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Working Paper

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EHES Working Paper, No. 209

Provided in Cooperation with:

European Historical Economics Society (EHES)

Suggested Citation: Garcia-López, Miquel-Àngel; Herranz-Loncán, Alfonso; Tassinari, Filippo; Viladecans-Marsal, Elisabet (2021) : Paving the way to modern growth. Evidence from Bourbon roads in Spain, EHES Working Paper, No. 209, European Historical Economics Society (EHES), s.l.

This Version is available at:

<https://hdl.handle.net/10419/247139>

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EHES Working Paper | No. 209 | February 2021

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Abstract

This paper analyses the impact that Spanish road construction had on local population growth between 1787 and 1857. We find that the increase in market access associated to road accessibility had a substantial effect on local population growth. The impact was substantially higher on the municipalities that were connected earlier and that had a more diversified occupational structure. By contrast, the effect of the new network on population growth was negative in municipalities close but without direct access to the roads. We interpret these findings as evidence of a process of rural-to-rural migration due to the new roads.

JEL Codes: H54, N73, N93

Keywords: roads, accessibility, market access, population growth, pre-railway transport, Spain

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^{*} We thank Nathaniel Baum-Snow, Dan Bogart, Felipe Carozzi, Danilo Cavapozzi, Alexandra Cermeño, Andrea Gentili, Clara Santamaría and Marta Santamaría for their helpful comments and suggestions, as well as all the participants at the 2020 Urban Economic Association virtual meeting, at the 6th Seminar in Economic History of Bank of Spain, and at the 8th SIdE-Bank of Italy Workshop. We are also grateful to Francisco Beltrán-Tapia, Alfonso Díez-Minguella, Guillermo Esteban, Julio Martínez-Galarraga, Federico Pablo-Martí, David Reher and Pau de Soto for the information and data provided, and to Lucía Díez for her research assistance with the digitization of population data. We acknowledge funding from the Spanish Ministry of Science and Innovation (grants ECO2016-75941-R, PID2019-108265RB-I00, PGC2018-095821-B-I00 and RTI2018-097401-B-I00) and the Catalan Government (grants 2017SGR796, 2017SGR1301 and 2017SGR1466).

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Paving the way to modern growth. Evidence from Bourbon roads in Spain

1. Introduction

In the central decades of the 19th century, railways brought about an unprecedented productivity boost in the European countries' inland transport sector. The railway represented the first massive application of the new technologies of the Industrial Revolution to transportation, with groundbreaking consequences in all areas, from the scale of infrastructure investment to the volumes of freight and passenger traffic. The contrast between this revolutionary change and the much less sophisticated preindustrial transport technologies explains the widespread belief that inland transport was stagnant before the arrival of the railway. Leaving aside the “canal revolution”, which was limited to a small number of countries, this interpretation would describe early 19th century domestic freight and passenger trade as burdened by the high cost and lack of technological change in the inland transport sector. This widespread view was only challenged for England, where the combination of canal investment, a geography quite adapted to coastal navigation and a growing network of turnpike roads allowed the English domestic markets to be close to full integration already in the mid-18th century (Bateman, 2015; Bogart, You, Alvarez-Palau, Satchell, & Shaw-Taylor, 2020; Brunt & Cannon, 2014; Granger & Elliott, 1967; Jacks, 2011; Shiue & Keller, 2007; Smith, 1776; Uebele, 2012).¹

The contrast between railway dynamism and earlier stagnation, however, has been questioned by recent research, and is currently being replaced by an alternative picture of slow but gradual long-term improvements in domestic transport productivity, starting well before the arrival of the railway. An early warning against an excessive simplification of the history of 19th century transport and the assumption that railways were superior to any previous transport mode can be found in Robert Fogel's words:

“It is a misleading oversimplification to identify wagons, waterways and railroads with a sequence of temporal stages in which each was predominant (...). The transportation system that evolved during the nineteenth century embraced all three modes. The quantities of service delivered by each mode increased throughout the nineteenth century, although at unequal rates. Each mode was more productive than the other two in some domain, and this pattern of specialized pre-eminence continued to the end of the nineteenth century” (Fogel, 1979).

¹ The Netherlands was another case of early domestic market integration, although not as advanced as England in the 18th century (Bateman 2015).

Fogel clearly rejected the idea of a stagnant road transport sector during the era of railway dominance. Recent research has provided evidence that road transport was quite dynamic also before the construction of the first railways. Early experiences of Smithian economic growth, starting before the 19th century, were by definition linked to the growth of “*the extent of the market*” (Smith, 1776), which was in turn associated to gradual improvements in transport technology, including roads. Such improvements have been clearly illustrated by Yrjö Kaukiainen, who provided evidence on the remarkable increase in the speed of information transmission in Europe well before the railway and the electric telegraph. He estimated that dispatch times decreased by two thirds between ca. 1820 and the 1850s and that the reduction in the time that information took to move was much larger before than after the introduction of the telegraph. At least in part, those early gains were the result of the increase in the speed of overland transport. While by 1820, road transport could not cover more than 100 km per day, except for Britain, northern France and, maybe, the Low Countries and part of Germany, by 1840 speed was higher than 200 km per day on many roads out of those areas, thanks to the better quality of infrastructure, better carriages and more efficient organization of coach lines (Kaukiainen, 2001).

Road transport improvement was parallel to substantial progress in domestic market integration across Europe before the generalization of the railway technology. In many European economies price dispersion was rather low already by 1830 (Federico & Persson, 2010), and Chilosì, Murphy, Studer, and Tunçer (2013) and Uebele (2012) have shown that most of the progress in the integration of the European wheat market took place before 1850. This literature indicates that, in the 19th century, European countries’ market integration was not specifically associated to the construction of railways, but was to a large extent the result of organizational and technological improvements in other segments of the transport sector (water and road transportation). The fact that most advances in market integration took place before 1850 clearly reduces the role of steam technologies in the process (Uebele, 2012).

This paper aims at contributing to the debate on the impact of pre-railway transport by analysing the case of Spanish roads before the first wave of massive railway construction in 1855-65. The Spanish road network before the railways has been the object of quite contradictory assessments. Some researchers have described Spanish pre-railway inland transport as rather inefficient and costly, and one of the structural obstacles preventing market integration and economic development (Gómez Mendoza, 1989; Ringrose, 1970). Spain would therefore be an example of late economic integration, specially compared with the most developed European economies, such as Britain or the Netherlands (Jacks, 2005; Uebele, 2012). Integration would have only advanced in the second half of the 19th century, largely due to railway construction (Rosés, Martínez-Galarraga, & Tirado, 2010). By contrast, other

authors have observed substantial progress in market integration since early modern times and, specially, in the decades before 1850 (Barquín Gil, 1997; Grafe, 2012; Llopis & Sotoca, 2005; Martínez Vara, 1999; Nogués-Marco, Herranz-Loncán, & Aslanidis, 2019; Reher, 2001). This would be consistent with a gradual reduction in transport costs starting at least in the last decades of the Ancien Régime, which would be reflected, for instance, in the significant decrease in travel times through the road network, as observed by Madrazo (1991), Grafe (2012) and Nogués-Marco, Herranz-Loncán, and Aslanidis (2019). It would also be consistent with Cermeño and Santiago-Caballero (2020) that states that, already in the mid-18th century, transport networks were allowing to overcome the obstacles to the integration of Spanish markets. The available evidence on the gradual development of the transport sector and markets in pre-railway Spain has driven Frax Rosales and Madrazo (2001) to drastically reject the long standing view of a stagnant traditional transport sector which had reached its limits in the 18th century.

Instead of looking at market integration gains, here we approach the improvements in pre-railway inland transport by analysing the growth impact of road construction between the late 18th and the mid-19th centuries. Starting in the late 1740s, the Spanish monarchy launched a program of construction of new, high-quality paved roads. Construction was extremely slow for some decades but accelerated since the late 18th century, and by 1855 a network of 8,324 km. had been built (Uriol Salcedo, 1992). The construction of paved roads went hand-in-hand with the reduction of travel times and increasing market integration during the early 19th century, being arguably one of their explanatory factors. In order to study the potential growth effects of these new roads, in this paper we study to what extent the increase in market access thanks to the new network between 1787 and 1855 was associated with a higher demographic dynamism at the local level. This analysis is based on the authors' construction of a new georeferenced database of the evolution of paved roads during the period under study.

Our work is related to previous research on the local impact of increasing accessibility through transport networks. This type of analysis has been carried out for several countries both for railway infrastructure in the 19th and early 20th century (Atack, Bateman, Haines, & Margo, 2010; Banerjee, Duflo, & Qian, 2020; Berger, 2019; Berger & Enflo, 2017; Bogart, You, et al., 2020; Büchel & Kyburz, 2020; Donaldson & Hornbeck, 2016; Hornung, 2015; Jedwab, Kerby, & Moradi, 2015) and for motorways in more recent times (Baum-Snow, 2007; Baum-Snow, Henderson, Turner, Zhang, & Brandt, 2020; Bird & Straub, 2020; Chandra & Thompson, 2000; Duranton & Turner, 2012; Garcia-López, Holl, & Viladecans-Marsal, 2015; Herzog, 2021; Jaworski & Kitchens, 2019; Jedwab & Storeygard, 2020; Michaels, 2008). However, this is one of the first applications of this approach to measuring the effects of pre-railway road infrastructure. The main precedent to our research is Bogart, Alvarez-Palau, Satchell,

and Shaw-Taylor (2020), which study the impact of multi-modal transport on local growth in England and Wales between 1680 and 1830. In addition, a number of recent papers analyse the impact of Roman roads on historical or present-day development levels and current infrastructure location (Dalgaard, Kaarsen, Olsson, & Selaya, 2018; De Benedictis, Licio, & Pinna, 2018; Flückiger, Hornung, Larch, Ludwig, & Mees, 2019; Wahl, 2017), although they differ from our study because they focus on very long-term persistence, while we analyse the short/medium-run effects of the new infrastructure.

One of the main challenges of this type of analysis is endogeneity. Generally, transport infrastructures are not randomly assigned across territories but are often correlated to specific local characteristics related to potential economic growth. Therefore, the assignment of infrastructures to territorial units is potentially non-random. In order to retrieve causality, an exogenous selection of municipalities which get access to roads is required. The advantage of the Spanish road network is that it did not seek specifically for routes with high potential trade, but was instead explicitly designed to directly connect Madrid to the main cities of the country. Therefore, our case study would be an ideal natural experiment for this type of analysis, in which the underlying hypothesis (no economic criteria behind network design and exogenous selection of the treated areas) would hold. However, to reinforce our case, we also adopt an inconsequential-unit approach, removing from the analysis the termini and other cities targeted in the network design, and considering only the municipalities which got accessibility due to their random location in the middle of two important cities. Finally, we adopt an instrumental variable strategy based on least cost paths between targeted nodes.

Our results provide clear evidence of a significant positive effect of road accessibility on the population growth of the treated municipalities. The size of the effect was substantially higher in municipalities that were connected earlier to the road network, as well as in those with a higher presence of manufacturing and commercial activities in their occupational structure. By contrast, the construction of the new roads decreased population growth in those municipalities close but without direct access to the network. These findings would be consistent with the new network of paved road provoking significant population displacement effects between municipalities well before the arrival of the railway. Given the average size of our sample of municipalities, those movements were predominantly of a rural-to-rural character. Our results therefore confirm that the Spanish transport sector was far from stagnant before the mid 19th century. Road infrastructure investment was transforming the territory before the railway era and, together with other improvements in the transport sector, would to some extent account for the slow but gradual process of Smithian growth that was taking place in the Spanish economy at the time (Álvarez-Nogal, Prados de la Escosura, & Santiago-Caballero, 2020).

2. Road transport and the Spanish economy before the railways

The Spanish inland transport system of the early 18th century was largely based on roads. The massive shape of the country limited the reach of coastal navigation, and its rough geography reduced waterways to just around 300 km of canals and some stretches of rivers Ebro and Guadalquivir. Under those circumstances, most traffic within the country relied on a dense but very low quality network of traditional roads and paths. The lack of investment in medieval and early modern times meant that part of that network, specially the entrances to cities, bridges, and mountain passes, was still based on ancient Roman infrastructure (Pablo-Martí, Alañón-Pardo, & Sánchez, 2020) and that many roads were not well adapted to wheeled traffic or were only passable in certain seasons, due to the low quality of the surface, the absence of bridges and other shortcomings (Alzola y Minondo, 1899; Dirección General de Obras Públicas, 1856; Madrazo, 1984). Municipalities were in charge of the construction and maintenance of the roads that crossed their territory, mainly through taxes on entrance and exit (*portazgos*). Limited trade and the resulting scarcity of municipal fiscal resources largely explain the state of disrepair of the network. Low quality seems to have been a characteristic shared by the whole road system, even the most important routes, such as those included in the main itineraries published during the period (Pablo-Martí, Alañón-Pardo, & Sánchez, 2020).

The consolidation of the new Bourbon dynasty after the War of Succession (1701-1713) brought with it a project of administrative modernisation of the country, which included significant changes in transport and communication policies. Already in 1716, the government nationalized and centralized the postal service and, four years later, completely reorganized it with a new regulation which included a catalogue of “post roads” of predominantly radial character. These post routes were probably better maintained than the rest of the network, given their specific interest for the Crown, and the presence of postal stops and frequent lodges would likely increase their safety and traffic. However, these improvements did not involve any significant infrastructure investment yet, and post roads remained largely unpaved and of relatively low quality (Pablo-Martí, Alañón-Pardo, & Sánchez, 2020).

This started to change in 1747, when the Spanish government, aware of the insufficiency of municipal budgets, entrusted the construction and maintenance of roads to the Director of the postal services, and established a regular funding mechanism by the Royal Treasury for the development and conservation of the main road network (Pablo-Martí, Alañón-Pardo, & Sánchez, 2020). Construction achievements during Fernando VI’s reign (1746-1759), however, were just limited to the Santander - Reinosa road in the North and the Guadarrama pass near Madrid. A systematic construction policy was only adopted in 1761, when a royal

decree passed by Carlos III approved the construction of a new road network. This construction plan should start with the roads that connected the Court with the provinces, following the model of the "post roads". As in the case of the postal system, this illustrates the administrative objectives of the road construction plans, clearly aimed at a better communication between Madrid and the rest of the territory in order to ease the administration and control of the country.

The new roads were characterized by its good quality, fully adapted to the requirements of high-speed wheeled transport. They had modern roadbeds, were equipped with bridges (a total of 1,074 had been built by 1868), had moderate gradients (ideally under 6%, although this limit was not always respected) and often allowed the crossing of mountain passes throughout the year ([Madrazo, 1984](#); [Uriol Salcedo, 1992](#)). The first finished route, from Reinosa to Santander, was a modern paved road 7.8 m wide, and the highways built thereafter were generally between 7 and 12 m, although some of them reached even 20 m ([Madrazo, 1984](#)). The progress of construction was rather slow until 1799, due to the shortage of adequately trained technicians, insufficient funding and organizational weaknesses. As a result, only ca. 2,000 km. of roads had been finished by the end of the century. In fact, this figure included a few hundred km that had not been built by the central government but by the Basque provincial institutions, which enjoyed a substantial fiscal autonomy at the time ([Alzola y Minondo, 1899](#)). Thanks to organizational changes and additional training efforts, road construction accelerated in the first years of the 19th century, and the network reached 3,409 km in 1808. The Napoleonic Wars interrupted construction and provoked the abandonment and deterioration of some of the new roads, but works were slowly resumed since 1816, and the resources invested in the network gradually increased during the following decades. Funds for road construction rose from 7.2 million reales per year between 1816 to 1833 to 8.3 million in 1834-40, 11.5 million in 1841-46 and 45.5 million in 1847-55. As a result, the length of the network reached 8,324 km in 1855, and by that year Madrid was already connected with the main cities of the country with high quality paved roads ([Dirección General de Obras Públicas, 1856](#); [Uriol Salcedo, 1992](#)). Although this was a small network, compared, for instance, with the 45,000 km of French roads at the time, it completely changed the conditions of transport in the main routes of the country.

The new roads, combined with the improvement in the organization of the postal system and the development of regular passenger transport services during the first half of the 19th century, had far-reaching effects. Organized passenger stagecoach services, limited before 1808 to the route Madrid-Cadiz and some short-distance lines around the capital, were established in 1816 between Madrid, Barcelona and Valencia and expanded to many other routes thereafter, gradually increasing their reliability, safety and speed and reducing their price. These

advances represented a revolutionary change in the movement of people ([Alzola y Minondo, 1899](#); [Madrazo, 1984](#)). Between 1822 and 1854 the price of stagecoach services decreased by 57 percent ([Madrazo, 1991](#)) and this was accompanied by a dramatic reduction in travel times. For instance, in the routes from Madrid to Barcelona, Cadiz or Santander, the speed of the movement of passengers and information increased from ca. 50 km per day in the 1820s to between 150 and 200 km per day in the 1850s, a figure that was close to the best standards in the most developed European economies. The core of the railway network, which would be built between 1855 and 1865 and gave service to a large extent to the same routes as the new paved road system, would obviously increase this figure significantly. However, the time saved thanks to the improvement in road transport between the 1820s and the 1850s (from ca. 13 to 3-4 days between Madrid and Barcelona, for instance) would be much higher than the additional 1-2 days savings provided by the railways ([Nogués-Marco, Herranz-Loncán, & Aslanidis, 2019](#)). In the case of freight, although the available information is much less abundant than for passengers, [Madrazo \(1984\)](#) provides some scattered data on the impressive traffic growth that took place in the century before 1850, such as the almost 20-fold increase in the number of vehicles using the Reinosa road between 1750 and 1850. The high efficiency of freight road transport in the mid 19th century has also been stressed by [Barquín Gil \(1997\)](#).

These transformations in the road transport sector took place in an economy that was far from stagnant before the arrival of the railways. The most recent long-term estimates of Spanish economic growth ([Álvarez-Nogal, Prados de la Escosura, & Santiago-Caballero, 2020](#); [Prados de la Escosura, 2017](#)) show an increase of ca. 60% in both population and GDP per capita in the century before 1856, when massive railway construction started. The potential progress in market integration and traffic that was partly associated to the new road transport infrastructure would be consistent with a slow but sustained process of economic growth of Smithian character which, despite the series of catastrophic events that affected the Spanish economy (loss of the empire, the Napoleonic invasion and the civil war of 1833-40), brought about significant changes in all aspects of economic life. The railways, therefore, would not have arrived to a stagnant economy or replaced a lethargic road sector, but might have represented the continuation of a long-lasting dynamic trend.

To illustrate such economic dynamism and the role of the transport sector, in this paper we aim at estimating the potential impact that the improvements in accessibility associated to the construction of the new road network had on the population growth of Spanish municipalities. The next section describes the data on which our estimation is based.

3. Data

In order to estimate the impact of road accessibility on local population growth between the late 18th and the mid-19th century, we have retrieved indicators of the development of the road network and population size at the municipal level, as well as a number of control variables.

3.1 Population data

As is usual in this type of research, and given the lack of alternative economic indicators at the municipal level, population is the outcome variable which we use to proxy local growth. Population data for the late 18th century come from the so-called “Floridablanca Census”. Published in 1787 and then expanded in 1789, it is the first Spanish census carried out with modern statistical techniques and allows, for all the municipalities at the time, to disaggregate population figures by sex, civil status, age and occupation.

In the case of the mid-19th century, we use the historical population data provided by the Spanish Statistical Institute (INE) website.² The period covered by this source starts in 1842. Figures for 1842, though, were not collected with homogeneous techniques all over the territory, and this population head count (usually known as the “*Censo de la Matrícula Catastral*” – Census of the Cadastre Register) is not considered as reliable or precise as the following ones. Thus, in our analysis we focus on data from the first modern census, carried out in 1857, discarding also later censuses due to the quick development of the railroad network after that date.

The administrative units employed for the analysis (municipalities) changed over time due to mergers and divisions. Since we do not have a map of municipality boundaries for the period under study, we had to rely on present-day maps and match the historical municipalities to the current ones using different sources. For those changes that took place after 1842, the INE website provides a complete catalogue ([Ministerio de Administraciones Públicas, 2008](#)). By contrast, the match between some of the municipalities included in the Floridablanca Census and the current ones is more complicated and not always possible.³ Due to this problem, we had to exclude a small share of the total Spanish population from our analysis, amounting to 1.13% in 1787 and 3.26% in 1857. The final sample includes a total of 7,216

² <http://www.ine.es/intercensal/>

³ We thank David Reher for providing us with the digitized version of the 1787 census, and Alfonso Díez-Minguela and Julio Martínez-Galarraga for their invaluable help for the matching process.

municipalities.⁴

3.2 Road network data

One of the strengths of our paper is represented by the quality and precision of the digitization of the new paved road network. Applying GIS techniques to information provided in [Madrazo \(1984\)](#) and [Dirección General de Obras Públicas \(1856\)](#), we have digitized the map of the network for four different years along the period under study (see Figure 1). First, we digitized the map of roads in 1855 that is included in [Dirección General de Obras Públicas \(1856\)](#) and is our baseline map. It reports the names of more than 500 municipalities crossed by the paved roads, which helped us to correct for the effects of the spatial distortions of the map on the specific location of each route. We then used information included in a series of hand-drawn maps in [Madrazo \(1984\)](#) to obtain digitized maps of the network in 1778, 1808 and 1840 by removing from our baseline map the road stretches that were still unfinished in those dates. Those maps have been used to compute the different measures of accessibility that we use in our analysis, including binary access (0/1) and market access. As is described in detail below, the latter has been calculated on the basis of the least cost path, which has required the use of travel time and cost parameters obtained from the careful analysis of several sources that report average speeds for passenger transport for different years in km per day in the main routes ([Grafe, 2012](#); [Madrazo, 1984](#); [Nogués-Marco, Herranz-Loncán, & Aslanidis, 2019](#)).

⁴ This only refers to peninsular municipalities; the islands and the North African cities of Ceuta and Melilla are not included in the analysis.

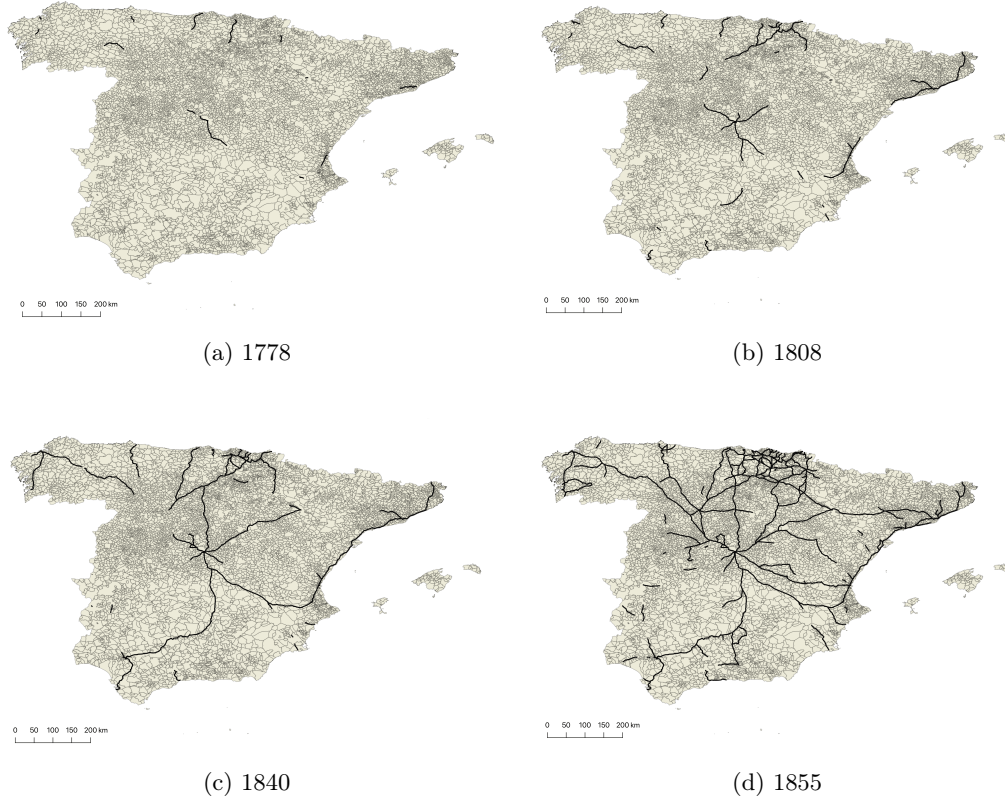


Figure 1: The Spanish paved road network, 1778, 1808, 1840 and 1855.

3.3 Control variables

Our analysis also accounts for a full set of controls to identify potential confounding factors. We account, first, for access to railroads in each municipality. The first Spanish railroad, opened in 1848, was a short (28 km) line between Barcelona and Mataró. By the end of our period of analysis (1857) the network had reached a length of 635 km. We have digitized those early railway lines, starting from the shapefile of current railways and following the chronological description of the construction process provided by [García Raya \(2006\)](#). We specifically control for the exact location of railways' stations operating by the end of the year 1857.⁵ We also account for the presence of the two navigable canals that were constructed in the 18th century: the Canal de Castilla and the Canal Imperial de Aragon, which have been digitized using information in Google Maps. Finally, we account for the 104 main Spanish ports at the time on the basis of [Dirección General de Aduanas \(1857\)](#). Railway stations, canals and the main ports are represented in Figure 2.

⁵ We thank Guillermo Esteban for providing us the precise location of those stations.

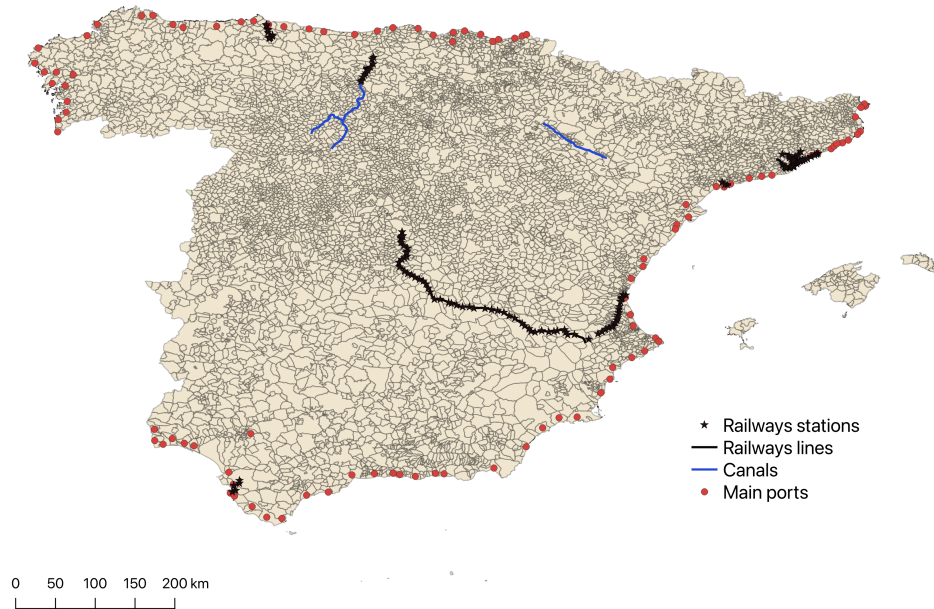


Figure 2: Railways, canals and main ports in 1857.

We have also gathered information on distance to the coast, presence of rivers and closeness to the Portuguese and French borders for each municipality using the shapefile of rivers and coastlines from Instituto Geografico Nacional (IGN). Finally, using the information provided by the Floridablanca Census, we have collected information on the population employed in a number of non-agrarian occupations (merchants, blacksmiths, craftsmen, lawyers and notaries) in each municipality at the end of the 18th century, and we have also gathered information on the main post offices in the late 18th century, taken from [Ita \(1789\)](#). Table 1 presents summary statistics of each variable.

Table 1: Summary statistics

	count	mean	sd	min	max	p25	p50	p75
Population 1787	7477	1288.83	3572.16	10.00	158642.00	297.00	575.00	1272.00
Population 1857	7647	1891.50	5818.91	76.00	296352.00	461.00	851.00	1781.00
Market access	7951	11823.87	27253.69	0.00	624165.00	0.00	0.00	0.00
Log Market Access	7951	1.99	4.25	0.00	13.34	0.00	0.00	0.00
Distance to coast (km)	7951	129.15	92.51	0.02	357.87	44.12	120.63	201.15
River accessibility (0/1)	7951	0.06	0.24	0.00	1.00	0.00	0.00	0.00
Port (0/1)	7951	0.01	0.11	0.00	1.00	0.00	0.00	0.00
Canal (0/1)	7951	0.01	0.08	0.00	1.00	0.00	0.00	0.00
Railroad's stations 1857 (0/1)	7951	0.01	0.10	0.00	1.00	0.00	0.00	0.00
5km from Portuguese border (0/1)	7951	0.02	0.12	0.00	1.00	0.00	0.00	0.00
5km from French border (0/1)	7951	0.01	0.11	0.00	1.00	0.00	0.00	0.00
Main Post station (0/1)	7951	0.03	0.17	0.00	1.00	0.00	0.00	0.00
Pop. share in secondary sector	7477	2.01	2.92	0.00	86.49	0.25	1.20	2.65

4. Empirical framework

As already mentioned, endogeneity is one of the main concerns when it comes to analyze the effects of transport infrastructure. Generally, transport infrastructure investment is not randomly assigned across territories, but is often correlated to specific local characteristics related to potential economic growth.⁶ In order to retrieve causality, an exogenous selection of municipalities which got access to roads is required. To deal with this, we exploit a historical quasi-natural experiment and we combine this with an inconsequential unit IV approach (Banerjee, Duflo, & Qian, 2020; Büchel & Kyburz, 2020).

In this regard, the advantage of the Spanish road network is that it did not seek specifically for routes with high potential trade, but it was instead explicitly designed to connect Madrid to the main cities in the Peninsula. However, to further reinforce our case against endogeneity, we complement this with an inconsequential unit approach. This strategy, firstly adopted by Chandra and Thompson (2000), is based on the idea that the municipalities lying between two important cities (main nodes) might have got exogenous access to a new road because of their random location on the path between the two targeted cities. The idea behind this approach is to identify all the cities targeted by the infrastructure investment planner and remove them from the analysis. The underlying hypothesis is that all the remaining municipalities got access to the network only due to their geographical position.

Our historical context, combined with the removal of the main nodes, should ensure the exogeneity of local accessibility variables. However, it is possible that the planner, while designing the road network, deliberately established detours from the most direct line connecting two targeted cities, for example to connect a third municipality with high growth potential. Those detours might induce selection effects and violate the underlying hypothesis. Thus, it might not be sufficient to exclude the main nodes from the analysis, and it is also common practice to adopt an instrumental variables approach based on straight lines or least-cost paths between the targeted nodes, in order to ensure the random allocation of local access to transport infrastructure. Here we also follow this strategy.

In order to define the targeted nodes that are both excluded from the analysis and used as nodes of the instrumental variable least-cost paths, we collect information from the 1720 general regulation of post services, whose main routes largely inspired the priorities in road construction as defined in the 1761 Royal Decree. As a result, we get a list of 57 targeted

⁶ Redding and Turner (2015) provide an exhaustive review of the current literature dealing with the endogenous placement of transport infrastructure

nodes,⁷ which are the cities and junctions mentioned in the description of those main post routes. We compute our instrument considering the roughness of the terrain, calculated through GIS techniques on the basis of the elevation raster of the Spanish geographical institute (IGN). Specifically, the algorithm calculates the optimal path to minimize the connection cost between the selected targeted nodes. We then use this cost-minimizing network as instrument for the real one. Figure 3 shows the 1855 paved road network, the least-cost paths and the targeted nodes.

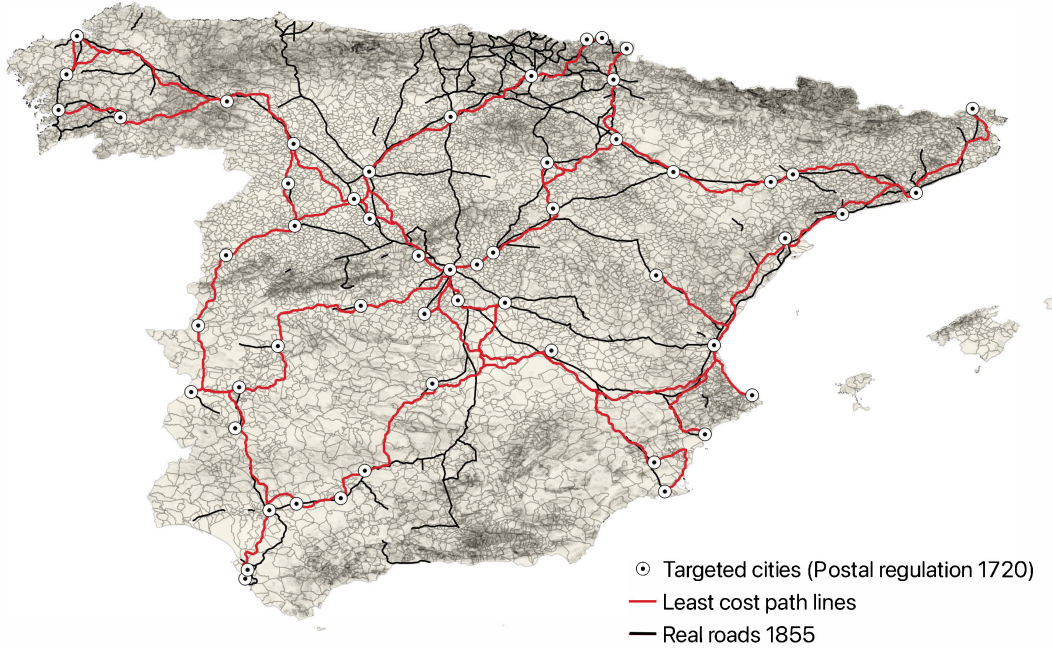


Figure 3: Instrumental variable approach: digitized roads and least cost path lines

A second crucial issue is the definition and measurement of road accessibility. A binary definition of accessibility has often been used in the literature ([Chandra & Thompson, 2000](#); [Michaels, 2008](#)), which differentiates between those municipalities that were crossed by a road and the rest. Binary accessibility indicators allow estimating the average impact of roads on local growth, but ignore the fact that the effect of the new infrastructure might have been very different depending on the location of each municipality and its distance to other population centres through the network. Towns close to big cities, for example, might

⁷ See [Grimaldo \(1720\)](#). The targeted nodes are: Corunna, Alcalá de Henares, Alcántara, Alicante, Aranjuez, Arévalo, Badajoz, Barcelona, Baztán, Benavente, Burgos, Cadiz, Carmona, Cartagena, Ciudad Real, Ciudad Rodrigo, Córdoba, Denia, San Sebastián, Écija, El Escorial, El Puerto de Santa María, Fraga, Getafe, Guadalajara, Irún, La Junquera, Lleida, Madrid, Medina del Campo, Medinaceli, Mérida, Molinaseca, Murcia, Ourense, Pamplona, Pontevedra, Salamanca, San Clemente, Santiago de Compostela, Seville, Soria, Talavera de la Reina, Tarancón, Tarragona, Teruel, Toledo, Torrelodones, Tortosa, Trujillo, Tudela, Valencia, Valladolid, Vitoria, Zafra, Zamora and Zaragoza.

have benefited more from accessibility than more remote places that were located far from the most developed and diversified areas, and this difference would not be captured by an analysis based on a mere binary accessibility variable. This requires using market access indicators instead, which have been widely applied in the more recent literature on the impact of infrastructure (Bogart, Alvarez-Palau, et al., 2020; Donaldson & Hornbeck, 2016; Gibbons, Lyytikäinen, Overman, & Sanchis-Guarner, 2019; Herzog, 2021; Jaworski & Kitchens, 2019; Jedwab & Storeygard, 2020). Market access captures the increase in local accessibility associated to all changes in the road network, and not just the average effect of the mere presence of a road. For those reasons, our main analysis uses the market access indicator as indicator of accessibility. In Appendix C we use the binary indicator of accessibility and the results remain the same.

For each municipality connected to the network, we compute market access as the weighted sum of inverted travel times (used as a proxy of transportation costs) to all other municipalities through the road network, using as weights the initial population at destination, which we take as an indicator of economic activity. Travel times are computed with a least cost path algorithm, assuming a homogeneous speed throughout the network. Our measure of market access is given by the following equation:

$$MA_{o,t} = \sum_d (t_{o,d})^{-\theta} * W_d \quad (1)$$

Where $MA_{o,t}$ is the market access measure for municipality o in year t ; $t_{o,d}$ is the travel distance between the municipality o (origin) and each municipality of destination d ; θ is the elasticity to travel distances; and W_d are weights to capture the size of economic activity at destinations (usually measured at $t-1$ to avoid endogeneity). In our case, we set $\theta = 1$ and $W_d = pop_{d,1787}$, and the market access indicator for each municipality is therefore calculated as:

$$MA_{o,t} = \sum_{d=1}^{M-1} \frac{pop_{d,1787}}{t_{o,d}} \quad (2)$$

Since we compute the shortest distances through the road network, we need to account for those roads that were not finished yet in 1855 and whose built fragments remained unconnected to the main network. The municipalities crossed by those fragments are shown in Figure 4. In order to account for these unfinished roads, we have added to the network a number of straight segments that connect them with the main network, and have imputed a much lower speed to them. Those added segments are represented in red in Figure 5. We impute them a speed of 30% of that of the main network, based on the difference between the average speed for passenger trips through the traditional roads and through the new paved roads, taken from Grafe (2012) and Madrazo (1984).

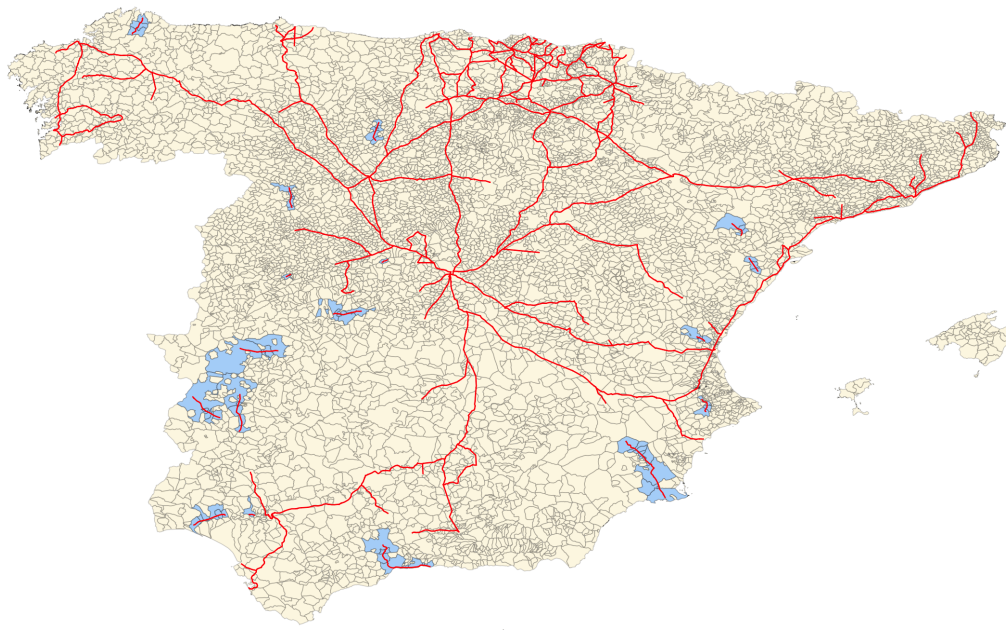


Figure 4: Municipalities crossed by a new paved road but not connected to the main network

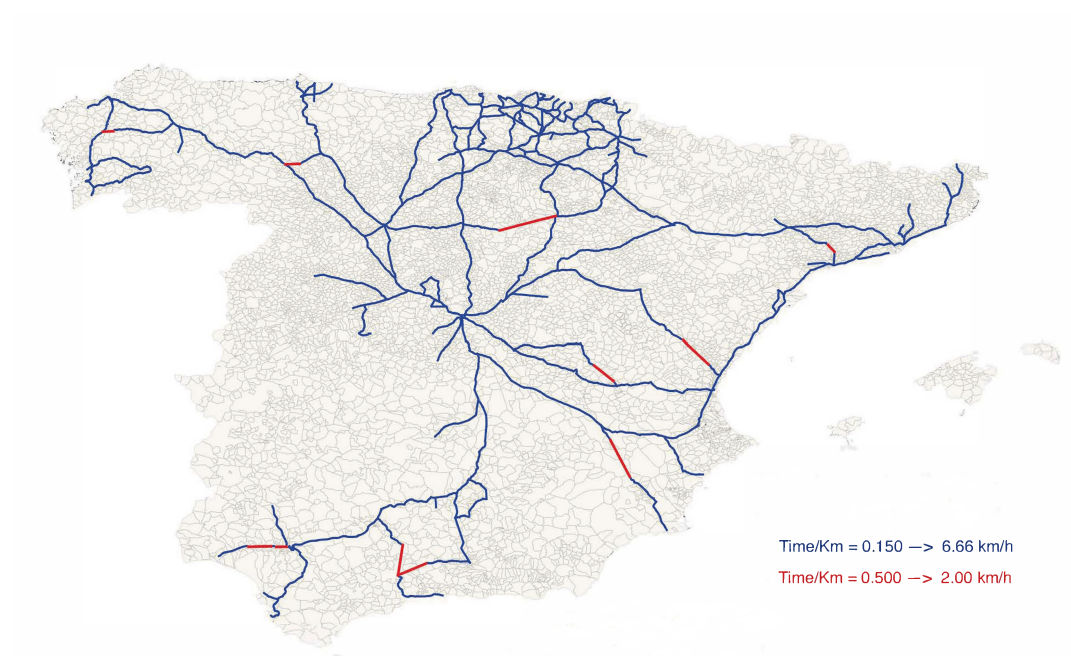


Figure 5: Network employed for global accessibility (market access) computation

In our analysis we regress the long-run difference (1857-1787) log population (equivalent to population growth) on changes in municipal market access through the road network, the logarithm of initial population as parameter of convergence ([Duranton & Puga, 2014](#)), a list

of controls and historical judicial district fixed effects.⁸ We assume a null market access through the paved road network for the initial year, since construction had barely started by then. Thus, for municipalities crossed by a paved road in 1855, the market access change variable takes the value of market access in that year, while for non-crossed municipalities it takes value 0. Therefore, market access enters the regression in levels, with positive values for connected municipalities and 0 for non-connected ones. As described, we exclude from the analysis the 57 targeted nodes and we instrument the log market access of the actual roads with the log market access of least-cost paths connecting the cities targeted by the government. The model we estimate is as follows:

$$\ln(1 + \text{MarketAccess}_m) = \alpha_0 + \beta_1 \ln(1 + \text{LCPMarketAccess}_m) + \beta_2 \ln(\text{pop}_{m,1787}) + \beta_3 X_m + \theta_p + \epsilon_m$$

(First Stage)

$$\ln(\text{pop}_{m,1857}) - \ln(\text{pop}_{m,1787}) = \alpha_0 + \beta_4 \ln(1 + \widehat{\text{MarketAccess}}_m) + \beta_5 \ln(\text{pop}_{m,1787}) + \beta_6 X_m + \theta_p + \epsilon_m$$

(Second Stage)

Where MarketAccess_m is market access through the new paved roads in 1855 for municipality m ; LCPMarketAccess_m is the market access computed through the least cost paths between nodes; $\ln(\text{pop}_{m,t})$ is the log of population in municipality m and year t ; X_m is a vector of control variables and θ_p are fixed effects for the 459 historical judicial districts.

5. Results

Table 2 presents our baseline results.⁹ Columns 1-3 present OLS estimates, while in columns 4-6 we instrument actual market access with market access computed using the least cost paths connecting targeted nodes.¹⁰ Specifications 1 and 4 do not add any control or fixed effects; columns 2 and 5 add historical judicial district fixed effects and columns 3 and 6 also add controls. The standard errors are clustered at the historical judicial district level. The small differences between the estimates reported in columns 5 and 6 suggest that the results are not driven by the controls. In addition, the first stage results and the F-tests reported in the table would be consistent with the validity of the chosen instrument. The difference in the main estimated coefficient between column 3 and 6 would suggest an endogenous road placement and a downward bias of the OLS estimates. This result might indicate that the new roads tended to be built in areas with relatively low growth potential. This might be

⁸ Judicial districts were the smaller supramunicipal territorial divisions at the time. We thank Francisco Beltrán-Tapia for sharing with us the shapefile of the Spanish judicial districts in 1860. Figure 6 in the appendix shows those administrative units.

⁹ Table 6 in the Appendix reports also the estimated coefficients for the control variables.

¹⁰ We also develop an alternative model in which the instrument is calculated based on straight lines connecting the targeted nodes. The results are consistent and are available upon request.

partially explained because they aimed at connecting Madrid with the periphery, rather than following the most active trade routes and, in order to do this, they had to cross some sparsely populated territories in the interior of the country. However, since we cannot exclude the presence of measurement errors, we do not put much weight on those differences.

Column 6 is our preferred specification. We find a negative and significant coefficient for the parameter of convergence (log of initial population), meaning that population tended to grow faster in small municipalities than in large ones. As for our main coefficient of interest, it is positive and statistically significant, suggesting a positive effect of road accessibility on city growth. According to the estimate, a 100% difference in market access thanks to the road network translated into 3.5 additional percentage points of local population growth over the period 1787-1857. The table also provides the standardized (beta) coefficient of the market access variable which indicates, in our preferred specification, that one standard deviation increase in market access was associated to around one third of a standard deviation increase in population growth. Setting all variables at their average values, the average increase in market access between 1787 and 1857 associated to the new roads would translate into 49 additional percentage points of population growth over the period. This is a substantial impact, specially taking into account that the average population growth between 1787 and 1857 across all Spanish municipalities was 67%. These results are robust to implementing different elasticities to travel times in the market access computation; using values from 0.25 to 2 we obtain coefficients for the market access variable between 0.028 and 0.038 (Table 3).

Table 2: Market access and local population growth

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Log Market Access	0.004** (0.002) [0.039]	0.009*** (0.001) [0.091]	0.007*** (0.001) [0.071]	0.039*** (0.010) [0.383]	0.037*** (0.010) [0.366]	0.035*** (0.012) [0.341]
Log population 1787	-0.129*** (0.010)	-0.231*** (0.010)	-0.248*** (0.011)	-0.152*** (0.012)	-0.250*** (0.012)	-0.262*** (0.012)
Controls			✓			✓
Fixed effects		✓	✓		✓	✓
First-Stage F-Statistic				73.84	42.97	25.77
R2	0.09	0.45	0.47			
N	7216	7216	7216	7216	7216	7216

Notes: The dependent variable is the long-run difference (1857-1787) in log municipal population. Fixed effects are taken at the historical judicial district level. Standard errors are clustered by historical judicial districts and are in parenthesis, and the standardised beta coefficients are within square brackets. *, ** and *** indicates significant at 1, 5, and 10 percent level, respectively.

Table 3: Market access and local population growth. Different elasticities

	IV						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	e=1	e=0.25	e=0.50	e=0.75	e=1.25	e=1.50	e=1.75
log Market Access	0.035*** (0.012)	0.028*** (0.010)	0.030*** (0.010)	0.032*** (0.011)	0.038** (0.015)	0.036*** (0.013)	0.038*** (0.014)
Log population 1787	-0.262*** (0.012)	-0.263*** (0.012)	-0.263*** (0.012)	-0.263*** (0.012)	-0.262*** (0.012)	-0.261*** (0.012)	-0.260*** (0.012)
Controls	✓	✓	✓	✓	✓	✓	✓
Fixed effects	✓	✓	✓	✓	✓	✓	✓
First-Stage F-Statistic	25.77	26.23	26.22	26.13	25.05	23.90	22.44
N	7216	7216	7216	7216	7216	7216	7216

Notes: The dependent variable is the long-run difference (1857-1787) in log municipal population. e refers to the elasticity to travel distances employed in the market access computation. Fixed effects are taken at the historical judicial district level. Standard errors are clustered by historical judicial districts and are in parenthesis. *, ** and *** indicates significant at 1, 5, and 10 percent level, respectively.

The previous results may be hiding a significant heterogeneity of effects across different municipalities. For instance, cities which got access to the road network at the beginning of the period might have grown more than those connected in the latter years. Alternatively, the growth effect might have been different for those municipalities whose new roads were not connected to the main network (see Figure 4 above). And, finally, the demographic impact of increasing market access might have changed depending on the occupational structure of the population. In order to test these hypotheses, we successively add to our baseline model different interaction terms composed by the market access indicator and a variable that captures the effect we want to analyse. In addition, we incorporate in the regression a second instrument: the interaction between the least cost path market access indicator and the variable of interest. We present the results in Table 4.

Table 4: Market access and local population growth. Heterogeneity analyses

	IV			
	(1) Time 1840	(2) Time 1808	(3) Unlinked roads	(4) Secondary sector
Log Market Access	0.038*** (0.014)	0.051** (0.020)	0.035*** (0.013)	0.030** (0.013)
Log Market Access \times Post 1840	-0.018* (0.011)			
Log Market Access \times Post 1808		-0.035** (0.016)		
Log Market Access \times Unlinked			-0.004 (0.015)	
Log Market Access \times % manuf. and commerce				0.004** (0.001)
Log population 1787	-0.259*** (0.011)	-0.259*** (0.011)	-0.262*** (0.012)	-0.267*** (0.013)
Controls	✓	✓	✓	✓
Fixed effects	✓	✓	✓	✓
First-Stage F-Statistic	12.50	9.05	12.14	12.41
N	7216	7216	7216	7216

Notes: In this long-difference regression, besides the accessibility indicator and the logarithm of initial population, we also add different interaction terms to analyse possible heterogeneous impact of market access. Accessibility to real roads and the interaction between market access and the variable of interest are instrumented with accessibility determined by least cost path lines and its interaction with that variable. The fixed effects are represented by historical judicial districts. Standard errors are clustered by historical judicial district and are in parenthesis. *, ** and *** indicates significant at 1, 5, and 10 percent level, respectively.

In Columns (1) and (2) we test for the effect of early versus late accessibility, adding an interaction term that indicates whether the municipality got access to the road before or after a certain date (1840 in Column 1 and 1808 in Column 2), based on information reported in [Madrazo \(1984\)](#). Our results suggest that the average effect presented above is driven by the group of municipalities connected in earlier years. Specifically, we observe that the additional long-term population growth associated to a 100 percent increase in market access amounted, in the case of municipalities that got access before 1840 (48% of the sample), to 3.8%, compared to 2% in those locations connected between 1840 and 1855 (52% of the sample). When we split the sample between municipalities connected before 1808 (29%) and those connected after that year (71%) we find an even higher difference between the two groups (5.1% vs. 1.6%). This would indicate that the impact of infrastructure accessibility on local growth only materializes in the long term. However, the F-test only satisfies the condition of non-weak instrument ($F > 10$) for the first regression, which indicates that the estimates using 1808 as a divide must be taken with some caution.

In Column (3) we account for the fact that some of the roads built in 1855 were not finished yet and remained unconnected to the main network (Figure 4).¹¹ In this case, the coefficient of the interacted parameter is not statistically significant, which would indicate that those

¹¹ While for the binary accessibility model presented in the appendix we can evaluate all the unlinked municipalities, here we are only able to distinguish between those for which the market access indicator is computable, i.e. for those that we artificially connected to the main network through added segments (see Figure 5).

municipalities crossed by the new roads started benefiting from them even before the completion of the routes. However, albeit the instrument seems to be good, those results might be affected by the small number of municipalities that were crossed by those unfinished roads.

Finally, in Column (4) we analyse whether the positive effect of increased accessibility on growth was higher in municipalities with a larger percentage of the total population working in manufacturing and commerce-related occupations in 1787, including merchants, blacksmiths, craftsmen, lawyers and notaries. The positive and statistically significant coefficient for the interaction term in Column (4) suggests that, within the crossed municipalities (those with a positive market access value in 1855), the higher the share of population working in manufacturing and commerce, the higher the growth impact of increasing market access. Accordingly, the new roads benefited relatively more those municipalities with a more diversified economic structure and higher presence of secondary and tertiary activities, compared to those in which the primary sector was predominant.

6. Mechanisms: growth vs. relocation

Our results indicate that access to Spanish pre-railway transport infrastructure had a positive impact on municipal population growth. We have shown that between 1787 and 1857 demographic growth was higher in those municipalities that gained access to the network than in those that remained deprived of paved roads. Such higher population growth might have been the result of either higher natural growth through fertility increases and mortality reductions or migrant attraction. In the context of the late 18th and early 19th centuries, when the demographic transition had not started in Spain¹², the second mechanism is much more likely than the first one. In addition, it is also consistent with predictions by theoretical models from regional and urban economics (see a summary in [Redding and Turner \(2015\)](#)), which show that better transport infrastructure generates a new population equilibrium through differential changes in market access. This new equilibrium is associated to the relocation of labor towards those places that benefit from larger reductions in trade costs.

The context of our research, though, is very different from the usual one to which those models are applied. Before 1857 Spain was still a predominantly rural country, and the extent of structural change and agglomeration economies was very limited. Given the low average size

¹² In Spain, both mortality and fertility remained at very high levels during the period under study. Still in the third quarter of the 19th century, Spanish life expectancy at birth was lower than 30, and the reduction of fertility remained at typical pre-industrial levels, except for some regions ([Nicolau, 2005](#))

of the municipalities in our sample¹³, our results would probably be reflecting rural-to-rural movements, rather than rural-urban migration. In addition, although, as indicated in the previous section, the impact of roads was higher in those municipalities with more presence of secondary and tertiary activities, even those places with higher capacity of attraction were still, on average, relatively small and predominantly agrarian. This differentiates our study from most analyses for the railway era ([Atack, Bateman, Haines, & Margo, 2010](#); [Berger & Enflo, 2017](#); [Bogart, You, Alvarez-Palau, Satchell, & Shaw-Taylor, 2020](#)), with the main exception of [Büchel and Kyburz \(2020\)](#), which also largely captures movements from rural to rural municipalities associated to railway construction in Switzerland. However, even in this case the context was much more industrialized than our own.

How likely were such rural-to-rural migration flows in the Spanish economy before 1857? The literature has often stressed that preindustrial societies could be highly mobile, although most movements were temporary and short-distance ([Silvestre, 2002](#)). There were also important rural-to-urban flows, although they hardly increased urban centers' population due to their comparatively high mortality rates. However, in Spain, as in other European economies, this situation was changing since the late 18th century, with an acceleration of urban growth, based on short-to-medium distance immigration in the most industrialized regions ([Cura, 1993](#)), and a widespread increase of long-distance movements in the 1850s ([Santiago-Caballero, 2020](#)). Thus, population mobility of an increasingly permanent character seems to have been growing substantially in Spain during the period under study. On the other hand, although the available evidence for Spain is mainly associated to rural-urban migrations, some studies on other countries have reported the increasing scope of rural-to-rural permanent movements. In addition to [Büchel and Kyburz \(2020\)](#), who show that the railways acted as a pull factor for migrants in rural Switzerland, [Dribe \(2003\)](#) has also shown the importance of short-distance permanent rural-to-rural mobility in mid-19 century Sweden. This author insists on the need to consider migration patterns that cannot be accounted for by the most traditional explanations of rural-urban movements, like wage differentials, and shows that those migrants stayed close to their place of origin and tended mostly to remain in typically rural activities.

Our results would indicate that changes in trade costs associated to the construction of the new network of paved roads might have fostered short-distance, largely permanent, rural-to-rural movements in Spain. The new roads increased certain municipalities' market access and offered as a consequence, specially to the most diversified populations, new opportunities for the growth of traditional sectors or the development of new specializations. Given the paucity of statistical information at the local level for the period under study, it is difficult

¹³ The population of the median municipality in our sample was 574 inhabitants in 1787 and 839 in 1857

to find evidence on these changes and their association with improvements in the transport network. Nevertheless, for the case of the medium sized town of Monforte, for instance, [Dubert \(1998\)](#) has explicitly linked the arrival of the road network to an increasing ability to attract migrants, despite the extremely slow transformation of the town's socioeconomic structure. From a different perspective, [Madrazo \(1984\)](#) has illustrated the way in which the expansion of passenger travel that followed the construction of paved roads could have transformed the economy of many municipalities that gained access to the new network. This author estimated that the yearly amount of travellers using regular stagecoach services in Spain increased from 2,000 in 1818 to 825,000 in 1850 (p. 534). Such a huge rise translated into new demands of lodging and catering services along the route as well as into the growing presence of certain jobs associated to the road: *"together with the staging post and the inn, resources at the service of traffic include the helper, ready to cover the hoofs of the horses, the blacksmith and wagoner to mend the cart axles, rods and wheels; the leather craftsman that sells or fixes harnesses, whips, collars and other tack..."* (p. 563). According to [Madrazo \(1984\)](#) these effects were not confined to passenger traffic. As has been pointed out, the increase in freight transport during the period under study, although much more difficult to estimate, would have also been impressive and, for instance, in the case of the Reinoso road, the aforementioned 20-fold increase in freight traffic would have stimulate the establishment of new industries along the route (pp. 689-90).

In order to capture the potential relocation effects associated with rural-to-rural migration, we analyse the impact of the new road network, not only on those municipalities crossed by a new road but also on those located at certain distance from the new infrastructure. Thus, we regress the long-run difference (1787-1857) log municipal population (equivalent to population growth) on the shortest linear distance from each municipality to the network¹⁴. The model we estimate is:

$$\ln(pop_{m,1857}) - \ln(pop_{m,1787}) = \alpha_0 + \beta_4 Distance_m + \beta_5 \ln(pop_{m,1787}) + \beta_6 X_m + \theta_p + \epsilon_m \quad (3)$$

Where $Distance_m$ is, for each municipality m , the straight line distance in kilometers from its centroid to the closest paved road in 1855; $\ln(pop_{m,t})$ represents the log of population in municipality m and year t ; X_m is a vector of control variables and θ_p are fixed effects for the 459 historical judicial districts. As in previous analyses, we cluster the standard errors at the historical judicial district level and exclude the 57 targeted cities, in line with the inconsequential-units approach. We compute distances through GIS techniques considering all roads, even those partially constructed (not connected to the main network). In addition, to account for the fact that the centroid of the geometrical borders of each municipality did not always coincide with the exact economic and social centre of the town, in the case of the

¹⁴ We develop only an OLS model in order to compare the results with the following model, for which IV estimates are not feasible.

municipalities crossed by a road we set the distance at 0, and accept a small bias for all the others. We show the results in Panel A of table 5. In column 1 we present the average effect for the full sample of Spanish municipalities. The coefficient for the distance variable is not statistically different from 0, suggesting that, away from the crossed municipalities, population growth was not affected by the proximity to the new paved roads. Then, in columns 2-5, we gradually restrict the sample to municipalities within a specific distance from the new roads (20km, 15km, 10km, 5km). The idea here is to look at areas at a walking distance from a paved road, where we would expect the effect to be noticeable. Indeed, when we restrict the sample to those areas, we do find a positive impact of proximity to the network on population growth. The negative coefficients reported in columns 2-5 indicate that the effect of road accessibility on long-term population growth tended to fade away with distance. In addition, the size of the coefficient increases in magnitude (in absolute terms) as we reduce the sample to those municipalities located at shorter distances from the roads. Thus, if for the sample of municipalities within 20km from the new roads we estimate 0.4% less growth for each additional kilometer farther away from the roads (column 2), this percentage increases to 2.0% in column 5, where we restrict the sample to municipalities 5km or less from the new paved roads.

Table 5: Road accessibility and population growth: distance to the roads

Panel A						Panel B				
	(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)
	All	<20km	<15km	<10km	<5km		bins=1km	bins=2km	bins=3km	bins=4km
Distance to roads (km)	-0.001	-0.004***	-0.005***	-0.009***	-0.020***	1 st distance bin	0.081***	0.067***	0.056***	0.039**
	(0.001)	(0.001)	(0.002)	(0.002)	(0.005)		(0.015)	(0.017)	(0.018)	(0.019)
						2 nd distance bin	-0.130*	-0.024	-0.037**	-0.029*
							(0.074)	(0.021)	(0.017)	(0.018)
						3 rd distance bin	-0.006	-0.035*	-0.014	-0.018
							(0.034)	(0.019)	(0.016)	(0.01)
Log population 1787	-0.244***	-0.236***	-0.235***	-0.226***	-0.221***	Log population 1787	-0.249***	-0.249***	-0.248***	-0.246***
	(0.011)	(0.013)	(0.014)	(0.017)	(0.020)		(0.011)	(0.011)	(0.011)	(0.011)
Controls	✓	✓	✓	✓	✓	Controls	✓	✓	✓	✓
Fixed effects	✓	✓	✓	✓	✓	Fixed effects	✓	✓	✓	✓
R2	0.46	0.48	0.47	0.49	0.52	R2	0.47	0.47	0.47	0.46
N	7216	4708	4023	3030	1879	N	7216	7216	7216	7216

Panel A - The long-run (1857-1787) log population difference is regressed on the linear distance (km) to the closest new road and the logarithm of initial population as parameter of convergence. In columns (1) we present the baseline results including all the municipalities in the sample. In the other columns, we restrict the sample to municipalities whose centroids are within a specific distance from the new paved roads. **Panel B** - The long-run (1857-1787) log population difference is regressed on the logarithm of initial population as parameter of convergence and a series of mutually exclusive distance bins indicating the distance between the municipality's centroid and the closest new paved road. For the municipalities crossed by a road we replace the distance from the centroid to the road by 0, so that they are all included in the first bin. The bins are defined as follow: Column (1) 0-1km, 1-2km, 2-3km; Column (2) 0-2km, 2-4km, 4-6km; Column (3) 0-3km, 3-6km, 6-9km; Column (4) 0-4km, 4-8km, 8-12km. **Notes:** Fixed effects correspond to the historical judicial districts. Standard errors are clustered by historical judicial districts and are in parenthesis. *, ** and *** indicates significant at 1, 5, and 10 percent level, respectively.

In a second model, presented in Panel B of table 5, we compare the impact of road accessibility on the municipalities crossed by the new paved roads with its effects on the neighbouring towns. In line with the methodology proposed by Büchel and Kyburz (2020), we modify our baseline equation above by replacing the market access indicator by a series of mutually exclusive binary distance bin dummies, defined by how far the centroid of each municipality was from the closest road. As before, distances are calculated through GIS techniques considering all the roads. In the case of the municipalities crossed by a road we set the distance to 0. This way we ensure that all the municipalities crossed by a road are included in the first distance bin. As in previous regressions, we add the convergence parameter, the same controls and historical judicial district fixed effects. We cluster the standard errors at the historical judicial districts level and remove the main nodes from the sample¹⁵. We perform four regressions, with 1, 2, 3 and 4km bins respectively. In each specification, the coefficient of the first dummy bin is positive and statistically different from 0, reflecting the positive effect of road accessibility on local population growth. Then, in three of the four columns, the coefficient for the second distance bin is negative and significant. The exception is Column 7 (2km bins), where we find a negative, although not statistically significant, coefficient for the municipalities in the second bin (with centroids 2 to 4km away from the new roads) and a negative and statistically significant coefficient for the 4-6km dummy. These results suggest that the growth of the crossed municipalities came partially at the expense of the neighboring areas, since the construction of paved roads negatively affected the demographic growth of those municipalities located at a small distance from the network. This was arguably the outcome of short distance, largely rural-to-rural migration movements, and would be consistent with the idea of the new road network fostering a demographic relocation process. To sum up, rather than being part of a stagnant transport sector, by transforming the economies of the small rural municipalities they crossed and their neighbouring areas the new roads might have brought about a significant spatial reorganization of rural Spain.

7. Conclusions

This paper analyses the effects of the construction of a new network of paved roads in Spain before the first wave of massive railway construction of 1856-66. Previous research was split between those scholars that stressed the stagnation and inefficiency of the Spanish pre-railway transport system and a number of works that highlighted the progress in market integration

¹⁵ In line with Büchel and Kyburz (2020), we only present OLS results because the inclusion of many bins leads to low power of the instruments.

that took place in the century before 1855. Here we adopt a different approach. Our research is inspired by a large body of recent literature that estimates the impact of new transport infrastructure on local growth using GIS techniques. Following this type of analysis, we generate a new georeferenced database of the paved road network and its evolution over time, and estimate the impact of the increase in market access associated to those new roads on the population growth of Spanish municipalities between 1787 and 1857. To deal with potential endogeneity, we take advantage of the fact that the initial network design was largely inspired by administrative reasons, rather than economic ones. In addition, we adopt an inconsequential unit strategy and use instrumental variables in order to remove further endogeneity concerns.

Our estimation results clearly show that the increase in market potential of the municipalities crossed by paved roads translated into a significantly higher population growth along the 70 years of the period under study. We also observe that the benefits of the new roads were higher in those municipalities that gained access to a road earlier in the period, and also in those whose occupational structure was more diversified and included a higher share of manufacturing and commerce-related activities in 1787. These results indicate that the new infrastructure had a substantial transformative capacity of local economies. Although road transport was indeed much more costly than railway transport, the investment effort carried out in the Spanish road system in the century before 1855 had persistent effects on the demographic dynamism of those locations that were crossed by the roads. Those effects are consistent with the available evidence on the growth in transport flows and market integration that took place in the decades before the mid-19th century and do not give support to the idea of a stagnant economy constrained by stationary transport costs before the railways.

In fact, the changes introduced by the new paved roads in the structure of transport costs were sufficient to provoke a new population equilibrium, in line with the predictions of the Urban Economics literature. Municipalities with higher market access were able to draw population from neighbouring areas, probably attracted by the capacity of the roads to stimulate the development of new activities along the route. Such attraction would be consistent with the results of a regression analysis in which we divide municipalities among different bins, defined by their distance to the roads. While those locations that were crossed by a road enjoyed significant positive effects, the impact of road construction was negative on the adjacent bins. This would indicate that roads triggered a process of spatial reorganization of population, with short-distance movements of population towards the vicinity of the new roads. Given the short distances involved and the low average size of the municipalities in the sample, such movements would have had a predominantly rural-to-rural character, in contrast with the rural-to-urban exodus that would characterize later periods.

In a country like Spain, with very small possibilities to use water transport for domestic trade, the railways represented a revolutionary change with long lasting effects on the integration and spatial reorganization of the economy. However, our results provide evidence on the relevance of earlier progress in the transport sector. Although the potential impact of the new paved roads would never be comparable to the effects of the railway system, their transformative capacity is an additional illustration of the dynamism of the Spanish economy in the century before 1855. Rather than awakening a dormant economy, the railways reinforced a process of change that, despite the difficulties associated to a difficult geography and recurrent political conflict, was well under way in the mid-19th century.

References

- Álvarez-Nogal, C., Prados de la Escosura, L., & Santiago-Caballero, C. (2020). *Growth recurring in preindustrial Spain: half a millennium perspective* (Working Papers in Economic History No. 01). Universidad Carlos III de Madrid.
- Alzola y Minondo, P. (1899). *Las obras públicas en España. Estudio histórico*. Bilbao: Imprenta de la Casa de Misericordia.
- Atack, J., Bateman, F., Haines, M., & Margo, R. A. (2010). Did railroads induce or follow economic growth? urbanization and population growth in the American Midwest, 1850-1860. *Social Science History*, 34(2), 171–197.
- Banerjee, A., Duflo, E., & Qian, N. (2020). On the road: Access to transportation infrastructure and economic growth in China. *Journal of Development Economics*, 145, 102442.
- Barquín Gil, R. (1997). Transporte y precio del trigo en el siglo XIX: creación y reordenación de un mercado nacional. *Revista de Historia Económica / Journal of Iberian and Latin American Economic History*, 15(1), 17–48.
- Bateman, V. N. (2015). *Markets and growth in early modern Europe*. London: Routledge.
- Baum-Snow, N. (2007, 05). Did Highways Cause Suburbanization? *The Quarterly Journal of Economics*, 122(2), 775–805.
- Baum-Snow, N., Henderson, J. V., Turner, M. A., Zhang, Q., & Brandt, L. (2020). Does investment in national highways help or hurt hinterland city growth? *Journal of Urban Economics*, 115, 103124. (Cities in China)
- Berger, T. (2019). Railroads and rural industrialization: evidence from a historical policy experiment. *Explorations in Economic History*, 74, 101277.
- Berger, T., & Enflo, K. (2017). Locomotives of local growth: The short- and long-term impact of railroads in Sweden. *Journal of Urban Economics*, 98, 124 - 138. (Urbanization in Developing Countries: Past and Present)

- Bird, J., & Straub, S. (2020). The brasilia experiment: The heterogeneous impact of road access on spatial development in brazil. *World Development*, 127(104739).
- Bogart, D., Alvarez-Palau, E., Satchell, M., & Shaw-Taylor, L. (2020, January). *Transport and urban growth in the first industrial revolution*. (Processed University of California Irvine)
- Bogart, D., You, X., Alvarez-Palau, E., Satchell, M., & Shaw-Taylor, L. (2020, November). *Railways, divergence, and structural change railways, divergence, and structural change in 19th century england and wales*. (Processed University of California Irvine)
- Brunt, L., & Cannon, E. (2014). Measuring integration in the english wheat market, 1770–1820: New methods, new answers. *Explorations in Economic History*, 52, 111 - 130.
- Büchel, K., & Kyburz, S. (2020). Fast track to growth? Railway access, population growth and local displacement in 19th century Switzerland. *Journal of Economic Geography*, 20(1), 155-195.
- Cermeño, A. L., & Santiago-Caballero, C. (2020). *All roads lead to market integration. Lessons from a spatial analysis of the wheat market in 18th century Spain* (Working Papers in Economic History No. 02). Universidad Carlos III de Madrid.
- Chandra, A., & Thompson, E. (2000). Does public infrastructure affect economic activity?: Evidence from the rural interstate highway system. *Regional Science and Urban Economics*, 30(4), 457 - 490.
- Chilosi, D., Murphy, T. E., Studer, R., & Tunçer, A. C. (2013). Europe's many integrations: Geography and grain markets, 1620–1913. *Explorations in Economic History*, 50(1), 46 - 68.
- Cura, E. C. (1993). Las migraciones locales en españa (siglos xvi-xix). *Revista de Demografía Histórica*, 11(1), 21-40.
- Dalgaard, C., Kaarsen, N., Olsson, O., & Selaya, P. (2018). *Roman roads to prosperity: Persistence and non-persistence of public goods provision* (CEPR Discussion Paper No. DP12745). Centre for Economic Policy Research.
- De Benedictis, L., Licio, V., & Pinna, A. (2018). *The long-term effects of the historical roman road network: trade costs of italian provinces* (CRENOS Working Paper No. 2018/01). Centre for North South Economic Research.
- Dirección General de Aduanas. (1857). *Estadística general del comercio de cabotaje entre los puertos de la Península e Islas Baleares en 1857*. Madrid: Dirección General de Aduanas.
- Dirección General de Obras Públicas. (1856). *Memoria sobre el estado de las obras públicas en España en 1856*. Madrid: Imprenta Nacional.
- Donaldson, D., & Hornbeck, R. (2016, 02). Railroads and American Economic Growth: A "Market Access" Approach. *The Quarterly Journal of Economics*, 131(2), 799-858.
- Dribe, M. (2003). Migration of rural families in 19th century southern sweden. a longitudinal analysis of local migration patterns. *The History of the Family*, 8(2), 247-265.
- Dubert, I. (1998). Mundo urbano y migraciones campo-ciudad en galicia, siglos xvi-xix. *Boletín de la Asociación de Demografía Histórica*, XVI, 39-86.
- Duranton, G., & Puga, D. (2014). The growth of cities. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of economic growth* (Vol. 2, p. 781 - 853). Elsevier.
- Duranton, G., & Turner, M. A. (2012, 03). Urban Growth and Transportation. *The Review of Economic Studies*, 79(4), 1407-1440.
- Federico, G., & Persson, K. G. (2010). *Market integration and convergence in the world wheat market*,

- 1800-2000 (Department of Economics Discussion Paper No. 06). University of Copenhagen.
- Flückiger, M., Hornung, E., Larch, M., Ludwig, M., & Mees, A. (2019). *Roman transport network connectivity and economic integration* (CESifo Working Paper No. 7740). CESifo.
- Fogel, R. W. (1979). Notes on the social saving controversy. *The Journal of Economic History*, 39(1), 1–54.
- Frax Rosales, E., & Madrazo, S. (2001). El transporte por carretera, siglos XVIII-XX. *Transportes, Servicios y Telecomunicaciones*, 1, 31-53.
- García-López, M.-Á., Holl, A., & Viladecans-Marsal, E. (2015). Suburbanization and highways in Spain when the romans and the bourbons still shape its cities. *Journal of Urban Economics*, 85, 52 - 67.
- García Raya, J. (2006). Cronología básica del ferrocarril español de vía ancha. In *Iv congreso historia ferroviaria*. Malaga.
- Gibbons, S., Lyytikäinen, T., Overman, H. G., & Sanchis-Guarner, R. (2019). New road infrastructure: The effects on firms. *Journal of Urban Economics*, 110, 35 - 50.
- Gómez Mendoza, A. (1989). *Ferrocarril, industria y mercado en la modernización de España*. Madrid: Espasa Calpe.
- Grafe, R. (2012). *Distant Tyranny. Markets, Power and Backwardness in Spain, 1650-1800*. Princeton: Princeton University Press.
- Granger, C. W. J., & Elliott, C. M. (1967). A fresh look at wheat prices and markets in the eighteenth century. *The Economic History Review*, 20(2), 257–265.
- Grimaldo, J. d. (1720). *Reglamento general expedido por su Magestad en 23 de abril de 1720 para la direccion, y gobierno de los oficios de correo mayor, y postas de España, en los viages que se hizieren y exempciones que han de gozar, y les estan concedidas à todos los dependientes de ellos*. Madrid: Imprenta de Juan de Ariztia.
- Herzog, I. (2021, March). National transportation networks, market access, and regional economic growth. *Journal of Urban Economics*, 122(103316).
- Hornung, E. (2015, 08). Railroads and Growth in Prussia. *Journal of the European Economic Association*, 13(4), 699-736.
- Ita, F. d. (1789). *Mapa Geografico que se extiende de Madrid al Sur de esta Península como de Oriente a Occidente*. Madrid.
- Jacks, D. S. (2005). Intra- and international commodity market integration in the atlantic economy, 1800–1913. *Explorations in Economic History*, 42(3), 381 - 413.
- Jacks, D. S. (2011). Foreign wars, domestic markets: England, 1793–1815. *European Review of Economic History*, 15(2), 277–311.
- Jaworski, T., & Kitchens, C. T. (2019). National policy for regional development: Historical evidence from appalachian highways. *The Review of Economics and Statistics*, 101(5), 777-790.
- Jedwab, R., Kerby, E., & Moradi, A. (2015). History, Path Dependence and Development: Evidence from Colonial Railways, Settlers and Cities In Kenya. *The Economic Journal*, 127(603), 1467-1494.
- Jedwab, R., & Storeygard, A. (2020). *The average and heterogenous effects of transportation investments: Evidence from sub-saharian africa*. (NBER wp 27670)
- Kaukiainen, Y. (2001). Shrinking the world: Improvements in the speed of information transmission,

- c. 1820–1870. *European Review of Economic History*, 5(1), 1–28.
- Llopis, A. E., & Sotoca, S. (2005). Antes, bastante antes: la primera fase de la integración del mercado español de trigo, 1725-1808. *Historia Agraria*, 36, 225-262.
- Madrazo, S. (1984). *El sistema de transportes en España, 1750-1850* (Turner, Ed.). Colegio de ingenieros de caminos, canales y puertos.
- Madrazo, S. (1991). *La edad de oro de las diligencias. Madrid y el tráfico de viajeros en España antes del ferrocarril*. Madrid: Nerea.
- Martinez Vara, T. (1999). La integración del mercado del trigo en el norte y la Castilla del Duero, 1800-1860. algunas reflexiones. *Historia Agraria*(19).
- Michaels, G. (2008). The effect of trade on the demand for skill: Evidence from the interstate highway system. *The Review of Economics and Statistics*, 90(4), 683-701.
- Ministerio de Administraciones Públicas. (2008). *Variaciones de los municipios de España desde 1842*. Madrid: Secretaría General Técnica del Ministerio de Administraciones Públicas.
- Nicolau, R. (2005). Población, salud y actividad. In A. Carreras & X. Tafunell (Eds.), *Estadísticas históricas de España, siglos XIX-XX* (Vol. 1, p. 77-154). Fundación BBVA.
- Nogués-Marco, P., Herranz-Loncán, A., & Aslanidis, N. (2019). The making of a national currency: Spatial transaction costs and money market integration in Spain (1825–1874). *Journal of Economic History*, 79(4), 1094-1128.
- Pablo-Martí, F., Alañón-Pardo, Á., & Sánchez, A. (2020). Complex networks to understand the past: the case of roads in Bourbon Spain. *Cliometrica*.
- Prados de la Escosura, L. (2017). *Spanish economic growth, 1850-2015*. London: Palgrave MacMillan.
- Redding, S. J., & Turner, M. A. (2015). Transportation costs and the spatial organization of economic activity. In G. Duranton, J. V. Henderson, & W. C. Strange (Eds.), *Handbook of regional and urban economics* (Vol. 5, p. 1339 - 1398). Elsevier.
- Reher, D. S. (2001). Producción, precios e integración de los mercados regionales de grano en la España preindustrial. *Revista de Historia Económica / Journal of Iberian and Latin American Economic History*, 19(3), 539–572.
- Ringrose, D. R. (1970). *Transportation and economic stagnation in Spain, 1750-1850*. Durham: Duke University Press.
- Rosés, J. R., Martínez-Galarraga, J., & Tirado, D. A. (2010). The upswing of regional income inequality in Spain (1860–1930). *Explorations in Economic History*, 47(2), 244 - 257.
- Santiago-Caballero, C. (2020). Domestic migrations in Spain during its first industrialisation, 1840s–1870s. *Cliometrica*.
- Shiue, C. H., & Keller, W. (2007, September). Markets in China and Europe on the eve of the industrial revolution. *American Economic Review*, 97(4), 1189-1216.
- Silvestre, J. (2002, 01). Las emigraciones interiores en España durante los siglos XIX y XX: Una revisión bibliográfica. *Ager*, 2, 227-248.
- Smith, A. (1776). *An inquiry into the nature and causes of the wealth of nations*. Basil: James Decker.
- Uebele, M. (2012, 04). What Drives Commodity Market Integration? Evidence from the 1800s. *CESifo Economic Studies*, 59(2), 412-442.

- Uriol Salcedo, J. I. (1992). *Historia de los caminos de españa*. Madrid: Colegio de Ingenieros de Caminos, Canales y Puertos.
- Wahl, F. (2017). Does european development have roman roots? evidence from the german limes. *Journal of Economic Growth*, 22(3), 313–349.

Appendix A. Additional tables

Table 6: Paved roads and population growth. Market Access

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Log Market Access	0.004** (0.002) [0.039]	0.009*** (0.001) [0.091]	0.007*** (0.001) [0.071]	0.039*** (0.010) [0.383]	0.037*** (0.010) [0.366]	0.035*** (0.012) [0.341]
Log population 1787	-0.129*** (0.010)	-0.231*** (0.010)	-0.248*** (0.011)	-0.152*** (0.012)	-0.250*** (0.012)	-0.262*** (0.012)
Log distance to coast			0.042** (0.020)			0.038* (0.023)
River accessibility (0/1)			0.083*** (0.022)			0.052* (0.027)
Port (0/1)			0.308*** (0.043)			0.284*** (0.044)
Canal (0/1)			0.142*** (0.040)			0.073 (0.053)
Station 1857 (0/1)			0.195*** (0.050)			0.129* (0.068)
5km from Portuguese border			-0.003 (0.056)			0.017 (0.053)
5km from French border			-0.001 (0.043)			0.026 (0.042)
Main Post station (0/1)			0.132*** (0.027)			0.007 (0.062)
Pop. share in secondary sector			0.007*** (0.002)			0.007*** (0.002)
Controls			✓			✓
Fixed effects		✓	✓		✓	✓
First-Stage F-Statistic				73.84	42.97	25.77
R2	0.09	0.45	0.47			
N	7216	7216	7216	7216	7216	7216

Notes: Fixed effects at historical judicial district level. Standard errors clustered by historical judicial districts in parenthesis. *, ** and *** indicates significant at 1, 5, and 10 percent level, respectively. Standardised beta coefficients within square brackets.

Appendix B. Additional figures

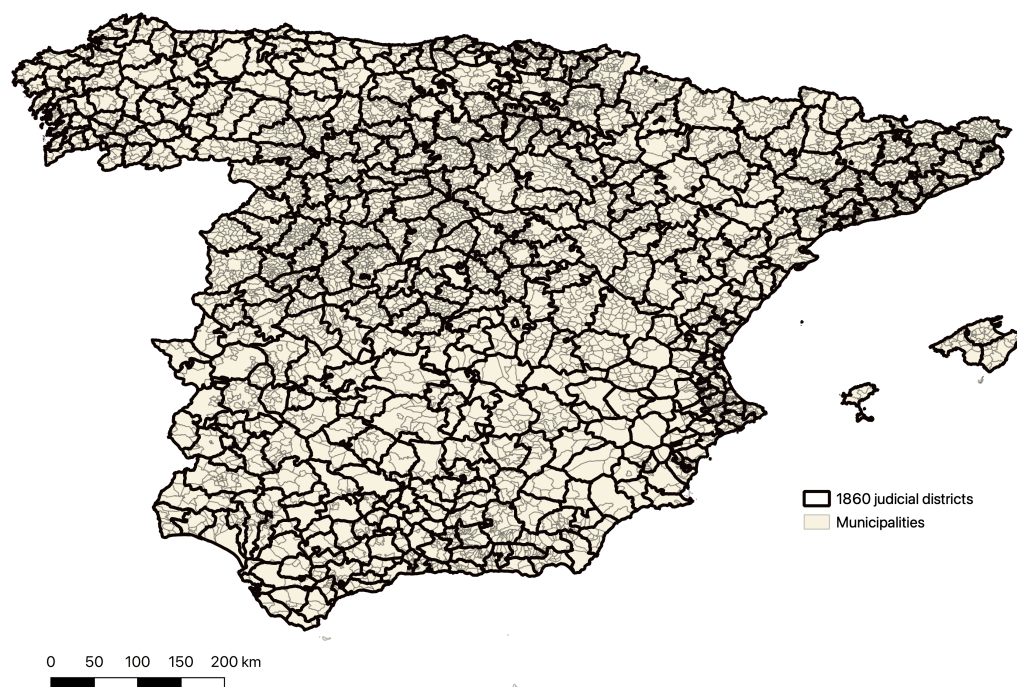


Figure 6: Spanish judicial districts in 1860.

Appendix C. Binary road accessibility

In this section we present the results of an analysis of the impact of road accessibility on local population growth that uses a binary indicator of road access (0/1) as accessibility variable (instead of market access). Table 7 reproduces the analysis reported in Table 2 using this variable; in the same way, Table 8 is equivalent to Table 4, using the binary accessibility instead of market access.

Table 7: Paved roads and population growth: binary accessibility indicator

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Road accessibility (0/1)	0.051*** (0.020)	0.107*** (0.015)	0.085*** (0.015)	0.424*** (0.105)	0.395*** (0.103)	0.365*** (0.125)
Log population 1787	-0.130*** (0.010)	-0.232*** (0.010)	-0.249*** (0.011)	-0.153*** (0.012)	-0.252*** (0.012)	-0.264*** (0.012)
Controls			✓			✓
Fixed effects		✓	✓		✓	✓
First-Stage F-Statistic				78.01	45.05	28.55
R2	0.10	0.46	0.47			
N	7216	7216	7216	7216	7216	7216

Notes: The dependent variable is the long-run difference (1857-1787) in log municipal population. Fixed effects are taken at the historical judicial district level. Standard errors are clustered by historical judicial districts and are in parenthesis. *, ** and *** indicates significant at 1, 5, and 10 percent level, respectively.

Table 8: Paved roads and population growth. Heterogeneity analysis using a binary accessibility indicator

	IV			
	(1) Time 1840	(2) Time 1808	(3) Unlinked roads	(4) Secondary sector
Road accessibility (0/1)	0.414*** (0.151)	0.573*** (0.219)	0.378*** (0.137)	0.313** (0.131)
Road accessibility × Post 1840	-0.220* (0.120)			
Road accessibility × Post 1808		-0.407** (0.182)		
Road accessibility × Unfinished			-0.138 (0.157)	
Road accessibility × Secondary sector share				0.038** (0.015)
Log population 1787	-0.259*** (0.011)	-0.259*** (0.011)	-0.263*** (0.012)	-0.270*** (0.013)
Controls	✓	✓	✓	✓
Fixed effects	✓	✓	✓	✓
First-Stage F-Statistic	12.83	9.08	12.66	13.95
N	7216	7216	7216	7216

Notes: In this long-difference regression, besides the accessibility indicator and the logarithm of initial population, we also add different interaction terms to analyse possible heterogeneous impact of binary accessibility. Accessibility to real roads and the interaction between this indicator and the variable of interest are instrumented with accessibility determined by least cost path lines and its interaction with that variable. The fixed effects are represented by historical judicial districts. Standard errors are clustered by historical judicial district and are in parenthesis. *, ** and *** indicates significant at 1, 5, and 10 percent level, respectively.

Column 6 of Table 7 indicates an impact of 36.5 percentage points of population long-run growth caused by road accessibility over the 70-year period. The first stage results and the F-tests reported in the table are consistent with the validity of the chosen instrument. Moreover, as in the case of our results using market access, the heterogeneity analysis in Table 8 suggests that the average effect presented above is driven by the group of municipalities connected earlier. In the case of the municipalities connected before 1840, the additional long-term population growth associated to road accessibility amounted to 41.4%, much higher than for those connected between 1840 and 1855 (19.4%). In Column (2) we use 1808 as divide and find an even higher difference between the two groups (57.3% vs. 16.6%). Column (3) confirms the absence of any differential impact on the group of municipalities whose roads were not connected to the main network in 1855. Finally, the positive and statistically significant coefficient for the interaction term in Column (4) suggests that, within the crossed municipalities, the higher the share of population working in manufacturing and commerce, the higher the growth impact of road accessibility. All these results are in line with those reported in the main text using market access as accessibility indicator.

Appendix D. Methodological note

In this section, we present a detailed description of all the procedures we followed for cleaning and preparing the data, together with the information on the construction of the instrument and the market access indicator.

D.1 Administrative units (municipalities) and population data

One of the biggest challenges while cleaning and preparing the data for the analysis has been the fact that the administrative units (municipalities) that we use changed over time due to mergers and divisions. This would already be a challenging issue for the changes occurred between the 18th and 19th centuries, within the 70-years of analysis. Furthermore, things get even more complicated since a historical map of municipality boundaries for the period under study is not available, and thus we had to rely on the maps of current municipalities¹⁶. To deal with these issues, we match the historical municipalities to the present ones using different sources. Specifically, after dropping non-peninsular municipalities, we observe 18,151 entries in the 1787 Floridablanca census, 10,146 in the first census carried whose data are reported by the Spanish Statistical Institute (the 1842 *Censo de la Matrícula Catastral*) and the current 7,676 municipal administrative units. For those changes that took place after 1842, the INE website provides a complete catalogue ([Ministerio de Administraciones Públicas, 2008](#)) and following those information we can assign the population data to the right municipalities and correct most of the bias. By contrast, the match between some of the municipalities included in the Floridablanca Census and the current ones is more complicated and not always possible due to the lack of information¹⁷. Besides aggregating the population to the right administrative units, we also needed to make a few changes - i.e. merging two or more municipalities - in the current shapefile. The reason is that the administrative geographical borders refer to a more recent period than the last population census (2011). We make some changes to take into account those units which have been created after 2011. In particular, Dehesas Viejas, Iznalloz and Domingo Pérez de Granada have been merged in a single administrative unit; the municipality of Balanegra has been incorporated into Berja; Jatar into Arenas del Rey; Montecorto and Serrato into Ronda; Pueblonuevo de Miramontes into Talayuela; and Valderrubio into Pinos Puente.

¹⁶ The shapefile of the Spanish municipalities is available on the website of the Centro Nacional de Información Geográfica (CNIG)

¹⁷ We thank Alfonso Díez-Minguela and Julio Martínez-Galarraga for their invaluable help for this matching process.

D.2 Historical roads digitalisation

One of the strengths of our paper is the quality and precision of the digitization of the new paved road network. Applying GIS techniques to information provided in [Madrazo \(1984\)](#) and [Dirección General de Obras Públicas \(1856\)](#), we have digitized the map of the network for four different years along the period under study (see Figure 1). The digitization process has been quite complicated since the original maps were hand-drawn and not always precise. Thus, the classical method of geo-referencing scanned maps could not be used. As a consequence, we also employ the shapefile of current Spanish roads as reference. We started with the map of roads in 1855 that is included in [Dirección General de Obras Públicas \(1856\)](#). This map reports the names of more than 500 municipalities crossed by the paved roads, which helped us to correct for the effects of the spatial distortions of the map on the specific location of each route. Thanks to this process we obtained the shapefile of our baseline map for the year 1855. We then used information included in a series of less precise hand-drawn maps in [Madrazo \(1984\)](#) to obtain digitized shapefiles of the network in 1778, 1808 and 1840 by removing from our baseline map the road stretches that were still unfinished in those dates.

D.3 Least cost path network

As already mentioned, our empirical strategy is based on an instrumental variable approach. Specifically, we instrument accessibility to the new paved roads with accessibility to an ideal cost-minimizing network within a group of municipalities intentionally connected by the designer of the new network. In order to define the targeted nodes we collect information from the 1720 general regulation of post services, whose main routes largely inspired the priorities in road construction as defined in the 1761 Royal Decree. The targeted nodes are: Corunna, Alcalá de Henares, Alcántara, Alicante, Aranjuez, Arévalo, Badajoz, Barcelona, Baztán, Benavente, Burgos, Cadiz, Carmona, Cartagena, Ciudad Real, Ciudad Rodrigo, Córdoba, Denia, San Sebastián, Écija, El Escorial, El Puerto de Santa María, Fraga, Getafe, Guadalajara, Irún, La Junquera, Lleida, Madrid, Medina del Campo, Medinaceli, Mérida, Molinaseca, Murcia, Ourense, Pamplona, Pontevedra, Salamanca, San Clemente, Santiago de Compostela, Seville, Soria, Talavera de la Reina, Tarancón, Tarragona, Teruel, Toledo, Torrelodones, Tortosa, Trujillo, Tudela, Valencia, Valladolid, Vitoria, Zafra, Zamora and Zaragoza (Source: [Grimaldo \(1720\)](#)). We then generate an hypothetical least cost path network connecting those municipalities by considering the roughness of the terrain. Specifically, we take two of those municipalities - having in mind the design of the network - at the time and we run the Dijkstra's algorithm to get optimal paths between their centroids. Based on the costs derived from the elevation raster of the Spanish geographical institute (IGN), the algorithm selects pixel by pixel the cost-minimizing route between them. We repeat the

process for all the couple of nodes we are interested in according to the design of the network. We then use accessibility measured through this cost-minimizing network as instrument for accessibility computed through the new paved network. Figure 3 shows the 1855 paved road network, the least-cost paths and the targeted nodes.

D.4 Market access computation

As already mentioned in the text, we compute for each municipality connected to the network an indicator of market access as the weighted sum of inverted travel times (as a proxy of transportation costs) to all other municipalities through the road network, using as weights the initial population at destination. Travel times are computed with a least cost path algorithm, assuming a homogeneous speed throughout the network. Specifically, we impute a speed of 6.66 km/h (cost parameter of 0.150) based on different historical sources. The algorithm we adopt fails to compute the least cost paths when some parts of the network are not connected. In order to avoid this problem, we artificially add some segments to connect the isolated parts of the network as well as some roads which were not totally built in 1855¹⁸. The added segments are visible in Figure 5. We impute them a speed of about 30% of that of the main network, based on the difference between the average speed for passenger trips through the traditional roads and through the new paved roads, taken from Grafe (2012) and Madrazo (1984) (2 km/h which results in a cost parameter of 0.500). Since the sample of crossed municipalities in 1855 is about 1500, the computational task to recover all the travel times is really demanding. To deal with this, we employed the software GRASS GIS¹⁹ which has the advantage of calculating those travel distances without building new topologies. Specifically, after importing the shapefiles of roads and the centroids of the connected municipalities (with the command *v.import*), we prepare the network by connecting the two topologies with the command *v.net* (option *connect*). In this way, we are able to split the different segments at each centroid intersection. After this, we employ the command *v.net.allpairs* to compute for each municipality the travel time value to reach all other municipalities through the network that we then employ in the market access formula. We import those parameters in STATA and we run a code to compute the market access index for each single municipality based on equation 2.

¹⁸ The idea here is that people were much more likely to walk off the new paved roads for few kilometers instead of taking long detours through the paved roads.

¹⁹ Geographic Resources Analysis Support System (GRASS) is a Geographic Information System (GIS) technology built for vector and raster geospatial data management, geoprocessing, spatial modelling and visualization. Source: <https://grass.osgeo.org/learn/overview/>

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