European
Historical
Economics
Society

EHES Working Paper | No. 280 | July 2025

Why railways fail: Colonial railways and economic development in Habsburg Bosnia-Herzegovina

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Abstract

Are railways always a harbinger of prosperity? We examine the economic effects of railways in Bosnia-Herzegovina under Habsburg colonial rule. Our novel dataset consistently tracks the non-agrarian population share of over 4,500 settlements in Habsburg Bosnia in 1885, 1895, and 1910, based on census records. Applying the inconsequential units approach, with least cost paths as our instrumental variable, we estimate the effect of railway access on structural transformation. Normal-gauge railways deindustrialized Bosnian settlements by exposing local crafts to imperial competition. Narrow-gauge railways accelerated structural transformation temporarily, primarily by attracting foreigners. Narrow-gauge railways had a more sustained impact on structural transformation in settlements endowed with human capital and secured by law enforcement. Our findings suggest colonial railways are no silver bullet for economic development; transport infrastructure requires development prerequisites to have a lasting positive effect.

JEL Codes: I25, J21, N94, O18, R11

Keywords: railways, occupational structure, Bosnia-Herzegovina, Habsburg Empire

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* We are grateful to Hakon Albers, Christine Binzel, Lars Börner, Carlo Ciccarelli, James Fenske, Michael Kopsidis, and Alexander Moradi for their valuable comments. We thank all the participants of the seminar at MLU Halle-Wittenberg, IOS Regensburg, the GfR Conference in Halle, the DENeB Workshop in Hamburg, the FRESH Workshop in Göteborg, the ENCHOS meeting in Paris, the GSWG Congress in Leipzig, the 63rd ERSA Congress, the Urban Economics Association meeting in Copenhagen, and the WEast Workshop in Dublin. Karima Bassit and Leonilla Grozavu provided excellent research assistance. Any remaining errors are ours. Magnus Neubert benefited from a doctoral scholarship by the Hans-Böckler-Stiftung. Stefan Nikolic acknowledges the support of ERC Horizon 2020 Starting Grant (803644) “Spoils of War" hosted by the Dondena Centre for Research on Social Dynamics and Public Policy at Bocconi University.

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1 Introduction

Transport infrastructure has paved the way for modern economic growth in the past and remains a key part of economic policy today, especially in developing countries.[1] Yet the literature on the economic effects of transport infrastructure is still inconclusive. Most scholars find overall positive effects on economic development due to improved market access (Redding and Turner 2015).[2] Other studies, however, uncover mixed evidence showing that infrastructure amplifies development in urban agglomerations at the cost of rural regions (Faber 2014; Tang 2014). This paper examines the economic impact of railways built for extracting natural resources in a colonial setting – Bosnia-Herzegovina under Habsburg colonial rule.[3] The multi-ethnic region resembles modern-day, low-income countries where agriculture and proto-industry dominate the economy.

This historical context enables us to examine if railway access contributed to structural transformation of settlements in the longer term.[4] We are able to distinguish the effects of normal- and narrow-gauge railways.[5] Before the Habsburg occupation, under Ottoman rule, Bosnia-Herzegovina had a primitive road network and only one short-lived, normal-gauge railway.[6] Habsburg authorities reconstructed the normal-gauge railway connecting it to the imperial network, and constructed more than 1,500 kilometers of new, narrow-gauge railways that followed colonial interests. Historical accounts either praise the construction of railways as an economic achievement in itself or criticize railways as a vehicle of economic extraction. We empirically test whether Habsburg colo-

[1] China's *Belt and Road Initiative*, for example, invests heavily in the infrastructure of developing countries to promote economic development.

[2] Recent studies include Donaldson and Hornbeck (2016) and Fenske, Kala and Wei (2023).

[3] Bosnia-Herzegovina fell under Austro-Hungarian rule in July 1878, by the Congress of Berlin. Austria-Hungary was a multi-national constitutional monarchy in Central Europe between 1867 and 1918, and constituted the last phase in the evolution of the Habsburg Empire. Bosnia-Herzegovina gets its name from the river *Bosna* and *Herzog*, a historical title (meaning duke). We will occasionally use Bosnia for short when referring to the country as a whole (not a specific region).

[4] Historical settings have enhanced our understanding of the long-run development impact of infrastructure investments (Hanlon and Heblich 2022).

[5] The basic difference between normal- and narrow-gauge is the track width which is 1,435 mm and 760 mm, respectively. The rolling stock has to match the track width and cannot operate on both railways. Normal-gauge railways are more costly to construct, since curves require a larger radius making for longer routes. Narrow-gauge railways are easier to construct in rugged territory, but they have a lower capacity limit, since the rolling stock is smaller and can handle a smaller freight volume.

[6] This isolated and 115 km long normal-gauge railway had operated only from 1873 to 1875.

nial railways succeeded or failed to unleash the forces of modern economic growth upon Bosnia-Herzegovina.

We introduce a novel dataset tracking over 4,500 settlements during Habsburg rule in Bosnia-Herzegovina. We collected data from each population censuses that Habsburg authorities conducted in Bosnia. The census data distinguishes the agrarian from the non-agrarian population in 1885, 1895, and 1910. This allows us to measure economic development with the share of non-agrarian population.[7] We georeferenced all settlements and transport infrastructure in Bosnia-Herzegovina using GIS software and historical maps. Our treatment comes from the reconstructed normal-gauge railway and the roll out of the narrow-gauge railway network, constructed in three waves that closely corresponded with census years.

We estimate the effect of railway access on structural transformation at the settlement-level applying both a fixed effects and instrumental variables approach. Our identification strategy compares settlements with and without railway access. We first use OLS to estimate the effects of receiving railway access, distinguishing railway treatment of each construction wave. This allows us to tease out the effects that railways had on structural transformation between each census period. We control for pre-treatment trends, district fixed effects, and a host of settlement-level characteristics potentially confounding our treatment effects. To tackle endogeneity concerns regarding the railway treatment, we apply the inconsequential unit approach, with least-cost paths as our instrumental variable. We exclude main railway nodes and surrounding settlements from our estimation, and focus on settlements that were randomly located on a least-cost path between main railway nodes.

We have three main findings. First, integrating into the more mature Habsburg market reversed local economic development in parts of Bosnia-Herzegovina. The share of population occupied outside of agriculture fell significantly in settlements with access to normal-gauge railways compared to other settlements. This effect operated via a

[7]Structural change, that is the shift of population outside of agriculture into higher value-added, secondary and tertiary sectors, may be taken as the most robust indicator of initiated economic development (Kuznets 1973; Herrendorf, Rogerson and Valentinyi 2014).

reduction in relative transport cost. Bosnian normal-gauge railway matched the gauge size of the Habsburg imperial network. This made normal-gauge railways cheaper to use than narrow-gauge railways, which required the cargo to be unloaded and then reloaded at an entrepôt before being exported. The reduction in relative transport costs opened up Bosnian settlements along the normal-gauge railway to imperial competition, which in turn had a negative effect on local proto-industry.

Second, the construction of narrow-gauge railways had a positive but temporary effect on local structural change. Settlements receiving access to narrow-gauge railways saw an increasing share of population occupied outside of agriculture. Our further investigations suggests that foreigner workers, rather than native businesses, were the agents of the short-term boost in structural transformation. Building and maintaining railway tracks, stations, and the rolling stock required numerous non-agrarian workers. The neglected schooling system in Bosnia limited the supply of domestic skilled labor. Rather than by hiring locals, Habsburg authorities satisfied this labor demand primarily by importing to Bosnia foreign workers and engineers from the Empire. The apparent positive effects of narrow-gauge railways on local structural transformation did not persist for long.

Third, narrow-gauge railways had a longer-term impact on structural transformation in settlements endowed with human capital and secured by law enforcement. Schooling and public safety are imperative for local economic development, but not all settlements in Bosnia had equal access to these development prerequisites. We exploit spatial variation in access to public elementary schools and armed forces to examine heterogeneous effects of narrow-gauge railways. While narrow-gauge railways initially contributed to structural transformation of settlements regardless of schooling access, only settlements with access to public elementary schools continued to grow in the longer-run. Similarly, we find that access to armed forces started to condition the economic effect of narrow-gauge railways in unstable areas towards the First World War.

In sum, our results suggest that a substantial reduction of transport costs and the integration of a pre-industrialized economy into an industrialized market might hinder proto-industries and prevent them from catching up. However, railway infrastructure

has the potential to foster structural transformation in areas endowed with sufficient human capital and secured by law enforcement. Investments in transport infrastructure, therefore, are by no means a silver bullet for economic development, but rather a double-edged sword depending on the availability of development prerequisites.

1.1 Contribution

Our study primarily contributes to a literature on the economic effects of transportation infrastructure. Scholars have studied the impact of roads, highways, and railways on a range of outcomes such as education, innovation, employment structure, land value, urban development, urbanization, migration, trade and specialization as well as economic growth in modern[8], historical[9], and long-term perspective[10]. Our study belongs to the historical camp, but our insights speak to the entire field.

Our case study is comparable to road and railway construction in overseas colonies such as India and sub-Saharan Africa. First, those roads and railways appear to be the first large-scale investments in transport infrastructure in regions with high pre-colonial transport costs. Second, transport infrastructure served the economic interests of colonial powers by accessing raw materials and opening new outlets for manufactured goods. We add the unique case of a European colony that is contiguous to the land-based metropolitan. Previous studies on sub-Saharan Africa found that transport infrastructure fostered agricultural specialization on cash crops and (urban) population growth, but not structural transformation. Interestingly, we find that colonial railways either reversed structural transformation or had a transitory positive impact. Our findings provide a

[8]Studies focusing on modern outcomes have examined the effects of highways (Baum-Snow 2007; Faber 2014; Agrawal, Galasso and Oettl 2017; Baum-Snow et al. 2020), roads (Adukia, Asher and Novosad 2020; Aggarwal 2018; Asher and Novosad 2020), and various transport infrastructure (Banerjee, Duflo and Qian 2020) in developed and developing countries.

[9]Recent studies have examined the economic impact of railways in the late 19th and early 20th century in the US (Donaldson and Hornbeck 2016), India (Donaldson 2018; Chaudhary and Fenske 2023; Fenske, Kala and Wei 2023), Japan (Tang 2014), Chile (Forero et al. 2021), Ottoman Empire (Hanedar and Uysal 2020), French Algeria (Maravall 2019), England and Wales (Bogart et al. 2022), Germany (Braun and Franke 2022), Italy (Ciccarelli, Magazzino and Marcucci 2021), the Netherlands (Koopmans, Rietveld and Huijg 2012), Prussia (Hornung 2015), Sweden (Berger and Enflo 2017; Berger 2019), and Switzerland (Büchel and Kyburz 2020).

[10]Jedwab and Moradi (2016), Jedwab, Kerby and Moradi (2017), Okoye, Pongou and Yokossi (2019), and Bertazzini (2022) investigated long-term effects of transportation infrastructure in sub-Saharan Africa. Marein (2022) studied persistent effects of colonial roads in Puerto Rico.

new perspective on how railways affect occupational structure and expand our current understanding that is largely based on more developed economies (Berger 2019; Bogart et al. 2022; Braun and Franke 2022). Moreover, our results relate to studies showing that early colonial investments in public goods are important for the colonial spatial equilibrium to persist until today (Jedwab, Kerby and Moradi 2017; Bertazzini 2022). While the data and context do not allow extending the analysis to the present day, we document sustained structural transformation spanning several decades in settlements with access to public schools and rule of law.

We also contribute to the broader debate about the economic effects of colonialism. One strand argues that colonialism left a positive legacy promoting economic development in the long-run (Dell and Olken 2020), whereas the other strand claims that colonialism persistently hampered economic development (Dell 2010). We stress the decisive role of human capital (Glaeser et al. 2004; Putterman and Weil 2010; Easterly and Levine 2016) and institutions (Acemoglu, Johnson and Robinson 2001; Acemoglu and Johnson 2005) in determining the economic effect of colonialism. In the context of colonial Bosnia-Herzegovina, we find that railway access benefited settlements in proximity to elementary schools and law enforcement. Our results confirm that basic human capital and rule of law are key for local economic development in tandem with railways.

Lastly, we contribute to the literature on the economic development of Bosnia-Herzegovina within the Habsburg Empire. Existing work has estimated economic growth and convergence (Komlos 1983; Good 1986; Good and Ma 1999; Schulze 2000) and has more recently explored regional development and market integration (Schulze 2007; Schulze and Wolf 2009; Reinold 2023*a*;*b*) across the Empire. Ours is the first quantitative study focusing on the economic development of Bosnia-Herzegovina under Habsburg rule. Our results lend empirical support to the less optimistic scholars (Hrelja 1961; Lampe and Jackson 1982; Hauptmann 1983; Juzbašić 2002), rather than the more optimistic accounts (Sugar 1963; Palairet 1993; 1997) of economic performance of Habsburg Bosnia-Herzegovina.

2 Background and conceptual framework

2.1 Economic development of Habsburg Bosnia-Herzegovina

The Habsburg Empire occupied Bosnia-Herzegovina in 1878 according to the Treaty of Berlin and formally annexed the former Ottoman province in 1908. Habsburg Bosnia-Herzegovina was a mountainous and landlocked region located in Southeast Europe in almost exactly the same borders as modern Bosnia-Herzegovina. Imperial Austria and Hungary appointed the *Landesregierung* (provincial government) and sent their civil servants to run the administration in order to develop and modernize the backward region (Ruthner 2014; Donia 2014; 2021). However, the empire imposed financial self-reliance, focused their economic policy on extracting abundant resources, and left the feudal Ottoman agrarian relations untouched.

When the Habsburg Empire occupied Bosnia-Herzegovina, the industrial sector had 2 saw mills, 2 flour mills, 3 breweries, an iron working center around Vareš, and salt production around Tuzla (Chester 2007). The agricultural sector was still feudally organized. Under Habsburg rule, agricultural production doubled between 1882 and 1896. By 1910, the important timber industry employed 22 modern and 109 water-driven saw mills and timber exports rose by 625% during the previous 12 years. In 1904, 64 factories were in public ownership and employed 14,848 workers, whereas 44,327 private enterprises employed 83,899 workers. However, 71% of these enterprises were run by the owner alone, 9% were small establishments (1-2 employees), and 3% were medium-scale factories (3-19 employees). Only a few enterprises (0.3%) were categorized as large-scale establishments (>19 employees), predominantly in extractive sectors such as mining and timber (Schmid 1914). Occupational censuses suggest a developing industrial sector. Between 1895 and 1910, the non-agrarian population share grew from 11.66% to 13.43% indicating structural transformation.

Human capital was a severe bottleneck for the economic development of Bosnia-Herzegovina. The first Habsburg census of Bosnia-Herzegovina (1879) reports the existence of 499 *mektebs* (Quran schools), 18 *medresa* (Muslim middle schools) and around

30 *ruždije* (reformed elementary schools). The *mektebs* focused on religious instructions and did not provide much practical knowledge, many pupils failing to even learn to read and write. The 54 Roman-Catholic and 56 Christian-Orthodox elementary schools in 1879 alone followed the European standard of elementary schools and professional teachers instructed their pupils along a modern curriculum in Serbo-Croatian language (Džaja 1994, pp. 65-83).[11] The provincial administration established 38 (1880) and another 101 (1881) non-confessional elementary schools. The imperial standard was applied including 4 years of elementary schooling, practical curriculum, and the native language as classroom language. In 1908, schooling became obligatory for all 7-years-old children that live within 3 km of an elementary school. From 1895 to 1910 the number of elementary schools grew from 263 to 458, excluding the *mektebs*, which did not qualify as elementary schools. Still, even by 1910, only 17.5% of children in schooling age were enrolled at an elementary school.[12]

Law and order was the key concern of the Habsburg administration after the occupation of Bosnia in 1878. Law enforcement was delegated to the local police established immediately after the occupation. Military corps aided the police in keeping major social unrest in check. The 1895 census reported 221 police stations and another 254 military positions spread across the province. By 1906, the police corps counted 2,300 men operating more than 200 police stations (K. K. Finanzministerium 1906). Since the very beginning of Habsburg occupation, fierce resistance of the native population against the new regime shattered the belief in long-term peace in the province. Occasional upheavals among the Serb population and banditry from beyond the border threatened public security and everyday business. Such fragile peace foreshadowed to the gunshots in Sarajevo in 1914 that triggered the First World War.

[11] The poor quality of the *mektebs* compared to the non-Muslim schools explains the literacy differences across the religions: 94.6% of the Muslim, 89.9% of the Christian-Orthodox and 77.4% of the Roman-Catholic population were illiterate in 1910 (Schmid 1914, pp. 698-736).

[12] According to K. K. Finanzministerium (1906, p. 20), 352 elementary schools existed, of which 239 were public, 103 confessional, and 10 private. This means 267 settlements had an elementary school and 1714 settlements were in reach of an elementary school.

2.2 Railways in Habsburg Bosnia-Herzegovina

Railways were an impressive Habsburg legacy in Bosnia-Herzegovina. Figure 1 illustrates railway expansion and economic development in the province. During the 40 years of Habsburg rule (1878-1918), more than 1,500 km of railways were built. However, railway construction in Bosnia-Herzegovina was neither coherently planned nor executed. It remained restricted by the colonial rivalry of Austria and Hungary, provincial budget constraints, as well as the local geological and geopolitical environment.[13]

When the Habsburg Empire took over Bosnia-Herzegovina, the sparse road network was in bad shape and no railway was in operation. Only a 115 km isolated normal-gauge track existed, connecting Banja Luka and Dobrljin (opened in 1872, the railway shut down already in 1875). Habsburg authorities quickly reconstructed the normal-gauge railway that restarted operation in 1879. Already in 1882, with the construction of the Dobrljin-Sisak section across the border in Croatia-Slavonia, Bosnia's normal-gauge railway became connected to the imperial network.

The construction of Bosnia's narrow-gauge railway network was accomplished in three waves. The first wave (1879-1882) aimed to secure control over Sarajavo, the provincial capital, immediately after the occupation. As a result, the first narrow-gauge railway line rapidly spread from the Austro-Hungarian border at Bosanski Brod to Zenica where a coal mine was set up to provide fuel for the locomotives. By 1882 the *Bosnabahn* was extended to Sarajevo. Opting for a narrow-gauge railway (760 mm) was a pragmatic choice. For one thing, narrow-gauge railways allowed crossing Bosnia's rugged terrain and narrow valleys. For another, excess rails and sleepers for narrow-gauge railways left over from the nearby and recently completed Timișoara–Orșova line were available. The choice of narrow-gauge for the trunk line, however reasonable at that time given the budget and time constraints, determined the track width for subsequent railways.

During the second construction wave (1885-1895), the economic interests of the colonial powers became decisive. Especially the connection to the sea became urgent, but the Hungarian agenda of making Rijeka overtake Trieste as most important Habsburg port

[13] Chester (2007) provides a thorough historical account of railways in Bosnia-Herzegovina.

impeded any direct link to an Adriatic port that could handle the outflow of timber, ores, coal, and agricultural products. Hungary only permitted the 1891 opened railway from Sarajevo via Mostar to Metković, which was a poor harbor because it was located 21 km inside the Neretva river delta and was only accessible by small ships. Austria and Hungary could not agree on an extension to better located ports such as Neum or Ploče. Since the connection to Metković did not provide the badly needed access to a proper harbor, the *Spalatobahn* was proposed, which would connect Split with the Zenica-Sarajevo line. The section Lašva-Bugojno via Travnik with a branch from Donji Vakuf to Jajce was completed on the Bosnian side in 1895. On the Dalmatian side, the section from Split to Sinj was built in 1903. But the conjunction of both sections failed because of Hungarian opposition. Elsewhere, in order to extract the abundant resources of Bosnia-Herzegovina, the north-south trunk line was extended by further new branch lines. By 1885, the manganese mines at Čevljanović were connected and, in 1886, the important branch to Tuzla was opened accessing rich coal fields, salt springs, and the most productive agricultural area of Bosnia-Herzegovina. Other branch lines connected the forests of the Usora valley and Vareš, center of Bosnian mining and metal industry, by 1895.

The third construction wave (1901-1906) was determined by the political deadlock between Austria and Hungary that rendered railway construction in Bosnia-Herzegovina almost impossible. To circumvent the Austro-Hungarian deadlock, forestry railways became a tool for developing the railway network in the interest of Bosnia-Herzegovina, because they were de facto not required to get the approval from Austria and Hungary. Two important forestry railways were completed by 1906. One running through the Krivaja valley and the *Steinbeisbahn* which linked Knin (Dalmatia) with Drvar and Oštrelj in western Bosnia and was later extended to Ribnik and Čardak, but remained isolated from the other Bosnian railways.

Only mounting tensions in the Balkans forced the Austrian and Hungarian governments to agree on new railways in Bosnia-Herzegovina at the eve of the First World War, because they served first and foremost the military interest of the Austro-Hungarian monarchy. The *Dalmatier-Bahn* was taken into operation in 1901 and run to Zelenika

at the Bay of Kotor with a branch line to Trebinje nearby the border to Montenegro. Only the branch line to Dubrovnik made economic sense, since it connected Bosnia-Herzegovina with a slightly better suited harbor than Metković. The last line to be built in the province before the First World War was the *Ostbahn* connecting Sarajevo with the Serbian and the Ottoman border from 1906 onward.

Although of respectable length, the Bosnian railway network did not reduce transport costs across the board. The main reason for uneven transport costs were railway tracks of different standard. The normal-gauge line was connected to the same imperial standard at the border-town Dobrljin. Passengers and freight could thus move uninterrupted between northwest Bosnia and the rest of the Empire. By contrast, Bosnia's narrow-gauge railways did not match the imperial network. The entire traffic leaving Bosnia-Herzegovina via narrow-gauge railways had to be reloaded at the border, in Brod, from narrow- to normal-gauge rolling stock. Reloading and high railway tariffs led to a relatively moderate reduction in transport costs by narrow-gauge railways.[14] Moreover, lacking a proper harbor, most of exported freight had to detour via Brod to Rijeka from where it could be shipped across the world.

Railways brought many foreign workers from the Empire to Bosnia. According to the 1885 census, 25,405 Austro-Hungarian citizens and another 2,165 people from other states lived permanently in Bosnia-Herzegovina only seven years after the occupation. This is more than 2.1% of the population. By 1895, this number rose to 64,450 and 3,022, respectively, and those foreigners accounted for 4.3% of the population. The Habsburg administration reports in 1906 that 9,016 persons worked in Bosnia's public service (civil servants, teachers, police officers, etc.) of which two-thirds were from Austria-Hungary (K. K. Finanzministerium 1906, p. 30). Since the Bosnian railways were publicly operated by the *Bosnische Staatsbahn*, those numbers include 1,365 railway workers of which 85% were Austro-Hungarian citizens (K. K. Finanzministerium 1906, 579). Moreover, Sugar (1963, pp. 167-171) estimates that as much as a quarter of the industrial workforce consisted of foreign workers. In 1904, 11.2% of all self-employed tradespeople in Bosnia-

[14]Railway tariffs in Bosnia-Herzegovina were on average 127% and 131% higher than Austrian and Hungarian tariffs, respectively (K. K. Finanzministerium 1906, p. 575).

Herzegovina were foreigners (K. K. Finanzministerium 1906, p. 346). Foreigners thus dominated public service and railway operation, but were also over-represented among industrial workers and self-employed tradespeople.

Alternative modes of transport were not as important as railways. The only navigable river was the Sava that demarcated the northern border of Bosnia-Herzegovina, whereas the other larger rivers within the province were suitable for floating timber at most. Road infrastructure was as neglected as much as railways when Austria-Hungary took over the province from the Ottomans. The provincial government refurbished and expanded the road network, yet in the absence of motorized vehicles at the time, roads facilitated rather local and short-distance trade. Long-distance transport operated predominantly via railways.

2.3 Conceptual framework

Empirical research on transportation infrastructure and structural transformation comes to ambiguous results. Aggregate welfare effects are undisputedly positive (Fogel 1964; Herranz-Loncán and Fourie 2018; Jedwab and Storeygard 2019), yet the effect on the spatial distribution of economic activity is more controversial. Theoretically, one can distinguish between *lifting* and *shifting*. The aggregate growth effect can be explained by reducing transport costs, integrating markets and subsequent economies of scale lifting productivity. Gravity models, however, predict transport infrastructure to shift economic activity from rural areas to agglomeration centers (Head and Mayer 2004; Redding and Turner 2015). Most empirical studies find positive level or growth effects (Atack, Haines and Margo 2008; Berger 2019; Banerjee, Duflo and Qian 2020; Ciccarelli, Magazzino and Marcucci 2021; Braun and Franke 2022), but another strand of literature associates those positive effects with relocation from non-accessed to accessed areas (Chandra and Thompson 2000; Büchel and Kyburz 2020; Bogart et al. 2022). In some cases, transport infrastructure even reduces industrial production in rural areas, because it fosters agglomeration in urban centers (Faber 2014). Tang (2014), for example, finds that railways in nineteenth-century Japan led to concentration of factories in populous regions without

any positive aggregate effect. We do not yet know exactly under which circumstances the aggregate growth effect prevails over the spatial reorganization effect and vice versa.

The literature has identified a number of channels that could explain the impact of transport infrastructure in developing economies. These include education (Aggarwal 2018; Okoye, Pongou and Yokossi 2019; Adukia, Asher and Novosad 2020; Chaudhary and Fenske 2023), innovation (Agrawal, Galasso and Oettl 2017), land and housing values (Donaldson and Hornbeck 2016; Braun and Franke 2022; Fernihough and Lyons 2022), specialization (Forero et al. 2021; Fajgelbaum and Redding 2022), and state capacity (Acemoglu, García-Jimeno and Robinson 2015). However, the entanglement of these channels with transport infrastructure and structural transformation is rarely considered empirically. We draw on Hirschman (1958) and his notion of *absorptive capacity* as the availability of skills and public goods that enables local communities to respond to development opportunities. According to Hirschman's unbalanced growth theory, investments in railway infrastructure encourage new investments in direct productive activities, yet a shortage in education or law enforcement might prevent those investments and, thus, a positive response to railway access.

In line with Acemoglu, Johnson and Robinson (2001; 2002) the economic legacy of colonialism depends on the implementation of inclusive or extractive institutions. If colonial powers transplanted modern European institutions and provided public goods, those economies prospered in the long-run (Iyer 2010; Mahoney 2010; Lee and Schultz 2012; Mattingly 2017; Dell and Olken 2020). Colonial institutions relying on forced labor and violating property rights undermined economic development (Mahoney 2003; Dell 2010). Habsburg Bosnia was special insofar that it constituted a hybrid case of colonial rule that established modern European institutions, but exploited the natural resources of the province to fund these public goods. As a result of financial self-reliance, public good provision remained spatially fragmented.

We will use the context of colonial Bosnia-Herzegovina and the available historical data to empirically test for heterogeneity in our results. We will measure if locations with better human capital or law enforcement benefited more from access to railways.

3 Data

This section describes our detailed spatial data on economic development and railway expansion in Bosnia-Herzegovina under Habsburg colonial rule. One of the contributions of this paper is our newly-constructed dataset, which we hope will be of use to other scholars interested in development of the South-East European economy.

3.1 Structural transformation

Structural transformation – the relocation of population from agriculture into higher value added sectors – is the prime indicator of initiated economic development. To measure local economic development, we have digitized data on population and occupational structure at settlement-level from Habsburg censuses of Bosnia-Herzegovina. The censuses recorded population in towns and villages in 1879, 1885, 1895, and 1910. From 1885, censuses distinguished agricultural from non-agricultural population. The non-agrarian population share, thus, provides a unique opportunity to track the evolution of local economic development in the Bosnian context.

We were able to match 4,646 settlements across four census years, and geolocate 4,590 of them using geographic information system (GIS) software, online atlases and historical maps.[15] In 1910, we observe the population of each matched settlement. Other years miss some observations. In our analysis, we focus on geolocated settlements for which we have data from 1885 to 1910, a total of 4,554 settlements. These towns and villages account for 90% or more of total population in each census year. Our sample is thus representative for the whole country. Figure 2 illustrates our sample of non-agrarian population shares at settlement-level in 1910. The administrative division grouped these settlements first at the municipality level ($m = 1982$), then on the district level ($d = 55$) and finally on the county level ($c = 7$).

[15]The matching was a laborious effort since settlement names are not fully consistent across censuses. Most issues arise from differences in spelling, rather than name changes. In addition, we differentiated settlements that share the same name with respect to the larger administrative unit in which they are located. Where necessary we merged settlements to ensure consistency over time (e.g. we often merged two adjacent settlements prefixed with "upper" and "lower").

3.2 Railways

We track the expansion of Bosnia's railway network using historical sources and GIS software. We georeferenced small-scale historical maps of the third Austro-Hungarian land survey (1:25,000) and military-geographic surveys (1:75,000) illustrating the transport network in Bosnia.[16] The historical maps are appropriately detailed to enable precise tracing of railways with GIS software. We first create a polyline shapefile of the entire railway system in 1910. Using information on opening dates of each railway line (Chester 2007), we then create shape files for each construction wave. Figure 3 maps the railway system in Habsburg Bosnia-Herzegovina distinguishing the three construction waves.

Table 1 reports summary statistics for the settlements in our dataset. Compared to settlements that never received railway access, settlements that received railway access had a significantly higher share of non-agrarian population. Moreover, structural transformation increased between 1895 and 1910 in settlements that received access to narrow-gauge railways. At the same time, structural transformation seems to have reversed in settlements with access to the normal-gauge railway. Structural transformation stagnated in settlements that did not receive access to the railway network.

3.3 Additional variables

Any causal effect of railways can only be established conditional on a number of confounding factors. For this purpose, we collected additional data to control for geographical, cultural and other factors that may have influenced structural change.

We control for other transport networks and first-nature geography, including roads, rivers, elevation, and soil suitability. We geocoded the road network at the beginning and end of our sample period based on the same historical maps as for railways. We also used these maps to create a shapefile of waterways. For elevation we obtained the information from the European Digital Elevation Model (European Environment Agency 2016) and for suitability of rain-fed wheat we used FAO (2020).

[16]These surveys were conducted and issued by the K.u.k. Militärgeographisches Institut. Digital maps are available via the Austrian Bundesamt für Eich- und Vermessungswesen.

We account for second-nature geography with market access and settlement status. Using population censuses we coded the administrative hierarchy of settlements. The censuses note whether a settlement held town or market status, and whether it was a county or district capital. We approximate market access by log distance from a settlement to a nearest town or market. We also code an indicator variable for district capitals.

We control for Bosnia's diverse cultural landscape. Historical censuses document religious denomination of the population by settlements. In 1910, for example, the main groups were Orthodox Christians (43%), Muslims (32%), and Roman Catholics (23%). A small number of Jews and Protestants were also recorded. Based on census data, we calculate the religious fractionalization index following Alesina et al. (2003).

We rely on Habsburg censuses of Bosnia for three additional variables that we will use in our estimations: foreigners, schools, and law enforcement. Censuses of 1885 and 1895 report the number of permanent residents with a foreign citizenship and separate this group into imperial foreigners and foreigners from outside the Austro-Hungarian Empire. We use these data to measure the share of foreigners in the total population. Next, censuses provide two types of settlement-level data on elementary schooling. The 1885 census recorded the number of teachers in a settlement, teaching in Roman Catholic, Christian Orthodox, or public non-confessional schools.[17] The 1895 census contains a rich set of information about public schools and their confessional ties. In our estimations, we will focus on non-Muslim elementary schools, because they taught modern curricula by professional teachers. We measure the presence of law enforcement, taking into account both police and military forces. The census of 1895 reports the military population and the existence of a police station at the settlement level.

We also digitized industrial railways as a control, and coded railway stations that we will use for testing robustness of our results. Industrial railways were extensions of the regular railways or isolated tracks used exclusively for transporting raw materials. We georeferenced their location based on the same historical maps we used for other railways. We coded an indicator variable for railway stations using the census of 1895 and 1910.

[17]Clerics, giving lessons in Muslim and Jewish schools, were reported in a separate census category.

4 Empirical strategy

4.1 Cross-sectional fixed effects model

We estimate the settlement-level effects of railway access on structural transformation in Bosnia-Herzegovina during Habsburg colonial rule. We use OLS to estimate models of the form:

$$NA_{id} = \alpha_d + \beta_n RAnormal_{id} + \sum_{w=1}^{3} \beta_w RAnarrow_{idw} + \gamma X_{id} + \epsilon_{id} \quad (1)$$

where NA_{id} is the non-agrarian population share in settlement i located in district d in 1895 or 1910. Four treatment variables are of interest. $RAnormal_{id}$ is a binary indicator variable taking the value of 1 if a settlement was within 1 km of the normal-gauge railway.[18] $RAnarrow_{idw}$ is a set of three binary variables indicating if a settlement received access to narrow-gauge railways during the first, second, or third construction wave w.[19]

We include a vector of other settlement-level variables X_{id} controlling for pre-treatment levels of structural transformation, access to industrial railways, road access, river access, elevation, wheat suitability, distance to nearest town or market, district capital status, and religious fractionalization. Estimating our model with a lagged dependent variable yields growth effects of railway access and controls for pre-treatment levels. α_d captures district fixed effects, controlling for unobserved characteristics specific to each district. The error term ϵ_{id} could be correlated across settlements that had access to a similar part of the railway. We therefore cluster standard errors at the level of 1982 municipalities.

[18] A 1 km distance cutoff for railway access implies a catchment area of 3.14 km^2 around the settlement center (using the formula for the area of a circle). Increasing the threshold to 2 km enlarges the catchment area to 12.57 km^2. Habsburg censuses did not report the area of settlements in Bosnia. Braun and Franke (2022) document that in 19th century Württemberg the median area of a parish was 8.6 km^2; Büchel and Kyburz (2020, p. 173) report that the median 19th century Swiss municipality was less than 7 km^2. Therefore, the 1 km threshold seem a reasonable approximation of railway access for Bosnian settlements.

[19] See Section 2 for details on each construction wave.

4.2 Instrumental variables

Estimating Equation 1 by OLS implies the assumption that railway access was randomly assigned to settlements. This assumption is unlikely to hold for all settlements since railways were often constructed to connect economically important regions and urban centers. Thus, railway access may be correlated with numerous observable and unobservable settlement characteristics. A standard way to solve this endogeneity issue is the *inconsequential units* instrumental variable (IV) approach.[20] The basic idea, applied in our context, is that consequential places (e.g. large urban centers) received railway access because of economic or strategic considerations. By contrast, inconsequential places gained railway access because they were randomly located on a cost-minimizing route connecting consequential places. The IV approach bases inference on a randomly chosen subset of settlements (i.e. inconsequential places). Being near the cost-minimizing route serves as the instrumental variable. The major challenges are to select the consequential places that are to be excluded from the sample and to create least-cost paths connecting them. As explained below, we adapt this established approach to fit our context.

Consequential places. Most studies select consequential places (also called nodes) either based on local observable characteristics or in combination with historical planned routes.[21] We also follow this approach. We selected 22 settlements as the main nodes based on two general criteria: economic and strategic importance. Our selection is informed by an early railway plan, observed pre-railway settlement characteristics, and historical literature (see Section 2). Table 2 lists the nodes and summarizes their selection criteria. Hilleprandt's plan of Bosnian railways drew six nodes along the envisioned trunk line: Sarajevo, the capital and largest town; Mostar, the second largest town; Bosanski Brod, the connection at the Austro-Hungarian border, and Doboj, the terminus of that railway segment; Metković, an important sea port; and Zenica, a large coal mine. In line with the railway plan, the rest of the nodes that we included are either

[20] Chandra and Thompson (2000) pioneered this approach which was also applied, for example, by Banerjee, Duflo and Qian (2020).

[21] For example, Büchel and Kyburz (2020) in their study of Switzerland selected consequential places combining 20 most populous locations in 1850 that held historical town status with 23 locations listed as central junctions in early railway plans.

large urban areas, important sources of raw materials, military-strategic locations, or a combination of these characteristics.[22] In our estimations, we will drop the main nodes and all settlements in 7 km radius around them from the sample.[23] This reduces the sample by approximately 8%.

Least-cost paths. We drew a least-cost path between nodes that had railway access during Habsburg rule between 1878 and 1910. We connected nodes with least-cost paths in chronological order of their railway access. Starting with the least-cost path from Banja Luka to Prijedor, we continued until each node has at least one railway connection. Knowing the timing of a node's rail access allows us to calculate the least-cost network for any given sample year, which we use in our analysis of the impact of railways in different periods. Importantly, we do not expect a perfect correlation between least-cost paths and actual railways. By design, the least-cost paths simulate a network based on selected nodes; they do not cover all locations on the actual network, neither do they establish all possible connections between the nodes, as this would introduce noise into the estimates.

For the selected inter-node lines, we draw cost-efficient routes factoring in distance, slope, and river crossings.[24] In order to estimate the cost parameters, we gather information from Chester (2007) and Sugar (1963) on the total construction costs of Bosnian railway lines built by 1910, and combine it with information on actual railway length to arrive at construction costs per kilometer. We use GIS to calculate the slopes covered by the actual route of the tracks. A regression of total construction costs per kilometer on the routes' average slope yields estimated construction costs of 12,000 crowns per kilometer and an additional 26,000 crowns penalty per degree climbed.[25] The costs of

[22] An approach based solely on one of these characteristics would inevitably leave out some important nodes and therefore bias our estimates.

[23] Bogart et al. (2022) report that in the late 19th century the built-up area of Birmingham, one of the largest industrial towns in Britain, was 7 km. We use this cutoff as a most conservative approach to measure urban agglomeration. In robustness checks, we also experimented with other thresholds, but the results remained qualitatively unchanged.

[24] The literature offers two standard ways to connect the selected nodes: straight lines and least-cost paths. For example, Banerjee, Duflo and Qian (2020) applied the former and Büchel and Kyburz (2020) and Bogart et al. (2022) the latter approach. We prefer the least-cost paths approach as it better accounts for Bosnia's mountainous terrain. As a robustness check, we also estimated specifications using the straight line approach. The baseline findings hold.

[25] The relative values of the estimated construction costs are in line with the ones reported by Bogart et al. (2022) for 19th century England and Wales.

building bridges are approximated based on information on bridge construction cost in nineteenth-century Switzerland. We feed these cost parameters to the LCP algorithm to calculate least-cost paths.[26] Finally, for each construction wave, we code an instrumental variable that equals 1 for each settlement that was within 1 km of a least-cost path available in that construction wave, and zero otherwise.

Exclusion restrictions. To ensure the validity of our IV two exclusion restrictions must hold. First, the IV must be exogenous and affect the endogenous variable. Least-cost paths are basically driven by the terrain between the nodes, which has been the same for ages before the railway construction. Second, the IV must affect structural change entirely through railway access. This condition is unlikely to be met, because the terrain that drives least-cost paths may also affect access to roads and rivers. To alleviate this concern, we control for many confounding factors including geographic controls such as elevation, wheat suitability, and log distance to nearest town or market. Since we drop all settlements within a 7 km radius around the nodes, we account for the concern that settlements in proximity to nodes are more likely to lie on least-cost paths and might benefit from spatial spillover effects. Non-random factors such as relative centrality are captured by including district fixed effects.

[26] We explain the calculation in detail in the appendix.

5 Results

In this section, we present our results. We first discuss the effects of railway access on structural transformation. We then explore potential mechanisms and heterogeneity of our results, before reporting robustness checks.

5.1 Structural transformation

Table 3 presents OLS and IV estimates of equation 1. Columns 1 and 3 report OLS results. Columns 2 and 4 present corresponding specifications for our instrumental variable estimates. Each specification includes the full set of settlement-level control variables and district fixed effects. As explained in Section 4, we drop the main railway nodes and surrounding settlements from the sample. This way we focus identification on settlements that accidentally found themselves on a least-cost path between main railway nodes.

Our first main finding is that access to narrow-gauge railways temporarily benefited local economic development. IV estimates suggest that railway access increased the non-agrarian population share by 2.8 percentage points in settlements accessed during the second construction wave (Column 2) and by 5.6 percentage points in settlements treated in the third construction wave (Column 4). This means an average annual increase of 0.28 percentage points from 1885 to 1895 and of 0.37 percentage points from 1895 to 1910. With the average non-agrarian population in our sample being 2.3% in 1895 and 2.9% in 1910, these are economically substantial effects. Although the average treatment effect of the second wave remains positive in the post-construction period (1895-1910), the estimate loses precision and becomes insignificant. Apparently, railway access initially boosted structural transformation, but not all settlements continued their economic transition. We will explore later under which circumstance settlements continued to industrialize. Next, our data allow for a placebo test. We would expect no significant effect of the third wave on structural transformation in the previous period. The null effect of the third wave during the previous construction period (1885-1895) confirms that no pre-treatment trend existed (cf. Column 1 and Column 2) and, thus, the

effect in the subsequent period is caused by railway access. Lastly, the first construction wave does not have any substantial effect on structural transformation.

Our second main finding is that access to normal-gauge railways reversed structural change. According to IV estimates, normal-gauge railways reduced the non-agrarian population share by 3.5 percentage points between 1885 and 1895 and then by 0.7 percentage points until 1910. This translates to an annual decrease of 0.35 percentage points from 1885 to 1895, and of 0.047 percentage points from 1895 to 1910. The effect is strongly statistically significant in 1895, whereas in 1910 it is not significant at conventional levels. The estimates suggests that settlements with access to normal-gauge railways underwent significant deindustrialization in the years between 1885 and 1895, while their economic development stagnated thereafter.

We control for industrial railways, which were extensions of the regular railways or isolated tracks for single purposes such as transporting timber to a sawmill nearby a river. Industrial railways were foremost privately owned and operated. Since we lack information about their exact opening dates, we model them as a single control variable. As expected, industrial railway access correlates positively with structural transformation. The estimates suggest that industrial railway access increased the non-agrarian population share by 2.8 percentage points from 1885 to 1895 and 8.6 percentage points between 1895 and 1910, which means 0.28 and 0.57 percentage points annually. The effects are statistically significant in the latter period. We suspect that this difference stems from most industrial railways opening towards the end of our study period.

Variables controlling for market access and other development correlates, are estimated as statistically significant and with the expected sign. Road access mattered but its magnitude is several times smaller than railway access. Market access, measured as log distance to the nearest town or market, is strongly associated with structural transformation. Settlements in proximity to towns or markets industrialized faster. District capitals also had a substantially higher pace of structural transformation. Lastly, human capital and law enforcement conditioned local economic development. Settlements nearer elementary schools or closer to armed forces developed faster than those further away.

In what follows, we first empirically explore why narrow-gauge railways had a temporary effect on structural transformation, and under what conditions the effect persisted. Then, in Section 6 we discuss the significance of our findings and provide additional micro evidence to qualify our interpretations.

5.2 Foreigners

We next explore if railways contributed to structural transformation by attracting foreigners. By 1885, 27,570 foreigners lived permanently in Bosnia-Herzegovina and this number more than doubled within the next ten years. The share of foreigners in the total population grew from 2.1% to 4.3% in this period. Foreigners were instrumental to the construction, maintenance, and operation of the Bosnian railway. By 1906, 85% of employees in the public railway company were foreigners. Most of the industrial companies, especially in the important timber sector, were also foreign enterprises relying on foreign workers. Fortunately, we are able to measure the share of foreigners in a settlement drawing on population censuses.[27]

Table 4 presents OLS and IV estimates of Equation 1, substituting non-agrarian population share with foreign population share as the dependent variable. Columns 1 and 2 measure the effect of railway access on foreign population share in 1895. Columns 3 and 4 focus on the railway effect on the share of Austo-Hungarian (Imperial) citizens in the same year. Columns 5 and 6 proxy foreign population share in 1910 with the share of Roman Catholics, since this was the dominant religion in Austria-Hungary.[28] In each specification, we control for the pre-treatment level of foreign population shares to capture the effect of railway access on the growth of foreign population.

Table 4 shows that gaining access to narrow-gauge railways in the second and third construction wave is associated with an increased population share of foreigners. The construction of narrow-gauge railways between 1885 and 1895 increased the share of foreigners in the population by 2.7 percentage points (Column 2). Most of the effect is

[27]Section 3 describes the available data.

[28]By comparison, in Bosnia-Herzegovina, about a fifth of the population was Roman Catholic.

driven by immigrants with Austro-Hungarian citizenship (Column 4).[29] Narrow-gauge railway construction enhanced the foreign population share by 0.27 percentage points per year during the second wave whereas the effect was at least 0.16 percentage points per year during the third wave. With the average settlement in our sample having 1.6% of foreign population in 1895, the estimated effects are economically sizable. Importantly, railway access in the second wave does not have a significant effect on foreign population shares in the subsequent period (Column 6), suggesting that narrow-gauge railways only attracted foreigners in the short-run. Lastly, normal-gauge and industrial railways do not significantly predict foreign population shares.

In sum, the emerging pattern from Table 4 resembles the narrow-gauge railway effects on structural transformation reported in Table 3. The magnitude and the timing of the estimated effects are closely aligned. Narrow-gauge railways attracted foreigners during the second and third construction wave. We do not find evidence that the share of foreigners continued to grow beyond the current construction wave. It is therefore plausible that an increasing share of foreigners working in non-agricultural jobs may explain why narrow-gauge railways increased structural transformation during construction periods but not thereafter.

5.3 Human capital

We explore heterogeneous effects of railways, conditional on two potentially relevant factors in our context: human capital and law enforcement.[30]

The uneven distribution of elementary schools across Bosnia-Herzegovina allows us to examine how access to lower-tail human capital conditioned the effect of railways on structural transformation. Human capital has been found a key determinant of local development (Gennaioli et al. 2013). We would thus expect that settlements with schooling access developed more after gaining railway access, compared to settlements with rail-

[29]Columns 1 and 2 report the effect on all foreign citizen, whereas Columns 3 and 4 focus on foreigners holding Austro-Hungarian (Imperial) citizenship.

[30]The effects of railways are seldom uniform in size and sign. For example, Bogart et al. (2022) find a population growth effect close to zero for the bottom six deciles. Braun and Franke (2022) estimate a larger effect for more industrialized parishes. Fenske, Kala and Wei (2023) estimate larger railway effects for initially smaller and more isolated cities.

way access but without access to a school. We use settlement-level data on the location of non-Muslim schools to estimate the effects of railway access conditional on human capital.[31]

We re-estimate Equation 1 in two subsamples divided by the distance to a non-Muslim elementary school and report the results in Figure 4. The full dots represent the point estimates of railway access among settlements close to a non-Muslim school, whereas the hollow points represent the point estimates of the railway effect among settlements beyond the distance threshold. The horizontal axis indicates the distance to a non-Muslim school serving as the threshold to split the sample.[32]

The results show that human capital mattered for structural transformation with a time lag. Our baseline estimations (Table 3) established that narrow-gauge railways had only a temporary effect on structural transformation. Conditional estimates (4a and 4c) show that this structural transformation persisted also in the subsequent, post-construction period, but only for those settlements with access to human capital. By contrast, we find no significant contemporaneous effects conditional on human capital (sub-figures 4b and 4d). In settlements within 1 km of both a school and a narrow-gauge railway, structural transformation advanced by around 1.3 percentage points per year in the period 1885-1895, and by 0.6 percentage points per year from 1895 to 1910. These effects are significantly larger than the estimated unconditional effects. Access to human capital thus made a significant difference. The effect is strongest for settlements within 2 km of a non-Muslim elementary school and gradually decays at larger distance thresholds. This is broadly in line with the contemporary law in Bosnia-Herzegovina that stipulated mandatory schooling for children living within 3 km of a school.

[31]Section 3 describes our data.

[32]For example, at the zero distance threshold, the full dot gives the railway access estimate for settlements with a non-Muslim school, whereas the hollow point reports the estimate for settlements without a non-Muslim school. At the 1 km distance threshold, the full dot gives the railway access estimate for settlements within the threshold distance of a non-Muslim school, whereas the hollow point reports the estimate for settlements beyond the threshold distance of a non-Muslim school. And so on.

5.4 Law enforcement

Spatial variation in the location of armed forces enables us to test the effect of railway access conditional on law enforcement. We would expect that railways had a larger effect on structural transformation in settlements secured by law enforcement. Secure property rights provide investment incentives and are essential for economic development (Besley 1995). Hence, crafts and other businesses were more likely to develop in proximity to armed forces. We exploit settlement-level data on police stations and military corps to gauge the outreach of law enforcement by the log distance to the nearest armed forces.

We re-estimate Equation 1 in two subsamples divided by the distance to law enforcement and report the results in Figure 5. The full dots represent the point estimates of railway access among settlements close to armed forces, whereas the hollow points represent the point estimates of the railway effect among settlements beyond the distance threshold. The horizontal axis indicates the distance to law enforcement serving as the threshold to split the sample.

The results suggest that having access to law enforcement became significant for structural transformation in 1895-1910, in settlements that received railway access in the second construction wave (Figure 5b). In such settlements located within 1 km of armed forces, structural transformation advanced by 0.6 percentage points per year from 1895 to 1910. The magnitudes of the law enforcement effect are comparable to the effect of human capital in the same period. The conditional effect gradually decays with distance and becomes statistically insignificant at the 3 km distance cutoff. Figures 5a and 5c indicate that there is no statistically significant difference between the two sub-samples (settlements with vs without access to armed forces) in the contemporaneous effect of the second or the third construction wave.

In short, access to law enforcement conditioned the effect of narrow-gauge railways on structural transformation in peripheral settlements where the rule of law was more fragile. The effect became salient in the last studied period, that is towards the First World War.

5.5 Robustness

We test the robustness of our results to alternative specifications, estimators, and sample restrictions.

Alternative treatment. We begin by testing the robustness of our results to an alternative treatment variable. The 1895 and 1910 census records the existence of a railway station for each settlement and, thus, we replace our railway access variable with the railway station variable. The results, presented in Table A1, confirm our baseline findings. The railway station treatment yields larger effects than the baseline treatment. This is expected as railway effects attenuate with distance, and railway stations are a strict measure of railway access. This is not our preferred measure, however, since treatment with a station was less exogenous than being located within 1 km distance of a railway track, as larger settlements with a higher growth potential were more likely to have a railway station. Moreover, railway stations are not an ideal measure of railway access as certain branch lines that extended to mines or factories did not have a proper railway station and yet they were connected to the railway network.

Alternative estimator. Our baseline estimation treats all settlements equally regardless of size. Our sample mostly consists of villages of several hundred people. Larger settlements with several thousand inhabitants are relatively few (in the full sample, only 72 settlements had more than 2,000 inhabitants in 1910). Moreover, as explained in Section 4, as part of our identification strategy, we drop main nodes and surrounding settlements from the full sample. This practically means that we already exclude outliers in terms of population from our baseline estimation sample. Nevertheless, we employ a population-weighted estimator to test the sensitivity of our results to the remaining variation in settlement population. Table A2 shows that our estimates become less precise, but the general picture remains. The temporary effects of the normal-gauge railway and the second railway wave become larger in size and remain statistically significant (Column 2). The effect of the third construction wave becomes less statistically significant (Column 4). This is explained by the population-weighted estimator placing larger weight on larger settlements that already received railway access by the third wave.

Alternative samples. We next test the robustness of our results to alternative sample restrictions. As mentioned, our baseline sample excludes railway nodes and all settlements within a 7 km radius of the nodes. While this sample restriction is necessary to avoid endogeneity, we might underestimate the railway effect by excluding agglomeration centers from the sample. We thus re-estimate Equation 1, varying the radius around the nodes that determines the sample restriction. Figure A1 reports the results of this exercise. The point estimates on the far right within each sub-figure reproduce our baseline results. The size of the point estimates is very stable at different cut-offs, which suggests that by restricting the sample we do not underestimate the magnitude of the railway effects. The same coefficients as in our baseline remain highly statistically significant in most cases. The only exception is 1895, at lower cut-offs (0-3 km), where endogeneity is a larger concern. Here, the effects of the normal-gauge and second wave railways become statistically insignificant at conventional levels.

Additional controls. We next control for two potentially confounding factors: serfdom and religion. Bosnia was among the last few European countries to abolish serfdom. During the Ottoman period the Muslim landowners controlled most of the arable land while most of the Christian population were serfs. Austro-Hungarian rule introduced some changes such as permitting serfs to purchase land from the landlords, but it never ended feudal relationships (Sugar 1963). According to the census in 1910, around a third of the agrarian population were some form of serfs (*kmets*). Moreover, landholdings in Bosnia were largely distributed along religious lines. Muslims accounted for 85% of landlords but only for 6% of serfs. The main religious groups (Muslims, Orthodox Christians, and Roman Catholics) were more equally represented among free peasants. We therefore additionally control for land relations and religious segregation.

Table A3 presents results of controlling for the share of serfs in settlement population. Table A4 reports the estimates after controlling for religious composition. In both cases, the baseline results remain qualitatively unchanged. The contemporaneous effects of the second and third wave on structural transformation remain similar in size and highly statistically significant. The IV effect of the normal-gauge railway on structural transfor-

mation in the period 1885-1895 is statistically significant and estimated with a negative sign also in the two robustness checks.

6 Discussion

6.1 Transport costs matter

The construction of the Bosnian railway network lowered transport costs across the country. Transports costs fell more for settlements with access to the normal-gauge railway than for settlements with access to narrow-gauge railways. The normal-gauge railway matched the imperial network. Passengers and cargo could thus be transferred between northwestern Bosnia and the rest of the Empire without interruption. By contrast, narrow-gauge railways were specific to Bosnia and required offloading and reloading of shipments at the provincial border before further distribution. This made transport via narrow-gauge railways more costly relative to the normal-gauge railway.

When the Austro-Hungarian administration connected the normal-gauge line to Banja Luka with the imperial network, northwestern Bosnia became integrated with the imperial market. Reduced transport costs enabled industrial manufacturers from the imperial center to sell their goods in Bosnia and exposed local craftsmen to intense competition. Most craftsmen could not scale their production in small shops and were driven out of the market, because they were less productive (Besarović 1913). These craftsmen gave up their business, returned to agriculture and, thus, reversed structural transformation near the normal-gauge railway. Any newly-created jobs did not outweigh the negative impact of imperial competition. Reduction of transport costs thus led to re-allocation of manufacturing from the backward periphery of the empire to the industrial centers. Such agglomeration effects, also found in other contexts (Faber 2014; Tang 2014; Chandra and Thompson 2000), might depend on the relative backwardness of the accessed region.

Narrow-gauge railways did not reduce transport costs as much as normal-gauge railways and, thus, did not hamper structural transformation on average. Narrow-gauge railways rather integrated the domestic market in Bosnia-Herzegovina and shielded tra-

ditional crafts from cutthroat competition with imperial industrial manufacturers. Despite the absence of internal tariffs within the Empire, high railway tariffs and the cost of reloading the freight at the provincial border worked as a sort of protection of infant industries (Lee 1997; Chang 2003; Melitz 2005). Nonetheless, the shortage of human capital and limited law enforcement hampered the native population to respond to incentives of internal market integration as we argue below.

6.2 Railways and foreigners

The construction of narrow-gauge railways had a transitory positive effect on structural transformation of settlements receiving railway access. Building and maintaining railway facilities including tracks, rolling stock, and stations required numerous non-agrarian workers. Moreover, railway traffic stimulated local business activity, including trade, communication, and hospitality industry. These kind of effects of transport infrastructure are well known in the literature (Ghani, Goswami and Kerr 2016). Accessed regions move to a new equilibrium ahead of the hinterlands, but do not grow faster afterwards.

In Habsburg Bosnia, new jobs created by railways were almost entirely filled with foreign workers predominantly from Austria-Hungary. Our empirical finding that foreign workers propelled structural change of settlements with railway access is supported by historical accounts. Chester (2007, p. 19) reports that the contractor of the first field railway from Bosanski Brod to Sarajevo could not attract a sufficient local workforce despite offering high wages: "In the event virtually all of the 4,000 men and 40 engineers ultimately employed on the contract had to be brought to Bosnia from other, often quite distant parts of the Monarchy." Though this might have changed over the course of the occupation, the lack of qualified workers and the reluctance of the local population towards the empire likely kept the local labor supply short. Furthermore, the public sector in Bosnia-Herzegovina, including the public railway company (*Bosnisch-Herzegowinische Staatsbahn*), relied on foreign public servants from other parts of the empire. Schmid (1914, pp. 51-67) reports that most of the Ottoman civil servants left the province and were replaced by civil servants from Austria-Hungary. After 1885, the civil service opened

up for native applicants but their numbers grew only gradually. Lastly, new businesses were largely started by foreigners. This was characteristic for the entire Balkan peninsula. As Sugar (1982) describes: "New emerging industries often owned by foreigners were also run by foreign workers, since the natives lacked the required skills."

In short, the provincial government faced a severe lack of qualified labor in Bosnia-Herzegovina. To construct, maintain, and operate railways, Habsburg authorities had to rely predominantly on foreign workers as domestic labor supply responded only slowly to the demand for skilled workers. One reason is the neglected schooling system, which we discuss next.

6.3 Conditions for sustained development

Human capital is crucial for catch-up industrialization and economic development (Cipolla 1969; Benhabib and Spiegel 2005; Becker, Hornung and Woessmann 2011). Human capital endowment enabled settlements in Bosnia-Herzegovina to respond to growth opportunities offered by railways. Settlements in proximity to a non-Muslim elementary school continued to transform structurally after receiving railway access. Moreover, this sustained effect on structural transformation was foremost driven by natives, educated in local schools. Equipped with sufficient knowledge and skills, the native population filled the new jobs in the non-agrarian sector or started their own business. An educated native workforce eventually attracted entrepreneurs since they could employ native workers for lower wages than foreign workers requested to work abroad. As Sugar (1963, 169) reports: "The pits and plants were situated in the regions in which a semi-skilled labor pool was available, and expansion of the work force could be handled partly by training and partly by recruiting among the peasantry in the immediate vinicity."

State capacity facilitates economic development (Dincecco and Katz 2016; Dincecco and Wang 2022; Johnson and Koyama 2017), but the reach of the state diminishes at the periphery and law enforcement becomes more costly in remote and sparsely populated areas (Soifer 2008; Chang and Wang 2024). Colonial Bosnia-Herzegovina was no different. Settlements close to armed forces benefited from law enforcement and public safety.

Rule of law attracted businesses and fostered trade. Settlement outside the reach of law enforcement were prone to banditry and nationalist upheavals such as the 1882 uprising in the Herzegovina (Ovčina, Smajić and Mešić 2022). Inhabitants of remote settlements arguably found it more costly to use modern legal institutions (courts of law) and, thus, they tended to rely on traditional law and customs (La Porta and Shleifer 2014).

7 Conclusion

Are railways always a harbinger of prosperity? The economic effects of railways in Bosnia-Herzegovina under Habsburg colonial rule were heterogeneous. The new narrow-gauge network spurred industrial development, firstly by attracting foreign businesses and workers in the short-run. Growth effects of narrow-gauge railways persisted in settlements with access to elementary schooling and protection of armed forces. The normal-gauge railway had the opposite effect. It deindustrialized Bosnian settlements connected to the imperial railway network. Integration of a pre-industrialized colonial economy into an industrialized market thus had a dual effect. In areas with development prerequisites – schools and rule of law – railways helped sustain economic development. In less developed areas, railways hurt development by exposing local crafts to imperial competition. These findings provide a cautionary tale on long-term effects of transport infrastructure that may hold relevance for similar, present-day developing economies.

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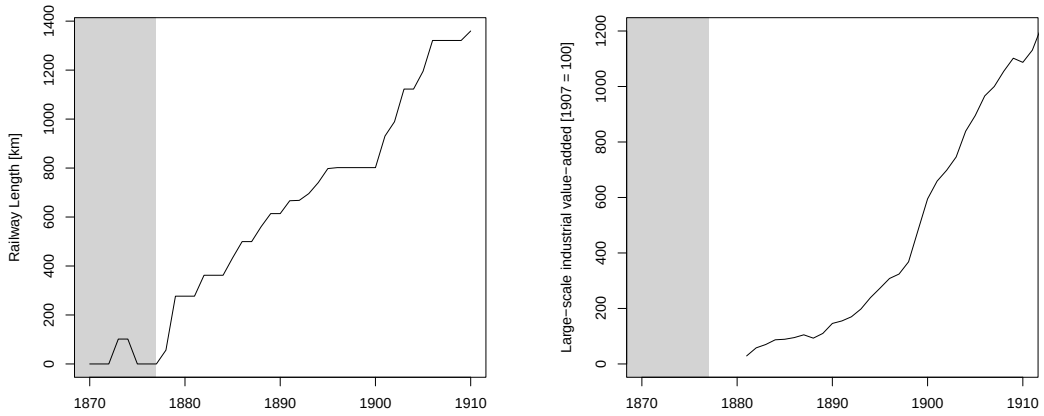
Figures and tables

Figure 1: Railways and economic development in Bosnia-Herzegovina

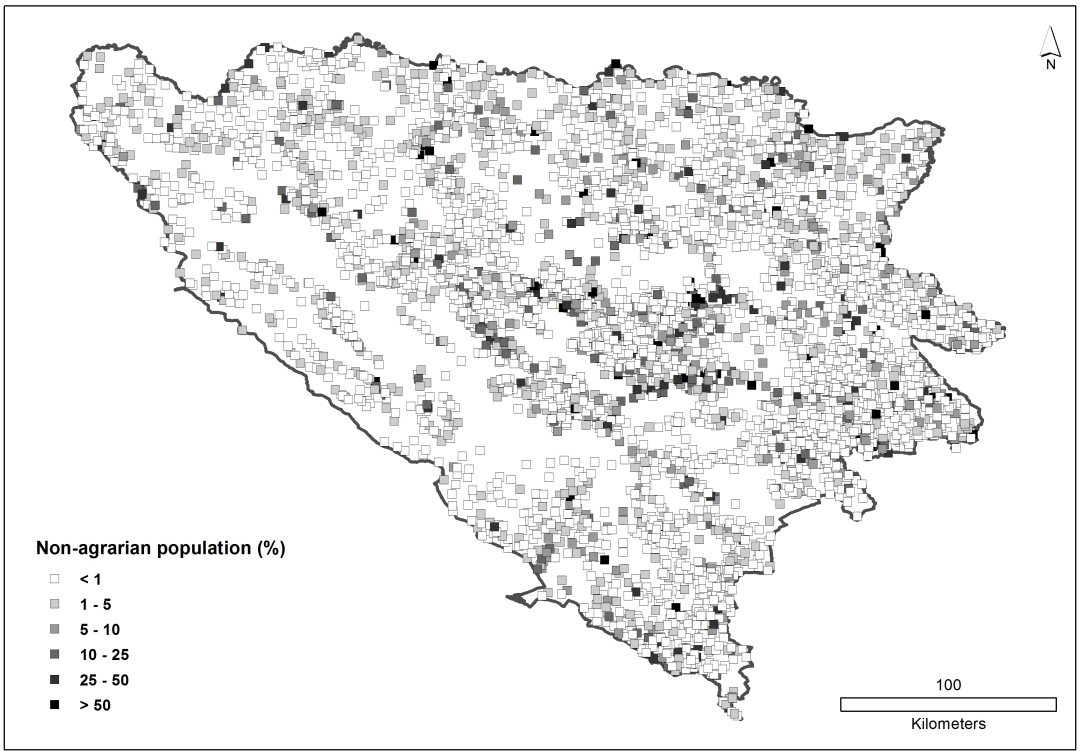


(a) Railway construction

(b) Industrialization

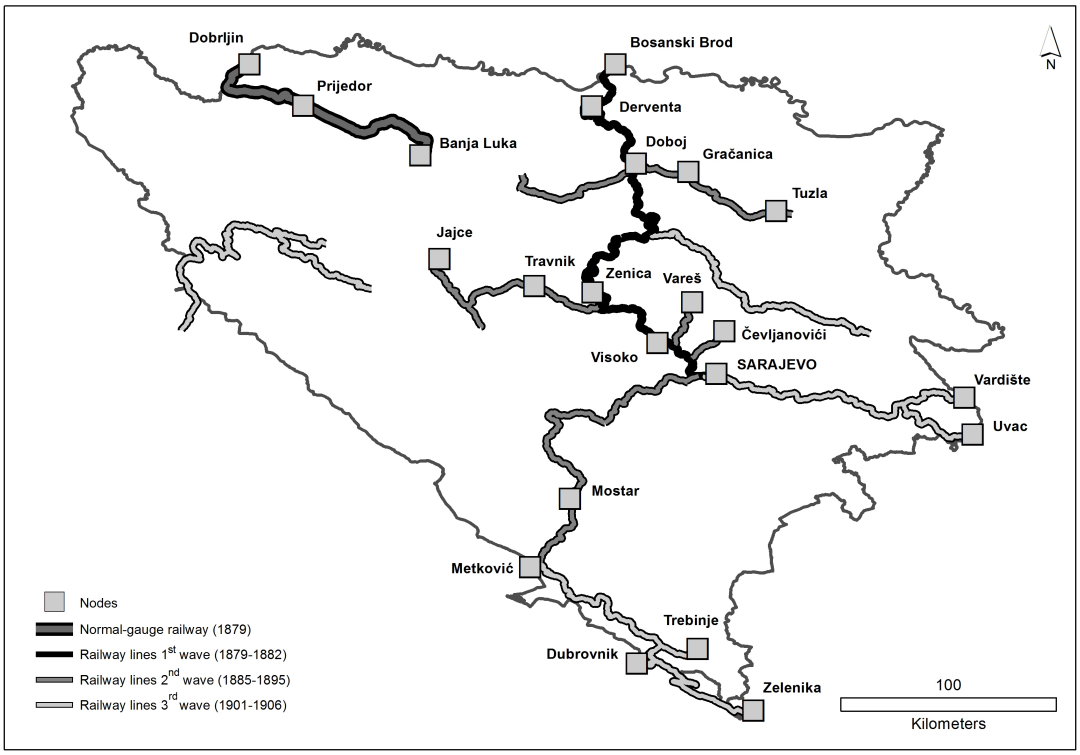
Note: Grey areas indicate the Ottoman era.
Sources: (a) own GIS data (see Section 3); (b) Palairet (1993).

Figure 2: Structural transformation in Bosnia-Herzegovina, 1910



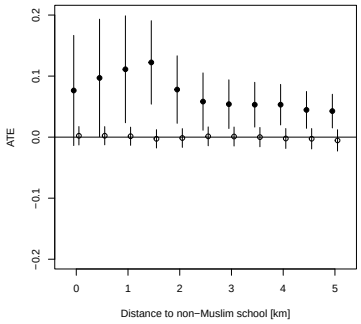
Sources: Own illustration based on the population census of 1910.

Figure 3: Railway network in Bosnia-Herzegovina, 1878-1910

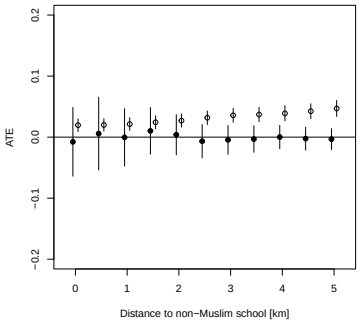


Sources: Own illustration based on the sources noted in Section 3.

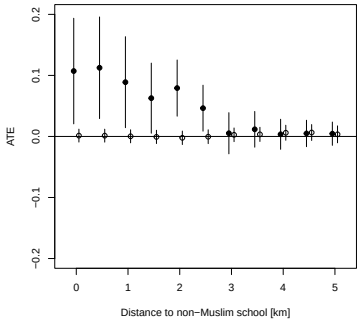
Figure 4: Heterogeneity: human capital



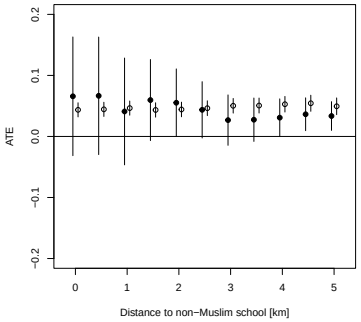
(a) 1st wave, 1885-1895



(b) 2nd wave, 1885-1895



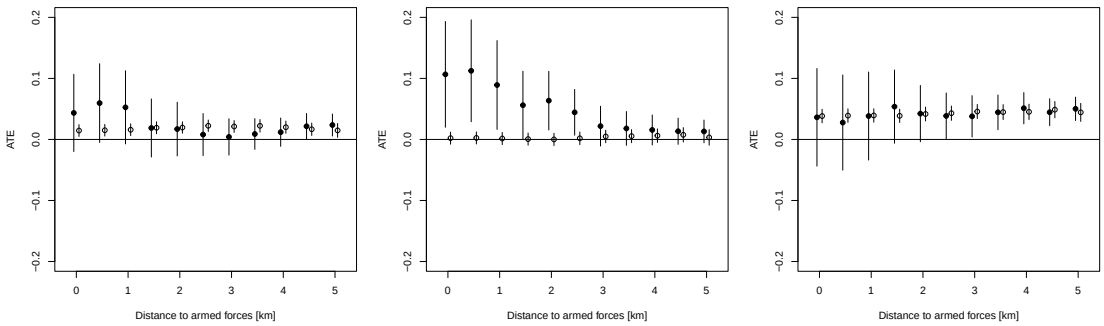
(c) 2nd wave, 1895-1910



(d) 3rd wave, 1895-1910

Notes: the X-axis labels the thresholds to split the sample into treatment and control subsamples, with respect to treatment with human capital as measured by proximity to a non-Muslim elementary school. A full point represents a coefficient in a treatment sample and the hollow point represents a coefficient in a control sample. Vertical lines around point estimates represent 90% confidence intervals. (a) shows the effect of the first wave of narrow-gauge railways (1879-1882) on structural transformation during the post-construction period (1885-1895), conditional on human capital. (b) shows the conditional effect of the second wave of narrow-gauge railways (1885-1895) on structural transformation in the same period. (c) shows the conditional effect of the same railways as in (b) yet in the subsequent period (1895-1910). (d) shows the conditional effect of the third wave of narrow-gauge railways (1901-1906) on structural transformation in the last period (1895-1910).

Figure 5: Heterogeneity: law enforcement



(a) 2nd wave, 1885-1895 (b) 2nd wave, 1895-1910 (c) 3rd wave, 1895-1910

Notes: the X-axis labels the thresholds to split the sample into treatment and control subsamples, with respect to treatment with law enforcement as measured by proximity to armed forces. A full point represents a coefficient in a treatment sample and the hollow point represents a coefficient in a control sample. Vertical lines around point estimates represent 90% confidence intervals. (a) shows the effect of the second wave of narrow-gauge railways (1885-1895) on structural transformation in the same period, conditional on the distance to the armed forces. (b) shows the conditional effect of the same railways as in (a) yet in the subsequent period (1895-1910). (c) shows the conditional effect of the third wave of narrow-gauge railways (1901-1906) on structural transformation in the last period (1895-1910).

Table 1: Summary statistics

	Full sample		Normal-gauge	Narrow-gauge			
			1879	1st wave	2nd wave	3rd wave	no railway
	Mean	SD	Mean	Mean	Mean	Mean	Mean
Non-agrarian population share, 1885	0.092	0.140	0.250	0.147	0.157	0.136	0.087
Non-agrarian population share, 1895	0.026	0.094	0.133	0.089	0.093	0.046	0.021
Non-agrarian population share, 1910	0.033	0.101	0.113	0.115	0.110	0.099	0.026
Foreign population share, 1885	0.010	0.057	0.031	0.018	0.007	0.009	0.010
Foreign population share, 1895	0.016	0.065	0.072	0.036	0.030	0.017	0.015
Roman Catholic population share, 1895	0.184	0.343	0.292	0.284	0.335	0.072	0.179
Roman Catholic population share, 1910	0.190	0.343	0.305	0.299	0.336	0.105	0.185
Road access	0.187	0.390	0.440	0.494	0.800	0.180	0.156
River access	0.141	0.348	0.440	0.728	0.588	0.577	0.099
Distance to nearest town or market [km]	11.1	6.6	9.3	6.2	7.0	14.022	11.244
Wheat suitability	5052	1870	6415	5234	4436	4269	5088
Elevation [m]	569.1	302.3	161.8	299.8	454.1	488.1	583.6
District capital	0.010	0.097	0.080	0.062	0.030	0.027	0.007
Religious fractionalization index, 1885	0.139	0.191	0.159	0.209	0.249	0.115	0.134
Religious fractionalization index, 1895	0.146	0.192	0.165	0.241	0.261	0.126	0.140
Human capital	8.226	4.951	6.499	5.616	5.199	6.151	8.463
Law enforcement	5.706	3.205	3.380	4.337	4.633	4.521	5.818
Observations	4554		25	81	165	110	4173

Notes: Non-agrarian population share in 1885 included only household heads. Non-agrarian population share in 1895 and 1910 included all household members. Hence, the non-agrarian population share in 1885 is overestimated compared to the later censuses. Road access is a binary variable indicating if a settlement is within 1 km of road in 1885. River access is a binary variable indicating if a settlement is within 1 km of river. Elevation is measured in meters. District capital is a binary variable indicating if a settlement is a district capital. Religious fractionalization index follows Alesina et al. (2003). Human capital is distance to nearest non-Muslim elementary school in 1895. Law enforcement is distance to nearest armed forces in 1895. Distance is measured in km.
Sources: see Section 3.

Table 2: Railway network nodes

Node	Railway access	Purpose
Banja Luka	1878	top-3 town and coal mine
Prijedor	1878	iron ore mine and top-8 town
Dobrljin	1879	border to Austria-Hungary
	First wave	
Bosanski Brod	1879	Hilleprandt plan and border to Austria-Hungary
Derventa	1879	top-13 town
Doboj	1879	Hilleprandt plan
Zenica	1879	Hilleprandt plan and coal mine
Visoko	1882	top-11 town
Sarajevo	1882	Hilleprandt plan, capital and top-1 town
	Second wave	
Čevljanovići	1885	manganese ore mine
Mostar	1885	Hilleprandt plan, capital and top-2 town
Metković	1885	Hilleprandt plan and sea port
Tuzla	1886	top-7 town and salt sources
Travnik	1893	top-5 town
Jajce	1895	top-12 town
Vareš	1895	iron ore mine
	Third wave	
Zelenika (Dalmatia)	1901	military
Dubrovnik (Dalmatia)	1901	sea port
Trebinje	1901	military
Vardište	1906	military
Uvac	1906	military

Notes: Nodes are obtained from Chester (2007).

Table 3: Railway access and structural transformation

	(1)	(2)	(3)	(4)
	Non-agrarian population share			
	1895		1910	
	OLS	IV	OLS	IV
Railway access 1879 (normal-gauge)	0.031	-0.047***	-0.026	-0.007
	(0.038)	(0.013)	(0.021)	(0.010)
Railway access 1879-1882 (1st wave)	0.016	0.017	0.005	0.023
	(0.013)	(0.016)	(0.015)	(0.021)
Railway access 1885-1895 (2nd wave)	0.021**	0.028**	0.009	0.031
	(0.010)	(0.013)	(0.008)	(0.020)
Railway access 1901-1906 (3rd wave)	0.000	0.001	0.043***	0.056***
	(0.010)	(0.013)	(0.012)	(0.018)
Industrial railway access	0.029	0.028	0.086***	0.086***
	(0.021)	(0.021)	(0.023)	(0.023)
Road access	0.010***	0.009**	0.009***	0.006*
	(0.003)	(0.003)	(0.003)	(0.004)
Market access	-0.013***	-0.013***	-0.006**	-0.006**
	(0.003)	(0.003)	(0.003)	(0.003)
District capital	0.162***	0.164***	0.113***	0.112***
	(0.041)	(0.040)	(0.035)	(0.035)
Human capital	-0.001***	-0.001***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Law enforcement	-0.004***	-0.004***	-0.005***	-0.005***
	(0.001)	(0.001)	(0.001)	(0.001)
Controls	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Kleibergen-Paap F statistic		22.5		24.5
Dep. Var. μ	0.023	0.023	0.029	0.029
R^2	0.472	0.469	0.519	0.517
Observations	4179	4179	4179	4179

Notes: Table reports results of OLS and IV estimation of Equation 1. Controls are lagged dependent variable, industrial railway access, road access in 1885, log distance to nearest town/market (market access), district capital status, log distance to elementary school (human capital), log distance to armed forces (law enforcement), religious fractionalization index in 1885 and 1895, river access, log wheat suitability index and log elevation. Standard errors, clustered at the municipality level, are given in parentheses. ***, **, and * refer to $p<0.01$, $p<0.05$, and $p<0.10$, respectively.

Table 4: Railway access and population share of foreigners

	(1)	(2)	(3)	(4)	(5)	(6)
	Foreign population share					
	Total, 1895		Imperial, 1895		Catholics, 1910	
	OLS	IV	OLS	IV	OLS	IV
Railway access 1879 (normal-gauge)	0.009	-0.013	-0.000	-0.009	0.013	-0.001
	(0.026)	(0.018)	(0.017)	(0.018)	(0.013)	(0.017)
Railway access 1879-1882 (1st wave)	-0.003	-0.001	-0.004	-0.002	-0.012	-0.003
	(0.005)	(0.005)	(0.004)	(0.005)	(0.008)	(0.011)
Railway access 1885-1895 (2nd wave)	0.021***	0.027***	0.018***	0.022***	-0.006	0.007
	(0.007)	(0.009)	(0.006)	(0.007)	(0.007)	(0.013)
Railway access 1901-1906 (3rd wave)	0.001	0.005	0.001	0.004	0.027***	0.024**
	(0.003)	(0.005)	(0.003)	(0.004)	(0.007)	(0.010)
Industrial railway access	0.012	0.012	0.012	0.012	0.023	0.024
	(0.013)	(0.013)	(0.013)	(0.013)	(0.019)	(0.019)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap F statistic		21.1		21.1		19.8
Dep. Var. μ	0.016	0.016	0.015	0.015	0.176	0.176
R^2	0.619	0.618	0.684	0.684	0.944	0.944
Observations	4179	4179	4179	4179	4179	4179

Notes: Controls are lagged dependent variable, industrial railway access, road access in 1885, log distance to nearest town/market (market access), district capital status, log distance to elementary school (human capital), log distance to armed forces (law enforcement), religious fractionalization index in 1885 and 1895, river access, log wheat suitability index and log elevation. Standard errors, clustered at the district level, are given in parentheses. ***, **, and * refer to p<0.01, p<0.05, and p<0.10, respectively.

A Appendix figures and tables

Table A1: Alternative treatment: railway station

	(1)	(2)	(3)	(4)
	Non-agrarian population share			
	1895		1910	
	OLS	IV	OLS	IV
Railway access 1879 (normal-gauge)	-0.021*	-0.092*	-0.005	-0.045
	(0.011)	(0.048)	(0.012)	(0.067)
Railway access 1879-1882 (1st wave)	0.030	0.052	-0.006	0.068
	(0.021)	(0.044)	(0.012)	(0.060)
Railway access 1885-1895 (2nd wave)	0.079***	0.091**	0.069***	0.109*
	(0.019)	(0.039)	(0.024)	(0.064)
Railway access 1901-1906 (3rd wave)	-0.003	0.006	0.081***	0.211***
	(0.011)	(0.048)	(0.027)	(0.070)
Controls	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Kleibergen-Paap F statistic		8.7		0.4
Dep. Var. μ	0.022	0.022	0.029	0.029
R^2	0.477	0.476	0.524	0.507
Observations	4179	4179	4179	4179

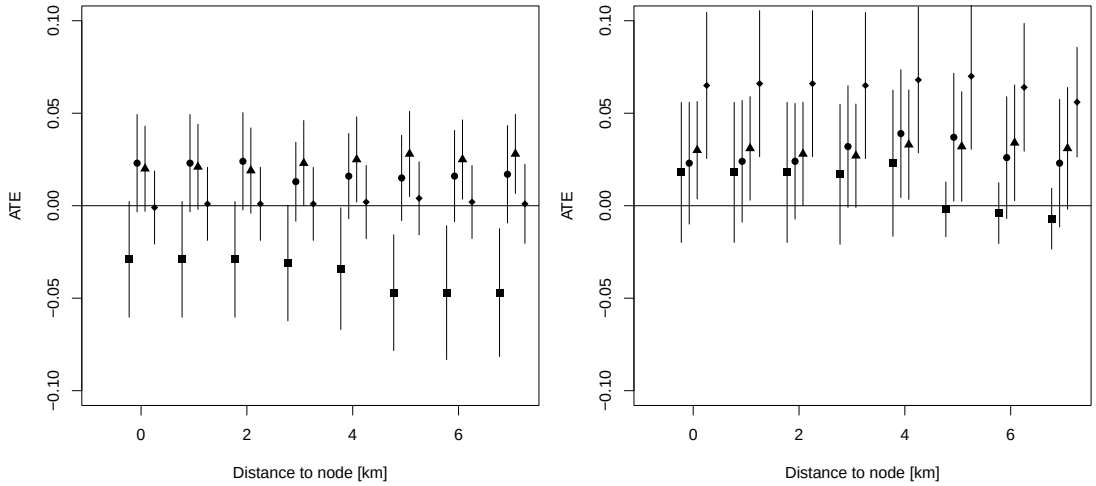
Notes: Settlements with railway stations have railway access. Controls are the same as in Table 3. Standard errors clustered at municipality level in parentheses. ***, **, and * refer to p<0.01, p<0.05, and p<0.10, respectively.

Table A2: Alternative estimator: population-weighted estimates

	(1)	(2)	(3)	(4)
	Non-agrarian population share			
	1895		1910	
	OLS	IV	OLS	IV
Railway access 1879 (normal-gauge)	0.002	-0.073**	-0.012	-0.016
	(0.030)	(0.029)	(0.011)	(0.013)
Railway access 1879-1882 (1st wave)	0.029	0.024	-0.013	0.001
	(0.040)	(0.050)	(0.021)	(0.029)
Railway access 1885-1895 (2nd wave)	0.051***	0.060**	0.038	0.019
	(0.018)	(0.028)	(0.028)	(0.026)
Railway access 1901-1906 (3rd wave)	-0.003	-0.019	0.040	0.072*
	(0.015)	(0.024)	(0.025)	(0.042)
Controls	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Kleibergen-Paap F statistic		23.8		24.1
Dep. Var. μ	0.070	0.070	0.069	0.069
R^2	0.795	0.793	0.822	0.820
Observations	4179	4179	4179	4179

Notes: Estimates are weighted by settlement population in the respective year. Controls are the same as in Table 3. Standard errors clustered at municipality level in parentheses. ***, **, and * refer to p<0.01, p<0.05, and p<0.10, respectively.

Figure A1: Alternative sample restriction: varying radius around the nodes



(a) Railway effects on structural transformation, 1895

(b) Railway effects on structural transformation, 1910

Notes: the X-axis indicates the distance thresholds to drop settlements around nodes. Thus all settlements within a certain radium around the nodes are excluded from the respective estimation. Squares represent regression coefficients of normal-gauge railways, dots represent coefficients of first wave narrow-gauge railways (1879-1882), triangles represent coefficients of second wave narrow-gauge railways (1885-1895), and diamonds represent coefficients of third wave narrow-gauge railways (1901-1906). Vertical lines around point estimates indicate 90% confidence intervals.

Table A3: Additional controls: controlling for serfdom

	(1)	(2)	(3)	(4)
	Non-agrarian population share			
	1895		1910	
	OLS	IV	OLS	IV
Railway access 1879 (normal-gauge)	0.031	-0.047**	-0.026	-0.007
	(0.038)	(0.021)	(0.021)	(0.010)
Railway access 1879-1882 (1st wave)	0.016	0.017	0.005	0.023
	(0.013)	(0.016)	(0.015)	(0.021)
Railway access 1885-1895 (2nd wave)	0.021**	0.028**	0.009	0.031
	(0.010)	(0.013)	(0.008)	(0.020)
Railway access 1901-1906 (3rd wave)	0.000	0.001	0.043***	0.056***
	(0.010)	(0.013)	(0.012)	(0.018)
Controls	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Kleibergen-Paap F statistic		22.5		24.7
Dep. Var. μ	0.023	0.023	0.029	0.029
R^2	0.472	0.469	0.519	0.517
Observations	4179	4179	4179	4179

Notes: Controls are the same as in Table 3. Additionally, we control for the 1885 and 1895 share of kmets (serfs) in the agrarian population. Standard errors, clustered at the municipality level, are given in parentheses. ***, **, and * refer to p<0.01, p<0.05, and p<0.10, respectively.

Table A4: Additional controls: controlling for religion

	(1)	(2)	(3)	(4)
	Non-agrarian population share			
	1895		1910	
	OLS	IV	OLS	IV
Railway access 1879 (normal-gauge)	0.033	-0.043**	-0.025	-0.006
	(0.038)	(0.021)	(0.021)	(0.010)
Railway access 1879-1882 (1st wave)	0.014	0.015	0.004	0.018
	(0.012)	(0.015)	(0.015)	(0.021)
Railway access 1885-1895 (2nd wave)	0.020**	0.027**	0.006	0.030
	(0.009)	(0.013)	(0.008)	(0.020)
Railway access 1901-1906 (3rd wave)	-0.001	-0.001	0.041***	0.053***
	(0.010)	(0.013)	(0.011)	(0.017)
Controls	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Kleibergen-Paap F statistic		20.4		24.0
Dep. Var. μ	0.023	0.023	0.029	0.029
R^2	0.489	0.486	0.524	0.522
Observations	4179	4179	4179	4179

Notes: Controls are the same as in Table 3 Additionally, we control for the 1885 and 1895 population share of Catholics, Muslims, Jews and other confessional groups against Orthodox Christians, which are the reference category. Standard errors, clustered at the municipality level, are given in parentheses. ***, **, and * refer to $p<0.01$, $p<0.05$, and $p<0.10$, respectively.

B Least-cost paths

We provide detailed steps on our procedure of calculating least-cost paths.

1. Selection of 22 main nodes (as listed in Table 2) based on the following criteria: economic and strategic importance. First, 6 nodes highlighted in Hilleprandt's railway plan for Bosnia: Bosanski Brod, Doboj, Zenica, Sarajevo, Mostar, and Metković. Second, 10 major population centers and/or sources of raw materials along the railway network: Banja Luka, Prijedor, Derventa, Visoko, Tuzla, Travnik, Jajce, Gračanica, Vareš, and Čeljanovići. Third, 6 strategic locations near the sea or border: Dobrljin, Dubrovnik, Zelenika, Uvac, Vardište, and Trebinje.

2. Selection of main lines. We connect nodes with least-cost paths in chronological order of their railway access until each node has at least one railway connection.

3. Collection of information on construction costs of railway lines built between 1879 and 1910. Chester (2007, Table 8.II) and Sugar (1963, appendix VII) provide largely consistent data on railway construction costs per km. With the exception of few private mining railways, the data cover all Bosnian railways constructed during Habsbug rule.

4. Calculation of the gradient (average degree of slopes per km) of railway lines. We created a slope raster using QGIS built-in functions (slope in degrees), based on the Global topography dataset (30 x 30 arcsec resolution) generated from SRTM panels from the NASA server https://earthdata.nasa.gov/ and processed using QGIS 3.16.16.

5. Regression of railway construction costs:

$$cost\ per\ km_i = \alpha + \beta\ degree\ per\ km_i + \varepsilon_i \tag{2}$$

where *cost per* km_i is the total construction cost of railway i per kilometer, *degree per* km_i is the average slope per km measured in degrees, and α is a constant. We obtain 12,023 for α and 26,235 for β. In line with Büchel and Kyburz (2020), we interpret β as costs related to rough terrain (kilometer costs per average gradient measured in degrees) and α as costs related to track length (cost per additional kilometer).

6. Approximation of the cost of bridge construction. The main purpose of introducing

this parameter is to attach a cost to crossing a river and therefore prevent unnecessary river-crossings. Büchel and Kyburz (2020, p. 182) estimate that bridge construction costs ca. 20 times more than building railways per km. We apply this ratio to Bosnia so that the bridge construction coefficient per km is 240,460 (20*12,023).

7. Compilation of the cost-raster for Bosnia in QGIS that calculates railway construction costs for each 27 x 27 m grid cell based on the above parameters (i.e. costs of distance, costs of gradients, costs of bridges). We use the slope raster from step 4 to assign costs to each cell. For each central pixel, a new slope cost raster is created with values multiplying the average slope by the average slope parameter plus the cost per additional km. The cost parameters have been linearly scaled down to correspond to pixels of 27 x 27m. We digitized rivers based on the same historical maps as railways and created a new river cost raster with the same resolution using parameters for bridge construction cost. The final cost raster used in least-cost path calculations is produced by combining the cost rasters (keeping maximum values per pixel using the QGIS calculator and the Mosaic Raster Layers function).

8. Calculation of hypothetical least-cost paths for main lines selected in step 2 using QGIS tool "Least Cost Path" and final cost raster from step 7.

9. Assigning each least-cost path an opening date, which corresponds with the opening date of the actual railway line.

10. Coding of the LCP indicator, coded 1 if a settlement was within 1 kilometer from a least-cost path during period t, and 0 otherwise.

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