CONTRIBUTI DI RICERCA CRENOS

UNIVERSITÀ DI CAGLIARI UNIVERSITÀ DI SASSARI
CENTRE FOR NORTH SOUTH ECONOMIC RESEARCH
CRENoS
CENTRO RICERCHE ECONOMICHE NORD SUD

EARLY RAILWAYS AND INDUSTRIAL DEVELOPMENT: LOCAL EVIDENCE FROM SARDINIA IN 1871–1911

Ugo M. Gragnolati
Luigi Moretti
Roberto Ricciuti

WORKING PAPERS

2023/07

arkadia

Centro Ricerche Economiche Nord Sud
(CRENoS)
Università di Cagliari
Università di Sassari

CRENOS was set up in 1993 with the purpose of organising the joint research effort of economists from the two Sardinian universities (Cagliari and Sassari) investigating dualism at the international and regional level. CRENoS' primary aim is to improve knowledge on the economic gap between areas and to provide useful information for policy intervention. Particular attention is paid to the role of institutions, technological progress and diffusion of innovation in the process of convergence or divergence between economic areas. To carry out its research, CRENoS collaborates with research centres and universities at both national and international level. The centre is also active in the field of scientific dissemination, organizing conferences and workshops along with other activities such as seminars and summer schools.
CRENoS creates and manages several databases of various socio-economic variables on Italy and Sardinia. At the local level, CRENoS promotes and participates to projects impacting on the most relevant issues in the Sardinian economy, such as tourism, environment, transports and macroeconomic forecasts.

www.crenos.unica.it
crenos@unica.it

CRENoS – Cagliari
Via San Giorgio 12, I-09124 Cagliari, Italia
tel. +39-070-6756397; fax +39-070- 6756402

CRENoS - Sassari
Via MURONI 25, I-07100 Sassari, Italia
tel. +39-079-213511

Title: EARLY RAILWAYS AND INDUSTRIAL DEVELOPMENT: LOCAL EVIDENCE FROM SARDINIA IN 1871–1911

Prima Edizione: Giugno 2023

ISBN: 978 88 68514 709

Viale Bonaria 98 - 09125 Cagliari
Tel. 070/6848663 - info@arkadiaeditore.it
www.arkadiaeditore.it

Early railways and industrial development: Local evidence from Sardinia in 1871–1911*

Ugo M. Gragnolati∝
University of Cagliari (Italy), Université Paris 1 Panthéon-Sorbonne (France) & CRENoS
Luigi Moretti
University of Bergamo (Italy)
Roberto Ricciuti
University of Verona (Italy) & CESifo (Germany)

Abstract

Similarly to other countries, the development of an early national railway network took place in Italy during the second half of the 19th century. Railroads were then regarded as carriers of modernity that could reach isolated areas, expand market potential, and favor the structural transition from an agricultural economy toward an industrial one. Did the newly constructed railways actually have medium-run effects on the development and structure of industrial sectors at the local level? We bring new evidence to the existing literature by looking at the case of Sardinia. According to our estimates, municipalities that received a railway station during the 19th century did not have a significantly higher future probability to host at least one industrial firm, as compared to municipalities without a railway station. However, in those municipalities that received a railway station during the 19th century, specific industrial sub-sectors such as foodstuff and metal processing had higher employment by 1911. Moreover, these industrial sub-sectors tended also to display more firms in those municipalities that received a railway station, although this latter effect is statistically weaker. These outcomes are especially strong in locations having direct access to the main railway line with standard gauge rails, while the effects of secondary narrow gauge lines do not find a similar empirical support. Results are robust to a large set of control variables and district fixed effects and to the use of an instrumental variable based on least-cost paths.

Keywords: Early railways, Industrial development, Developing economy, Insular economy, Least cost paths.
Jel Classification: N73, N93, O14, O18, R12.

---

* The usual disclaimers apply.

∝ Corresponding author (ugom.gragnolati@unica.it).

1 Introduction

By the mid-19th century, a young Piedmontese aristocrat and businessman that would soon become member of parliament and emerge as a major figure of the Italian unification process wrote vividly about one of the main technological innovations of his time:

> The influence of railroads will extend across the universe. In highly civilized countries, they will transmit an immense boost to industry; their economic performances will be magnificent from the beginning and they will accelerate the gradual move of society. But the related moral effects—which appear even greater than material ones—will be especially remarkable among laggards in the ascending march of modern nations. For these countries, railroads will be more than a mean to greater wealth: they will be a powerful weapon to triumph against the retarding forces that retain them in a fatal state of industrial and political infancy. (Cavour, 1846, pp. 4–5, own translation).

Similar ideas about the possible effects of railroads on industrial development were so widespread among 19th century elites that most European countries engaged in massive public investments to construct their national railway networks. In this view, while railroads could reinforce industrial performance in more advanced economies, they could also favor the spread of industrialization toward less advanced regions. Locomotives were then supposed to be carriers of modernity, by promoting a structural change from an agricultural society toward an industrial economy. Did railroads actually meet the high hopes under which they were built?

In this paper, we bring new evidence about the medium-run effects of early railways on the development of industrial sectors at the municipal level. To this end, we focus on the Italian island of Sardinia, in which abut 1000 kilometers of railways were built from 1871 to 1898. Specifically, we compare municipalities that received direct access to the railway network over this period of time against municipalities that did not receive it. We proxy access to railways with the presence of a station. Our outcomes of interest are represented by a series of proxies capturing the structure of industrial sectors in 1911, so as to look at medium-term effects. In particular, we ask whether those municipalities that received a railway station between 1871–1898 displayed a higher probability to host at least one industrial firm by 1911, or whether by that year they had more employment or firms active in the industrial sector.

By and large, this paper contributes to a burgeoning literature that investigates the economic and social effects of transport infrastructures in various historical contexts. Within this literature, early railroads represent by far the more frequently assessed mean of transport.[1] This is possibly

[1] Among others, see the earlier contribution by Fogel (1962) and more recent quantitative works such as

due to the fact that early railway networks were typically developed in a relatively short period of time on territories where alternative means of transport were generally very scant or nonexistent. This facilitates the identification of first-order effects as compared to alternative scenarios in which improvements of transport infrastructures occurred more incrementally on a territory that already offered multiple transport options.

Our focus on the specific case of Sardinia has several concomitant motivations, which ultimately favor the identification of causal effects. First, when adopting a wider scale of analysis on a highly differentiated country like Italy during the 19th and early 20th centuries, one runs unavoidably into the well-known institutional heterogeneity that characterized the country after its unification. In turn, the intrinsic difficulty associated with the measurement of institutional factors may generally make it hard to properly control for them, thus casting doubts about the accuracy with which the effects of railway development are identified. By contrast, focusing on a single isolated region such as Sardinia can guarantee a much greater institutional homogeneity across the territory under analysis. Second, the substantial geographical isolation of Sardinia allows to severely control for possible spatial spillovers deriving from underlying variations in neighboring regions. Essentially, for the time period under analysis, the spatial interactions of Sardinia with the rest of the world would necessarily manifest through its ports, which can be controlled for in regression analysis. Third, over the time period at stake, the road network of Sardinia as well as its seaway connections remained substantially unchanged vis-à-vis about 1000 kilometers of newly constructed railways. In this sense, if railway development in Sardinia had any effect at all, it would be unlikely to derive from the concomitant development of other ways of transport. Fourth, the morphology of Sardinia together with the explicit criterion of cost-effectiveness adopted by the Italian government to build railways in this region were key in the choice of railway routes. In turn, this facilitates the use of instrumental variables based of least-cost paths, thus helping to isolate causal effects. Fifth, although the focus on a regional scale necessarily reduces the size of the area under analysis, Sardinia presents a highly varied internal territory that can possibly favor the external validity of our results. Overall, then, these various features make of Sardinia an especially useful "laboratory" to study the possible effects or railway development under somewhat more controlled conditions than elsewhere (see also Gragnolati and Moretti, 2023).

Nonetheless, our empirical analysis still has to deal with the possibility that pork-barrel politics, lobbying, or other unobserved factors may have contributed to define the actual routes of railway lines, as pointed out by Bonfatti et al. (2021, 2022). For this reason, we present and discuss

Atack et al. (2010), Berger (2019), Bogart (2018), Bogart et al. (2022), Büchel and Kyburz (2020), Donaldson and Hornbeck (2016), Fenske et al. (2022), Forero et al. (2021), Hornung (2015), as well as Basile et al. (2022), Bonfatti et al. (2021, 2022), Ciccarelli et al. (2021), Pontarollo and Ricciuti (2020) for the particular case of Italy.

estimation results using a large set of control variables at the level of municipalities, district-fixed effects, and an instrumental variable relying on the identification of a least cost path (LCP) for each trunk of the railway network. In line with other contributions in the literature, we instrument the presence of a station in a municipality with the distance between the main town of each municipality and the nearest LCP (see for instance Berger, 2019). This variable indicates how far a municipality is from an "incidental" railway trunk that connects two pre-determined endpoints via a cost-minimizing route.

Estimation results show that, on average, receiving a railway station between 1871–1898 is not associated to a higher probability of observing at least one industrial firm at the municipal level in 1911. However, intensive margins played a role. Namely, municipalities that received a railway station between 1871–1898 display higher industrial employment in 1911, both in the industrial sector as a whole and in two of its main sub-sectors (i.e., food and metal processing). Moreover, we find similar results also when considering as an outcome the number of industrial firms, although these latter estimates are less robust.[2]

To favor the interpretation of our results, we also conduct a series of additional estimations. First, we find that receiving a railway station has an effect on the share of population employed in industrial firms: i.e., for a given population size, having railway access is associated to more people working in manufacturing industries. This result allows to rule out the possibility that more people become employed in industrial firms merely as a result of local population growth. Second, we do not find support about the possible conditional role of natural resources: namely, the effects of railway access are similar across areas that are otherwise heterogeneous in terms of crop and forest suitability as well as for the presence of active mines. Third, we find that being located along the main standard-gauge railway lines—as opposed to secondary narrow-gauge lines—is a key conditional element in our results. Namely, the effects of railway access on subsequent industrial development are present for that subset of municipalities that are located along the main railway line, while such effects are not statistically significant for those municipalities that received a railway station along secondary lines.

The literature that is closer to our paper deals with the effects of early railways on industrial dynamics. Among the more recent contributions, Ciccarelli et al. (2021) analyze the case of early railways in Italy using regional data and find that they had positive effects on the industrial growth of northern regions, while the effects were modest for the country as a whole. Berger (2019) looks instead at small administrative units in Sweden and finds that being closer to an early railroad led to more rapid population growth and relocation of workers in industrial activities. Such effects

[2] These relationships, instead, find less support in the data for other industries, although they are observed in a smaller number of municipalities and estimates are not necessarily reliable. We present these results in the Appendix.

are found to be very local as they attenuate in areas located more than 5 kilometers away from the railway lines. In a similar spirit, also our paper focuses on local effects at the municipal level, but it also offers evidence on the different industries that composed the industrial sector.

Our work is also closely related to Bonfatti et al. (2022). They analyze the impact of railway access on the long-run dynamics of the industrial and commercial sectors and sub-sectors at the level of Italian municipalities. Our work differs from Bonfatti et al. in some key aspects, other than our focus on Sardinia. First, we concentrate on medium-term effects. Our dependent variables are taken in 1911 and for that year we also look at the performance in industrial sub-sectors. Instead, Bonfatti et al. focus on sub-sectors from 1951 onward, while for 1911 they only look at the performance of the industrial sector as a whole. Second, our instrumental variable is based on the LCP approach, while they use an instrument that exploits some randomness in municipal elections. Third, we look at the effects of receiving a railway station, whereas they look at the effects of a municipality being located along a railway line. Fourth, we also look at the probability to observe an industrial activity in a municipality, so as to capture the possible spatial diffusion of the industrial sector. Interestingly, our results indicate that having access to early railways entailed some positive effects on the industrial sector by 1911, and such effects were mainly driven by sub-sectors such as foodstuff and metal processing. Instead, Bonfatti et al. do not find significant results for 1911 when looking at the industrial sector as a whole, but they find that sub-sectors such as foodstuff and metal processing recorded the strongest growth in the long run.

The rest of this paper is structured as follows. In Section 2, we give an overview of the historical and institutional context of Sardinia between 1861 and 1911. In Section 3, we present the empirical setting together with the description of the data used to construct the variables underlying our empirical analyses. Section 4 shows estimation results which are grounded on the inclusion of control variables at the of municipal level and district fixed effects to identify the effects of railway access on industrial activities. Then, in Section 5 we present our instrumental variable analyses, both discussing the construction and validity of the instrument and presenting the 2SLS estimates. In Section 6, we show further results on alternative outcomes as well as heterogeneous effects, which help us to qualify the main results. Section 7 concludes.

2 Historical context

This paper assesses the effect of railway development on industrial firms, focusing in particular on the situation of Sardinia as recorded at the first Italian census of industrial firms published in 1911. By then, the medium-term effects of railways were plausibly detectable, if existing at all, given that the historical railways of Sardinia were laid out between 1871–1898. In this respect, it is worth to highlight some aspects that characterized the process of railway development in Sardinia over the time period of interest, so as to define the socio-economic context underlying our empirical analysis.

In the second half of the 19th century, railways spread across the Italian territory and gradually came to connect major cities as well as smaller towns, thus accomplishing what was widely regarded as a necessary step on the path to modernization. In particular, some key political figures in Italy regarded England as a reference model that could serve to guide industrial policies, and the construction of railways was seen as a cornerstone of such model. For instance, Cavour (1846) makes repeated references to England as a way to discuss what he believed to be some of the possible effects of railway construction in Italy.[3] At the same time, the comparatively late start of Italy in the construction of its national railway network created the possibility to observe the variety of ways in which railways were financed and managed in other countries, so as to evaluate the feasibility of these various methods in the different local contexts that composed the Italian territory. For instance, Petitti (1845) devotes the entire second chapter of his lectures to discuss "the various systems adopted for the organization of railroads across different nations", essentially pointing to some of the most common ways in which private and public capitals could be mixed to build and manage railways.[4]

Under these premises, a detailed overview of the spatial diffusion of railroads in Italy can be grasped through the work of Ciccarelli and Groote (2017). By and large, railroads remained rather sporadic and scarcely interconnected in Italy until the mid-19th century, to then gradually expand in the following few decades. Specifically, in the years preceding unification, in 1861, railways became comparatively more dense in the north-west due in particular to the pivotal role of Piedmont. Then, after unification, also the main national lines were constructed so as to link north and south as well as east and west in some central corridors of the peninsula. Finally, particularly after the so-called "Baccarini law" in 1879, several small towns were linked to the network via secondary railways (see Bonfatti et al., 2022, for further details).

With respect to its interior geography, Sardinia presented a rather clear characterization. At the first unitary census in 1861, the region counted about 583,000 inhabitants distributed on a surface of about 2.4 million hectares. Hence, overall population density was low. Nonetheless, the two main cities, Cagliari and Sassari, counted respectively 29,000 and 22,000 residents, while

[3] Camillo Cavour was an aristocrat and businessman who got elected as member of parliament in 1848 for the Kingdom of Piedmont-Sardinia, for which he served as minister between 1850–1852 and then as prime minister until unification in 1861. Starting with his appointment as minister of finance, in 1851, Cavour began to actively promote and fund the construction of railways, which soon led Piedmont to become the Italian region with the highest density of railways (see Ciccarelli and Groote, 2017, for further details).

[4] Carlo Ilarione Petitti was an aristocrat, state official, and economist that served as senator for the Kingdom of Piedmont-Sardinia between 1848–1850.

smaller towns did not exceed 8000 residents. In this sense, the population of Sardinia presented a non negligible degree of spatial concentration that made of Cagliari and Sassari two evident poles, located respectively to the south and north of the island. As a consequence, the early projects of railroad construction that began to circulate in 1860 focused primarily on connecting these two regional poles, while also passing by the western port of Oristano to ultimately stretch toward the north-eastern ports of Terranova (now Olbia) and Golfo Aranci. However, these early projects were much debated and partly opposed, which ultimately led construction works to start more than ten years after the first proposals were put forward. By then, expectations on the role that railways would play for the economic development of the island were especially high, particularly because the opening of the Suez Canal in 1869 had sparked hopes that Sardinia would gain centrality in Mediterranean trade routes (Ortu, 2005, p. 89–90).

Indeed, the first railway stations opened on the island in 1871, as part of the trunk that was completed a year later and connected Cagliari to Oristano. By then, also another trunk was constructed to link Cagliari to Iglesias, a mining center in the south-west. Then, it took until 1880 for Sassari and the near port town of Porto Torres to be fully linked with Cagliari by railway, while the north-eastern ports of Terranova and Golfo Aranci were finally reached by 1881 and 1883 respectively. This completed the primary railways of Sardinia, which spanned 410 kilometers with standard gauge rails. Starting from 1888, instead, secondary railways began to be constructed with narrow gauge rails, so that an extra 570 kilometers of railroads were laid out by 1898. At the end of these various waves of development, the railway network of Sardinia appeared as in Figure 1 and it extended over nearly 1000 kilometers. As a remark, secondary railways reached rather remote and small villages in some of the inner areas of Sardinia, and they were generally constructed under tighter budget constraints. Specifically, they resorted to narrow gauge rails precisely to achieve greater curvature, which in turn allowed to skirt the side of mountainous reliefs and minimize tunnels (see Altara, 1992, for further details). In turn, the use of different gauge widths did not allow for direct interconnections between primary and secondary lines, and this often drove the shipment of goods from inner areas to gravitate toward the only large center to which they were directly connected (Ogliari, 1978).

For what concerns the methods of financing, the Italian government constructed railroads in Sardinia relying primarily on long-term concessions to publicly traded companies. The main legal sources that defined the economic terms of these concessions were the laws 1105/1863 and 3011/1885, which regulated the concession of primary and secondary railways respectively (Gazzetta Ufficiale del Regno d'Italia, 1863, 1885). In summary, concessionaires engaged to build and manage a set of railway trunks for a period of time that could reach up to ninety-nine years. The endpoints of each trunk were defined in the concession, and and so were the prices of transport for freight and passengers. In turn, the government guaranteed a net subsidy rate in the range of

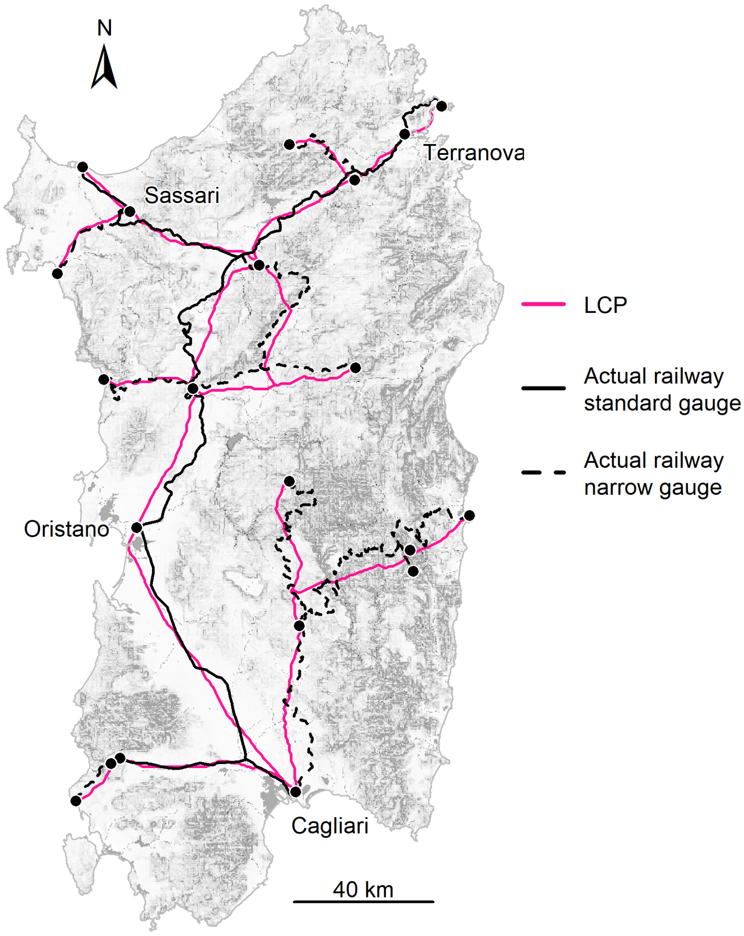

Figure 1: An overview of the railway network of Sardinia by 1898.

Note: The figure illustrates an overview of the railway network of Sardinia by 1898. In particular, actual railways are taken from Ciccarelli and Groote (2017) and they are distinguished according to their gauge width, which in this case also marks the difference between so-called "primary" and "secondary" railways. Moreover, the figure also shows the least cost path (LCP) associated to each trunk as defined by law (Gazzetta Ufficiale del Regno d'Italia, 1863, 1885). The dots in the figure represent the endpoints of such trunks. The cost surface on which LCPs are computed is shown on the background and it is defined according to the cost function put forward by Bonfatti et al. (2021), which in turn relies on the parameter estimates proposed by Büchel and Kyburz (2020). In brief, construction costs increase with terrain slope and with the extent of water bodies, as explained in greater detail in Section 5.1. In the figure, a darker color of the cost surface indicates a higher construction cost per meter.

9000–12,000£/km per year: to give a term of comparison, Italian GDP per capita expressed at current prices amounted to 279£ in 1861 (see ISTAT[b], historical boundaries, main time series). Moreover, the government tried to attract investors for the construction of primary railways also by granting 200,000 hectares of land taken from the public domain to the concessionary company, which ultimately resulted to be the *Compagnia reale delle ferrovie sarde*. Normally, this land could not be sold by the concessionaire and also the possibility to exploit its forests was severely limited by the concession its self, so that the land could not be easily destined to any use other than railway construction. At any rate, the land grant ultimately took place only to a limited extent, due to the difficulties that arose in defining property rights. Specifically, the land to be granted through the first railway concession was to be extracted from plots in the public domain that originally listed as common land under feudal rule, the so-called "ademprivi" and "cussorgie". As a result, the exact boundaries of such plots were often hard to define, considering also that feudal rule persisted in Sardinia until 1839. The Italian government made various attempts to establish exact property rights on land, and thus to define which plots were to be granted. Such attempts, however, typically faced strong social unrest, both from commoners and private owners who feared to be at least partly expropriated. This legal and political difficulty represented a major source of delay in the construction of primary railways and it ultimately forced the government to drastically reduce the land grant, possibly to only 10% of the amount that was initially foreseen (Ortu, 2005, p. 91–114).

Crucially, railways spread in Sardinia over a period of time in which the road network did not have a significant expansion or improvement. The last major addition to the road network of the island was completed in 1829, by connecting Cagliari to the north via the state road commonly named "Carlo Felice", which remains the main road of Sardinia to present. In particular, although also other projects of road construction were approved after the completion of this main artery, nearly all of them were not concretely executed due to the lack of financial resources on the side of municipalities (Ortu, 2005, p. 85–87). In this sense, for many areas of Sardinia, railways represented the first transportation network ever available to reach beyond a strictly local range.

In terms of its productive structure, Sardinia was essentially a developing economy relying on the exploitation of natural resources. In particular, relative to the Italian economy as a whole, the industrial production of Sardinia was much less involved in manufacturing, while being strongly specialized in extractive activities. To illustrate this evidence, the radar chart in Figure 2 shows the employment share for each of the seven sub-sectors in which production is classified in the first available census of industrial firms (Ministero di Agricoltura, industria e commercio, 1911). These data show that, in 1911, industrial employment in Sardinia was largely captured by extractive activities and food processing. However, the latter occupied a comparatively large share also in the rest of Italy, whereas the extraction of minerals such as lead, silver, and zinc clearly represented

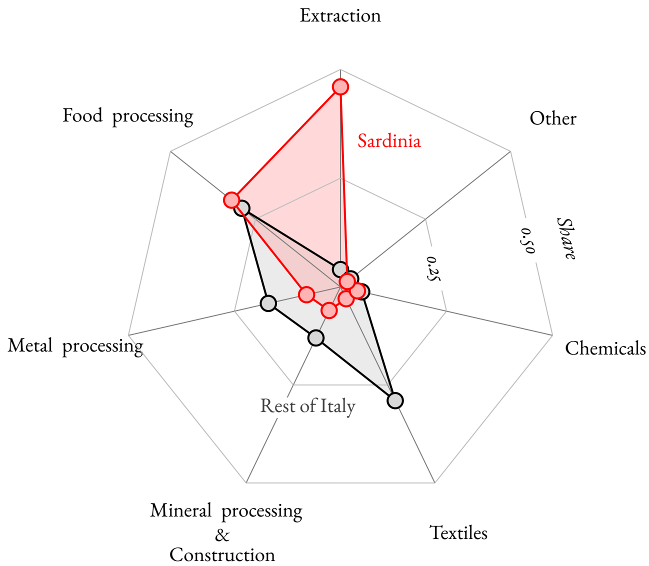

Figure 2: Share of industrial employment by sub-sector in 1911.

Note: Labeling as n_i the number of persons employed in industrial firms operating in sub-sector i, the corresponding sub-sectoral share is $s_i = n_i / \sum_i n_i$. Such shares are here computed separately for Sardinia and the rest of Italy. The data are from Ministero di Agricoltura, industria e commercio (1911). A further description of each sub-sector can be found in Section 3.1.

a productive specificity of Sardinia.[5]

3 Empirical setting and data

In this paper we test whether gaining access to railways in the second half of the 19th century had any effect on the development of manufacturing firms by the beginning of the 20th century. We aim at estimating such a relationship at the municipal level in the context of Sardinia. As anticipated above, this setting presents some advantages due both to the intrinsic conditions of a remote

[5]A similar profile emerges also when using value added data from Ciccarelli and Fenoaltea (2009), although industrial sub-sectors are there classified in a different way. Using that data to compare 1911 to previous years also shows that the productive specialization of Sardinia with respect to Italy has remained relatively stable over the time period 1861–1911. In parallel, the industrial census data reported by Ministero di Agricoltura, industria e commercio (1911) allow also to construct a proxy of mechanization looking at horsepower intensity across industries: again, while production seemed generally less mechanized in Sardinia relative to the rest of Italy, extractive activities represented a clear exception. See also Chilosi and Ciccarelli (2022) and Basile and Ciccarelli (2018) for further discussions about the evolution of sectoral composition before and after unification.

island and to the specificities of Sardinia. On the one hand, focusing on an island located about 200 kilometers away from the mainland shields from the spatial spillovers of neighboring regions, while also generally ensuring a greater institutional homogeneity. On the other hand, Sardinia in particular did not witness any significant development in other types of transport network over the time period at stake, while also being characterized by a relatively large internal morphological variety that could help the external validity of our results. These characteristics make Sardinia a more controlled environment, which can prove useful to establish a causal relationship between railway access and industrial development. Moreover, following key insights from the empirical literature on the effects of early railways, we believe that using municipalities as a granular unit of analysis is paramount to better capture local effects as well as to further limit the role of omitted variables by controlling for strictly local confounding factors.

To empirically analyze our relation of interest, we face a constraint related to the availability of data on industrial firms. In Italy, the first available census with systematic data at the municipal level was in 1911. Consequently, in our aim to estimate the medium term impact of railways, we need to rely on a model specification for cross-sectional data at the municipal level. Namely,

$$Y_{m,1911} = \alpha + \beta RailAccess_{m,1871-1898} + X_m\gamma + \epsilon_m \ , \tag{1}$$

where Y is one of the alternative outcome measures about industrial firms in municipality m as observed in 1911, railway access is proxied by the dummy variable $RailAccess$ taking value 1 if municipality m hosts a railway station that opened between 1871–1898 and 0 otherwise, and finally X is a set of controls at the municipality level and district fixed effects. These different sets of variables are presented and discussed in Sections 3.1, 3.2, and 3.3.

3.1 Industrial firms

A first operational choice is related to the measurement of our outcome variables concerning the structure of manufacturing by municipality. To this end, we digitize data from the 1911 Italian census of industrial firms run by the Ministero di Agricoltura, industria e commercio (1911). This census contains information at the municipal level about the number of firms and the number of employed persons for the industrial sector as a whole (*Total*), and for seven sub-sectors, namely: firms in the extractive sector (*Extractive*); firms that process and use agricultural, hunting and fishing products (*Food*); firms that process and use metals (*Metals*); firms that process and use minerals, or are active in building, road and hydraulic constructions (*Minerals & Construction*); firms that process and use textile fibers (*Textiles*); firms in the chemical sector (*Chemicals*); firms in industries and services for collective and general needs (*Other*).

It is important to note that these data, while collected during a census, do not encompass the entirety of manufacturing firms. Rather, they include those firms that operated from a location distinct from the owner's residence and employed more than one person (see Fenoaltea, 2007).[6] As shown in the summary statistics reported in Table 1, about 36% of the municipalities do not host any industrial firm as defined in the census: this is unsurprising given the limited economic development of Sardinia at the beginning of the 20th century.[7] The most diffused industrial sub-sector was *Food* (about 60% of the municipalities have at least one firm in this sector), followed by *Metals* (in about 42% of the municipalities), *Textiles* (in about 19% of the municipalities), *Chemicals* (in about 15% of the municipalities), *Mineral & Construction* (in about 12% of the municipalities), *Extractive* (in about 8% of the municipalities), and *Others* (in about 4% of the municipalities).

3.2 Access to the railway network

In setting our empirical analyses, a second operational decision consists in choosing a suitable proxy to disentangle municipalities that are exposed to the influence of railway development from those that are not (or at least less so). In the economic history literature, there are two broad categories of approaches on this point. The first approach is based on the estimation of general equilibrium effects. In this view, the construction of railroads generates a heterogeneous variation in market access for the territorial units under analysis (see, among others, Donaldson and Hornbeck, 2016, Fenske et al., 2022). It follows that the effects of railroads are backed up by estimating the impact of these changes in market access on the outcome variables of interest. A second approach, instead, consists in estimating local treatment effects. In this view, the impact of railroads is captured by a variable representing the distance of the territorial unit from the railway network (see, among others, Berger, 2019, Bogart et al., 2022, Bonfatti et al., 2021, Büchel and Kyburz, 2020, Hornung, 2015). Such a variable can also be dichotomized to distinguish between municipalities that have access to the railway network and those that do not.

We adopt this second type of approach. In particular, our main independent variable of interest is a dummy (*Station*), which takes the value 1 in those municipalities hosting at least one railway station that opened to traffic between 1871 and 1898, and value 0 otherwise. We digitize this variable using information about the geographical coordinates of all stations and their opening days as reported on Wikipedia.[8]

[6] This aspect will receive special consideration when interpreting the results. In particular, in Section 4.1 we show that the probability to encounter a firm in our sample does not differ between locations with and without a railway station.

[7] Within the old northern and southern provinces of Sardinia, the latter has about 43% of the municipalities which do not display any firm in the industrial sector, while the former about 18% of the municipalities.

[8] Notice that: (i) we double-checked the information about the opening days and names of all stations

Out of the 361 municipalities in our sample, 98 (27.15%) have received at least one station over the time period of interest (i.e. $Station = 1$). Within this subset, 64 municipalities with a railway station are located in the old province of Cagliari (i.e., in the southern part of the island), while the remaining 34 are placed in the old province of Sassari (i.e., in the northern part of the island). In about 30% of these 98 municipalities, a station was opened during the 1870s, while in about 47% of them during the 1880s, and in the remaining 22% during the 1890s. The staggered openings of railway stations are due to the different timing in the construction of railway trunks across the various areas of the island, thus making municipalities heterogeneously exposed to the effects of railways. In Section 6.3, we bring evidence and further discuss the heterogeneity between railways trunks constructed in different periods and with different gauge widths. In any case, only a handful of minor stations in our sample were opened with some delay relative to the opening of the trunk to which they pertain. This is reassuring as it rules out the possibility of strategic openings after that could occur after having observed the effects of railways on other municipalities.

3.3 Control variables

To reduce misinterpretation of the estimated associations between the presence of a railway station and the presence of industrial activities, as a first approach, we include in the model specification a large set of control variables. These variables represent potential confounding factors and underlying characteristics of the municipalities that might influence both the dependent variable and the presence of a railway station. By and large, our control variables can be classified as capturing geographic features, natural resource endowments, and population characteristics.

For what concerns geographic features, we consider the following control variables at municipality level. First, we consider surface size, as larger municipalities could have a higher probability to receive a station or to host industrial firms. Second, we include a dummy variable taking value 1 if the municipality is located along the coast and 0 otherwise, since coastal municipalities could have a different probability of receiving stations and industrial firms as well as ports. Third, we control for the altitude and ruggedness of the municipality, to account for further residual and unobserved geographical factors. These measures are all obtained from the digital terrain model of Sardinia (see Sardegna Geoportale). Fourth, we consider a variable indicating the distance between the main town or village in the municipality and the closest terminal of a railway trunk.[9]

For what concerns natural resource endowments, we consider the following control variables at municipal level. First, we include a dummy variable indicating whether the municipality hosted

with Altara (1992); (ii) we also double-checked that the geographical coordinates in Wikipedia match the geo-referenced railway trunks from Ciccarelli and Groote (2017, 2018).

[9]See Section 5.2 for a discussion on this variable.

some mining site over the period 1861–1911. Detailed information including the geo-referenced location and the year of opening of each historical mining site is taken from the Italian Institute for Environmental Protection and Research (ISPRA). As already discussed in Section 2, controlling for the presence of mines is key, given the importance of the extractive sector in Sardinia during the period of analysis. Moreover, mines could be correlated both with the presence of railways and with the development of an industrial sector. Second, following Berger (2019), we also include two control variables measuring the percentage of municipal soil that is classified as at least very suitable for two representative crops such as barley and citrus. Data on land suitability by crop is taken from FAO-IAASA.[10] Relatedly, we use data from EEA-Copernicus to measure the percentage of municipal soil covered by forests.[11] On the one hand, these variables aim at capturing direct links between soil suitability and the diffusion of some industrial sectors such as, for instance, manufacturing firms that process agricultural or forestry products. On the other hand, information about crop suitability serves also to control for potential differences between municipalities with and without railway access, in case any selection bias were to emerge indicating, for instance, that railway stations were more likely in municipalities with a higher crop productivity.

Finally, population characteristics could also play a confounding role and thus need to be controlled for along several different dimensions. First, we use census data from ISTAT[a] to control for population size in 1861, that is before the arrival of railways in Sardinia. Second, we include the number of pupils per capita enrolled in school in 1862–1863 as an (imperfect) proxy for the average level of education by municipality in the following decades. The data on the number of pupils by municipality is taken from Statistiche del Regno d'Italia (1865).[12] Third, we include a dummy variable indicating whether a municipality is the capital of one of the nine *circondari* that represented the old administrative districts of Sardinia, so as to capture the particular centrality of these municipalities in the territorial hierarchy of the region. Relatedly, we also include administrative district fixed effects to exploit within-district variability.

[10] Notice that we have tried to use the suitability class also for other crops such as rye and wheat, but they are highly correlated with barley. For this reason, in our regressions we use only barley and citrus.

[11] Beccu (2000) points out that forest coverage did not diminish in Sardinia between the 19th and 20th century, despite temporary increases in the demand for wood. In fact, the development of forest management practices—combined with the fact that trees targeted for cutting belonged to polliniferous species—typically sufficed to compensate for the relatively higher exploitation of forests that occurred during periods of higher demand. For this reason, 19th-century "forest areas in Sardinia [...] were the same that still characterize the island to the present day" (Beccu, 2000, p. 392).

[12] Taking these variables before the construction of railways—rather than contemporaneously—ensures some degree of exogeneity; however, it is important to bear in mind that these measures do not capture future migration of the population.

Table 1: Summary statistics

Variable	Municipalities (N)	Mean	50th percentile	SD
	Dependent variables (by sector)			
	Total			
At least one firm (dummy)	361	0.643	1.000	0.480
Number of firms	232	16.884	8.000	34.150
Employed persons	232	136.720	29.500	569.245
	Extraction			
At least one firm (dummy)	361	0.083	0.000	0.276
Number of firms	30	3.433	1.500	4.861
Employed persons	30	490.967	65.000	1250.095
	Food			
At least one firm (dummy)	361	0.598	1.000	0.491
Number of firms	216	11.560	6.000	21.688
Employed persons	216	46.620	19.500	138.437
	Metals			
At least one firm (dummy)	361	0.427	0.000	0.495
Number of firms	154	4.649	3.000	7.590
Employed persons	154	15.143	6.000	59.302
	Minerals & Construction			
At least one firm (dummy)	361	0.119	0.000	0.324
Number of firms	43	4.535	3.000	6.367
Employed persons	43	42.465	10.000	84.961
	Textiles			
At least one firm (dummy)	361	0.186	0.000	0.389
Number of firms	67	3.746	2.000	4.106
Employed persons	67	14.284	7.000	24.558
	Chemicals			
At least one firm (dummy)	361	0.147	0.000	0.354
Number of firms	53	2.189	1.000	2.001
Employed persons	53	23.094	6.000	103.026
	Other			
At least one firm (dummy)	361	0.039	0.000	0.193
Number of firms	14	2.786	1.000	3.534
Employed persons	14	41.500	12.000	71.394
	Treatment			
Station (dummy)	361	0.271	0.000	0.445
	Main instrument			
Distance from LCP	361	9.255	7.348	8.300
	Control variables			
Mine (dummy)	361	0.108	0.000	0.311
1861 Population	361	1,614	1,113	2,370
District capital (dummy)	361	0.025	0.000	0.156
Area	361	66.432	40.720	81.580
Coast (dummy)	361	0.158	0.000	0.365
Altitude	361	283.648	248.000	227.805
Ruggedness	361	33.558	29.850	23.813
Share of citrus soil	361	0.085	0.000	0.203
Share of forest soil	361	0.048	0.011	0.078
Share of barley soil	361	0.208	0.000	0.323
1862 pupils per capita	354	0.039	0.032	0.030
Distance from endpoint	361	16.890	16.644	9.056

4 OLS estimates

4.1 Diffusion and observation of industrial firms

As previously discussed, the 1911 industrial census does not report firms that employ less than two persons and firms located at the exact same residential address as the owner. Therefore, in order to proceed with our empirical analysis, we first need to test whether the municipalities with direct access to the railway network had a different probability of being reported in the census of industrial firms (i.e., a different probability of hosting firms with the aforementioned characteristics). To this end, we estimate the following model specification:

$$D_{m,1911} = \alpha + \beta Station_{m,1871-1898} + X_m\gamma + \epsilon_m \quad (2)$$

where D_m is a dummy variable equal to 1 if at least some industrial activity is present in the municipality m, and 0 otherwise. First, we build this variable for the total industrial sector and we estimate the model specification to test whether the presence of a station during the last three decades of the 19th century is associated with the presence of industrial activities of any type in 1911. Then, we separately build the dummy variable for each of the sub-sectors to test whether the presence of the station is associated with some specific industrial activity. In other words, we look at whether having direct access to a railway station favored the diffusion of industrial firms at the municipality level.

In Table 2, we report estimates for the linear probability model specified in equation 2. Conditional on the set of municipal level controls and district fixed effects, results indicate that, on average, municipalities that received a station between 1871–1898 do not have a higher future probability of hosting at least one industrial firm in 1911. This evidence holds both when firms are considered jointly (column 1) and when the various sub-sectors are assessed separately (columns 3 to 8), with the partial exception of the extractive sector (column 2).

We check whether these preliminary OLS estimates are robust to alternative estimators. Tables A1 and A2 in the Appendix report estimates obtained with Probit and Logit regressions respectively. These additional results confirm that receiving a railway station between 1871–1898 is not associated with the future probability of hosting at least one industrial firm in the municipality. Besides extractive activities, other partial exceptions are represented by the positive but weakly significant coefficients of the dummy $Station$ for presence of chemicals and mineral processing industries.

As discussed below, these industries, together with textiles and others, will be removed from the rest of our analysis. The main reason to do so is that the census reports firms in these sectors

Table 2: Diffusion of industrial firms

Dependent	At least one firm = 1							
Sector	Total	Extractive	Food	Minerals & Construction	Metals	Textiles	Chemicals	Other
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station	0.061	0.056*	0.020	0.069	0.089	0.015	0.064	0.019
	(0.061)	(0.034)	(0.064)	(0.047)	(0.065)	(0.052)	(0.048)	(0.019)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	354	354	354	354	354	354	354	354
R-squared	0.272	0.344	0.234	0.247	0.263	0.238	0.258	0.537

OLS estimates. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

as being present only in less than 20% of all municipalities. This does not leave enough degrees of freedom in estimating the model specification, given the large (and necessary) set of covariates.[13]

4.2 Intensity of industrial firms and railway access

After having tested the relationship between the presence of a station and the future geographical diffusion of industrial activities, we also test the intensive margins of the relationship. In particular, we estimate the following model specification:

$$y_m = \alpha + \beta Station_m + X_m\gamma + \epsilon_m \quad (3)$$

where y_m represents the number of industrial firms or, alternatively, the number of persons employed in industrial firms located in municipality m in 1911, for those municipalities that have at least some industrial activity. Here $Station$ is again a dummy variable taking value 1 for municipalities that received at least one railway station between 1871–1898, and 0 otherwise. On the side of controls, X_m includes the same set of variables described above. Also in this case we estimate equation (3) using considering the dependent variable both for the industrial sector as a whole and, separately, for each sub-sector.[14]

The estimates reported in Table 3 are obtained through OLS estimation of equation 3, which contains the set of municipality-level covariates and district fixed effects. The estimated coefficient of the dummy $Station$ is positive but barely significant when we consider the overall number of industrial firms at municipal level (column 1), while it is positive and statistically significant at the 5% level when estimated specifically for firm operating in food processing activities (column 2). Instead, the corresponding coefficient is positive but not statistically significant when estimated for firms operating in metal processing activities.

We then turn to the effects of direct railway access on the number of employed persons, and we obtain similar but more statistically robust results. The coefficient associated with the dummy $Station$ is again positive and statistically significant when looking at the industrial sector as a

[13]Nonetheless, for the sake of completeness, the Appendix reports also the results for these less-diffused industries obtained with different estimators but removing district fixed effects.

[14]Variables related to the number of firms and the number of employed persons have some peculiarities that are worth noting (see Table 1). In fact, these are counting variables with skewed distributions. For instance, the average number of industrial firms in a municipality is 16, while the median is 8. Similarly, the average number of persons employed in industrial firms by municipality is 137 and the median is 29. These skewed distributions are present also across sub-sectors. For these reasons, in our main analyses based on OLS and IV estimations we take the logarithmic transformation of these variables. Moreover, as anticipated above, we exclude those sub-sectors with industrial activities in an excessively limited number of municipalities, so as to preserve enough degrees of freedom in the estimations.

Table 3: Number of firms and employed persons

Dependent	Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
Station	0.328*	0.364**	0.201	0.536***	0.495***	0.241*
	(0.190)	(0.167)	(0.144)	(0.181)	(0.163)	(0.141)
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	228	212	150	228	212	150
R-squared	0.347	0.397	0.437	0.504	0.488	0.583

OLS estimates. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

whole (column 4) and at food processing activities in particular (column 5). Moreover, also in this case, the coefficient for metal processing industries is positive but weakly statistically significant (column 6).[15]

Taken together, these OLS estimates indicate that the probability to host generic industrial firms a few decades after the completion of the railway network does not significantly differ between municipalities with and without a railway station. However, having a station increases the number of persons employed in food processing activities as well as the number of firms in this sub-sector. In turn, food processing activities represent the largest sub-sector, and therefore they drive the increase in overall industrial employment and firms.

5 IV approach

Although the estimated equations 2 and 3 contain a large set of control variables at municipal level, endogeneity concerns remain an issue. Indeed, omitted variables could drive the relationship between the presence of a railway station and industrial activities. On the one hand, these concerns may be particularly critical in our empirical setting as we estimate a cross-sectional regression model in levels. On the other hand, the historical and geographical specificities related to development of early railways in Sardinia may possibly reduce potential endogeneity concerns regarding their location. In this Section we offer evidence based on 2SLS estimates after having instrumented the presence of a railway station in the municipal territory.

[15]In Table A3 in the Appendix, we report the estimates for the other sub-sectors that are located in only a few municipalities. Estimated coefficients are mostly statistically non-significant.

5.1 Least cost paths

In line with much of the recent literature on the impact of historical railroads, we instrument the access to the railway network via a least cost path (LCP) approach (see, among others, Berger, 2019, Bogart et al., 2022, Bonfatti et al., 2021, Büchel and Kyburz, 2020, Fenske et al., 2022, Yu et al., 2019, Zheng et al., 2022, for some studies that use a similar approach). This method requires to specify a cost surface spanning the region of interest and a set of endpoint pairs. Provided these inputs, the LCP approach consists in connecting each pair of endpoints via a route that minimizes construction costs, so as to generate a hypothetical network linking all the provided endpoints. In general, the cost surface reflects local terrain characteristics such as slope or the presence of water bodies, which get ultimately combined with distance via a cost function. Here we specify the cost function according to the existing literature as "200,000£ per kilometer, 18,000£ additional per degree climbed and 450,000£ per 100 meters of bridge built" (Bonfatti et al., 2021, Appendix A, p. 44).[16] When applied to Sardinia, this function implies an average unit cost of about 716,000£/km on the LCP network and 1,237,000£/km on the actual railway network. Also for what concerns the endpoint pairs to be supplied for LCP identification, we follow the aforementioned literature by using the municipalities identified as trunk terminals in the railway concessions discussed in Section 2 (see also Gazzetta Ufficiale del Regno d'Italia, 1863, 1885). Figure 1 overlays the LCP network we obtain to the the actual railways.

In line with the literature, our main instrumental variable $\log(Distance\ LCP)$ measures the logarithm of the Euclidean distance between the main town in each municipality and its nearest LCP trunk. As we discuss below in greater detail, the basic intuition behind the LCP approach is two-fold. For what concerns the relevance of the instrument, while actual railway paths might deviate due to potentially endogenous factors, they often broadly align with cost-minimizing corridors due to construction technology, which is a characteristic embodied by the LCP. Consequently, the closer a municipality is to a LCP, the higher its likelihood of hosting a station on actual railways. For what concerns the exogeneity of the instrument, as a LCP is designed to connect two trunk endpoints following the most cost-efficient trajectory, it "incidentally" passes through intermediate areas. As such, the distance from a given town to the closest LCP is a byproduct of this incidental intersection and not a reflection of the town's own characteristics. Nonetheless, the empirical conditions that are required to guarantee that the instrument is both relevant and exogenous need further qualification and discussion.

[16] Note that Bonfatti et al. (2021) rely on the parameter estimates by Büchel and Kyburz (2020).

5.2 Relevance of the IV and exclusion restrictions

The use of $Distance\ LCP$ as an instrumental variable for the presence of actual railway stations needs to be empirically disciplined in light of potential shortcomings associated with the use of such instrument.

Table 4: First-stage results

Dependent	Station		
	(1)	(2)	(3)
log(Distance LCP)	-0.298***	-0.285***	-0.295***
	(0.021)	(0.036)	(0.042)
Controls	NO	YES	YES
District FE	NO	NO	YES
Observations	232	228	228
R-squared	0.371	0.412	0.447

OLS estimates
Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

First, we test for instrument relevance by looking at whether $Distance\ LCP$ is actually correlated with the endogenous variable $Station$. Table 4 shows first-stage results. As expected, the coefficient of $Distance\ LCP$ is negative: that is, a smaller distance from the LCP entails a higher probability for a municipality to receive a railway station. Reassuringly, such an association does not change in magnitude and remains statistically significant at the 1% level when we add control variables at municipal level and the set of district fixed effects. Indeed, the LCP explains a large share of station location variability even in the specification without any additional control ($R^2 = 0.37$).[17]

Second, we tackle the issue of instrument exogeneity. Given the just-identified model at stake, we need to rely on the assumption that $Distance\ LCP$ does not influence the industrial structure of a municipality through non-controlled channels. The main problems with this assumption derive from two different sources of potential endogeneity.

On the one hand, $Distance\ LCP$ could violate the exclusions restrictions due to the fact that LCPs tend to be associated with more favorable terrain conditions. For example, while being cost-effective for railway construction, a flat area may also be characterized by more productive land: this could increase local crop yield and thus affect local economic incentives to engage in

[17] In the rest of the paper, when we report second-stage results, we also show the first-stage F-statistics (i.e., the Kleibergen-Paap F statistics).

industrial activities. In order to limit this possible source of violation in instrument validity, we systematically include in all model specifications the set of covariates presented in Section 3.3. These include several geographical and terrain characteristics at municipal level, so as to locally control for the type of channels described above. Additionally, the set of covariates includes also some pre-determined outcomes such as population and education at the beginning of the 1860s.

On the other hand, $Distance\ LCP$ could violate the exclusion restrictions because the endpoints used to construct LCPs are taken as given. In fact, these particular towns could have been selected by policymakers precisely because of some unobserved factors that may ultimately affect also the dependent variables at stake. For example, a certain town or its immediate surroundings could have some unobserved growth potential that ultimately drove policymakers to preferentially connect that particular area to the network instead of others, thus selecting it as an endpoint. Normally, the literature deals with this second possible source of endogeneity by removing from the sample those spatial units that correspond to a trunk terminal and/or some of their neighboring units. Another way to deal with the potentially endogenous endpoints is to include a variable indicating the distance between each municipality and the closer endpoint, assuming that the effects deriving from endpoint selection decay in space. In this case, intermediate spatial units between trunk terminals (or some of their neighbors thereof) can be better regarded as "incidentally" crossed by the corresponding LCP, which is orthogonal to their possible unobserved characteristics. For this reason, we include in all model specifications a variable indicating the distance between each municipality and its closest endpoint. Furthermore, in Section 5.5, we include a robustness check in which municipalities around the endpoints of the railway network are dropped from the estimated sample, so as to further mitigate concerns about possible biases associated with endpoint selection in the LCP approach.

5.3 Reduced-form estimates

Reduced-form estimates are usually a valid starting point to understand the effects of the instruments on the dependent variables of interest. Results can be interpreted as intention-to-treatment effects. Estimates in Table 5 indicate that, once we control for covariates at municipal level and district fixed effects, being closer to a LCP is associated with a higher number of firms and employed persons in the industrial sector as a whole (columns 1 and 4), as well as in sub-sectors food (columns 2 and 5) and metal processing (columns 3 and 6). However, these effects display a weaker statistical significance when looking at the number of firms, as compared to effects estimated for the number of employed persons. These results are in line with the OLS estimates shown in Table 3 and they confirm that exposition to railway access (here captured by the distance from the

LCP) is associated with a higher intensity of industrial activities in the sub-sectors at stake.[18]

Table 5: Reduced form: Number of firms and employed persons

Dependent	Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
log(Distance LCP)	-0.267**	-0.185*	-0.233***	-0.417***	-0.276***	-0.333***
	(0.119)	(0.108)	(0.087)	(0.118)	(0.104)	(0.092)
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	228	212	150	228	212	150
R-squared	0.352	0.391	0.455	0.513	0.482	0.616

OLS estimates. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

5.4 2SLS estimates

Table 6 reports the second-stage results of the 2SLS estimations for the number of firms and employed persons at the level of municipalities. These results are obtained after instrumenting the potentially endogenous dummy $Station$ with the distance of the main town in each municipality from its nearest LCP trunk, that is $Distance\ LCP$ as discussed above. The first-stage F-statistics is larger than 10 in any model specification, thus indicating that the instrument is not weak. The signs and statistical significance of the estimated coefficients for $Station$ are in line with those obtained with OLS: municipalities with direct access to the railway network have a more firms and persons employed in the industrial sector as a whole and in sub-sectors food and metal processing.[19]

[18] In the Appendix, in Table A4, we report reduced-form estimates for the presence of industrial firms in our sample. Reassuringly, and in line with evidence shown in Section 4.1, estimates indicate the absence of selection in firm presence induced by distance from the LCP. In Table A5, we also report reduced form estimates for the other sectors.

[19] The magnitudes of the coefficients for $Station$ estimated with 2SLS are larger than those obtained with OLS. This is a typical finding in the empirical literature on the effects of early railways. A possible—and often used—argument for the downward bias of OLS estimates rests on the possibility of redistributive motives: namely, relatively disadvantaged areas may have been a preferential target for railway location. See Berger (2019), Bonfatti et al. (2021) for recent discussions.

Table 6: 2SLS: Number of firms and employed persons

Dependent	Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
Station	0.905**	0.641*	0.865***	1.412***	0.958***	1.237***
	(0.388)	(0.353)	(0.332)	(0.381)	(0.344)	(0.383)
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	228	212	150	228	212	150
R-squared	0.285	0.344	0.287	0.395	0.427	0.371
F-stat first stage	50.21	42.38	23.62	50.21	42.38	23.62

2SLS estimates. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

5.5 Robustness checks

We conduct two robustness checks that are meant to test the stability of our 2SLS results.

First, as discussed in Section 5.2, a possible source of concerns about the exogeneity of LCPs is related to the endogenous selection of trunk terminals. These endpoints contribute to define both the actual and the hypothetical railway network deriving from LCPs. In all model specifications, we include a variable measuring the distance from each municipality to the nearest endpoint, so as to capture the influence of potentially endogenous endpoints. As suggested in the related literature, another way to deal with these concerns is to exclude from the analyzed sample those observations that are related to the endpoints. We follow Bogart et al. (2022) in excluding from our sample those municipalities within 7 kilometers from the endpoints.[20] The resulting 2SLS estimates are reported in Table 7 and they are in line with those of the main analysis, although the estimated coefficients are now smaller than their counterparts in Table 6 while still being larger than OLS estimates in Table 3.

Second, we use a dummy that indicates whether a municipality is crossed by a LCP as an alternative instrument for the actual presence of railway stations. With respect to the distance from the nearest LCP, this alternative instrument has at least two possible shortcoming that make it somewhat less appealing. Nonetheless, some of the related results it delivers are still worth of dis-

[20] Bogart et al. (2022) apply this criterion in the context of early railways in England. Notice that it might be difficult to define a priori the areas that may potentially bear stronger relations with the endpoints, as intermediate municipalities could form coalitions with candidate endpoints in order to jointly attract a railway line in some territory. For a treatment of the role of coalitions between locations, see, for instance, Bogart (2018).

Table 7: Excluding an area of 7 km around LCP endpoints: 2SLS - Number of firms and employed persons

Dependent	Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
Station	0.986**	0.632*	0.777**	1.178***	0.780**	0.791**
	(0.411)	(0.369)	(0.331)	(0.370)	(0.352)	(0.340)
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	192	178	124	192	178	124
R-squared	0.244	0.297	0.151	0.374	0.335	0.300
F-stat first stage	37.97	33.91	22.14	37.97	33.91	22.14

2SLS estimates. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

cussion. This alternative instrument has both general and specific limitations. On the one hand, being exactly on the LCP may generally make it harder to interpret the location of municipalities as fully "incidental". In fact, for unobserved reasons, municipalities could influence the choice of the endpoints and, in turn, define the LCP (see Gragnolati and Moretti, 2023). On the other hand, in the specific case of Sardinia, LCPs are very close to the actual railway network and about 80% of the municipalities with a station are also on a LCP. Despite such limitations, 2SLS estimates based on this alternative instrument suggest that municipalities with a railway station tend indeed to display a greater intensity in industrial activities, but this effect unfolds primarily via more employment in industrial firms rather than through their numerosity. In particular, this result holds both when looking at the industrial sector as a whole and when separately considering the food and metal processing sub-sectors. The corresponding estimates are reported in the Appendix in Table A6.

6 Discussion

To further qualify and interpret the main results obtained above, here we offer additional evidence based on alternative outcome variables in Section 6.1 and a discussion on possible heterogeneity in the effects in Sections 6.2–6.3.

6.1 Alternative outcomes

The estimates presented thus far suggest that both the number of firms and persons employed in the industrial sector are positively affected by having direct access to the railway network at the level of municipalities. However, the effects on industrial employment could generally be the result of different underlying components. First, industrial employment may be higher in municipalities with direct access to the railway network as a mere consequence of the fact that the number of industrial firms is higher there. Second, industrial employment may be higher because the average size of industrial firms is larger in municipalities with direct access to the railway network, other things being equal. Third, industrial employment may be higher where there is direct local access to the railway network because in such municipalities relatively more employment tends to engage in industrial activities as opposed to other types of economic activities. In order to gauge the relative importance of these different underlying components, we estimate two further specifications of equation 3. Coherently with the rest of the paper, we run such estimations for the industrial sector as a whole and for the separate sub-sectors.

First, we adopt as a dependent variable the average size of industrial firms by municipality in 1911. This variable is built as the number of employed persons over the number of industrial firms in a municipality. The related estimates indicate that, in general, municipalities with a station are associated to a larger average firm size relative to those without direct access to the railway network. However, these estimates are barely statistically significant for the industrial sector as a whole, while statistical significance is entirely lost for food and metal processing sub-sectors (see columns 1 to 3 in Table 8).

Second, we adopt as a dependent variable the population share employed in the industrial sector in 1911. This variable is defined a ratio between the number of persons employed in the industrial sector or sub-sectors and the population in each municipality. Estimates indicate that such a ratio tends to be higher in municipalities with a station as compared to municipalities that do not have direct access to the railway network. The related coefficients display a statistical significance below 5% both in the industrial sector as a whole and in the food and metal processing sub-sectors (see columns 4 to 6 in Table 8). As a remark, given that the 1911 industrial census did not report all firms and persons operating in the industry, this evidence should be interpreted with some caution.[21]

[21] To deal with possible concerns about the role of individual and domestic manufacturing activities that are not observed in the 1911 industrial census, we show in the Appendix, in Table A8, that municipalities with a railway station are not associated with a significantly different number and intensity in the use of domestic weaving looms in 1886. These data contain a finer detail at the municipality level for the province of Cagliari (see Ministero di Agricoltura, industria e commercio, 1887).

Table 8: 2SLS: Average firm size and share of employed persons over population

Dependent	Average firm size			Share of employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
Station	8.710*	0.859	0.930	0.022***	0.007**	0.004**
	(4.704)	(1.069)	(0.835)	(0.008)	(0.003)	(0.002)
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	228	212	150	228	212	150
F-stat first stage	50.21	42.38	23.62	50.21	42.38	23.62

2SLS estimates. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

6.2 The role of soil suitability and mines

A somehow obvious question is whether the evidence we find about the positive relationship between the presence of a railway station and the intensity of industrial activities is conditional on the availability of natural resources at the local level. While our set of covariates allow us to compare, to some extent, the effect of railway access for a variety of local characteristics, here we ask in particular whether having a railway station spurs industrial activities especially in those municipalities that are richer in natural resources. As discussed in Section 2, the economy of Sardinia relied especially heavily on natural resources to define its productive specialization of Sardinian in the early 20th century, and this also a distinguishing feature of several contemporary developing economies. In general terms, while an improved regional transportation network can be expected to lower the final price of raw materials by lowering their transportation cost, it is not obvious a priori whether this should increase the chance that locations with a higher endowment of natural resources will also be characterized by a higher intensity of other industrial activities. For instance, lower transport costs may soften spatial constraints in the location of downstream industrial activities that use raw materials as inputs.

Table 9: OLS: Number of firms and employed persons

Dependent	Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A			
Station	0.290	0.307*	0.105	0.500**	0.494***	0.175
	(0.202)	(0.180)	(0.163)	(0.199)	(0.180)	(0.156)
Citrus	-0.794	-0.746	-0.294	-1.011**	-0.751	-0.083
	(0.524)	(0.524)	(0.532)	(0.509)	(0.505)	(0.472)
Station × Citrus	0.450	0.670	1.186*	0.420	0.018	0.813
	(0.772)	(0.614)	(0.664)	(0.793)	(0.612)	(0.778)
R-squared	0.348	0.399	0.447	0.505	0.488	0.587
			Panel B			
Station	0.429**	0.338*	0.151	0.636***	0.555***	0.260
	(0.208)	(0.183)	(0.162)	(0.202)	(0.182)	(0.164)
Forest	0.860	0.584	0.815	0.951	1.323	0.926
	(1.274)	(1.142)	(0.922)	(1.181)	(1.129)	(0.791)
Station × Forest	-3.060	0.892	1.653	-3.051*	-2.013	-0.646
	(2.567)	(2.189)	(1.815)	(1.797)	(2.080)	(1.734)
R-squared	0.352	0.397	0.440	0.508	0.490	0.583
			Panel C			
Station	0.266	0.302	0.131	0.563***	0.562***	0.225
	(0.213)	(0.191)	(0.174)	(0.215)	(0.195)	(0.163)
Barley	0.274	0.167	-0.105	0.726	0.604	-0.007
	(0.427)	(0.445)	(0.392)	(0.447)	(0.403)	(0.389)
Station × Barley	0.362	0.354	0.363	-0.159	-0.381	0.079
	(0.540)	(0.460)	(0.405)	(0.536)	(0.448)	(0.417)
R-squared	0.348	0.398	0.440	0.504	0.489	0.583
			Panel D			
Station	0.368*	0.358**	0.199	0.544***	0.498***	0.244*
	(0.192)	(0.169)	(0.145)	(0.190)	(0.166)	(0.143)
Mines	-0.060	-0.186	0.435	1.163***	0.119	0.539**
	(0.297)	(0.305)	(0.324)	(0.319)	(0.319)	(0.264)
Station × Mines	-0.528	0.164	0.037	-0.105	-0.059	-0.090
	(0.485)	(0.478)	(0.425)	(0.478)	(0.394)	(0.359)
R-squared	0.350	0.397	0.437	0.504	0.488	0.583
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	228	212	150	228	212	150

OLS estimates. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

In Table 9, we show estimates that illustrate whether the number of firms and persons employed in the industrial sector in 1911 was indeed affected by the interaction between the dummy $Station$ and a municipality's *(i)* soil suitability for some representative crops (Panels A and C), *(ii)* forest coverage (Panel B), or *(iii)* presence of mines (Panel D).[22] Estimation results suggest that the effects of direct access to the railway network are not driven by the local availability of natural resources. While it could be difficult to imagine how the joint presence of a station and abundance of some specific natural resources could affect industrial activities in some sectors (e.g., it is hard to imagine that the presence of mine could directly condition the effects of the railway access on industrial firms related to the transformation of agricultural products/food), the evidence is particularly telling for the overall intensity of the industrial activities (columns 1 and 4). Other revealing interactions are those which relate crop suitability and forest coverage to the intensity of industrial activities involving the processing of agricultural and forestry products (columns 2 and 5): again, estimates suggest that the local endowment of favorable soil for crops and forests was not a channel through which railway development affected the local intensity of industrial activities.

6.3 The role of main and secondary railway lines

Another potential conditioning factor that could have shaped the effects of railway access on local industrial activity is the specific technology with which different railway trunks were build and, relatedly, the varying market potential of the areas they covered. Specifically, as detailed in Section 2, railway trunks were built with different gauge widths depending on whether belonged to primary or secondary lines. In turn, primary lines built with standard gauge rails connected the two main cities on the island as well as the major ports, while secondary lines built with narrow gauge rails connected smaller towns and villages. In this sense, primary lines generally had more market potential relative to secondary lines. Here we test whether the overall average effects of railway access on the intensity of industrial activities are indeed related to the different gauge widths with which primary and secondary lines were built.

Table 10 shows estimates comparing the effects of railway stations on the intensity of industrial activities according depending on the type of gauge width for the corresponding railway lines. Estimates in columns 1 to 6 are based on the full sample of municipalities and show that the effects of a railway station on the local intensity of industrial activities are positive and statistically

[22] We report these interactions estimated via OLS instead of 2SLS to limit concerns about the risk of violating monotonicity in the interaction involving the instrument. In the Appendix, in Table A7, we report estimates of the interactions in a reduced form approach, using distance from the nearest LCP as instrument. Estimation results are similar across these various specifications.

significant only for municipalities that have direct access to standard gauge railways, that is to the primary lines of Sardinia.

To further test the robustness of these results, in columns 7 to 12 (13 to 18), we focus on the effects of a station along the standard (narrow) gauge trunks, excluding from the sample those municipalities located along the narrow (standard) trunks, so as to limit possible spillovers between primary and secondary lines. These estimates confirm that having direct access to standard gauge trunks that compose the primary railway lines of Sardinia is indeed associated to a higher local intensity of industrial activities. In particular, these coefficient estimates have an especially strong statistical significance for industrial activities in the food sub-sector, while still being positive and significant at 5% level also for the metal processing sub-sector.[23]

Overall, these results suggest that having access to secondary narrow gauge railways did not lead municipalities to obtain a boost in intensity of their industrial activities relative to similar unconnected areas. This result may possibly derive from the fact that freight or passengers from small towns and villages located along secondary railways had first to reach a station where they could connect to the primary line, then switch from narrow to standard gauge carts, and finally reach the larger markets that were accessible via primary lines. In this sense, having a station on the secondary line generally entailed higher transportation costs to access the same market size that could be reached via primary lines. By contrast, gaining direct access to primary standard gauge railways entailed a positive effect on the local intensity of industrial activities.

As a remark, these results have potentially useful implications for some historical and political debates that have emerged over time as railways developed. In particular, those areas that were historically excluded from having easy access to railway lines have often lamented the negative consequences of such a political choice on local path of economic growth. However, while focused on the specific context of Sardinia at the turn of the 19th century, the evidence we provide here suggests that having direct access to secondary lines did not automatically contribute per se to favor the development of industrial activities.

7 Conclusion

This paper presents estimates on the local effects of direct access to early railways on the diffusion and intensity of industrial activities. We focus on the case study of the isolated economy

[23]Notice that in the Appendix, in Table A9, we show that the presence of railway stations along standard or narrow gauge trunks is not related to the different diffusion of industrial activities. Moreover, in Tables A10 and A11, we show 2SLS estimates that confirm how the positive effects of stations on the local intensity of industrial activities are specifically associated to standard gauge trunks only.

of Sardinia, which facilitates the control of the experimental setting. Namely, at the turn of the 19th century, Sardinia was characterized by a simple economy without any other type of modern transport infrastructures, an approximately constant road network, and virtually without spillovers from neighboring regions. Estimates at the municipal level indicate that railways did not contribute to the further geographical diffusion of industrial firms, but they increased the number of firms and persons employed in the industrial sector. This effect was particularly clear in the sub-sector of food processing, which represented a large share of the total industrial sector. The same type of effects were also present in the sub-sector of metal processing, but they were less statistically robust.

The cross-sectional evidence presented in the paper is robust to the inclusion of control variables and fixed effects, as well as to the use of an instrumental variable approach. Moreover, we find heterogeneity in the types of rail gauge widths that characterized primary and secondary lines in Sardinia: the positive effects induced by railway development are particularly strong in locations having direct access to the main railway line with standard gauge rails, while the effects of secondary narrow gauge lines do not find similar empirical support.

Table 10: Standard vs Narrow gauges: Number of firms and employed persons

Sample							10 km away from narrow gauge						10 km away from Standard gauge					
Dependent	Log of Number of firms			Log of Employed persons			Log of Number of firms			Log of Employed persons			Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals	Total	Food	Metals	Total	Food	Metals	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Standard	0.433*	0.606***	0.394***	0.616***	0.668***	0.443***	0.503*	0.669***	0.521**	0.550**	0.701***	0.439**						
	(0.224)	(0.175)	(0.145)	(0.219)	(0.162)	(0.168)	(0.296)	(0.229)	(0.204)	(0.265)	(0.189)	(0.199)						
Narrow	0.095	0.065	-0.136	0.277	0.226	0.029							0.144	-0.013	-0.080	0.322	0.203	0.064
	(0.223)	(0.207)	(0.181)	(0.232)	(0.217)	(0.179)							(0.255)	(0.231)	(0.219)	(0.249)	(0.239)	(0.196)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	228	212	150	228	212	150	147	135	92	147	135	92	163	153	107	163	153	107
R-squared	0.348	0.407	0.454	0.503	0.493	0.596	0.350	0.416	0.395	0.553	0.532	0.565	0.351	0.358	0.385	0.478	0.422	0.471

OLS estimates. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

References

E. Altara. *Binari a Golfo Aranci: Ferrovie e treni in Sardegna dal 1874 ad oggi*. Ermanno Albertelli Editore, Parma, 1992.

J. Atack, F. Bateman, M. Haines, and R.A. Margo. Did railroads induce or follow economic growth? Urbanization and population growth in the American Midwest, 1850–1860. *Social Science History*, 34(2):171–197, 2010.

R. Basile and C. Ciccarelli. The location of the Italian manufacturing industry, 1871–1911: a sectoral analysis. *Journal of Economic Geography*, 18(3):627–661, 2018.

R. Basile, C. Ciccarelli, and P. Groote. The legacy of literacy: evidence from Italian regions. *Regional Studies*, 56(5):794–807, 2022.

E. Beccu. *Tra cronaca e storia le vicende del patrimonio boschivo della Sardegna*. Carlo Delfino editore, Sassari, 2000.

T. Berger. Railroads and rural industrialization: Evidence from a historical policy experiment. *Explorations in Economic History*, 74:101277, 2019.

D. Bogart. Party connections, interest groups and the slow diffusion of infrastructure: Evidence from Britain's first transport revolution. *Economic Journal*, 128(609):541–575, 2018.

D. Bogart, X. You, E.J. Alvarez-Palau, M. Satchell, and L. Shaw-Taylor. Railways, divergence, and structural change in 19th century England and Wales. *Journal of Urban Economics*, 128:103390, 2022.

R. Bonfatti, G. Facchini, A. Tarasov, GL. Tedeschi, and C. Testa. Pork, infrastructure and growth: Evidence from the Italian railway expansion, 2021. CEPR Discussion Paper No. DP16462.

R. Bonfatti, G. Facchini, A. Tarasov, GL. Tedeschi, and C. Testa. The Baccarini Law Railways (1880-1890): Their Long-Run Sectoral Economic Impact. *Rivista di Storia Economica*, XXXVIII:233–261, 2022.

K. Büchel and S. Kyburz. Fast track to growth? Railway access, population growth and local displacement in 19th century Switzerland. *Journal of Economic Geography*, 20(1):155–195, 2020.

C.B. Cavour. *Des chemins de fer en Italie*. Plon Frères, Paris, 1846.

D. Chilosi and C. Ciccarelli. Evolving gaps: Occupational structure in southern and northern Italy, 1400–1861. *Economic History Review*, 75(4):1349–1378, 2022.

C. Ciccarelli and S. Fenoaltea. *La produzione industriale delle regioni d'Italia, 1861-1913: una ricostruzione quantitativa*. Banca d'Italia, Rome, 2009.

C. Ciccarelli and P. Groote. Railway endowment in Italy's provinces, 1839-1913. *Rivista di Storica Economica*, 1:45–88, 2017.

C. Ciccarelli and P. Groote. The spread of railroads in Italian provinces: a GIS approach. *Scienze Regionali - Italian Journal of Regional Science*, 2:189–224, 2018.

C. Ciccarelli, C. Magazzino, and E. Marcucci. Early Development of Italian Railways and Industrial Growth: A Regional Analysis. *Research in Transportation Economics*, 88:100916, 2021.

D. Donaldson and R. Hornbeck. Railroads and American economic growth: A "market access" approach. *Quarterly Journal of Economics*, 131(2):799–858, 2016.

EEA-Copernicus. European Environment Agency, Copernicus Land Monitoring Service. Corine Land Cover, 1990. URL https://rb.gy/szjy5. Last consulted on September 28, 2022.

FAO-IIASA. Food and Agriculture Organization of the United Nations and International Institute for Applied Systems Analysis. Global Agro Ecological Zones version 4 (GAEZ v4). URL http://www.fao.org/gaez/. Downloaded and last consulted on April, 1, 2023 from https://gaez.fao.org/pages/data-viewer-theme-4.

S. Fenoaltea. I due fallimenti della storia economica: il periodo post-unitario. *Rivista di politica economica*, 97(3/4):341–358, 2007.

J. Fenske, N. Kala, and J. Wei. Railways and cities in India. *Journal of Development Economics*, page 103038, 2022.

R. W. Fogel. A quantitative approach to the study of railroads in American economic growth: a report of some preliminary findings. *Journal of Economic History*, 22(2):163–197, 1962.

A. Forero, F.A. Gallego, F. Gonzalez, and M. Tapia. Railroads, specialization, and population growth: evidence from the first globalization. *Journal of Population Economics*, 34:1027–1072, 2021.

Gazzetta Ufficiale del Regno d'Italia. Law 1105/1863, 1863.

Gazzetta Ufficiale del Regno d'Italia. Law 3011/1885, 1885.

U. Gragnolati and L. Moretti. Detecting the exogenous location probability of large-scale inland transport networks. *mimeo*, 2023.

E. Hornung. Railroads and growth in Prussia. *Journal of the European Economic Association*, 13 (4):699–736, 2015.

ISPRA. Istituto Superiore per la Protezione e la Ricerca Ambientale. Censimento nazionale dei siti minerari dismessi. Database nazionale cave e miniere, 2006. URL https://rb.gy/cz0u5. Last consulted on September 28, 2022.

ISTAT[a]. Istituto Nazionale di Statistica. Popolazione: Censimento generale (31 dicembre 1861). URL https://rb.gy/qmc4j. Last consulted on September 28, 2022.

ISTAT[b]. Istituto Nazionale di Statistica. Serie storiche. Conti economici nazionali. La ricostruzione Banca d'Italia-ISTAT (1861–2017). URL https://rb.gy/g7ej9. Last consulted on September 28, 2022.

Ministero di Agricoltura, industria e commercio. Annali di statistica. Statistica industriale. Fascicolo XI. Notizie sulle condizioni industriali dell'isola di Sardegna, 1887. URL https://rb.gy/3wr6z. Last consulted on September 28, 2022.

Ministero di Agricoltura, industria e commercio. Censimento degli opifici e delle imprese industriali, 1911. URL https://rb.gy/080er. Last consulted on September 28, 2022.

F. Ogliari. La sospirata rete. In *Storia dei trasporti italiani*, volume 32, Milan, 1978. Cavallotti Editore. Sardegna (vols. 1–4).

L. Ortu. *La questione sarda tra Ottocento e Novecento*. CUEC - Cooperativa Universitaria Editrice Cagliaritana, Cagliari, 2005.

C.I. Petitti. *Delle strade ferrate italiane e del migliore ordinamento di esse*. Tipografia e libreria Elvetica, Capolago, Canton Ticino, 1845.

N. Pontarollo and R. Ricciuti. Railways and manufacturing productivity in Italy after unification. *Journal of Regional Studies*, 60:775–800, 2020.

Sardegna Geoportale. Modelli digitali del terreno e delle superfici). URL https://rb.gy/pi2la. Last consulted on September 28, 2022.

Statistiche del Regno d'Italia. Istruzione primaria, istruzione elementare pubblica per comuni, anno scolastico 1862-1863, 1865. URL https://rb.gy/hgeqb. Last consulted on September 28, 2022.

F. Yu, F. Lin, Y. Tang, and C. Zhong. High-speed railway to success? The effects of high-speed rail connection on regional economic development in China. *Journal of Regional Science*, 59 (4):723–742, 2019.

L. Zheng, Z. Chang, and A.G. Martinez. High-speed rail, market access, and the rise of consumer cities: Evidence from China. *Transportation Research Part A: Policy and Practice*, 165:454–470, 2022.

Appendix

Table A1: Probit estimates: Diffusion of industrial firms

Dependent				At least one firm = 1				
Sector	Total	Extractive	Food	Min. & Const.	Metals	Textiles	Chemicals	Other
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station	0.081	0.614**	-0.116	0.445*	0.213	0.059	0.452*	0.225
	(0.209)	(0.300)	(0.211)	(0.259)	(0.198)	(0.232)	(0.260)	(0.236)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	338	316	338	354	345	328	354	354

Probit estimates. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A2: Logit estimates: Diffusion of industrial firms

Dependent				At least one firm = 1				
Sector	Total	Extractive	Food	Min.& Const.	Metals	Textiles	Chemicals	Other
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station	0.087	1.272**	-0.120	0.899*	0.389	0.062	0.924*	0.399
	(0.372)	(0.638)	(0.359)	(0.542)	(0.330)	(0.437)	(0.533)	(0.751)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	338	316	338	354	345	328	354	354

Logistic estimates. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A3: Number of firms and employed persons

Dependent	Log of Number of firms				Log of Employed persons			
Sector	Extractive	Min. & Const.	Textiles	Chemicals	Extractive	Min. & Const.	Textiles	Chemicals
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station	-0.618	0.500	-0.002	-0.111	-0.340	0.726	-0.102	-0.436*
	(0.451)	(0.301)	(0.265)	(0.185)	(0.717)	(0.508)	(0.333)	(0.233)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Observations	30	42	66	51	30	42	66	51
R-squared	0.567	0.479	0.372	0.511	0.781	0.607	0.524	0.741

OLS estimates. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A4: Reduced form: Diffusion of industrial firms

Dependent	At least one firm = 1							
Sector	Total	Extractive	Food	Min. & Const.	Metals	Textiles	Chemicals	Other
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(Distance LCP)	0.000	-0.011	-0.012	-0.029	-0.021	-0.048*	-0.059**	-0.002
	(0.037)	(0.017)	(0.038)	(0.028)	(0.037)	(0.028)	(0.028)	(0.010)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	354	354	354	354	354	354	354	354
R-squared	0.269	0.339	0.234	0.244	0.259	0.244	0.264	0.536

OLS estimates. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A5: Reduced form: Number of firms and employed persons

Dependent	Log of Number of firms				Log of Employed persons			
Sector	Extractive	Min. & Const.	Textiles	Chemicals	Extractive	Min. & Const.	Textiles	Chemicals
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(Distance LCP)	0.606*	-0.280*	-0.016	-0.094	0.125	-0.309	-0.107	-0.092
	(0.328)	(0.146)	(0.176)	(0.103)	(0.553)	(0.247)	(0.209)	(0.131)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Observations	30	42	66	51	30	42	66	51
R-squared	0.598	0.480	0.372	0.516	0.778	0.596	0.526	0.722

OLS estimates. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A6: 2SLS (dummy LCP as instrument): Number of firms and employed persons

Dependent	Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
Station	0.399	0.289	0.310	0.824***	0.661**	0.538**
	(0.298)	(0.269)	(0.244)	(0.285)	(0.259)	(0.237)
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	228	212	150	228	212	150
R-squared	0.317	0.352	0.381	0.447	0.446	0.531
F-stat first stage	80.05	68.50	40.03	80.05	68.50	40.03

2SLS estimates. Robust standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A7: Reduced form: Number of firms and employed persons

Dependent	Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A			
log(Distance LCP)	-0.254**	-0.158	-0.233**	-0.410***	-0.286**	-0.346***
	(0.123)	(0.113)	(0.094)	(0.126)	(0.112)	(0.096)
Citrus	-0.352	0.082	-0.086	-0.684	-0.905	-0.159
	(0.832)	(0.777)	(0.931)	(0.900)	(0.817)	(0.800)
log(Distance LCP) x Citrus	-0.137	-0.291	0.003	-0.072	0.115	0.111
	(0.339)	(0.315)	(0.364)	(0.368)	(0.349)	(0.315)
R-squared	0.353	0.393	0.455	0.513	0.482	0.616
			Panel B			
log(Distance LCP)	-0.304**	-0.176	-0.254***	-0.462***	-0.312***	-0.375***
	(0.124)	(0.113)	(0.092)	(0.122)	(0.108)	(0.096)
Forest	-2.264	1.287	-0.566	-2.760	-1.765	-2.337
	(3.134)	(2.382)	(1.545)	(2.128)	(3.013)	(1.845)
log(Distance LCP) x Forest	1.128	-0.289	0.743	1.374	1.187	1.448*
	(1.249)	(0.979)	(0.720)	(0.966)	(1.057)	(0.732)
R-squared	0.356	0.391	0.457	0.517	0.485	0.625
			Panel C			
log(Distance LCP)	-0.191	-0.102	-0.260**	-0.381***	-0.245**	-0.378***
	(0.130)	(0.121)	(0.100)	(0.138)	(0.124)	(0.099)
Barley	1.218*	1.203**	-0.184	1.084	0.848	-0.326
	(0.656)	(0.603)	(0.576)	(0.681)	(0.654)	(0.580)
log(Distance LCP) x Barley	-0.418	-0.483*	0.120	-0.199	-0.177	0.198
	(0.259)	(0.246)	(0.249)	(0.298)	(0.274)	(0.229)
R-squared	0.359	0.401	0.456	0.514	0.483	0.618
			Panel D			
log(Distance LCP)	-0.277**	-0.174	-0.221**	-0.420***	-0.276***	-0.336***
	(0.120)	(0.109)	(0.088)	(0.123)	(0.105)	(0.094)
Mines	-0.445	0.333	0.838**	1.054**	0.072	0.407
	(0.557)	(0.491)	(0.381)	(0.531)	(0.489)	(0.386)
log(Distance LCP) x Mines	0.099	-0.211	-0.190	0.025	0.010	0.036
	(0.201)	(0.175)	(0.159)	(0.240)	(0.194)	(0.152)
R-squared	0.353	0.394	0.460	0.513	0.482	0.616
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	228	212	150	228	212	150

OLS estimates. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Table A8: Weaving looms

Dependent (in logs)	Linen & Wool	Total (Cagliari province)	Days of activity (Cagliari province)
	(1)	(2)	(3)
Station in 1886	0.015	-0.037	-0.160
	(0.289)	(0.271)	(0.190)
Controls	YES	YES	YES
District FE	YES	YES	YES
Observations	198	160	160
R-squared	0.434	0.490	0.068

OLS estimates. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A9: Standard vs Narrow gauge: Diffusion of industrial firms

Dependent				At least one firm = 1					
Sample				10 km away from narrow gauge			10 km away from standard gauge		
Sector	Total	Food	Metals	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Standard	0.074	0.006	0.111	0.047	0.014	0.086			
	(0.074)	(0.082)	(0.081)	(0.083)	(0.094)	(0.097)			
Narrow	0.010	-0.021	0.053				0.001	0.019	0.032
	(0.079)	(0.082)	(0.082)				(0.088)	(0.088)	(0.088)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	354	354	354	237	237	237	253	253	253
R-squared	0.272	0.234	0.263	0.426	0.364	0.364	0.341	0.332	0.302

OLS estimates. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A10: Standard gauge: Number of firms and employed persons

Sample	10 km away from narrow gauge					
Dependent	Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
Station	1.694***	1.436***	1.232***	1.658***	1.174***	1.186***
	(0.477)	(0.408)	(0.274)	(0.410)	(0.332)	(0.281)
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	147	135	92	147	135	92
R-squared	0.214	0.324	0.254	0.432	0.471	0.388
F-stat first stage	43.68	38.69	33.63	43.68	38.69	33.63

2SLS estimates. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A11: Narrow gauge: Number of firms and employed persons

Sample	10 km away from standard gauge					
Dependent	Log of Number of firms			Log of Employed persons		
Sector	Total	Food	Metals	Total	Food	Metals
	(1)	(2)	(3)	(4)	(5)	(6)
Station	0.481	-0.287	0.649	1.086	0.570	1.625
	(0.641)	(0.585)	(0.936)	(0.668)	(0.609)	(1.202)
Controls	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
Observations	163	153	107	163	153	107
R-squared	0.289	0.257	0.212	0.393	0.341	-0.011
F-stat first stage	14.40	13.21	3.349	14.40	13.21	3.349

2SLS estimates. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Ultimi Contributi di Ricerca CRENoS

I Paper sono disponibili in: http://www.crenos.unica.it

23/06 *Giampiero M. Gallo, Demetrio Lacava, Edoardo Otranto* "Volatility jumps and the classification of monetary policy announcements"
23/05 *Diego Dessì, Raffaele Paci,* "The impact of Global Value Chains participation on countries' productivity"
23/04 *Edoardo Otranto, Luca Scaffidi Domianello,* "On the relationship between Markov Switching inference and Fuzzy Clustering: A Monte Carlo evidence"
23/03 *Mario Agostino Maggioni, Emanuela Marrocu, Teodora Erika Uberti, Stefano Usai,* "The role of localised, recombinant and exogenous technological change in European regions"
23/02 *Bianca Biagi, Laura Ciucci, Claudio Detotto, Manuela Pulina,* "University study programmes and students dynamics"
23/01 *Giovanni B. Concu, Claudio Detotto, Marco Vannini,* "Drivers of intentions and drivers of actions: willingness to participate versus actual participation in fire management in Sardinia, Italy"
22/06 *Alberto Tidu, Stefano Usai, Frederick Guy,* Measuring spatial dispersion: an experimental test on the M-index
22/05 *Luca Scaffidi Domianello, Giampiero M. Gallo, Edoardo Otranto,* "Smooth and Abrupt Dynamics in Financial Volatility: the MS-MEM-MIDAS"
22/04 *Claudio Detotto, Riccardo Marselli, Bryan C. McCannon, Marco Vannini,* "Experts and Arbitration Outcomes: Insights from Public Procurement Contract Disputes"
22/03 *Gerardo Marletto, Cécile Sillig,* "Global influence and national diversity in socio-technical transitions: a sectoral taxonomy"
22/02 *Federico Aresu, Emanuela Marrocu, Raffaele Paci,* "Public capital and institutions' quality in the Italian regions"
22/01 *Gabriele Cardullo, Maurizio Conti, Andrea Ricci, Sergio Scicchitano, Giovanni Sulis,* "On the Emergence of Cooperative Industrial and Labor Relations"
21/11 *Gianfranco Atzeni, Luca G. Deidda, Marco Delogu, Dimitri Paolini,* "Effects of migration with endogenous labor supply and heterogeneous skills"
21/10 *Alberto Tidu, Stefano Usai, Frederick Guy,* "Agglomeration in manufacturing and services: an experimental application of a distance-based measure to Sardinia"
21/09 *Andrea Caria, Fabio Cerina, Marco Nieddu,* "Political Selection and Monetary Incentives in Local Parliamentary Systems"
21/08 *Giorgio Garau, Alessio Tola, Maria Veronica Camerada, Salvatore Lampreu, Silvia Carrus,* "Economic and social polarization dynamics in the EU"
21/07 *Emanuela Marrocu, Raffaele Paci, Stefano Usai,* "Direct and indirect effects of universities on European regional productivity"
21/06 *Pasqualina Arca, Gianfranco Atzeni, Luca Deidda,* "The Signalling Role of Trade Credit on Loan Contracts: Evidence from a Counterfactual Analysis"
21/05 *Grazia Sveva Ascione, Laura Ciucci, Claudio Detotto, Valerio Sterzi,* Do universities look like patent trolls? An Empirical Study of University Patent Infringement Litigation in the United States
21/04 *Michele Battisti, Massimo Del Gatto, Antonio Francesco Gravina, Christopher F. Parmeter,* "Robots versus labor skills: a complementarity / substitutability analysis"
21/03 *William Addessi, Marco Delogu,* "Infrastructure Accumulation in Developing Countries: the Role of the Informal Sector"
21/02 *Luca De Benedictis, Vania Licio, Anna Maria Pinna,* "From the historical Roman road network to modern infrastructure in Italy"

www.crenos.unica.it

ISBN 9788868514709