCP) for railway placement.

Let $y_{i,t}$ denote regional economic performance. I use two complementary dependent variables: (i) *levels*, $\ln(\text{GDPpc}_{i,t+h})$ (with h a lead/horizon used in the empirical implementation); and (ii) *catch-up relative to Montevideo*, $\ln\left(\frac{\text{GDPpc}_{i,t}}{\text{GDPpc}_{\text{MVD}}}\right)$. The first speaks directly to whether railway expansion increased local economic performance. The second speaks to the distributional hypothesis emphasised by core–periphery logic (Fujita et al., 1999; Krugman, 1991b).

6.2.2 Mapping theory objects into empirical proxies: $RII_{i,t}$ and $MA_{i,t}$

In this thesis, the railway infrastructure index $RII_{i,t}$ is interpreted as a department-level measure of railway endowment and (hub-oriented) network position. It combines time-varying infrastructure components (e.g. depreciated investment, distance to stations, network density) with a hub-centrality component (geodesic proximity to Montevideo) that captures baseline radial frictions. The guiding interpretation is: *within a department over time*, increases in $RII_{i,t}$ should be associated with lower generalised transport costs faced by department i, primarily through improvements in effective travel times along the transport network. The geodesic component (proximity to Montevideo) is time-invariant and is therefore absorbed by department fixed effects in TWFE specifications. However, because TOPSIS rescales the underlying variables period by period, a time-invariant attribute can still contribute mechanically to year-to-year variation in the composite score through the normalisation step. In the 2SLS specifications, identification comes from the component of $\ln(RII_{i,t})$ shifted by $Z_{i,t}^{\text{LCP}}$; in practice, that variation is driven mainly by the time-varying railway endowment components, with baseline centrality affecting the level and scaling of the index.

The conceptual block motivates market access (i.e. demand reached) as an equilibrium exposure object in equation 10, with iceberg trade costs $\tau_{ij,t} \geq 1$ that are increasing in generalised travel time. Following the common reduced-form mapping, I treat trade costs as a monotone function of travel time:

$$\tau_{ij,t} = \exp(\kappa \, TT_{ij,t}), \qquad \kappa > 0, \tag{28}$$

so that $\tau_{ij,t}^{1-\sigma} = \exp\big(-(\sigma-1)\kappa \, TT_{ij,t}\big)$ provides a smooth discounting of distant markets (Donaldson and Hornbeck, 2016; Redding and Turner, 2015; Redding and Venables, 2004).

Empirically, I compute $TT_{ij,t}$ as the minimum generalised travel time between department centroids under the prevailing transport technology at time t[14]: cart-only[15] before a connection exists; rail+cart thereafter, allowing routes to use rail segments when available. I then construct a market-potential index that aggregates economic mass discounted by travel time. The baseline implementation uses a decreasing function $g(\cdot)$:

$$MA_{i,t} \equiv \sum_{j=1}^{N} M_{j,t} \, g(TT_{ij,t}) \,, \qquad g'(\cdot) < 0, \tag{29}$$

where $M_{j,t}$ is the destination mass (e.g. GDP, expenditure proxy). In the main specification, $g(TT) = 1/TT$, consistent with the idea that farther destinations receive less weight.

In the empirical implementation, $E_{j,t}$ is proxied by observed economic mass $M_{j,t}$ (e.g. GDP or an expenditure proxy), and $\tau_{ij,t}^{1-\sigma}$ is operationalised as a decreasing function of generalised travel time, $g(TT_{ij,t})$, consistent with (28).

In a monocentric setting, an informative special case focuses on access to the dominant center:

$$MA_{i,t}^{\text{MVD}} \equiv M_{\text{MVD},t} \, g(TT_{i,\text{MVD},t}) \,, \tag{30}$$

which isolates the component of accessibility operating through Montevideo.

The theory implies that the payoff to an infrastructure improvement may be larger when it translates into greater access to economically large destinations. In the empirical strategy, this motivates allowing the marginal effect of $\ln(RII_{i,t})$ to vary with $\ln(MA_{i,t})$ via an interaction term. Because $MA_{i,t}$ is itself shaped by the transport network, regressions including both $RII_{i,t}$ and $MA_{i,t}$ are interpreted as evidence consistent with an accessibility mechanism rather than as a clean decomposition of independent causal channels.

[14] I do this as cart was the only available land transport before railway existed (Baracchini, 1978; Díaz, 2015), and when roads started to grow *en masse* around the 1920s, railways were already present in every department.

[15] When no railway connection exists, I approximate cart travel by following the later railway alignments, since many tracks were built along pre-existing cart routes.

6.2.3 Reduced-form specifications

The baseline reduced-form panel specification for the levels outcome is:

$$\ln\big(\text{GDPpc}_{i,t+h}\big) = \beta_1 \ln(RII_{i,t}) + \beta_2 \ln(MA_{i,t}) + \beta_3 \Big[\ln(RII_{i,t}) \times \ln(MA_{i,t})\Big] + X'_{i,t}\gamma + \mu_i + \lambda_t + \varepsilon_{i,t}, \tag{31}$$

where $X_{i,t}$ includes time-varying controls (which were presented in section 6.1), and a time-invariant one in soil quality, μ_i are department fixed effects, and λ_t are year fixed effects. Standard errors are clustered at the department level.

For the distributional outcome, I estimate:

$$\begin{aligned} \ln\left(\frac{\text{GDPpc}_{i,t}}{\text{GDPpc}_{\text{MVD}}}\right) &= \beta_1^{rel} \ln(RII_{i,t}) + \beta_2^{rel} \ln(MA_{i,t}) \\ +\beta_3^{rel}\Big[\ln(RII_{i,t}) \times \ln(MA_{i,t})\Big] &+ X'_{i,t}\gamma^{rel} + \mu_i + \lambda_t + \varepsilon_{i,t}^{rel}, \end{aligned} \tag{32}$$

typically excluding Montevideo from the sample.

With the interaction in logs, the within-department marginal effect of railway exposure is:

$$\frac{\partial \ln y_{i,t}}{\partial \ln RII_{i,t}} = \beta_1 + \beta_3 \ln(MA_{i,t}), \tag{33}$$

where $y_{i,t}$ denotes the relevant outcome (levels or relative). This is the object reported and tracked over time in the empirical results.

6.2.4 Heterogeneous Spatial Durbin Model (HSDM) and the interpretation of total effects

The empirical strategy allows railway exposure to affect regional outcomes both *directly* (within a department) and *indirectly* through spatial interaction across departments. A natural reduced-form representation for these forces is the Spatial Durbin Model (SDM), which combines (i) an endogenous spatial lag of the dependent variable (spatial feedback) with (ii) spatial lags of covariates (covariate spillovers). In the Uruguayan setting, however, it is also plausible that departments respond heterogeneously to railway exposure and accessibility, given differences in initial conditions, sectoral composition, and the way each department connects to the hub. For this reason, I adopt an SDM that allows department-specific responses (a heterogeneous-coefficient SDM), which preserves the SDM logic of spatial feedback while allowing the main coefficients of interest to vary by department (Aquaro et al., 2021; Elhorst, 2014; LeSage and Chih, 2016, 2018; LeSage and Pace, 2009).

Let $y_{i,t}$ denote the outcome (e.g. $\ln(\text{GDPpc}_{i,t})$ or $\ln(\text{GDPpc}_{i,t}/\text{GDPpc}_{\text{MVD},t})$), let W be a row-standardised $N \times N$ spatial-weights matrix, and define the key regressor block

$$z_{i,t} \equiv \begin{bmatrix} r_{i,t} \\ m_{i,t} \\ v_{i,t} \end{bmatrix} = \begin{bmatrix} \ln(RII_{i,t}) \\ \ln(MA_{i,t}) \\ \ln(RII_{i,t}) \times \ln(MA_{i,t}) \end{bmatrix}, \qquad x_{i,t} \equiv \text{controls.}$$

The HSDM specification is

$$y_{i,t} = \rho \sum_j w_{ij} y_{j,t} + z'_{i,t}\beta_i + \left(\sum_j w_{ij} z_{j,t}\right)' \theta_i + x'_{i,t}\gamma + \left(\sum_j w_{ij} x_{j,t}\right)' \varphi + \mu_i + \lambda_t + \varepsilon_{i,t}, \quad (34)$$

where ρ captures outcome spillovers/feedback, θ_i captures spillovers operating through neighbors' regressors, and μ_i and λ_t are department and year effects. Relative to the SDM, the HSDM relaxes slope homogeneity by allowing (β_i, θ_i) to differ by department for the regressors of interest (Cornwall and Parent, 2017).

Coefficient heterogeneity is modeled using a hierarchical (random-coefficients) structure: $\beta_i = \bar{\beta} + b_i$, $\theta_i = \bar{\theta} + d_i$, with $(b'_i, d'_i)'$ drawn from a common distribution. This specification delivers partial pooling while allowing department-specific responses.

$$\begin{bmatrix} b_i \\ d_i \end{bmatrix} \sim \mathcal{N}(\mathbf{0}, \Sigma), \quad (35)$$

so that the data identify both (i) department-specific responses and (ii) a well-defined population (national) distribution of effects (Aquaro et al., 2021; LeSage and Chih, 2016).

Because (34) contains the endogenous spatial lag $\rho W y_t$, the coefficient vectors are not directly interpretable as ceteris-paribus partial derivatives. Any change in a regressor in one department affects its outcome, which affects neighbors' outcomes, and so on. This propagation is summarised by the spatial multiplier $(I - \rho W)^{-1}$, implying that interpretation should be based on *impact measures* (direct, indirect, and total) computed from the reduced form (Elhorst, 2012; LeSage and Pace, 2009).

Let $\mathbf{y}_t$ stack $y_{i,t}$ across departments, and let $\mathbf{S}(\rho) \equiv (I - \rho W)^{-1}$. Suppressing fixed effects for compactness, the reduced form has the generic structure

$$\mathbf{y}_t = \mathbf{S}(\rho)\Big(\mathbf{Z}_t\beta + W\mathbf{Z}_t\theta + \mathbf{X}_t\gamma + W\mathbf{X}_t\varphi\Big) + \mathbf{S}(\rho)\varepsilon_t, \quad (36)$$

where in the HSDM the coefficients vary by department. A convenient way to write the implied derivatives is to introduce diagonal coefficient matrices for each component (e.g. for $r = \ln(RII)$),

$$\mathbf{B}_r \equiv \text{diag}(\beta_{r,1}, \ldots, \beta_{r,N}), \qquad \boldsymbol{\Theta}_r \equiv \text{diag}(\theta_{r,1}, \ldots, \theta_{r,N}),$$

and similarly for the interaction term $v = r \times m$. Let $\mathbf{r}_t$ and $\mathbf{m}_t$ be the stacked vectors of $r_{i,t}$ and $m_{i,t}$, and define $\mathbf{D}(\mathbf{m}_t) \equiv \text{diag}(\mathbf{m}_t)$ so that $\mathbf{v}_t = \mathbf{D}(\mathbf{m}_t)\mathbf{r}_t$. Then the *conditional* impact matrix of rail exposure (holding $\mathbf{m}_t$ fixed) is

$$\mathbf{G}_{r,t}(\mathbf{m}_t) \equiv \frac{\partial \mathbf{y}_t}{\partial \mathbf{r}'_t} = \mathbf{S}(\rho)\Big[\mathbf{B}_r + \boldsymbol{\Theta}_r W + \mathbf{B}_v \mathbf{D}(\mathbf{m}_t) + \boldsymbol{\Theta}_v W \mathbf{D}(\mathbf{m}_t)\Big]. \quad (37)$$

Equation (37) makes explicit how the interaction enters the marginal effect: rail exposure has a larger (or smaller) impact when $\ln(MA)$ is higher, and this dependence is propagated through the spatial multiplier.

The matrix $\mathbf{G}_{r,t}(\mathbf{m}_t)$ contains all own and cross-department effects. Following the standard impact decomposition, define the global (average) effects:

$$\text{Direct}_{r,t} \equiv \frac{1}{N}\,\text{tr}(\mathbf{G}_{r,t}(\mathbf{m}_t))\,, \tag{38}$$

$$\text{Total}_{r,t} \equiv \frac{1}{N}\boldsymbol{\iota}'\mathbf{G}_{r,t}(\mathbf{m}_t)\boldsymbol{\iota}, \tag{39}$$

$$\text{Indirect}_{r,t} \equiv \text{Total}_{r,t} - \text{Direct}_{r,t}, \tag{40}$$

where $\boldsymbol{\iota}$ is an $N \times 1$ vector of ones (Elhorst, 2012; LeSage and Pace, 2009). The **direct** effect averages the diagonal elements of $\mathbf{G}_{r,t}$ and therefore captures the within-department effect of a change in $\ln(RII)$ *including feedback loops* (e.g. $i \to j \to i$). The **indirect** effect summarises spillovers to other departments (off-diagonal impacts). The **total** effect is their sum.

In the main results, I focus on the *total* marginal effect of rail exposure, $\text{Total}_{r,t}$ in (39). This is the appropriate single-number summary when the object of interest is the overall development consequence of railway-induced changes in connectivity in a spatial system: rail improvements can raise (or lower) local performance and simultaneously reallocate activity across space, so an effect that aggregates own and spillover responses is the natural counterpart to the spatial-equilibrium motivation. At the same time, the distinction between direct and indirect effects remains conceptually important, and it is useful to discuss it explicitly because it clarifies whether estimated gains are primarily local (direct) or operate through spillovers and feedback (indirect).

Because (37) depends on $\mathbf{m}_t = \ln(MA_t)$, the marginal effect of $\ln(RII)$ is evaluated at a chosen accessibility level. In practice, the year-by-year "global total marginal effect" $\partial \ln y/\partial \ln(RII)$ reported in the results is obtained by summarising (37) through (39) at the scenario-specific $\mathbf{m}_t$ (often using the national mean $\overline{\ln(MA)}_t$ for readability). This mapping is the precise connection between the interaction regression and the time-varying marginal effects plotted and tabulated in the empirical section.

Although $MA_{i,t}$ is constructed from the transport network and can itself respond to infrastructure, the HSDM is interpreted in reduced-form terms as delivering the *partial* derivative of outcomes with respect to $\ln(RII)$, conditional on the realised (or scenario-defined) $\ln(MA)$. Formally, this corresponds to holding $\mathbf{m}_t$ fixed in (37). Allowing $\mathbf{m}_t = \mathbf{m}_t(\mathbf{r}_t)$ would introduce additional chain-rule terms; I do not impose that structural restriction in the empirical specification, consistent with the goal of estimating flexible reduced-form effects while using MA to discipline heterogeneity in the railway payoff.

6.2.5 Identification for endogenous placement: IV with least-cost paths (LCP)

A central threat to causal interpretation is endogenous railway placement: lines and associated investments may be built where growth potential was higher, where political influence was stronger, or where strategic and fiscal considerations favoured connection (Redding and Turner, 2015). These forces can induce correlation between rail exposure/accessibility and unobserved determinants of development. To address this, I use an instrumental-variables strategy based on least-cost paths (LCP) constructed from geography and engineering frictions, which provides plausibly exogenous variation in predicted railway integration driven by terrain rather than realised economic outcomes. Least-cost-path instruments are widely used in economic history and related empirical work on transport infrastructure (Esteban-Oliver, 2023; Faber, 2014; Fenske et al., 2023).

The LCP approach constructs a predicted network (or predicted connection costs) using a raster cost surface (e.g. slope, rivers, terrain ruggedness) and standard shortest-path routines (e.g. Dijkstra-type methods) to connect Montevideo to relevant nodes. The resulting predicted exposure measure $Z_{i,t}^{\text{LCP}}$ captures the feasibility and timing of railway integration through exogenous cost components. Intuitively, $Z_{i,t}^{\text{LCP}}$ should be relevant for observed rail exposure and/or accessibility, while being orthogonal to unobserved local growth shocks once fixed effects and controls are included.

This intuition stems from the seemingly pure mechanism of picturing an engineer who would decide which route is faster and less costly (as calculated by the Dijkstra algorithm) to reach point B from point A, disregarding factors that are not natural (e.g., rivers or slopes). This creates a different network by ignoring, for example, that to go from Montevideo to Artigas one must first pass through other cities, and that lobbying by powerful departments should not matter in this. A decision was made with this instrument: the network has to start, as historically, in Montevideo and move outwards, following speed capital, calculated as British railway investment in Uruguay from 1871 to 1913, from Stone (1999). This last decision also has the important implication that the hypothetical network did not reach the departments' capitals (i.e., the end points) at the same time it actually did, potentially cleaning up that endogeneity.

As aforementioned, $RII_{i,t}$ is constructed via TOPSIS using both time-varying infrastructure components and a time-invariant hub-centrality component (geodesic proximity to Montevideo). In panel specifications with department fixed effects μ_i, the level effect of any time-invariant component is absorbed by μ_i. Accordingly, the IV strategy identifies the effect of the component of $\ln(RII_{i,t})$ that is shifted by $Z_{i,t}^{\text{LCP}}$, i.e. variation in rail exposure driven by predicted network feasibility/timing rather than by persistent cross-sectional geography.

Two-stage least squares (2SLS).

A representative implementation instruments $\ln(RII_{i,t})$ using $Z_{i,t}^{\text{LCP}}$:

$$\ln(RII_{i,t}) = \pi_1 Z_{i,t}^{\text{LCP}} + X_{i,t}'\pi + \mu_i + \lambda_t + u_{i,t}, \tag{41}$$

$$\ln\big(\text{GDPpc}_{i,t+h}\big) = \beta_1 \ln(\widehat{RII_{i,t}}) + \beta_2 \ln(MA_{i,t}) + \beta_3 \Big[\ln(\widehat{RII_{i,t}}) \times \ln(MA_{i,t})\Big] + X_{i,t}'\gamma + \mu_i + \lambda_t + \varepsilon_{i,t}. \tag{42}$$

Inference uses cluster-robust standard errors at the department level. The 2SLS estimates identify the effect of the component of rail exposure shifted by the LCP instrument under standard relevance and exclusion assumptions.

Because the interaction includes an endogenous component, a standard approach is to instrument both $\ln(RII_{i,t})$ and $\ln(RII_{i,t}) \times \ln(MA_{i,t})$. If $\ln(MA_{i,t})$ is treated as exogenous (or predetermined) in the second stage, valid instruments include $Z_{i,t}^{\text{LCP}}$ and $Z_{i,t}^{\text{LCP}} \times \ln(MA_{i,t})$:

$$\ln(RII_{i,t}) = \pi_1 Z_{i,t}^{\text{LCP}} + \dots, \qquad \ln(RII_{i,t}) \times \ln(MA_{i,t}) = \tilde{\pi}_1 \Big[Z_{i,t}^{\text{LCP}} \times \ln(MA_{i,t}) \Big] + \dots, \tag{43}$$

so that β_3 is identified from exogenous shifts in rail exposure interacted with observed accessibility.

The identifying assumption is that $Z_{i,t}^{\text{LCP}}$ affects regional outcomes only through its effect on rail exposure and the induced changes in generalised travel times (and hence market access), conditional on controls and fixed effects. The political-economy channel enters as a threat to this assumption in the *observed* network: lobbying, strategic priorities, and fiscal capacity may correlate with both railway placement and local development. The LCP construction mitigates this by basing predicted integration on engineering/geography rather than realised political and economic decisions; remaining concerns are addressed by the fixed-effects structure and rich controls (Faber, 2014; Redding and Turner, 2015).

6.2.6 Estimands and reporting

Across approaches, the primary object reported is the marginal effect of railway exposure on economic performance:

$$\frac{\partial \ln y_{i,t}}{\partial \ln RII_{i,t}} = \beta_1 + \beta_3 \ln(MA_{i,t}), \tag{44}$$

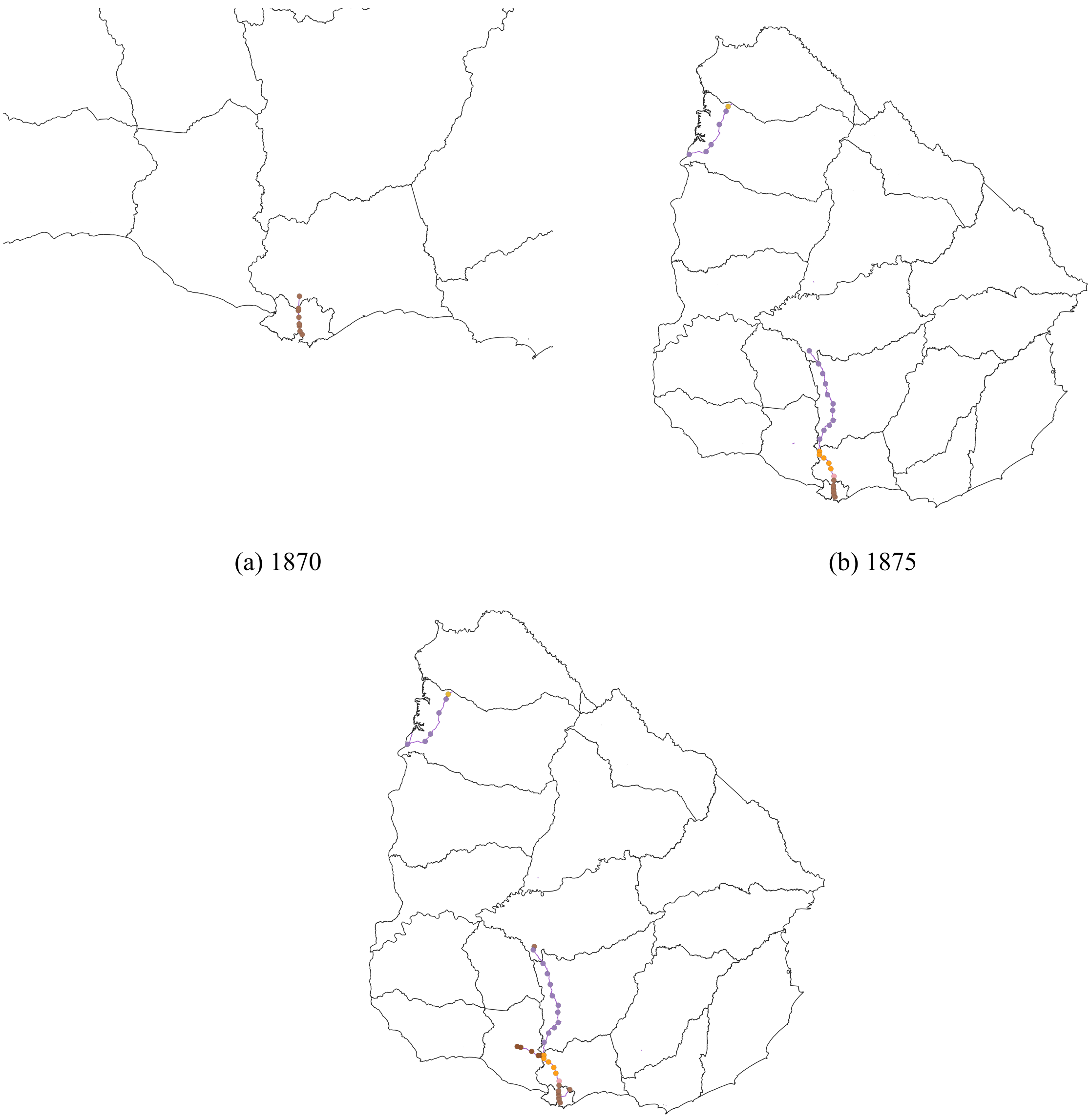
evaluated either at department-specific $\ln(MA_{i,t})$ or at a reference value (e.g. the national mean in year t), depending on the aggregation reported. In the spatial model, reported effects are mapped through the spatial multiplier and decomposed into direct/indirect/total components; in IV, the estimand corresponds to the LCP-shifted component of $\ln(RII_{i,t})$. Where relevant, Monte Carlo or posterior draws of (β_1, β_3) are propagated through (44) to obtain uncertainty intervals that match the reporting convention in the Results section (e.g. 90% intervals).

7 Results

This section reports summary statistics and the main empirical results for the two research questions. Following the empirical strategy, I evaluate railway impacts using two complementary outcome definitions. First, I study departmental GDP per capita in levels, which speaks directly to whether railway expansion was associated with higher local economic performance. Second, I study departmental GDP per capita *relative* to Montevideo, which targets the convergence (regional inequality) hypothesis in a strongly monocentric setting.

Before presenting the econometric results, I summarise the evolution of the railway network using georeferenced reconstructions based on Statistical Yearbooks and company/state annual reports. It was noted that the current configuration of the country, with 19 departments, was not in place until 1885; however, for simplicity and given the short time frame, the first three images will use the actual administrative borders. Another clarification is that the dots on the maps represent the stations, and the different colors correspond to the years the stations were built and, therefore, the corresponding section was built. For interpretative clarity, I group network development into five stages: (I) an early phase of liberal concessions and uneven build-out (1869–1884); (II) the first construction boom (1885–1891); (III) a slowdown following the Baring crisis (1892–1901); (IV) a second, smaller private-led boom

(1902–1914); and (V) predominantly state-led expansion (1915–1938). The maps below illustrate these stages in five-year snapshots.

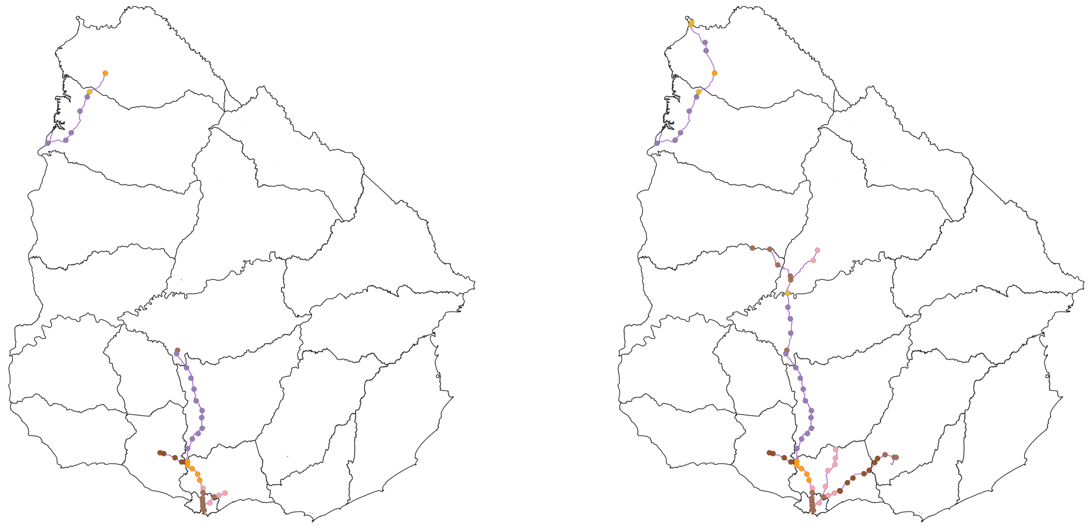


(a) 1870 (b) 1875

(c) 1880

Figure 4: Railway network evolution during Stage I (liberal concessions, 1869–1884).
Source: Own calculations based on Annual Yearbooks and Annual Reports from companies.

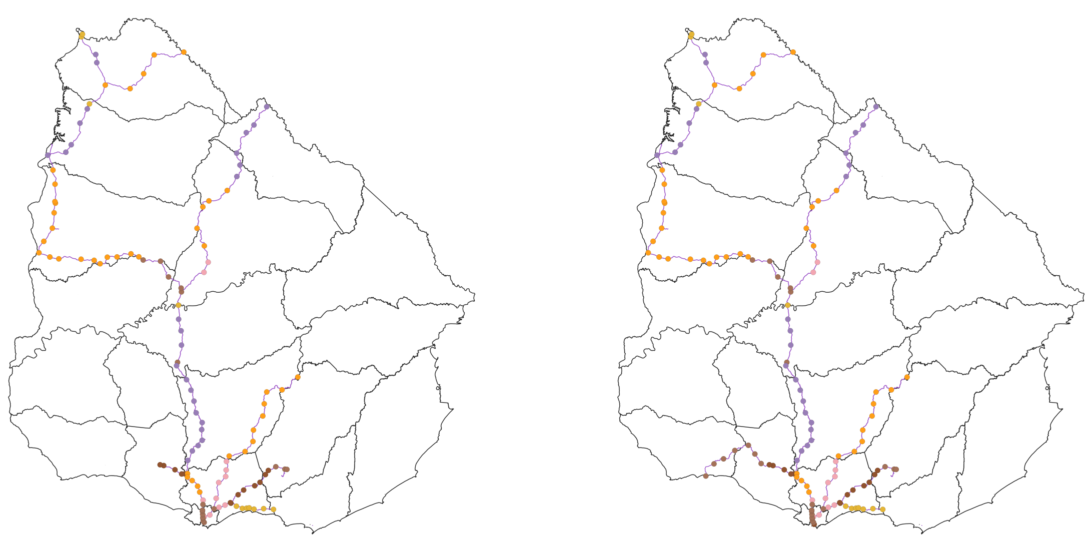
Stage I illustrates the limits of the early concession regime. Although concessions were granted broadly, the resulting build-out was uneven and progressed slowly. Although this is not known, as no reference to this was found, it is possible that the first locomotives for the Northern section arrived directly by maritime transport to Salto, as it was not possible to transport any materials from the south. Fifteen years after the first sections opened, the network remained relatively small and fragmented, indicating that many proposed projects were delayed or never executed.



(a) 1885 (b) 1890

Figure 5: Railway network evolution during Stage II (first boom, 1885–1891).
Source: Own calculations based on Annual Yearbooks and Annual Reports from companies.

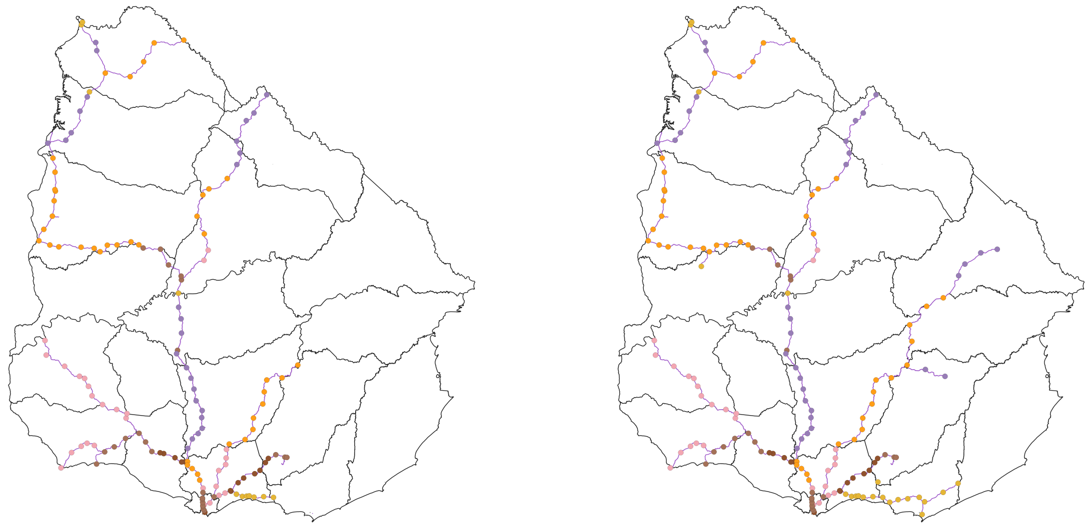
Stage II marks a clear acceleration and a more coherent spatial pattern, consistent with the tighter policy framework introduced by the Railway Laws. By 1890, the bridge over the Río Negro made a continuous north–south rail connection feasible, a key milestone for national integration. Construction peaked around 1891; for consistency with the five-year snapshots, the corresponding changes are shown in the next map set.



(a) 1895 (b) 1900

Figure 6: Railway network evolution during Stage III (slowdown, 1892–1901).
Source: Own calculations based on Annual Yearbooks and Annual Reports from companies.

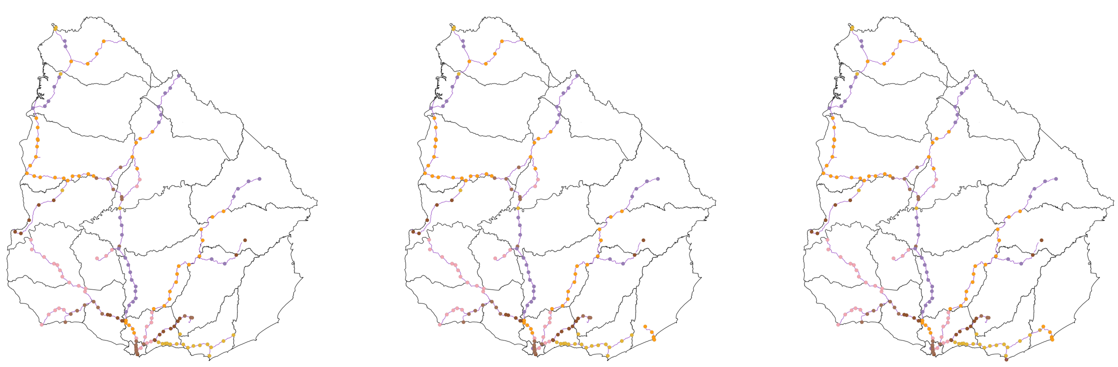
Stage III reflects the post-crisis slowdown. Much of the remaining private build-out was completed around 1891–1892, including the consolidation of the north–south spine and the extension toward Rivera. Thereafter, new construction was limited (notably the lines toward Maldonado and Colonia), consistent with tighter financing conditions following the Baring crisis.



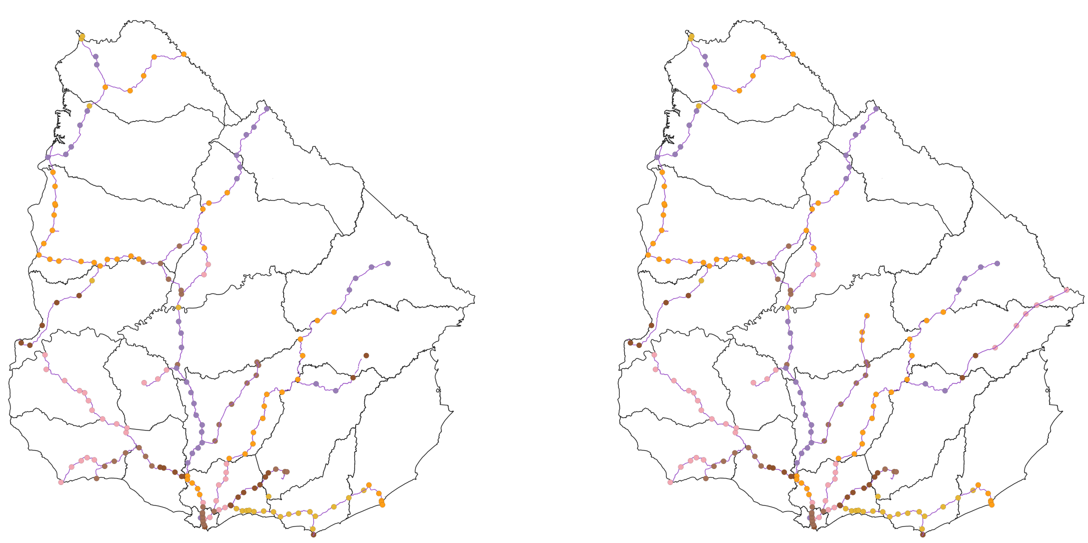
(a) 1905 (b) 1910

Figure 7: Railway network evolution during Stage IV (second boom, 1902–1914).
Source: Own calculations based on Annual Yearbooks and Annual Reports from companies.

Stage IV corresponds to a second, smaller private-led boom. By this point the network approached its final configuration: most departmental capitals were connected, and the remaining gaps were concentrated in Rocha and Treinta y Tres. By the end of the period, Treinta y Tres was largely reached, while Rocha remained outside the connected system until its later connection (1928).



(a) 1915 (b) 1920 (c) 1930



(d) 1935 (e) 1940

Figure 8: Railway network evolution during Stage V (state-led construction, 1915–1938; includes a 1940 map as post-stage reference).
Source: Own calculations based on Annual Yearbooks and Annual Reports from companies.

Stage V is characterised by predominantly state-led expansion. The network reached full coverage of departmental capitals once Rocha was connected in 1928; subsequent extensions mainly served additional settlements rather than new capitals. The 1940 map (included as a post-stage reference) shows the network after the last major construction in 1938. This is essentially the system the state acquired in 1948 with the purchase of the British companies, later unified institutionally with the creation of A.F.E. in 1952.

Table 1: Summary statistics by group (department-period averages)

	Unit	Montevideo	Canelones	Other departments
Panel A. 1870–1952				
Railway Infrastructure Index	[0, 1] *index (worst–best)*	0.422	0.193	0.122 (0.109)
Market access (billions)	*2005 UYU*	42.63	80.80	10.27 (7.33)
GDP per capita	*2005 UYU*	65,789	29,576	30,786 (8,301)
Population (thousands)	*Thousands of people*	439.7	108.2	40.6 (11.5)
Education	$\frac{\textit{Dept. school enrollment}}{\textit{National avg.}}$	1.683	0.887	0.967 (0.160)
Soil quality	*CONEAT index*	115.49	112.50	91.40 (23.12)
Rainfall	mm/year	988.6	966.0	1,122.4 (126.3)
Road infrastructure	*Roads per* km^2	0.074	0.050	0.006 (0.006)
Telephone coverage	$\frac{\textit{Telephone lines}}{\textit{Population}}$	0.0295	0.0017	0.0081 (0.0064)
Mechanisation	$\frac{\textit{Dept. machinery value}}{\textit{National avg.}}$	2.606	1.514	0.851 (0.881)
Sanitary conditions	$\frac{\textit{Dept. child mortality}}{\textit{Dept. total mortality}}$	0.105	0.078	0.099 (0.015)
Public banking participation	*Share of banks in dept.*	0.3602	0.0726	0.0334 (0.0118)
Panel B. 1870–1914				
Railway Infrastructure Index	[0, 1] *index (worst–best)*	0.392	0.159	0.096 (0.103)
Market access (billions)	*2005 UYU*	19.94	37.57	3.86 (3.59)
GDP per capita	*2005 UYU*	63,565	26,630	26,503 (8,492)
Population (thousands)	*Thousands of people*	218.2	64.6	27.8 (8.7)
Education	$\frac{\textit{Dept. school enrollment}}{\textit{National avg.}}$	2.009	0.982	0.942 (0.250)
Soil quality	*CONEAT index*	115.49	112.50	91.40 (23.12)
Rainfall	mm/year	925.8	873.2	1,100.3 (177.7)
Road infrastructure	*Roads per* km^2	0.072	0.045	0.002 (0.005)
Telephone coverage	$\frac{\textit{Telephone lines}}{\textit{Population}}$	0.0226	0.0000	0.0059 (0.0052)
Mechanisation	$\frac{\textit{Dept. machinery value}}{\textit{National avg.}}$	3.592	1.630	0.801 (1.171)
Sanitary conditions	$\frac{\textit{Dept. child mortality}}{\textit{Dept. total mortality}}$	0.113	0.091	0.105 (0.017)
Public banking participation	*Share of banks in dept.*	0.3637	0.0630	0.0337 (0.0109)
Panel C. 1915–1952				
Railway Infrastructure Index	[0, 1] *index (worst–best)*	0.458	0.234	0.153 (0.123)
Market access (billions)	*2005 UYU*	69.49	131.99	17.88 (11.90)
GDP per capita	*2005 UYU*	68,422	33,064	35,858 (9,106)
Population (thousands)	*Thousands of people*	701.9	159.8	55.9 (15.3)
Education	$\frac{\textit{Dept. school enrollment}}{\textit{National avg.}}$	1.297	0.774	0.996 (0.121)
Soil quality	*CONEAT index*	115.49	112.50	91.40 (23.12)
Rainfall	mm/year	1,062.9	1,076.0	1,148.5 (83.4)
Road infrastructure	*Roads per* km^2	0.076	0.055	0.011 (0.008)
Telephone coverage	$\frac{\textit{Telephone lines}}{\textit{Population}}$	0.0376	0.0036	0.0107 (0.0081)
Mechanisation	$\frac{\textit{Dept. machinery value}}{\textit{National avg.}}$	1.439	1.377	0.910 (0.629)
Sanitary conditions	$\frac{\textit{Dept. child mortality}}{\textit{Dept. total mortality}}$	0.095	0.063	0.092 (0.018)
Public banking participation	*Share of banks in dept.*	0.3561	0.0840	0.0329 (0.0149)

Notes: Entries are means of department-level period averages. For "Other departments", standard deviations across departments are in parentheses; Montevideo and Canelones are singletons.

Consistent with the historical and regional-development literature on Uruguay, the database highlights the country's pronounced spatial asymmetry. Montevideo stands out as an outlier in levels of GDP per capita and in several development-related covariates, reflecting the long-run primacy of the capital in economic and political activity. Canelones, while far below Montevideo in income levels, is distinctive in terms of accessibility: its proximity to the capital and central position within the transport network translate into substantially higher market-access values than those of most other departments. This combination, high accessibility but weaker performance in several development indicators, helps motivate treating Canelones as a special case in the construction and interpretation of railway-exposure measures, and it reinforces the importance of separating "hub proximity" from broader local development capacity when assessing railway impacts.

Given the limited number of observations available for the historical period under study, statistical power is an important concern throughout. Although it is possible to report department-specific estimates, I first emphasise results aggregated at the national level to provide a clearer overall picture of whether, on average, railway infrastructure had a positive effect. I then disaggregate the analysis by department to assess the extent to which effects were heterogeneous across space.

Table 2: National (global) marginal *total* effect of railway infrastructure on y (90% intervals)

Scenario	Method	Effect in 1870	Effect in 1952	Sig.+	Sig.-
Level y; MA	HSDM	0.078	0.025	46%	0%
	IV	0.004	0.148	64%	0%
Rel. y to MVD; MA	HSDM	0.051	-0.019	29%	0%
	IV	-0.012	-0.008	0%	0%
Rel. y to MVD; MA to MVD	HSDM	0.072	-0.032	28%	0%
	IV	-0.010	0.171	63%	0%

Notes: The effect is the global (department-average) *total* marginal effect $\partial \ln y / \partial \ln \text{RII}$. With interaction, $\partial \ln y / \partial \ln \text{RII} = \text{Total}(\ln\text{RII}) + \text{Total}(\ln\text{RII} \times \ln \text{MA}) \cdot \ln \text{MA}$. For each year, $\ln \text{MA}$ is the corresponding national mean in that year (under the scenario's MA definition). For scenarios where y is relative to Montevideo, the global average excludes Montevideo. HSDM intervals are posterior percentiles. IV (pooled FE) intervals come from Monte Carlo draws of $(\hat{\beta}_{\ln\text{RII}}, \hat{\beta}_{\text{INT}}) \sim \mathcal{N}(\hat{\beta}, \widehat{\text{Var}}(\hat{\beta}))$ mapped into the marginal effect. IVW is an inverse-variance weighted mean of department-level IV marginal effects. **Sig.+** (**Sig.-**) is the share of years with a result statistically different from zero.

Table 2 can be read through the lens of the two mechanisms in the conceptual block. For productive development in levels, a broadly positive marginal effect is consistent with the idea that railways reduced generalised trade costs and improved demand-weighted accessibility, thereby raising real income and/or local production in the average department. For catch-up relative to Montevideo, the relevant mechanism is not simply "more access is good," but whether connectivity shifts the spatial distribution of activity in a way that raises departments' performance *relative* to the hub. In particular, convergence can occur if railways (i) lower peripheral trade costs enough to support local production, (ii) erode hub-specific intermediation rents, or (iii) relax isolation constraints that limit factor accumulation outside the capital. Conversely, convergence may fail (or reverse) if lower trade costs primarily strengthen hub-serving firms, induce migration toward the hub, or intensify competition that displaces marginal local activity. Therefore, weaker or episodic relative effects do not contradict a positive level effect; rather, they are consistent with the reallocation logic embedded in core–periphery environments.

At the aggregate level, railway infrastructure appears to have had a positive impact, with time period depending on the outcome and estimation strategy (Table 2). As a matter of fact, the positive results are identified in different non-overlapping periods for each estimation method, indicating that the railways exhibited a dynamic that remained stable across the whole period, even as it decayed. For *levels* of GDP per capita, both approaches deliver a mild-to-positive marginal effect over the long run. This pattern is consistent with the market-access and real-income channels emphasised in the conceptual block: departments that become better connected face lower generalised transport frictions and gain access to larger demand, which can translate into higher local performance even if the magnitude varies across time and space.

For *catch-up relative to Montevideo*, the evidence is weaker but focused on a specific time period, from its inception to 1887. This is a particular moment in the history of Uruguayan railways, as the network was concentrated mostly in the south and had a short branch in the north, from Salto to Artigas. The convergence stopped as soon as both sides of the country were connected in 1887, and even if, unlike other countries, the network did not appear to create divergence, it can be assumed that the north did not leverage the railways for reducing inequality; this seems to have been a specific phenomenon in the south in a particular period. The HSDM estimates suggest convergence in a specific historical phase, whereas the 2SLS-based evidence is closer to zero on average. Mechanistically, this divergence across outcomes is expected: relative performance depends not only on whether a department benefits from lower trade costs, but also on whether connectivity induces reallocation that favors the periphery relative to the hub (e.g., through local production expansion or reduced hub rents) or instead strengthens Montevideo's relative position (e.g., through agglomeration, migration, or hub-dominant firm expansion). The relative outcome therefore provides a disciplined, but inherently demanding, test of the inequality hypothesis: it identifies periods in which the spatial-equilibrium adjustment to connectivity is consistent with catch-up rather than simply improved integration in levels.

Table 3: Department-level evolution of the marginal railway effect (HSDM vs. IV)

	HSDM Model			**2SLS Model (by department)**		
Department	1870	1952	Transition	1870	1952	Transition
Scenario 1: $GDPpc_{t+5}, MA$						
Artigas	0.020	0.189*	Pos. after 1878	0.378	2.136	Insig. after 1937
Canelones	0.034	0.353	Insignificant	0.387	1.438	Insignificant
Cerro Largo	0.020	-0.148*	Neg. after 1909	0.029	0.127	Insignificant
Colonia	0.218*	-0.045	Insig. after 1899	-0.123*	0.615*	Flip in 1901
Durazno	-0.291*	0.995*	Flip in 1874	0.117*	0.342	Insig. after 1873
Flores	0.067	-0.219*	Neg. after 1885	0.311	-0.109	Insignificant
Florida	-0.029	-0.696*	Neg. After 1872	0.047	0.624*	Pos. after 1871
Lavalleja	0.520*	-0.936*	Flip in 1889	-0.864*	0.850*	Flip in 1937
Maldonado	0.098	0.396	Pos. 1910-1924	-0.003	0.090	Insignificant
Montevideo	0.520*	0.780*	Always Positive	-0.891*	-2.907*	Always Neg.
Paysandú	-0.108*	-0.066	Insig. after 1894	-0.424	4.285	Insignificant
Río Negro	-0.066	0.157	Insignificant	-0.005	0.140	Insignificant
Rivera	0.139*	-0.487*	Flip in 1892	0.380*	0.026	Insig. after 1891
Rocha	0.146*	-0.097	Insig. after 1909	0.430	0.086	Pos. 1910-1928
Salto	0.005	0.007	Insignificant	-0.054	1.008	Insignificant
San José	0.085*	0.169	Insig. after 1875	-0.185*	0.038	Insig. after 1880
Soriano	0.017	0.140*	Pos. after 1901	-0.309*	0.528*	Flip in 1901
Tacuarembó	0.006	-0.041	Insignificant	0.608	-5.134*	Neg. after 1888
Treinta y Tres	0.082	0.058	Pos. 1883-1909	-0.154*	0.282*	Flip in 1922
Scenario 2: $GDPpc_{t+5}/MVD, MA$						
Artigas	0.001	0.203*	Pos. after 1883	-0.104	1.169	Pos. after 1893
Canelones	0.047	0.318	Insignificant	0.261	3.172	Insignificant
Cerro Largo	0.020	-0.147*	Neg. after 1909	0.021	0.020	Insignificant
Colonia	0.222*	-0.052	Insig. after 1898	0.012	0.391	Insignificant
Durazno	-0.282*	0.944*	Flip in 1874	0.073	-0.830*	Neg. after 1946
Flores	0.037	-0.194*	Neg. after 1885	0.317	-0.141	Insignificant
Florida	-0.037	-0.667*	Neg. after 1872	-0.009	0.096	Insignificant
Lavalleja	0.588*	-1.053*	Flip in 1888	-1.158*	0.663	Insig. after 1881
Maldonado	0.054	0.441*	Pos. after 1910	0.049	0.007	Insignificant
Paysandú	-0.113*	-0.090	Insig. after 1900	-0.307	3.328	Insignificant

	HSDM Model			2SLS Model		
Department	1870	1952	Transition	1870	1952	Transition
Río Negro	-0.075	0.155	Insignificant	-0.020	-0.001	Insignificant
Rivera	0.135*	-0.477*	Flip in 1892	0.032	-0.078	Insignificant
Rocha	0.128*	-0.087	Insig. after 1909	1.264	-0.428	Insignificant
Salto	0.003	0.010	Insignificant	-0.082	1.510	Insignificant
San José	0.101*	0.200	Insig. after 1875	-0.079*	-0.019	Insig. after 1884
Soriano	0.012	0.143*	Pos. after 1901	-0.119	0.232	Insignificant
Tacuarembó	0.005	-0.041	Insignificant	0.065	-1.545*	Neg. after 1883
Treinta y Tres	0.078	0.051	Pos. 1885-1909	-0.055	-0.028	Insignificant

Notes: Effects are marginal effects of ln(RII) on $\ln(y)$. Significance (*) denotes the 90% credible interval excluding zero (HSDM) or two-sided 10% significance (2SLS). Transition describes the year the marginal effect became statistically significant or changed sign.

Table 3 reports department-level marginal effects under two outcome definitions, which map directly into the two research questions. The upper block (GDPpc$t+5$) speaks to productive development in levels, while the lower block (GDPpc$t+5$/MVD) speaks to catch-up relative to Montevideo. In both cases, the model-based interpretation follows the same logic, railways matter insofar as they reduce generalised travel times and thereby (i) lower trade-cost burdens and (ii) increase effective access to economically large markets. Heterogeneity is therefore expected, because identical rail exposure can translate into very different accessibility gains depending on a department's position in the network and its proximity to large demand nodes.

In levels, the dominant mechanism is most likely the access-to-demand, or market-access, channel, departments benefit when rail investment meaningfully reduces travel times to large markets, raising profitability and supporting local production and wages. Positive effects are therefore consistent with departments that either become better connected to major domestic demand centers or occupy advantageous positions within the national network. Negative effects, by contrast, are consistent with two non-mutually-exclusive mechanisms. First, some departments may function primarily as *corridors* rather than beneficiaries of local agglomeration, connectivity passes through them, but activity relocates toward other destinations, which is the corridor, bypass, or alleyway mechanism. Second, integration can intensify competition from better positioned producers elsewhere, reducing local value added in departments that do not develop a strong comparative advantage after integration. The fact that HSDM and department-by-department 2SLS sometimes differ in sign or magnitude is not unexpected. HSDM reports *total* effects, including spillovers and feedback through the spatial multiplier, whereas 2SLS emphasises variation in rail exposure shifted by the LCP instrument and is closer to a local causal response. When the spatial system reallocates activity across space, these two perspectives need not coincide.

For the relative outcome, the same connectivity improvement can generate ambiguous effects because the estimand is inherently comparative, a department catches up only if it gains *more* than Montevideo, not merely if it gains in levels. Convergence can arise if railways erode hub rents or reduce the capital's relative advantage in intermediation, allowing peripheral departments to grow faster, but divergence can arise if falling trade costs strengthen the hub or induce relocation toward already dominant nodes. Accordingly, weaker or mixed relative effects are consistent with general-equilibrium reallocation, railways may raise GDP per capita in many departments while also raising, or protecting, Montevideo's relative position, or they may raise output in Montevideo while population inflows dampen GDP per capita. This is why relative effects are expected to be less uniform over time and across space than level effects, and why identifying winners and losers is central for evaluating the inequality hypothesis.

When turning to the effect of railways on department-level GDP per capita at $t + 5$, the conclusions are substantially clearer. Both methods indicate a positive, economically meaningful impact of railway infrastructure at different points in time. This allows me to answer the first part of the research question; the evidence supports the conclusion that railway expansion had a strong, positive impact on economic performance, as measured by departmental GDP per capita.

To address the second part of the research question, whether the effects were heterogeneous across departments, I then examine the department-level estimates. A key caveat is again statistical power; in some departments, the absence of statistical significance may reflect large standard errors rather than a true absence of an effect. With that caveat in mind, the patterns nonetheless reveal meaningful heterogeneity across space.

Heterogeneity across departments is a direct prediction of the mechanism. The same increase in $RII_{i,t}$ need not translate into the same drop in effective travel times or the same increase in demand-weighted accessibility, departments differ in initial remoteness, in whether the network makes them *terminals* or *corridors*, in how strongly connectivity reduces costs, especially to large markets, and in their exposure to competitive pressure from the hub and other connected regions. In the conceptual block, these differences map into variation in the marginal payoff to connectivity through the interaction logic, rail exposure matters most when it meaningfully increases access to economically large destinations, and it can matter less, or even negatively in net terms, when connectivity mainly routes flows through the department or intensifies competition without generating local production gains.

The two approaches address different endogeneity concerns. HSDM is designed to account for spatial dependence and spatial endogeneity, capturing direct effects as well as spillovers and feedback through the spatial multiplier, whereas the 2SLS strategy primarily targets endogeneity arising from omitted variables correlated with railway infrastructure. Since both spatial and non-spatial endogeneity are plausible in this setting, the results should be interpreted as complementary rather than strictly comparable.

Because department-level effects are more method-dependent, I begin with the specification that explicitly accounts for spatial endogeneity, the HSDM, where the winner-loser patterns and the border or border-commerce interpretation emerge most clearly (Table 3). The HSDM dynamics are particularly interesting. In the early stages of the network, many departments display an initially positive railway effect on economic activity. At that stage, the pattern appears relatively widespread, and neither the positive nor the negative cases show a clear geographical regularity. However, as the network became denser, the pattern changed. Some departments appear to have suffered from either a relocation of economic activity or a negative agglomeration effect, while others were able to sustain initial gains or benefited precisely as the network expanded.

Among the departments that appear to have benefited, Montevideo is the clearest case of a department that remained on the *right track*. Maldonado, San José, and Colonia are also examples of southern departments that display positive effects at some point in time, plausibly through neighboring spillovers, improved connectivity to larger markets, positive relocation of economic activities, or some form of von Thünen dynamic as explained by Travieso (2017) associated with proximity to Montevideo. Soriano is another southern department with a positive effect, visible as soon as the network reached the department, possibly due to improved access to larger markets, the characteristics of the branch structure, or the same von Thünen-type mechanism.

Durazno and Artigas are particularly interesting, but for different reasons. Durazno, a southern department located on the main branch, initially displays a negative effect, but once the branch reached the department the effect turned positive and remained so until the end of the period. It is the only department on that main corridor, excluding Montevideo, that appears to have clearly leveraged railway connectivity. One possibility is that its initial conditions or institutional setting differentiated it from nearby counterparts such as Florida. Artigas is also worth emphasising. It is not only the only department outside the south to display a positive effect,[16] but it is also a border department and part of the first branch constructed not to connect to Montevideo, but to Brazil. This suggests internal dynamics that merit future research. Its distance from Montevideo may not only have protected it from the suction effects of the hub, but may also have given it an advantage over other northern departments in trade with Brazil.

On the other side are the departments that, as the network became denser, appear to have been negatively affected by railway expansion, either because connectivity exposed them to stronger competition from larger markets or because local conditions prevented them from capturing the gains from integration. As discussed above, the mechanisms may include economic reallocation or the inability, due to institutional or initial conditions, to translate railway access into local growth.

Lavalleja is a particularly clear case. It began on a favorable path, most likely due to spillover effects, but as soon as the network reached the department the effect turned negative. This is consistent with what I call an *alleyway effect*, in which a department forms part of a corridor to the main port without capturing much of the associated wealth. This may have been reinforced by Montevideo's role as an *entrepôt*, drawing activity through intermediary departments between the border and the capital without leaving commensurate local gains.

Flores and Florida are also central for understanding that, even if railways seem to have favored the south in general, not every department in the region benefited. Flores may have been affected by a late connection to the network, implemented by the state-led company, and linked only to the main branch. Although it was not itself on the main branch, this connection may have absorbed potential gains rather than generating them locally. Florida, by contrast, lies on the southern side of the main branch and may have been another case of the *alleyway effect*. Alternatively, the network may simply

[16]Not considering Treinta y Tres, where the effect turns not significantly different from zero when the department is connected to the network in 1909.

have been overextended there, in the sense that investment outpaced the department's ability to absorb it into profitable activity.

Cerro Largo and Rivera also require separate discussion, because although both are border departments, they may have been affected through different mechanisms. Cerro Largo had two branches within the department, but the branch linking it to Brazil was built late, with the international connection completed only in 1939. Since the department shows negative effects well before that, the likely driver was the earlier branch reaching Melo, the departmental capital. This is consistent with the idea that Montevideo may have functioned as a suction pump for the eastern side of the country, especially when considered alongside the case of Lavalleja. Rivera is less straightforward. It may have been affected by a mechanism similar to Lavalleja's, given that it lies on the main branch connecting to Brazil. Alternatively, the southern portion of that main corridor may have functioned as a suction pump for its northern counterpart, either by drawing activity toward the south or by using the northern departments primarily as transit space. In this sense, the contrast between Artigas and Rivera is itself a promising future research question, since the two departments appear similar on paper but display very different outcomes.

The 2SLS results yield a different spatial pattern. By the end of the period, positive impacts appear in Colonia, Florida, Lavalleja, Rocha, Soriano, and Treinta y Tres, while negative impacts appear in Montevideo and Tacuarembó. Interpreted through a framework that corrects for endogeneity in railway placement, the clearest regularity is that most positive effects are concentrated in the south of the country. Indeed, all of the departments with positive effects lie south of the Río Negro and, more specifically, half of them can be considered part of the south proper, Colonia, Florida, and Soriano. This is broadly consistent with the HSDM evidence, where the south also appears as a relatively favored region, and it points to the possibility that initial conditions, including institutional settings and local absorptive capacity, mattered for taking advantage of railway connectivity. This southward concentration is also coherent with a market-integration interpretation, since the network was densest in the south, where integration was plausibly strongest. Artigas also displays a positive effect through most of the period, which again suggests that connection to Brazil, together with partial insulation from the suction dynamics of the main corridor, may have mattered.

At the same time, there are important exceptions and nuances within this southern regularity. Lavalleja, Rocha, and Treinta y Tres can all be associated with the southeast and are relatively closer to Brazil, which makes the border dimension a plausible part of the explanation. Another noteworthy feature of the 2SLS pattern is that many positive effects lie outside the Montevideo–Rivera main branch, suggesting that peripheral branches and southern connectivity may have been particularly relevant for local development. Relatedly, Lavalleja and Treinta y Tres lie on the same branch, and in this specification that branch appears to have benefited the departments along its path.

Lavalleja is especially interesting in comparative terms. Under HSDM, it is a candidate for a clear loser, consistent with the *alleyway effect*. Under 2SLS, however, it appears able to capture positive railway effects. This contrast suggests that the department may have had characteristics that allowed it to benefit under one identification strategy but not the other. Possible explanations include the composition of what was traded, local productive conditions, institutional differences, or branch-specific features. In this sense, the local economic conditions of Lavalleja, and possibly of neighboring departments on the same branch, may have interacted with the branch's connection to Brazil in ways that deserve closer study.

On the negative side, the 2SLS results leave only Montevideo and Tacuarembó as losers by the end of the period. The negative effect for Tacuarembó is consistent with the *alleyway effect* described above, investment and traffic may pass through the department without generating proportional local gains. Montevideo, however, is a much more puzzling case. As the network hub, a negative effect is counterintuitive, especially since Montevideo's effect is positive under HSDM. I do not attempt to resolve this puzzle here, but several plausible mechanisms motivate future research. First, by sharply lowering transport costs, railways may have facilitated the relocation of economic activity away from the hub, reallocating production, and perhaps some forms of commerce, toward other departments. Second, greater connectivity may have accelerated population growth in Montevideo faster than output growth, reducing GDP per capita even if total output increased. Third, if Montevideo's comparative advantage increasingly lay in services and intermediation, rail-based integration may have reduced monopoly-like intermediation rents previously concentrated in the capital, depressing local value added relative to a counterfactual without rail expansion.

Taken together, the comparison across methods suggests that southern departments were frequently among the beneficiaries of railway expansion, while some departments were harmed. Under one approach, the negatively affected departments are either border departments or departments located on the eastern side of the country. Under the other, Montevideo emerges as a potential loser, although this depends on how spatial endogeneity is treated. A further point worth emphasising is that Rivera and Artigas are, in themselves, cases for deeper study, because their divergent trajectories appear to reflect not only past conditions but also the specific branch structures through which they were connected. This tension connects naturally to the New Economic Geography literature, where the spatial distribution of gains from transport infrastructure depends on initial conditions, market access, and the equilibrium reallocation of activity as trade costs fall. In this setting, it also underscores the importance of clarifying which endogeneity concern is most relevant for interpretation, and what effect is being estimated, local within-department responses or total spatial impacts including spillovers.

To avoid the interpretational complications introduced by Montevideo's level outcome, and to speak directly to the regional inequality hypothesis, I re-estimate the models using GDP per capita relative to Montevideo as the dependent variable, as specified in the empirical strategy. In this specification, the aggregate results are less clear-cut. The 2SLS estimates again suggest no detectable effect. By contrast, the HSDM results identify one specific period in which railway expansion appears to have facilitated convergence, an early phase from 1870 to 1887 (Table 2). This is precisely the phase in which a hub-and-spoke network can generate relative gains outside the capital. Early diffusion can sharply reduce peripheral isolation and may reallocate some activity away from Montevideo. However, once the network became larger and connected both sides of the country, railways do not appear to have harmed convergence, but neither do they appear to have systematically driven it. This is consistent with spatial reallocation forces, once trade costs become sufficiently low, activity can re-concentrate in the hub or in a subset of better-positioned regions, offsetting simple market-access gains in relative terms.

This convergence period corresponds to the initial diffusion of railways and the start of the subsequent boom, ending with the construction of the bridge that linked the north and the south. A coherent interpretation is that, in this early phase, improved access to the capital allowed other departments to erode part of Montevideo's rents and enabled some reallocation of activity, promoting convergence, at least in part of the country and especially in the south.

Department-level heterogeneity in the relative specification is again revealing (Table 3). Under 2SLS, the pattern is essentially one of no effects. Only Tacuarembó, Artigas, and Durazno (and for Durazno only in the final six years) show a measurable impact, and the signs are mixed. This is broadly consistent with the aggregate result. For this reason, in the inequality specification I focus on the facts that can be more confidently inferred from the spatial model. Under HSDM, by contrast, the results again show both winners and losers in terms of convergence relative to Montevideo. By the end of the period, four departments exhibit a convergence effect, Artigas, Durazno, Maldonado, and Soriano, while five show a divergence effect, Cerro Largo, Flores, Florida, Lavalleja, and Rivera. In this relative specification, positive and negative effects appear more geographically clustered than in the levels specification, although both richer and poorer departments appear in each group. Even so, some suggestive regularities remain.

On the positive side, the departments with convergence effects at the end of the period, Artigas, Durazno, Maldonado, and Soriano, tend either to be located in the south, Durazno, Maldonado, and Soriano, or to be border departments connected to Brazil through branches outside the main corridor, as in the case of Artigas. This again raises the possibility that both border connectivity and network layout mattered, particularly the advantage of not being directly embedded in the main corridor.

On the negative side, the departments with divergence effects, Cerro Largo, Flores, Florida, Lavalleja, and Rivera, also reflect the patterns discussed earlier. Lavalleja again appears to lag behind in a way consistent with the *alleyway effect*. Rivera also appears again as a losing department, suggesting that the main corridor may have had a suction-pump effect on the north. If one also considers the 2SLS evidence, this possibility may extend, at least partly, to Tacuarembó. Rivera, in this reading, loses not only in its contribution to economic activity but also in its ability to converge toward Montevideo.

Flores and Florida also emerge as losers under HSDM, although likely for different reasons. In Flores, the result may reflect both the nature of its connection to the main branch and the lateness of its incorporation into the network, which occurred only in 1915. Given the time needed for railway investments to mature, rail services in the 1920s may already have faced strong competition from other transport modes, which could have limited railway gains in a department where rail likely served not only freight collection but also civilian transport. Florida, by contrast, may have functioned as an *alleyway* within the south. More broadly, the main branch appears to have harmed many of the departments along its path. In the north, the pattern is especially clear. In the south, Montevideo and Durazno perform well, but Flores and Florida do not. Overall, this reinforces the conclusion that the distributional consequences of railway expansion were heterogeneous, and that the observed decline in inequality is consistent with a mechanism in which Montevideo converged downward toward the mean while some departments converged upward and others did not.

Across specifications, an additional takeaway that is relatively less method-dependent, because it does not rest on any single department, is that southern departments tend to display mild to positive railway marginal effects. This pattern appears in both GDP per capita levels and convergence relative to Montevideo. A plausible interpretation is that the railway network complemented distinct initial conditions in the south, including institutional settings and market conditions that allowed these departments to use railway access more productively. If a causal interpretation is warranted, and considering that several of these departments were not comparatively rich in 1870, the results are also consistent with the possibility that railways were one of the drivers of growth in this group.

A second, weaker pattern is that Artigas, a department connected to Brazil, also tends to show positive results in both economic activity and convergence toward Montevideo. Since it is the only border department that appears to have benefited from railways, this raises an important question for future research, whether stronger railway connectivity to Brazil, together with insulation from the main-corridor dynamics, could generate gains outside the south, and, if so, what specific conditions made that possible. It may be that the connection to Brazil, together with the disconnection from Montevideo until the 1890s, enabled autonomous development that favoured specific local dynamics, thereby allowing the railways to be leveraged. This possibility is up to future research, and it would be informative about how isolated regions in a developing country develop when they have the option to establish their own connections outside the country they are part of.

Relatedly, the main branch itself appears to have favored certain departments in the south more than those in the north. The evidence is consistent with the view that the northern section of the Montevideo–Rivera line was relatively drained by the railway, in the sense that it may have functioned more as a corridor through which activity was reallocated toward the south than as a local engine of growth. This contrast is particularly visible in Rivera and Tacuarembó, which tend to show negative railway effects, while southern departments linked to the same branch tend to range from neutral to positive, with Florida as the main exception. Among all branches, this is the clearest case of a sharp contrast in the effect of railway exposure.

Overall, the results support three main conclusions. First, with respect to the effect of railways on economic performance, the evidence is strong, railway expansion had a positive but heterogeneous impact on departmental productive development. Second, with respect to regional inequality, the evidence is more nuanced. The results are not uniformly strong across methods, but the HSDM estimates suggest that railways contributed, weakly but detectably, to convergence relative to Montevideo during a specific period, 1870–1887, that is, in the earliest phase of network formation. Third, there appears to have been an unintended consequence of railway expansion, what I call the *alleyway effect*, in which a department's role as a corridor through which connectivity passes does not translate into stronger local productive capacity or convergence toward Montevideo. This pattern is particularly visible, albeit not uniformly across methods, in departments such as Lavalleja and Tacuarembó.

Conversely, the south appears as a broad beneficiary of railway connectivity in terms of productive development, and the evidence also weakly suggests that southern departments were among the main beneficiaries in terms of convergence relative to Montevideo. While some southern departments diverged, most of the departments that converged are located there as well. Under this interpretation, railway expansion would be one of the mechanisms contributing to the broader decline in regional inequality, at least in the south and in the border department of Artigas, connected to Brazil, as documented by Rodríguez Miranda and Willebald (2024) and consistent with the patterns identified in this paper.

It is also worth noting an additional implication. While the first hypothesis is supported, the second is only weakly supported, especially if one considers the role of the State. As noted earlier, the State became increasingly important after the railway laws enacted between 1884 and 1889. However, the absence of general convergence after 1887 suggests that this greater State role did not translate into a sustained reduction in regional inequality through railways. This, too, opens an important avenue for future research.

Finally, Uruguayan railways appear to differ from much of the previous evidence in one relevant sense, they were not inequality-enhancing at any point in time. This can be considered a relatively positive feature of the network in comparative perspective. There were clear winners and losers, and these groups appear to have been spatially patterned, but the railway system cannot be straightforwardly characterised as an inequality-enhancing infrastructure in Uruguay. A key question for future research is why. One possibility is that the network eventually reached every department. Other possibilities include Uruguay's strongly monocentric urban structure, with few large urban agglomerations outside Montevideo, or the country's small territorial scale itself.

I follow by performing a robustness check considering a different definition of Market Access. Most empirical studies in this literature use market access (MA) to summarise how transport infrastructure changes access to demand. In Uruguay's strongly monocentric setting, however, not all bilateral connections are equally relevant: Montevideo is the dominant domestic market and the main gateway for international commerce. I therefore conduct a robustness check that replaces national MA with a Montevideo-only measure, constructed from travel time to Montevideo and weighted by Montevideo's economic mass.

Table 4 in Appendix C shows that redefining market access in a monocentric way leaves the main conclusions mostly unchanged, and if anything, it makes the southern pattern clearer, as Artigas only has a positive effect in a specific moment in time, and Flores outcome does not seem as negative as in the main specification. Across both scenarios, the department-level patterns are similar to the baseline results, with only minor differences in magnitudes and timing. This robustness supports interpreting the headline findings, a mild-to-positive average effect in levels and heterogeneous department-specific effects, as stable to the market-access definition.

8 Concluding Remarks

This thesis revisited the historical role of railway expansion in Uruguay from a regional perspective over the long run (1870–1952). While the Uruguayan railway has been studied through the lenses of profitability and social savings, much of the existing evidence emphasises earlier phases of the network and does not fully incorporate the identification challenges posed by endogenous placement and spatial interdependence across regions. Building on this literature, the contribution of this study is twofold. First, it constructs a novel department-year measure of railway exposure, the Railway Infrastructure Index ($RII_{i,t}$), together with a complementary accessibility proxy ($MA_{i,t}$). Second, it evaluates their relationship with regional performance using an empirical framework that explicitly accommodates both spatial spillovers and endogeneity (TWFE, spatial Durbin-type models with heterogeneous effects, and an IV strategy based on least-cost paths).

The main empirical results indicate that the average marginal effect of rail exposure is mild-to-positive for productive performance, and that the implied distributional consequences are heterogeneous. In levels, increases in $RII_{i,t}$, particularly when interacting with higher market access, are associated with higher department GDP per capita. In relative terms (GDP per capita relative to Montevideo), the evidence is consistent with the view that rail connectivity could help to contribute to regional catch-up, but not uniformly, or at least that local conditions helped to prevent the inequality-enhancing characteristic of railways. The department-specific estimates reveal substantial heterogeneity in both magnitude and sign, suggesting that railway expansion may have generated localised gains in some areas while shifting activity away from others. Episodes with statistically weak effects are also consistent with limited effective sample size and the inherent scarcity of benchmark information, which motivates caution when interpreting null results as evidence of no relationship.

A third takeaway is spatial. Although the department-specific estimates are not perfectly clustered, the results suggest a disproportionate concentration of positive effects in the south, both in levels and in convergence relative to Montevideo. In addition, one Brazil-facing connection also performs relatively well, pointing to the possibility that cross-border integration, as well as being protected from the main branch, which may have acted as a suction pump, constituted an additional margin through which railways translated into local gains. Taken together, these patterns imply that, once regional heterogeneity is taken into account, the relevant mechanisms may cluster in parts of the country with specific structural features, including early access, denser connectivity, and border-facing opportunities. At the same time, the evidence does not support the Herrera y Obes hypothesis in aggregate terms, since convergence appears only up to the period surrounding the railway laws debate (1870–1887). Nor does it support a regionalised interpretation in which the extension of railways into unprofitable areas is the main explanation for the reduction in inequality. Many of the locations that appear to benefit are southern departments that received rail access early, while several late or state-led connections do not stand out as engines of catch-up. An additional conclusion is that, unlike in many other national cases, railways in Uruguay did not increase inequality in general. Finally, the trunk Montevideo–Rivera corridor is consistent with a hub-and-spoke dynamic in its northern segment: some southern departments seem to thrive, while Rivera and Tacuarembó perform poorly not only in economic activity but also in their capacity to catch up with Montevideo. There is also the aforementioned case of

Florida, which is especially noteworthy because it appears surprisingly negative and may have been subject to a mechanism similar to Tacuarembó's.

These findings help reconcile the apparent tension between, on the one hand, claims that the Uruguayan network was overextended in economic terms and, on the other, the broader historical significance commonly attributed to railways. Even if the aggregate economic payoff appears modest in some specifications, a point stressed in parts of the historical literature, the railway network plausibly mattered through channels that are not fully captured by GDP per capita alone. The consolidation of territorial integration, the facilitation of state presence in distant departments, and the social transformation associated with stations, employment, and the emergence or expansion of localities are all dimensions highlighted in the historiography of the Uruguayan railway, and they remain central for interpreting the long-run legacy of the network (Baracchini, 1978; Barrán and Nahum, 1971; Millot and Bertino, 1996). In this sense, the results suggest that the railway's relevance should be evaluated not only through aggregate output effects, but also through state-capacity, political integration, and broader economic and social development mechanisms. To answer the title briefly, not all tracks led to Montevideo, but many led to the South, of which Montevideo forms part, except for some that led to the border.

This thesis also has clear limitations. First, the regional GDP per capita series relies on benchmark information and an imputation procedure to recover annual variation. Although this approach is motivated by recent spatiotemporal methods, measurement error and model dependence remain important concerns. Second, GDP per capita is an incomplete proxy for development, particularly in a context where infrastructure may reshape welfare through public services, migration, urbanisation, or sectoral change. Third, while the least-cost-path IV strategy is designed to mitigate endogenous placement, it still relies on an exclusion restriction that cannot be tested directly, and therefore it should be interpreted as strengthening, rather than replacing, the reduced-form evidence. Finally, I do not yet have complete data on development variables, which forces strong assumptions and is a key reason why the initial objective of measuring development outcomes was postponed. Once the dataset on development indicators is completed, future work will be able to estimate directly the effect of railway infrastructure on departmental development.

Future research could proceed in several directions. One direction is to expand the outcome set beyond GDP per capita, incorporating labour-market indicators, urbanisation and demographic change, education and health proxies, and land values, which are often more directly connected to development mechanisms. A second direction is to deepen the political economy dimension by linking route selection and the timing of connections to legislative episodes and state capacity, which would allow a more direct test of the inequality hypothesis associated with the railway laws. This is particularly important because, unlike in previous studies, railways in Uruguay do not appear to have increased inequality. Future research could therefore seek to uncover why the Uruguayan network was not an inequality enhancer, and to what extent the Herrera y Obes vision of how railways should be conceived, together with the early intervention of the State in the railway system, may have contributed to that outcome in combination with political economy mechanisms.

A third direction, given that the positive effects are concentrated mostly in the south, and that this is also the most developed region in Uruguay today (Rodríguez Miranda and Willebald, 2024; Rodríguez Miranda et al., 2024), is to investigate development outcomes there more directly, in order to assess more precisely what role railways played. A fourth direction, also related to the south, is to study the role of railways in structural change. Since much of the change in sectoral specialisation appears to have occurred there, with movement toward industrialisation, complexity, and services. In connection with this, future work could investigate more systematically the relationship between railways and the south, and, more generally, identify which territories are best able to leverage the positive impacts of railways through improved connectivity and lower travel times, and therefore lower transportation costs. There may be specific enabling conditions, such as density, the spatial concentration of urban agglomerations, initial productive conditions, or institutional settings, that help explain how railways can generate positive effects in a developing country. At the same time, understanding why some places within an otherwise favoured region fail to benefit would also be essential for a fuller interpretation of the long-run development effects of railway infrastructure. An additional direction concerns the border departments. It would be particularly informative to understand why Artigas appear to have followed trajectories different from Rivera's. A deeper analysis of the connection with the Brazilian side could help clarify the factors at play and potentially determine whether connections to another country, while isolated from its own, can be a promoter of autonomous development with local dynamics.

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Appendices

A Annual departamental GDP per capita

The regional income series used in the thesis is available only for a limited set of benchmark years. Constructing an annual panel is nevertheless necessary to match the timing of railway investment and network expansion. For that reason, I impute missing department–year observations using a spatiotemporal imputation approach based on PriSTI (Spatiotemporal Imputation with Enhanced Prior Modeling) (Liu et al., 2023). This appendix documents the imputation procedure, notation, modeling choices, and validation steps.

A.1 PriSTI-style diffusion imputation of sectoral *between* shares

A.2 Objects and notation

I observe sectoral *between* shares at the department–year–sector level. Let $i = 1, \ldots, D$ index departments, $t = 1, \ldots, T$ years, and $k = 1, \ldots, K$ sectors. The raw input is

$$S^B_{i,t,k} \in [0,1], \qquad \sum_{i=1}^{D} S^B_{i,t,k} = 1 \ \ \forall (t,k),$$

with missing entries for some (i,t,k). I define an observation mask $M_{i,t,k} \in \{0,1\}$ indicating whether $S^B_{i,t,k}$ is observed.

For each sector k, I work with a simplex-constrained prediction $\widehat{\mathbf{s}}_t \in \Delta^{D-1}$ where $\widehat{\mathbf{s}}_t = (\widehat{s}_{1,t}, \ldots, \widehat{s}_{D,t})$ and $\widehat{s}_{i,t} \geq 0$, $\sum_i \widehat{s}_{i,t} = 1$. I parameterise shares using logits $\mathbf{x}_t \in \mathbb{R}^D$:

$$\widehat{\mathbf{s}}_t = \mathrm{softmax}(\mathbf{x}_t).$$

A.3 Prior (base path) in logit space

To stabilise learning with sparse anchors, I build a deterministic *base* logit trajectory $\mathbf{x}_t^{\text{prior}}$ using the observed anchors for each department separately:

1. I transform observed shares to logits with a clipped logit map.
2. For each department i, I linearly interpolate logits between observed years (piecewise-linear), and use flat tails before the first and after the last observation.
3. I re-center each year t so that $\sum_i \exp(x^{\text{prior}}_{i,t}) = 1$ (log-sum-exp normalisation).

This produces a smooth baseline in logit space even when the share observations are intermittent.

A.4 Diffusion model on residuals around the base

Rather than diffusing the full logits, I diffuse a residual around the base:

$$\mathbf{x}_t = \mathbf{x}_t^{\text{base}} + \mathbf{r}_t, \qquad \mathbf{x}_t^{\text{base}} = \mathbf{x}_t^{\text{prior}} + \omega_{\text{dev}}\, \mathbf{b}_t,$$

where $\mathbf{b}_t$ is an optional learned logit bias from auxiliary development covariates (when available) and ω_{dev} is a small weight.

I use a standard forward diffusion on the residual $\mathbf{r}$:

$$\mathbf{r}_t^{(m)} = \sqrt{\bar{\alpha}_m}\,\mathbf{r}_t^{(0)} + \sqrt{1-\bar{\alpha}_m}\,\boldsymbol{\epsilon}, \qquad \boldsymbol{\epsilon} \sim \mathcal{N}(\mathbf{0}, \mathbf{I}),$$

for diffusion step $m \in \{0, \ldots, M-1\}$. In my implementation I set $\mathbf{r}_t^{(0)} = \mathbf{0}$ and learn to predict the injected noise $\boldsymbol{\epsilon}$.

The denoiser $\epsilon_\theta(\cdot)$ is a GRU-based sequence model operating over time:

$$\widehat{\boldsymbol{\epsilon}} = \epsilon_\theta\left(\mathbf{r}_{1:T}^{(m)},\ \mathbf{x}_{1:T}^{\text{base}},\ \mathbf{c}_{1:T},\ m\right),$$

where $\mathbf{c}_t$ are time-varying conditioning features (e.g. national sector growth and aggregate GDP growth) and m is embedded via a sinusoidal time-step embedding.

A.5 Training losses (per sector)

At each iteration I sample a diffusion step m uniformly, draw noise $\boldsymbol{\epsilon}$, and minimise a weighted objective consisting of:

(i) Diffusion noise loss.

$$\mathcal{L}_{\text{eps}} = \|\widehat{\boldsymbol{\epsilon}} - \boldsymbol{\epsilon}\|^2.$$

(ii) Anchor fit losses (pre-projection). From $\widehat{\boldsymbol{\epsilon}}$ I reconstruct $\widehat{\mathbf{r}}^{(0)}$ and hence logits $\widehat{\mathbf{x}}$ and shares $\widehat{\mathbf{s}} = \text{softmax}(\widehat{\mathbf{x}})$. On observed anchors I penalise:

- cross-entropy on observed cells (masked),
- a band ("corridor") loss that penalises deviations only when predictions fall outside a $\pm p$ band around anchors,
- a windowed anchor-level loss: in a small time window around each anchor I blend the target toward the anchor value with a taper $(1, \gamma_1, \gamma_2, \ldots)$ and apply cross-entropy to that blended target,
- a mild slope/curvature match at anchor points to discourage sharp dents at anchors.

(iii) Structural regularisation (pre-projection). I add smoothness and spatial structure penalties:

- adjacency consistency: $\widehat{\mathbf{s}}_t$ is encouraged to be close to its adjacency-smoothed version, using a year-specific adjacency matrix $\mathbf{A}_t$ (early vs. late network),
- total variation and curvature penalties on the residual logits $\widehat{\mathbf{x}} - \mathbf{x}^{\text{base}}$ across time,
- a weak background prior penalty that keeps unobserved cells close to the base trajectory,
- a proximity ("halo") penalty (stronger near anchor years) that limits residual drift near anchors,

(iv) Deterministic head loss (optional stabiliser). In addition to the stochastic diffusion step, I compute a deterministic "$m = 0$" forward pass and include the same anchor losses on that deterministic output.

A.6 Non-differentiable tapered anchor projection (training cadence)

To prevent the projection step from dominating gradients, I apply the anchor projection *without gradients* (inside `no_grad`) and only every N epochs (`project_every`). When executed, the projection softly enforces an anchor at time t^* and tapers enforcement to neighbors within a half-width h:

$$\widehat{s}_{i,t^*} \leftarrow s^{\text{obs}}_{i,t^*}, \qquad \widehat{s}_{i,t^*\pm 1} \leftarrow (1-\gamma_1)\widehat{s}_{i,t^*\pm 1} + \gamma_1 s^{\text{obs}}_{i,t^*}, \ \ldots$$

with renormalisation to preserve the simplex. Optionally, I use department "resistance weights" to distribute the compensating mass across non-anchored departments when enforcing an anchor.

On projection epochs I also compute post-projection anchor losses (lightly weighted) as a safeguard; on non-projection epochs these post losses are set to zero.

A.7 Validation and early stopping

I hold out a random fraction of observed anchors for validation. Validation is computed on the deterministic ($m = 0$) output *without projection* and uses a masked anchor metric (cross-entropy plus corridor loss). I early-stop when the validation metric fails to improve by a minimum delta for a fixed patience in validation checks.

A.8 Final inference and exact anchor reinstatement

For the published output I use the deterministic ($m = 0$) reconstruction and then:

1. apply the tapered anchor projection on *all* observed anchors,
2. perform a final *joint, exact* anchor projection: for each year t, I set all observed departments exactly to their observed shares and rescale the remaining (unobserved) departments so that the row sums to one. This guarantees $\widehat{S}^B_{i,t,k} = S^B_{i,t,k}$ for all observed (i, t, k).

I can compare the resulting series with the one of Martínez-Galarraga et al. (2020) by contrasting the results of inequality measured by the Coefficient of Variance.

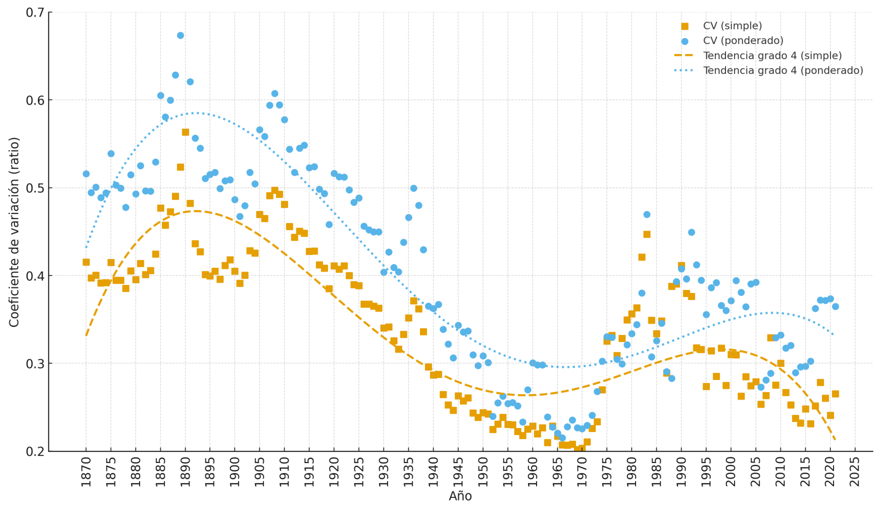

Figure 9: Own estimations based on the annualised GDP per capita series.

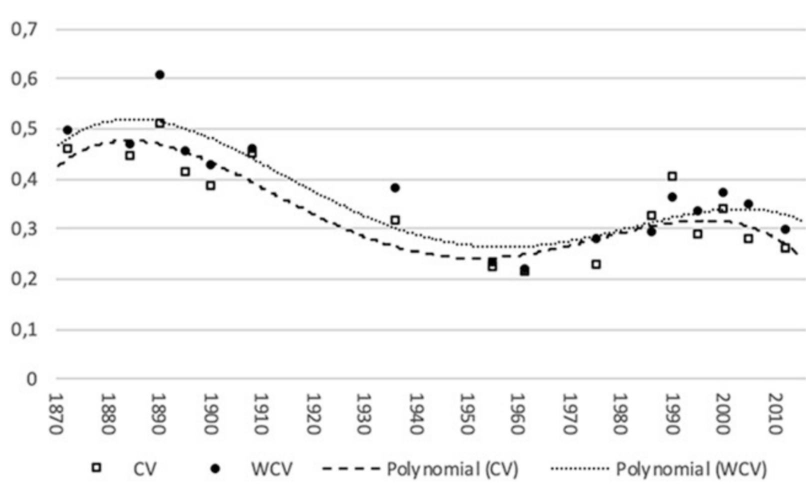

Figure 10: Source: Taken from Martínez-Galarraga et al. (2020)

We can see in Figure 9 that using a polynomial of degree 4 yields results remarkably similar to those in Figure 10, with the most likely explanation for any difference being an update to historical GDP benchmarks, which naturally affected newer estimations. However, the tendency is similar. In other words, we tell the same story.

B Investment Database and Railway Infrastructure components

This section is intended to show what a typical page in the company's reports looked like, which helps clarify how decisions were made when assigning investments by department and the process of collecting information. It is worth noting that I first obtained source access by visiting the Guildhall Library in London to take images of the Annual Reports of British companies that operated in Uruguay. As a rule, British companies were required to send these reports back to London, where, over time, they were donated to the Library and collected into the Foreign Railways Reports archive. As well, in the case of national companies, I relied on the excellent archive given to me by Gastón Díaz, which consisted of primary sources, and on recollecting data from the Facultad de Ciencias Económicas y Administración Library, which had information on State-owned companies from 1948 to 1952.

The process of assembling this database was carried out in several steps, which will be presented next. First, as can be observed both in figures 11 and 12, capital expenditure was registered in different ways, while The Central Uruguay Railway usually preferred the first one, the rest of the companies relied more on the latter. In here we can observe that there were many ways in which information was disclosed, in some cases, for small expenditures or in rolling stock, location of investment was not disclosed (sometimes in the case of rolling stock was divided by branches), and in other cases, which were many, and when expenditure was high enough, information on location was given. This was fundamental because my strategy was to disaggregate investment as much as I could with the available information. I placed all the disclosed investments in the departments they corresponded to. Then, if I could not get a specific place, I divided it by the branch, and finally any remaining expenditure was divided equally among all the departments served by the Company. The case of State-owned companies, as shown in figure 13, is somewhat different because the companies disclosed the location of their investments as much as possible, leaving little expenditure without a location. The same rules that applied to privately owned companies also applied to state-owned companies regarding investment placement.

COMPANY OF MONTE VIDEO, LIMITED. 53

A A.—ABSTRACT. CAPITAL EXPENDED IN MONTE VIDEO ON WORKS COMPLETED AT 30TH JUNE, 1902, AND ON WORKS STILL IN PROGRESS.

	£ s. d.	£ s. d.
COMPLETED WORKS—		
MAIN LINE—		
Macadamizing Rampla Sud America and Paving Miguelete Street	76 8 11	
Extension of Peñarol Workshops and Additional Machinery	2,394 1 4	
House for Sectional Engineer, Toledo	464 0 7	
Water Service at San José	2,258 1 1	
Turntable at San José	885 18 10	
Running Shed at San José	1,014 2 5	
Barriers at Independencia	30 12 4	
Drainage at Kilom. 4·950, Main Line	130 15 3	
10 Water Meters for Central Station	77 3 10	
Additions to Boilers, Peñarol Shops	291 19 8	
Lands expropriated—Main Line	88 4 7	
ROLLING STOCK—		
2 Bogie Sleeping Saloons	3,819 4 11	
6 Bogie Composite Saloons	9,282 17 10	
5 Bogie 1st Class Saloons	7,775 10 8	
10 Bogie Sheep Wagons	2,635 14 9	
		31,224 17 0
NORTH EASTERN BRANCH—		
Lands expropriated for Line		98 7 1
		31,323 4 1
Less— Sale of Locomotives, Nos. 38 and 41		1,000 0 0
		30,323 4 1
WORKS IN PROGRESS—		
MAIN LINE—		
General Fencing of Line	13,637 14 4	
NORTH EASTERN BRANCH—		
General Fencing of Line	5,269 3 7	
		18,906 17 11
		49,230 2 0
Less— Expended in connection with the above at 30th June, 1901		26,286 1 0
Expended during the year		£ 22,944 1 0

Figure 11: 1902 Central Uruguay Railway Annual Report Investment Appendix

1. STATEMENT OF SHARE CAPITAL, DEBENTURE STOCK AND BONDS AUTHORISED AND ISSUED.

Description.	Authorised.	Issued.	Unissued.	Redeemed.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Shares of £1 each	125,000 0 0	124,640 0 0	360 0 0	—
Four per Cent. Debenture Stock	184,980 0 0	184,980 0 0	—	—
Five per Cent. First Mortgage Gold Bonds of £20 each	319,500 0 0	319,500 0 0	3108>0	8,680 0 0
	629,480 0 0	629,120 0 0	360 0 0	8,680 0 0

2. Dr. RECEIPTS AND EXPENDITURE ON CAPITAL ACCOUNT TO 30th JUNE, 1914. Cr.

	£ s. d.		£ s. d. 5
To Capital Expenditure—		By Receipts—	
As per last Balance Sheet	598,066 19 1	Shares of £1 each	124,640 0 0
Outlay during year ending 30th June, 1914	8,670 13 7	Four per Cent. Debenture Stock...	184,980 0 0
	606,737 12 8	Five per Cent. First Mortgage Gold Bonds	319,500 0 0
Deduct— Debentures of Railway and Works Company, Limited, paid off 22nd December, 1913 ...	138 16 3	„ Uruguayan Government— Proceeds of Subvention *re* Extension	45,615 17 5
	606,598 16 5		
„ Discount, Commission and Expenses *re* Issue of First Mortgage Gold Bonds	66,279 6 3		
„ Balance carried to Balance Sheet	1,857 14 9		
	£674,735 17 5		£674,735 17 5

Figure 12: 1914 Uruguayan East Coast Railway Annual Report Investment Section

Folio	Concepto	Parcial	Total
	Transporte	$ 54.185,63	
51	**— VIA Y OBRAS**		
	Desvios (Continuación)		
369	Durazno — Mejoras desvios	" 2.309,11	
374	P. Coloradas — Extensión desvios	" 1.743,33	
378	Tacuarembó — Ampliación desvios ...	" 15.564,06	$ 73.802,13
	Edificios y Estaciones		
328	Ing. V. B. Sudriers — Construcción cabina señales	$ 1.800,38	
330	Tupambaé — Ampliación vivienda capataz cuadrilla V. P.	" 85,66	
342	Rivera — Ampliación edificio estación .	" 5.277,43	
343	Achar y P. Sola — Construcción viviendas Cuadrillas V. P.	" 622,23	
346	Central — Nuevas oficinas Electricidad y señales Galpón "A"	" 1.240,82	
348	Durazno — Vivienda capataz cuadrilla V. P.	" 700,34	
349	Artigas — Construcción W. C. publico .	" 18,52	
354	Rebeledo — Construcción vivienda telegrafistas y W. C. público	" 3.480,93	
358	Pampa — Mejoras edificio estación ...	" 15,65	
359	Parada Liebig's — Construcción vivienda segundo capataz cuadrilla	" 2.121,34	
361	Parada Francia — Ampliación vivienda encargado	" 4.213,24	
363	C. Colorado — Construcción W. C. Públicos	" 1.358,53	
367	Tapia — Construcción vivienda peones cuadrilla V. P.	" 3.815,32	
376	Paysandú — Ampliación oficina Talleres	" 8.792,70	
384	Quebracho — Nueva sala espera y depósito encomiendas	" 188,23	
390	Tranqueras — Construcción casilla telegrafistas	" 1.789,72	
397	Salto — Alojamiento personal trenes ..	" 110,00	
410	I. Cabellos — Alojamiento personal trenes	" 9.980,09	" 45.611,13
	Instalaciones Sanitarias		
383	Paysandú — Instalación servicios higiénicos Talleres	$ 1.487,09	" 1.487,09
	Varios		

Folio	Concepto	Parcial	Total
	Transporte	$ 307,81	" 120.900,35
	Varios (Continuación).		
353	Línea Salto y Rivera — Nuevo empalme Chamberlain	" 48.289,93	
398	Refuerzo rubros e imprevistos	" 8.317,27	
	1 — Rausa — Ampliación desvío y rampa .... $ 5.095,34		
	2 — Línea T. y Tres — Aumento en peso rieles .... $ 3.221,93		
411	Salto — Construcción cercos y veredas	" 68,25	" 56.983,26
52	**— TALLERES Y TRACCION**		
	Maquinaria		
100	Peñarol — Reemplazo maquinaria y herramientas Talleres	$ 53.745,78	" 53.745,73
	Locomotoras y Tren Rodante		
095	Peñarol — Equipar 5 locomotoras con luz eléctrica	$ 3.477,30	
113	Peñarol — Instalación alumbrado eléctrico en 16 furgones para trenes de pasajeros	" 185,22	
117	Adquisición 10 vagones tanques	" 122.977,73	
118	Adquisición 5 locomotoras Henschel ...	" 600.000,00	" 726.640,25
	Varios		
094A	Reboledo — Bomba automática para servicio de agua	$ 3.610,83	" 3.610,83
54	**— ELECTRICIDAD Y SEÑALES**		
	Señales		
137	Nico Pérez — Nueva señalización	$ 481,08	
138	Algorta — Nueva señalización	" 4.305,71	
139	Tres Arboles — Nueva señalización ...	" 1.130,24	
140	Paysandú — Nueva señalización	" 3.240,34	
141	Km. 216 Linea N. Pérez — Instalación señales	" 591,54	" 8.786,75
	Varios		
123	Central, Sayago, Peñarol — Cables telegráficos, telefónicos	$ 2.945,63	
128	Central y Peñarol — Instalación nuevas centralitas telefónicas	" 3.595,33	
142	Construcción circuito telefónico de control P. Toros - Chamberlain	" 4.413,67	" 10.954,63
			$ 981.621,85

Figure 13: 1950 Administración del Ferrocarril Central del Uruguay Annual Report Investment Section

As can be seen here, companies had different ways of reporting, some were cummulative, and others year-by-year, this was taken into account. Also the place where the company operated served to place the generic investment, as for example we know that by 1914 all Uruguayan East Coast company investment would go to Canelones and Maldonado, as for example the North Western in 1874 would go only to Salto, this helped to minimise the generalisation errors, and when possible exact investment was placed (usually large investments were placed in the location they were made).

The official railway map of Uruguay was taken from the webpage of the Ministry of Transport and Public Works[17], the map included many of the older stations, even if inactive, as well as sections that were removed, the only non existent section in the map was the one between Carmelo and Nueva Palmira, for which I constructed using official maps in older Annual Reports. For non-existent stations or stops, I relied on different sources, such as Annual Reports or Statistical Yearbooks, and as mentioned before, a wonderful recent recopilation by Seijas Giménez (2024a,b). I was able to trace each station's year of construction. With this, I could map where each section was constructed and, therefore, map each year's railways, obtaining not only the Stations but also the Km of railways in each department by year.

Because I wanted to also make in the index the centrality of the department in the network, I used the geodesic distance (due to the earth being an ellipsoid), with the Haversine formula (sphere simplification), between the centroids of the departments as follows:

Let centroid 1 be at latitude/longitude (ϕ_1, λ_1) and centroid 2 at (ϕ_2, λ_2). All angles are expressed in *radians*. Let R be the Earth radius (e.g., $R = 6,371$ km).

[17]https://geoportal.mtop.gub.uy/geoservicios

$$\Delta\phi = \phi_2 - \phi_1 \qquad \text{(difference in latitude)} \tag{45}$$

$$\Delta\lambda = \lambda_2 - \lambda_1 \qquad \text{(difference in longitude)} \tag{46}$$

$$a = \sin^2\left(\frac{\Delta\phi}{2}\right) + \cos(\phi_1)\cos(\phi_2)\sin^2\left(\frac{\Delta\lambda}{2}\right) \qquad \text{(Haversine term)} \tag{47}$$

$$c = 2\ \text{arctan2}\left(\sqrt{a},\ \sqrt{1-a}\right) \qquad \text{(central angle between points on the sphere)} \tag{48}$$

$$d = R\,c \qquad \text{(great-circle distance; in the same units as } R\text{).} \tag{49}$$

Following this I present some results of the capital stock which was important for this index, this is the depreciated investment stock.

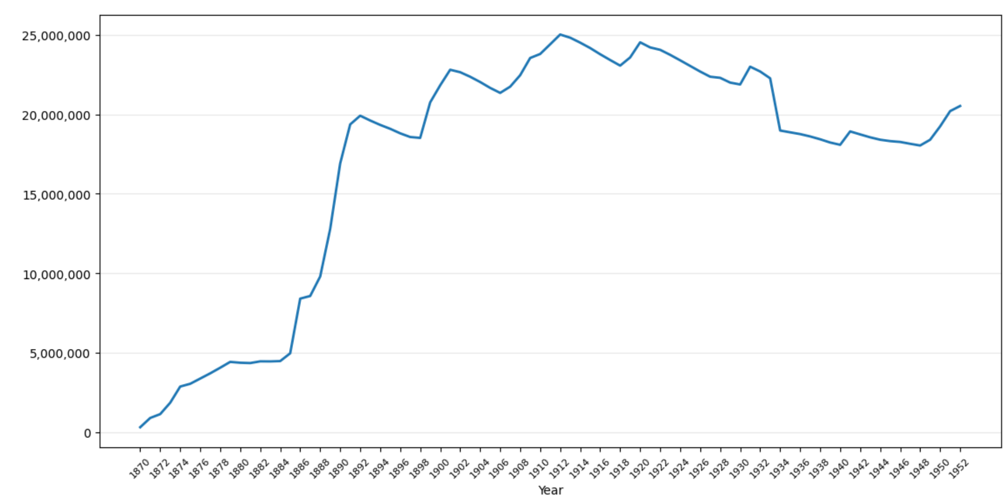

Figure 14: National capital stock of railways (1869-1952)

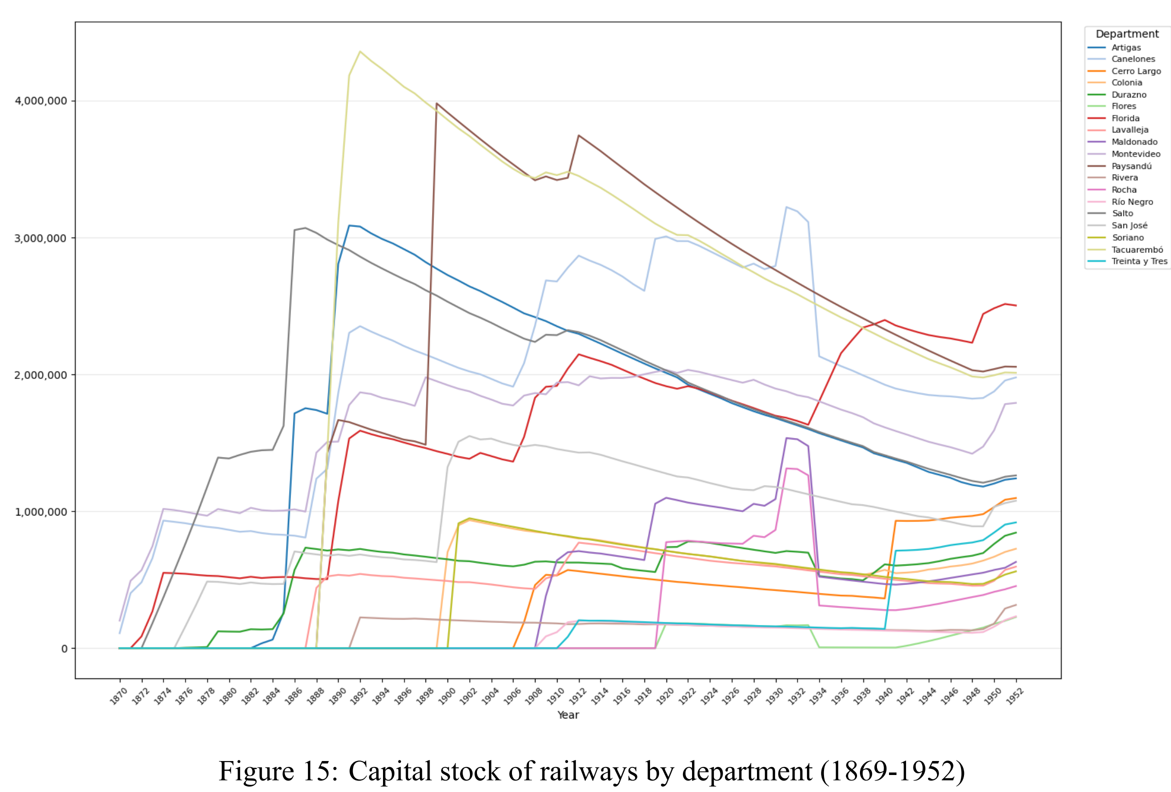

Figure 15: Capital stock of railways by department (1869-1952)

As can be seen in figure 14 it conforms well with known patterns. During the railway boom, the stock grew exponentially, then continued to grow until it reached its peak in 1913. Then, due to

Government disputes with British companies, the network was underinvested for decades, a problem that was exacerbated in the 1930s. Last, when the Government took over the British companies, and therefore the entire network, long-delayed investments resumed, as shown by the late growth in capital stock, ending with similar levels in 1952 as in the 1900s.

When we concentrate on the departamental story, in figure 15 it can be seen the capital stock had different patterns, which makes sense considering the railways reached at different points in time the different departments. We can see here departments in which large investments occurred once, for example, during the railway boom in Tacuarembó, and then never again were investments sufficient to offset capital depreciation. And there were others like Montevideo that, while they had their moments of underinvestment, in general, the capital expended was enough to grow the capital stock. Another interesting point is that the severe underinvestment in the 1930s was mostly concentrated in a few departments, such as Canelones, Maldonado, and Rocha. A further interesting fact is that, while every department began replenishing its stock once the Government took over, this mostly happened in Montevideo. This was because many of the rolling stock, locomotives, and workshops were in Montevideo and, as such, disclosed there, which indicated the urgent need to salvage underinvested companies.

C Robustness

Table 4: Evolution of the Marginal Railway Effect: Robustness Checks

	HSDM Model			2SLS Model (by department)		
Department	1870	1952	Transition	1870	1952	Transition
Scenario: $GDPpc_{t+5}, MA/MVD$						
Artigas	0.057	-0.008	Pos. 1874-1884	0.396*	0.406	Insig. after 1888
Canelones	0.064	0.220	Insignificant	0.615	3.061	Insignificant
Cerro Largo	0.140*	-0.145*	Flip in 1949	0.147	0.084	Insig. after 1921
Colonia	0.376*	-0.261	Insig. after 1899	-0.203*	0.270*	Flip in 1918
Durazno	-0.177*	0.719*	Flip in 1874	0.051	0.067	Insignificant
Flores	-0.043	0.218	Insignificant	0.356	-0.123	Insignificant
Florida	-0.056	-0.449*	Neg. after 1872	0.035	0.588*	Pos. after 1872
Lavalleja	0.297*	-0.249	Insig. after 1888	-0.501*	0.706*	Flip in 1889
Maldonado	0.077	-0.064	Insignificant	0.024	0.035	Insignificant
Montevideo	0.312	0.458	Insignificant	-0.989*	-4.891*	Always Neg.
Paysandú	-0.161*	-0.005	Insig. after 1891	-0.332	1.351	Insignificant
Río Negro	-0.099	0.173	Insignificant	0.034	0.013	Insignificant
Rivera	0.238*	-0.624*	Flip in 1907	0.372*	-0.304	Insig. after 1894
Rocha	0.129*	-0.089	Insig. after 1888	0.361	0.209*	Pos. after 1917
Salto	0.020	-0.055	Insignificant	-0.021	1.992*	Pos. after 1883
San José	0.053	-0.271	Insignificant	-0.146*	0.035	Insig. after 1876
Soriano	-0.086*	0.197*	Flip in 1901	-0.566*	0.241*	Flip in 1946
Tacuarembó	0.147*	-0.284*	Flip in 1891	0.652	-2.773*	Neg. after 1886
Treinta y Tres	0.088	-0.095	Insignificant	-0.333*	0.305*	Flip in 1917
Scenario: $GDPpc_{t+5}/MVD, MA/MVD$						
Artigas	0.058	-0.009	Insignificant	-0.165	0.151	Insignificant
Canelones	0.112	0.390	Insignificant	0.183	2.375	Insignificant
Cerro Largo	0.143*	-0.137	Insig. after 1903	0.100	-0.054	Insignificant
Colonia	0.379*	-0.295	Insig. after 1899	-0.076*	0.125	Insig. after 1872
Durazno	-0.132*	0.584*	Flip in 1874	0.090	-0.971	Insignificant
Flores	-0.054	0.250*	Pos. after 1915	-0.146	-0.008	Insignificant
Florida	-0.049	-0.419*	Neg. after 1872	-0.008	0.072	Insignificant
Lavalleja	0.284*	-0.265	Insig. after 1885	-0.505*	0.717*	Flip in 1889
Maldonado	0.158	-0.060	Insignificant	0.319*	-0.403	Insig. after 1895
Paysandú	-0.158*	-0.005	Insig. after 1891	-0.154	0.595	Insignificant
Río Negro	-0.096	0.150	Insignificant	-0.006	-0.030	Insignificant
Rivera	0.226*	-0.555*	Flip in 1909	0.179*	-0.312*	Flip in 1919
Rocha	0.128*	-0.083	Insig. after 1888	0.284	0.087	Pos. 1923-1948
Salto	0.020*	-0.059	Insig. after 1872	0.005	0.848	Insignificant
San José	0.038	-0.265	Insignificant	-0.115*	-0.010	Insig. after 1885
Soriano	-0.098*	0.196*	Flip in 1901	-0.267*	0.086	Insig. after 1901
Tacuarembó	0.152*	-0.272*	Flip in 1891	0.125	-0.641*	Neg. after 1885
Treinta y Tres	0.098*	-0.088	Insig. after 1883	-0.117	0.058	Insignificant

Notes: Effects are marginal effects of $\ln(\text{RII})$ on $\ln(y)$. Significance (*) denotes the 90% credible interval excluding zero (HSDM) or two-sided 10% significance (2SLS). Transition describes the year the marginal effect became statistically significant or changed sign.

D Railways Laws

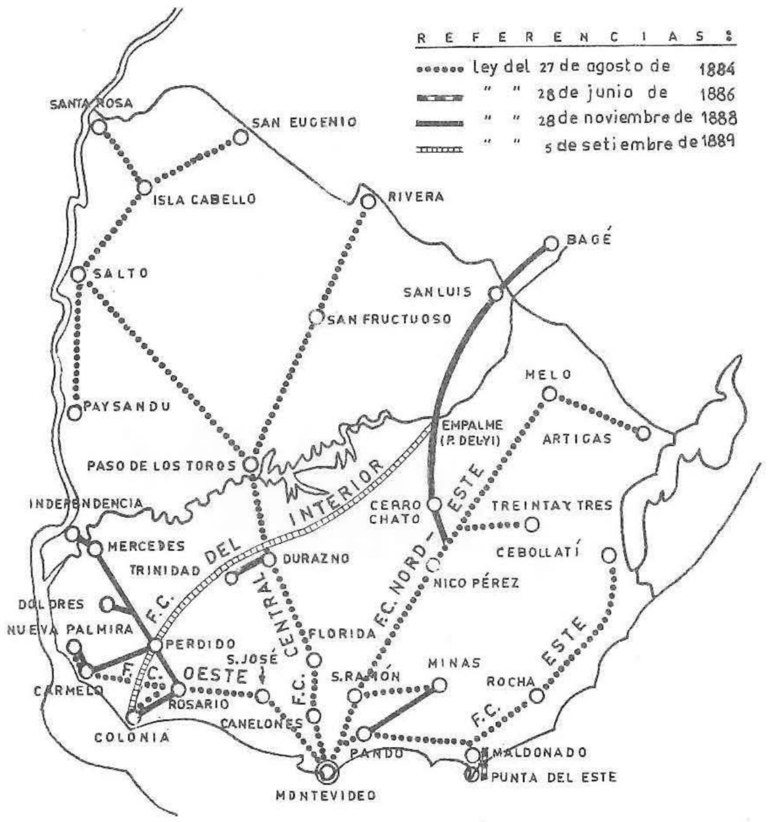

Fig. 39 - Interpretación gráfica de las leyes ferrocarrileras del 27 de agosto de 1884, 1.º de julio de 1886, 30 de noviembre de 1888 y 6 de setiembre de 1889

Figure 16: Projected Railway Map by the three laws
Source: Extracted from Baracchini (1978)

The following Railway Laws were taken from Baracchini (1978).

Proposed Routes in the Railway Act of 1884 and Subsequent Legislation

The route proposed in the Railway Act of 1884, enacted on August 27, 1884, was as follows:

1. **Central Uruguay Railway**, from Montevideo to the town of Rivera, passing through Durazno, Paso de los Toros on the Río Negro, and San Fructuoso, with a branch line from Paso de los Toros to Salto, and a sub-branch to Paysandú.

2. **Montevideo–Colonia Railway**, from Montevideo to Colonia, passing either through the mouth of the Santa Lucía River or via Paso de Balastiquí, through Colonia and the town of Rosario.

3. **Western Railway**, from 25 de Agosto to Carmelo and Nueva Palmira, passing through San José, Puntas del Rosario, and Puntas de Coya, with a branch to Mercedes.

4. **Northeastern Railway**, from Montevideo to Artigas[18], passing through San Ramón and Villa de Melo, with a branch to Treinta y Tres. The company was also granted the option to construct an additional branch from San Ramón to Minas. The line could alternatively begin in Canelones, Las Piedras, or Pando.

[18] Currently known as Río Branco.

5. **Uruguayan Eastern Railway**, from Montevideo to Laguna Merín, passing through Pando, Maldonado, San Carlos, and Rocha, with a branch to Minas between Pando and Maldonado, provided the Northeastern Railway did not construct it.

6. **Salto–Santa Rosa Railway**, with a branch line from Isla de Cabello to San Eugenio.

The law of November 30, 1888, supplemented the routes defined in the 1884 legislation as follows:

1. A railway from the city of Durazno to Trinidad, connecting with the Central line.

2. A railway to the frontier via the Bagé route, connecting with the Northeastern line near Cerro Chato, at the Puntas del Yí.

3. A branch line from Pando to Minas, on the Northeastern Railway from Montevideo to Artigas, passing through Pando, San Ramón, and Villa de Melo, with a branch to Treinta y Tres.

A portion of the text of the Railway Law enacted on September 6, 1889—which functioned as a contract between the State and the firm Castro, Petty & Cia.—outlined the following regarding the project plans:

> *The Central Interior Railway, from the port of Colonia to the Brazilian border, passing through Trinidad, Durazno, and Cerro Chato, in accordance with the provisions of the laws of August 27, 1884, November 30, 1888, and the Regulatory Decree of September 3, 1884, insofar as they do not contradict the present law. The line shall be divided into three main sections: the first, from the port of Colonia to the town of Durazno, passing through the Puntas del Perdido; the second, from Durazno to the Puntas del Yí or Cerro Chato, connecting with the Northeastern Railway; and the third, from the Puntas del Yí or Cerro Chato to the Brazilian border, following the direction of the Bagé route.*