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Fast Track to Growth?
The Impact of Railway Access on Regional Economic Development in 19th Century Switzerland*

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Abstract

We study the effect of railway access on regional development in 19th century Switzerland. The identification strategy in our analysis of geo-referenced railway network information, population growth rates, sectoral work shares and body height, relies on panel data techniques and an inconsequential units IV approach. Gaining railway access increased annual population growth by 0.4 percentage points compared to unconnected municipalities, mainly via the local migration balance. Railway improvements also promoted structural shifts from the primary to the secondary/tertiary sectors, and marginally accelerated body height growth.

Key words: Railway Access, Regional Development, Population Growth, Structural Change, Body Height, Switzerland.

JEL classification: I30, N33, N73, O18.

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1 Introduction

The rapid advance of railways is widely seen as a major driving force of economic development in the 19th century. It made overland transport at competitive rates possible, which facilitated the integration of formerly isolated areas into the regional and global economy. As this market widening enabled increased regional specialisation and gains from trade, it is argued that railway substantially accelerated aggregate economic growth.[1]

Then as now, investments in transportation infrastructure have repeatedly been endorsed by policy makers as a means to promote regional economic development. Economic considerations, both from a *national growth* and *regional development* point of view, also dominated the political debate on the foundation of a national railway network in 19th century Switzerland. Being a small export-oriented market with few natural resources, Switzerland was particularly dependent on fast and reliable means of transport. For this reason the federal government emphasized that a well designed railway network was critical to the country's welfare.[2] In 1852 the provision of railway infrastructure was mandated to private companies. From a regional economic growth perspective this raised concerns that domestic disparities would widen, if underdeveloped and thinly populated areas were neglected by railway entrepreneurs.[3]

How early railway access impacted regional growth in Switzerland has not yet been studied quantitatively. We compile a data set that combines geo-referenced railway network information and various proxies for regional economic development, including population growth rates for more than 2 800 municipalities as well as data on sectoral work shares and the body height of conscripts in 178 districts. The small-scale municipalities of Switzerland present a unique setup, that allows us to analyse the impact of railway at a level of detail not seen in other studies. Particular attention is paid to potential selection effects induced through strategic routing: An inconsequential units IV approach and placebo tests based on data from the pre-railway era allow us to infer whether transportation infrastructure indeed promoted growth or just followed favourable regional developments.

[1]Based on the concept of social savings, first proposed by Fogel (1962, 1964), the impact of railway infrastructure on aggregate output has been calculated to range between 5% and 10% for the US, and between 1% and 11% for European countries (Leunig, 2010). In a recent study, Donaldson and Hornbeck (forthcoming) show that extensions to internal waterways and roads would have mitigated at most 20% of the losses from removing railways in the US, refuting the famous argument by Fogel (1964) that railways could have been easily substituted by other available means of transport.

[2]Original quote from the federal council's statement delivered to the national assembly on 7th April 1851 [BBl 1851, Vol. 1(19):352]: "Was wir [...] vor Allem als Hauptzweck eines schweizerischen Eisenbahnnetzes betrachten, besteht in Erleichterung des Verkehrs im Innern. Auf dem europäischen Kontinent ist kaum ein Land wie die Schweiz, das so wenig im Stande ist, seine Bedürfnisse auf eigenem Boden zu erzeugen, das daher in so hohem Grade interessiert ist, dass es seine Konsumgegenstände, seine Rohprodukte wohlfeil beziehen und seine Fabrikate wohlfeil ausführen kann. Kaum ein Land [...] wo die Schnelligkeit des Personenverkehrs und der Warensendungen von so hohem Werthe ist, wo das Englische Sprichwort 'Zeit ist Geld' in gleichem Masse seine praktische Anwendung findet."

[3]Opponents of a private provision fiercely warned that railway companies will cherry-pick the most profitable lines, as the majority report by the parliamentary railway commission in 1852 illustrates [BBl 1852, Vol. 2(27): 49-127].

The empirical evaluation of how transport infrastructure affects economic activity has recently attracted increased attention (see Redding and Turner, 2014).[4] Fishlow (1965) was one of the first economic historians who systematically analysed the direction of causation in this context. Based on his study of 19th century USA, he concludes that railway construction seems to have followed demand rather than cause regional population growth. Combining GIS-tools and econometric methods, Atack et al. (2010) revisited Fishlow's analysis for counties in the American Midwest from 1850 to 1860. They find that railway access increased population density by about 3 percentage points within the decade studied. The impact of railway access in Switzerland was of comparable magnitude, as our preferred models yield an average railway induced growth effect of 0.4 percentage points per year. While Atack et al. (2010) explore the impact of railway on population growth in a mostly rural environment similar to our case, US counties are rather coarse units of analysis in comparison to Swiss municipalities. Exploiting the fine granular level of our data, we cannot only investigate the direct impact of railway access; we can also examine local displacement effects of railway infrastructure as well as effect heterogeneity along various dimensions.[5] Our results show a non-monotonic functional relation between distance to the railway network and population growth: The positive effect of railway was markedly localised, as municipalities situated more than 2 km from the railway network experienced a slowdown in growth. The negative effect of railway was largest for municipalities at 6 to 8 km distance from the railway tracks and reversed back to zero for places at least 20 km away.

A well-researched consequence of expanding railway infrastructure is the faster growth of cities, as documented by studies for Prussia (Hornung, 2015), Sweden (Berger and Enflo, forthcoming), and Africa (Jedwabi and Moradi, 2016). Switzerland also experienced rapid urbanisation during the early railway era, yet the vast majority of people lived in markedly small rural municipalities throughout the 19th century. Hence, our analysis naturally complements studies on railway and city growth, bringing the demographic developments in peripheral areas into focus. Our estimated effect of railway access on population growth is considerably smaller than the impact reported for cities, which typically ranges between 1 and 2 percentage points per year. This substantiates the notion that railway access primarily promoted growth in cities and regional centres, while the impact was considerably smaller in rural municipalities along the rail tracks. Nonetheless, our findings do

[4] In the main text, we only discuss studies on railways built in the 19th century. Comparable questions were also studied for highway infrastructure built in the 20th century, for instance by Duranton and Turner (2012) or Faber (2014). For Switzerland, Dessemontet (2011) documents in detail how the spatial pattern transformed from a very strong centre-periphery specialisation in 1939 to a much more sprawled distribution in 2000, with road-accessibility being an important determinant of employment density. In line with the results by Dessemontet (2011), Müller, Steinmeier and Küchler (2010) show that the rate of urban growth increases with proximity to a motorway exit.

[5] The second most detailed analysis in terms of spatial units is that of Koopmans, Rietveld and Huijg (2012) who analyse population growth in Dutch municipalities. Those are about ten times larger than Swiss municipalities, and the authors do not analyse local reorganisation or effect heterogeneity. Furthermore, it is questionable whether their results have a causal interpretation, as Koopmans, Rietveld and Huijg (2012) neither provide placebo tests nor exploit exogenous variation.

not lend support to the home market effect hypothesis as in Krugman (1980), since we find little evidence for negative growth effects of transportation infrastructure, even in the least populous communities.

Population growth often serves as a proxy for regional development, because comprehensive income and production statistics for the 19th century are scarce. On theoretical grounds, freedom of movement facilitates migration flows that equalise real wages across space, implying migration from uncompetitive to competitive areas (e.g. Redding and Sturm, 2008). Indeed, our analysis of birth, death, and migration statistics shows that railway access primarily had an impact on population growth via the local migration balance. Reduced trading costs are considered to be the main mechanism that links railway – and transportation infrastructure in general – to competitive advantages and economic activity. Donaldson (forthcoming) reports conclusive evidence for this channel; based on data for India between 1853 to 1930, he shows that the advance of railways substantially lowered trade costs and promoted intra-Indian trade flows. Improved trading conditions due to railway access caused a significant increase in agricultural income, as is documented for the US (Donaldson and Hornbeck, forthcoming), India (Donaldson, forthcoming), and Ghana (Jedwabi and Moradi, 2016). Other studies provide evidence that obtaining railway access accelerated industrialisation, since it promoted capital investments in manufacturing companies (Tang, 2014) and increased the average firm size (Atack, Haines and Margo, 2008; Hornung, 2015). These findings for the agricultural and industrial sector raise the question of what the net effect was of railway on structural change. We show that districts with average railway access experienced an additional 9 percentage point shift in labour shares from the agricultural to the manufacturing sector within 40 years compared to unconnected districts. This evidently suggests that improved railway infrastructure was an important driver of industrialisation in Switzerland. Considering that the (sparsely available) income records document higher wages in the manufacturing than in agriculture (see Brugger, 1978; Gruner, 1987), railway-induced industrialisation may have been a key pulling factor shaping migration patterns. Although we lack the data to investigate this claim in detail, an analysis of body height records provides evidence that railway indeed had a positive net effect on the population's (biological) well-being, most likely through improvements in nutrition and labour conditions.

The next section describes the historical setting. Section 3 introduces the data used in the empirical analysis. Section 4 explains the empirical strategy to identify the causal effect of railway access on regional development. Section 5 discusses the results for the municipality and district level. Section 6 concludes.

2 Historical Background

Although Switzerland was one of Europe's most industrialised countries in the early 19th century, railway technology caught up relatively late.[6] Since 1836 entrepreneurs in Zurich sought to connect Switzerland's largest city to the foreign railway network at the German border in Koblenz and the French border in Basel, but since they failed to raise enough funds their endeavour stopped halfway in Baden. The first 23 km of railway tracks in Switzerland, which are known as "Spanisch-Brötli-Bahn", were opened in 1847, at a time when Great Britain (9 800 km), Germany (5 800 km), France (2 900 km), and the US (13 500 km) had already built several thousand kilometres of railway.[7]

When the Swiss federal state was founded in 1848, the formation of a national railway network soon became one of the main priorities on the political agenda. Alfred Escher, president of the national council, forcefully warned his fellow members of parliament in 1849 that Switzerland would run the risk of becoming isolated within Europe if it failed to build a railway network quickly.[8] In 1850, the government commissioned two English engineers, Robert Stephenson and Henry Swinburne, to provide a technical expertise for the construction of a national railway system. After fierce debates and a close vote, the plan submitted by the English engineers for a state-run railway network was rejected by the national assembly. The Railway Act of 1852 authorised cantonal administrations to grant concessions to private companies, which were supposed to build and run Switzerland's railway network without public funding (Weissenbach, 1913, 6). This new legal framework along with the introduction of a single currency and the elimination of internal tariffs in 1848 evidently reassured previously reluctant investors, and within a decade private railway companies connected Switzerland's major cities north of the Alps. By the end of the century Switzerland had one of the world's densest railway networks with a total length of around 3 700 km (see Table 1).

Switzerland is a land-locked country with no navigable rivers except for the Rhine in the border town of Basel. Before railway became available, carts were the main means of transportation complemented by inland navigation on lakes.[9] It has been estimated that

[6]Bairoch (1965) compares nine European countries, the US, and Japan in terms of industrial development between 1800 and 1900, with Switzerland coming in fourth or fifth place throughout the 19th century.

[7]Humair (2008) cites the fragmented system of tariffs, currencies and jurisdictions of the pre-modern Swiss confederation as key institutional barriers that inhibited adequate funding by (foreign) investors. Furthermore, he points to the opposition of various social and economic stakeholders, as well as disputes about route planning that delayed railway investments. The international rail network statistics represent total track length in 1850 and are taken from Sperber (2009, 10) and Adams (1895, 6).

[8]Original quote from Alfred Escher's speech delivered in the national assembly on 12th November 1849 [BBl 1849, Vol. 3(6):161]: "Es tauchen Pläne auf, gemäss denen die [europäischen] Bahnen um die Schweiz herumgeführt werden sollen. Der Schweiz droht somit die Gefahr, gänzlich umgangen zu werden und in Folge dessen in der Zukunft das traurige Bild einer europäischen Einsiedelei darbieten zu müssen."

[9]The relative importance of inland navigation prior to 1848 has not yet been conclusively determined, as detailed transport statistics are not available for that period. The historical research available suggests that inland navigation was a regionally important – but *secondary* – complement to overland transport. First, Switzerland only had 25 steamboats in 1850 (Schiedt, 2009, 172). Second, costs for transshipping were significant, which limited potential savings on the relatively short portage routes on lakes (Schiedt,

Table 1: Railway Density in Selected Countries, 1900

	Railway Network in km per 10tsd Inhabitants	Railway Network in km per 100 Sq-Km
Germany	9.7	9.3
Austria-Hungary	8.2	5.4
France	10.9	7.9
Italy	5.0	5.5
Great Britain	8.6	11.0
USA	42.2	3.8
Switzerland	12.4	9.1
Lowland (excluding alpine area)[1]	11.6	18.4

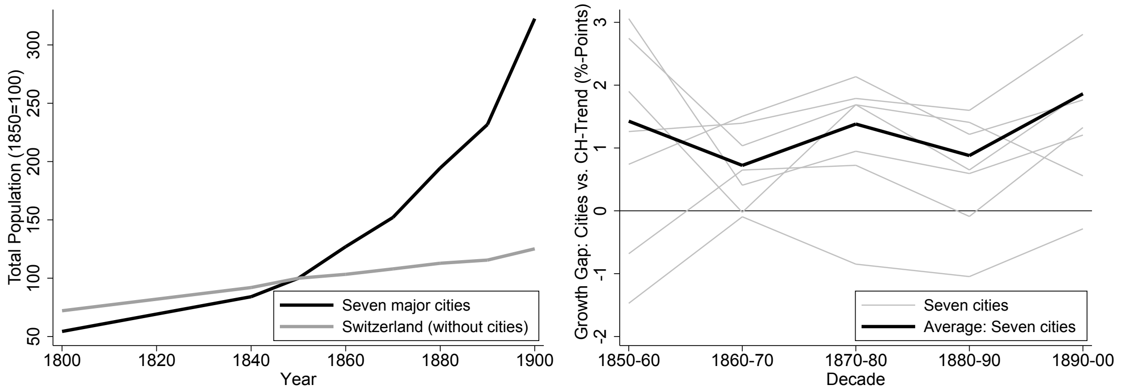
1: Railway lines and population of districts with a mean elevation below 1 000 m.a.s.l., representing the area of our robustness analysis. *Source:* Geering and Hotz (1903, 105-106).

railway reduced land transport costs by a factor of eight (Donaldson, forthcoming), which stimulated two major developments in Switzerland: First, the agricultural sector started shifting production from grain to dairy products. While the production of milk increased by more than 70% until the end of the century, the production of grain decreased by 40%, a drop that was compensated by the quadrupling of grain imports (Frey and Vogel, 1997, chapter 8). Second, railway triggered large quantities of coal imports from Germany and France, which increased from 1 360 tons in 1851 to 16 000 tons ten years later, and more than 200 000 tons at the end of the century, representing 15% to 20% of the freight transported by rail between 1850 and 1900. Coal promoted an improved mechanisation of the Swiss industry, and cleared the way for energy-intensive sectors such as steel works, salterns, and cement production (Marek, 1991, chapter 6).

Besides lowering the transportation costs of cargo, railway substantially shortened travel-times. Frey (2006) illustrates on the basis of detailed stagecoach and train schedules that the time required to visit all cantonal capitals was halved between 1850 and 1870. By the end of the century, travel-times were even reduced by 80% compared to the pre-railway period. Despite these substantial improvements in accessibility, Frey and Schiedt (2005, 57) argue that railway contributed little to the public's mobility during the first 40 years, as it was unaffordable for the vast majority.[10] In 1880, Swiss railway companies only carried 25 million passengers, which corresponds to an average of nine train journeys per person per year. A gradual decline in fares during the 1890s and rising incomes made train travel more widespread, with yearly passenger numbers rapidly increasing to 63 million

2009, 173). Third, estimates by Frey (2010) suggest that the accessibility of Swiss municipalities in 1850 was almost entirely determined by roads (93%-100%), and hardly influenced by inland navigation (0%-7%). Fourth, Schiedt (2007) documents the broad modernisation of Switzerland's road infrastructure from 1740 to 1780 (around 1 000 km) and from 1830 to 1840 (around 6 000 km). The fact that these investments accounted for up to 40% of cantonal finances underlines the importance attributed to roads by policy-makers in pre-modern Switzerland.

[10] A look at fares and wages in the 1880s illustrates this point: An average worker, who earned about 0.30 CHF per hour, had to pay 0.90 to 1.40 CHF for a return-ticket on a 10 km railway route (NOB, 1883).



(a) Population Development, 1800-1900 (Index: 1850=100).

(b) Difference in Difference: National Population Growth Rate p.A. vs. City Growth Rates p.A.

Figure 1: Urbanisation and Railway in Switzerland. *Source:* Own calculations based on the *HSSO* database, `www.fsw.uzh.ch/histstat/`
Notes: The sample of cities includes Zurich, Geneva, Bern, Basel, Winterthur, Thun, and Biel. Cities were selected only if their population statistics for 1800 and 1837 reflect the territorial borders of the 1850–1900 sample. Graph (b) shows difference-in-difference annual growth rates: The differences between national and city growth rates from 1837 to 1850 were subtracted from the annual growth rate differences between 1850 to 1900 .

in 1900 and 110 million in 1910.[11] For most of the 19th century, however, rail journeys remained a privilege for the wealthy and commuting by train was rather insignificant.

The advent of railway took place in a period characterised by strong growth: Swiss GDP estimates available for the period after 1850 reveal that real output grew by approximately 250% within 50 years, while the population increased from 1 665 000 inhabitants in 1800 to 2 393 000 in 1850, and 3 315 000 by the end of the 19th century. This growth was not uniformly distributed across the country, however, as Switzerland witnessed substantial domestic migration typically from peripheral regions to the fast growing urban centres (e.g. Rey, 2003). The acceleration of urban growth in Switzerland coincides with the construction of the earliest railway lines. To illustrate this point, Figure 1 part (a) plots population statistics (1850=100) for a sample of seven cities with comparable population data for 1800 and 1836/37. While cities grew at a similar rate to other municipalities prior to railway construction (i.e. between 1800 and 1847), the picture changed completely in the second half of the 19th century. Urban population started increasing tremendously while the rest of the country kept growing at a relatively constant rate. Part (b) of Figure 1 presents a simple difference-in-differences analysis of the annual population growth rate of the seven cities compared to the national population growth rate using periods before and after the introduction of railway technology. Except for Thun, the growth rates of the cities increased by 0.5 to 3 percentage points relative to the national trend after the railway network was established. Of course this simple analysis cannot establish a causal relation, since early railway construction coincides with improved market integration following the birth of the modern federal state in 1848. Nonetheless, it reveals a suggestive pattern that

[11] Passenger statistics were obtained from the *Schweizerische Eisenbahnstatistik* (SPE, 1900), which is partly accessible online at `http://www.bahndaten.ch/` (last access: 01.02.2016).

fits well with recent findings on urbanisation and railway access in other countries.[12]

Although urban centres experienced rapid growth, Switzerland remained a rurally dominated country throughout the 19th century. In 1850, less than 10% of Switzerland's population lived in towns of more than 10 000 inhabitants, a ratio that remained decidedly below the 50% mark until the end of the century. In the following, we primarily analyse how demographic dynamics in Switzerland's rural areas were affected by railway access.

3 Data

We track the expansion of Switzerland's railway network using data from the "GIS Dufour" project, which developed a digitial map of historic roads, railway, and waterway lines based on the first national map commissioned by Henri Dufour in 1850 (source: Egli et al., 2005). In addition to mapping traffic routes, the GIS Dufour project also collected information on their opening and closing dates from various historical sources. Based on this rich data set, we define a binary indicator, referred to as *railway access*, that takes the value 1 if one or more railway lines cross over the territory of a municipality.[13] Accordingly, we call municipalities "treated" after they received their first railway access, and "untreated" if no railway line passed through. Column 5 in Table 2 shows the percentage of treated municipalities for each decade and column 6 reports the population share that was connected to the railway.

Municipalities are the lowest administrative unit in Switzerland, with 1 to 40 municipalities forming a district, and 1 to 30 districts forming a canton, the equivalent of a US state. In order to evaluate the impact of railways at the district level, we calculate the population weighted share of municipalities that had direct access to the railway network for each district and decade.

Our main outcome of interest is annual population growth. Population statistics are taken from the census ("Eidgenössische Volkszählung") which has been conducted by the Swiss Statistical Office (and its precursor) since 1850.[14] The national census has always surveyed the population on the municipality level in intervals of 10 years, with the exception of the 1890-wave, which was collected in 1888. We infer the population for 1890 by performing an extrapolation of growth rates in the adjacent periods, i.e. 1880 to 1888 and 1888 to 1900, respectively.[15] In order to account for territorial reorganisations, we use the municipality classification for 2000 and clean population figures based on the data set's

[12]For instance, Hornung (2015) shows that railway access accelerated population growth in Prussian cities by an additional 1 to 2 percentage points per year, which is quantitatively similar to the increase in Switzerland's urban growth rates after 1850.

[13]We use municipal boundaries from official administrative maps of Switzerland valid from January 2000. This ensures that the spatial administrative division used to determine a municipality's railway access is congruent with the classification employed in the census data.

[14]Detailed information on the data set, which can be downloaded from `www.bfs.admin.ch`, is provided in Schuler, Ullmann and Haug (2002).

[15]Mathematically, we calculated the population count (POP_{90}) of 1890 as follows: $PGR_{80,88} = (\frac{POP_{88}}{POP_{80}})^{1/8}$; $PGR_{88,00} = (\frac{POP_{00}}{POP_{88}})^{1/12}$; $POP_{90} = \frac{1}{2} POP_{88} \cdot (PGR_{80,88})^2 + \frac{1}{2} POP_{88} \cdot (PGR_{88,00})^2$.

Table 2: Descriptive Statistics: Population and Railway Access in Swiss Municipalities

	Swiss Pop. (in mio.)	Average Pop.: All Municip.	Average Pop.: Municip. w. Rail	Share of Municip. with Rail (%)	Share of Pop. with Rail (%)
1850	2.39	840	8603	0.3	3.2
1860	2.51	877	2049	12.9	30.0
1870	2.66	927	2006	17.4	37.5
1880	2.83	986	1817	29.3	53.9
1890	2.92	1013	1797	35.1	62.4
1900	3.32	1150	2067	39.0	70.3

Source: Own calculations based on Swiss census data and GIS-Dufour data.

documentation on territorial mergers and divisions.[16] For the cantons of Zurich, Bern, Aargau and Solothurn, we complement the census data with population statistics from the "Helvetische Zählung" conducted around 1800 and the "Tagsatzung" in 1837. These early population counts are currently being harmonised with the post-1850 census data in an ongoing project by Schuler and Schluchter (in progress). In what follows, we refer to this subset of municipalities, representing around 900 of the 2700 municipalities, as the *pre-railway sample* or *pre-treatment sample* (see Figure 3). District population figures between 1850 and 1900 are derived by aggregating up municipality statistics, and are then complemented with district-level data for 1800 collected by Schluchter (1988). We construct our main dependent variable, the annual population growth rate for each municipality and each district based on the population figures for 1800, 1837 (municipalities only), and 1850 to 1900.[17]

A concern may be that population changes caused by railway-related *construction work* is falsely attributed to improvements in a municipality's or district's accessibility. In order to address such concerns, we resort to Rey (2003, 147–149) who compiled a list of Swiss municipalities and districts that experienced extraordinary demographic volatility due to railway construction work (mainly tunnelling). These observations are removed from our sample in all steps of the analysis that evaluate the affected time period.[18]

The population and railway access data is complemented with district statistics on surpluses of births over deaths so that migration balances can be calculated (source: census since 1870), as well as sectoral work shares (source: census since 1860) and the body height of conscripts (source: Staub, 2010) which we interpret as complementary proxies for regional development. In order to merge the data sets reliably, we define a common district identifier and compare the population figures as reported in the various sources. Differences in population counts are retraced using the documentation on territorial re-

[16]For instance, the municipality of Turgi (ID=4042) with a population of 645 in 1888, was part of the municipality Gebenstorf (ID=4029) until 1883. When calculating annual growth rates between 1880 and 1890 for Gebenstorf, we subtracted 645 from its population in 1880.

[17]Annual population growth is computed as follows: $APG^t = 100 \cdot (ln(POP_{t1}) - ln(POP_{t0}))/(t_1 - t_0)$.

[18]In this respect it is important to note that we evaluate the impact of railway access on *population growth rates* in the short- and long-term: While railway construction work may have had a confounding effect on short-term population growth rates, it is unlikely that long-term growth trends were affected by the inflow and outflow of construction workers.

organisations from the Swiss Statistical Office. Whenever applicable, district population figures are equalised between the data sources, for instance by changing the assignment of municipalities to districts. Districts where the revised population statistics differ by more than 2% are excluded from the statistical analysis.[19]

4 Empirical Strategy: Instrumental Variable Approach

Railway access is not randomly assigned to municipalities, but may be correlated with numerous observable and unobservable characteristics such as population size, growth potential, economic structure, or the availability of cheap land. Since Switzerland's main railway infrastructure was built and run by private entrepreneurs until 1902, concerns related to targeted and selective routing cannot be ignored. Although a number of control variables are available, cross-sectional OLS regression may not be sufficient to account for these endogeneity issues. A priori, it is unclear whether an upward or downward bias dominates, thus making it difficult to interpret plain regression estimates.

We address these concerns by adopting an *inconsequential units IV approach* first proposed by Banerjee, Duflo and Qian (2004; 2012) and later used in several studies on transport infrastructure, including Hornung (2015) and Atack et al. (2010). The underlying idea is compelling: In the early stages of transport infrastructure developments, major cities – hereinafter "main nodes" – are typically connected first. If railway companies built their routes such that two main nodes are connected as directly as possible, railway access would be randomly assigned to municipalities lying along these inter-node connections. It is likely, however, that railway companies deliberately take detours, for instance to connect municipalities with a high growth potential or to avoid expensive land acquisitions in dense areas. As these targeted detours induce selection effects, it is not sufficient to restrict the analysis to inter-node lines as they were actually built. Instrumental variables based on least-cost paths between nodes solve this issue. The IV approach bases inference on the randomly chosen subset of municipalities that received railway access because they lie on the most direct route between nodes, i.e. on a least-cost path.

4.1 Main Nodes

Main nodes are selected along two dimensions in this study, namely economic and transport strategic importance. As a first group, we chose the 20 most populous municipalities in 1850 that held the historical town status.[20] In medieval times, towns privileges included judicial liberties, coinage, the right to collect tariffs, and the right to hold markets, which we consider a good proxy for historically grown economic importance. These 20 nodes are supplemented by 23 locations listed as central traffic junctions in plans delivered to

[19]Table A.3 in the appendix provides a complete list of districts that are included in and excluded from the analysis, respectively.

[20]Whether or not a municipality held the historical town status is determined based on Guyer (1960).

Table 3: Main Nodes

Municipality	**Population in 1850**	**RW Access**	**Municipality**	**Population in 1850**	**RW Access**
Among 20 Largest Towns & Listed as Node in 1850-Expertise					
Zurich	41585	1847	Luzern	10068	1859
Bern	29670	1857	Schaffhausen	8477	1857
Basel	27844	1844/54	Chur	6183	1858
Lausanne	17108	1856	Thun	6019	1859
Winterthur	13651	1855	Solothurn	5370	1857
Among 20 Largest Towns			Listed as Node in 1850-Expertise		
Geneva	37724	1858	Aarau	4657	1856
St. Gallen	17858	1856	Yverdon	3619	1855
Chaux-de-Fonds	12638	1857	Morges	3241	1855
Fribourg	9065	1862	Bellinzona	3209	1874
Le Locle	8514	1857	Baden	3159	1847
Neuchatel	7901	1859	Locarno	2944	1874
Altstaetten	6492	1858	Biasca	2035	1874
Lugano	5939	1874	Walenstadt	1868	1859
Biel	5609	1857	Rorschach	1751	1856
Vevey	5201	1861	Olten	1634	1856
			Brugg	1581	1856
			Lyss	1568	1864
			Romanshorn	1408	1855

Notes: The 20 largest towns are selected based on the Swiss census and an index of municipalities with historical town privilege from Guyer (1960). The list of nodes as suggested in the 1850-expertise by R. Stephenson and H. Swinburne is taken from Weissenbach (1913). Population figures are based on municipality border zoning from January 2000.

the federal government by Robert Stephenson and Henry Swinburne in 1850.[21] Since 10 municipalities are included in both sets, this yields 33 main nodes, that we believe were of primary economic or transport strategic importance, thus making them attractive to railway companies. These 33 municipalities are excluded from the sample in all steps of the statistical analysis, as they have gained access to the railway for reasons potentially endogenous to population growth.

Table 3 shows that 30 out of 33 municipalities selected as main nodes were connected to the railway network by the early 1860s, which we consider to be the first wave of railway construction. The remaining four nodes, which are all located south of the Alps, received railway access in the 1870s, constituting the second wave of railway development in Switzerland.

[21] Figure A.1 in the appendix displays the original plan outlined by the two English engineers, including the set of main nodes used in our analysis.

4.2 Least-Cost Paths

Whether or not a least-cost path is drawn between two nodes is determined based on records of actual railway openings (source: Wägli, 1998; Weissenbach, 1913). Lines are selected only if the primary intention of the railway company was to connect two nodes, excluding routes that established inter-node connections gradually over long periods of time.[22] For the selected inter-node lines, we draw cost efficient routes on a 200 m x 200 m grid with the ArcGIS-tool "Least Cost Path" factoring in three cost parameters: distance, slope, and river crossings. In order to estimate the cost parameters, we extract information from the Swiss Traffic Atlas (source: NOB, 1883) on the total construction costs of 48 railway lines built by 1881, and combine it with information on mileage as well as slopes covered by the actual route of the tracks using a 25 m x 25 m height model for Switzerland (source: Swisstopo, 2004). A regression of total construction costs per kilometre on the routes' average slope yields average construction costs of 180 000 CHF per kilometre and an additional 15 000 CHF penalty per degree climbed. The costs of building bridges are determined based on the regression's residual for a 2 km track section that includes a 216 m long bridge over the river Rhine in Basel. We obtain costs of 800 000 CHF for the rail bridge in Basel, which we linearly scale down for smaller rivers based on federal water quantity statistics (source: Pfaundler and Schönenberger, 2013).

This procedure results in a least-cost path for every inter-node railway connection built in 19th century Switzerland, including information on the original route's opening date. Finally, we intersect the least-cost paths with municipal boundaries, giving us a measure, LCP^w, coded 1 if a municipality is traversed by a least-cost path during the construction wave w, and coded 0 if all the least-cost paths bypass outside the municipality in the given time span.

4.3 Estimation and Identifying Assumption

The data and instrumental variable, LCP^w_{ic}, described in the previous sections are used to estimate the effects of railway access, RA^w_{ic}, established during construction wave w, on annual population growth, APG^t_{ic}, in municipality i of canton c during decade t. The first and second stage regressions take the form

$$RA^w_{ic} = \alpha_1 + \beta_1 LCP^w_{ic} + \varphi_1 X^{1850}_{ic} + \kappa_{1c} + \epsilon_{ic}, \text{ and} \tag{1}$$

$$APG^t_{ic} = \alpha_2 + \beta_2 \widehat{RA}^w_{ic} + \varphi_2 X^{1850}_{ic} + \kappa_{2c} + \eta_{ic} \tag{2}$$

where κ_c denotes cantonal fixed effects, and X^{1850}_{ic} is a vector of municipality control

[22] This excludes, for instance, the railway line connecting the nodes Bern and Luzern: Its first part was finished in 1864, connecting Bern with Langnau, while the section Langnau–Luzern opened 11 years later in 1875.

(a) Length of Swiss Railway Network

(b) Share of Inter-Node Tracks Operating

Figure 2: Construction of the Swiss Railway Network: 1st Wave 1847–64, 2nd Wave 1869–82, 3rd Wave 1883–1900. *Source:* Own calculations based on GIS-Dufour data

variables described below.

A word on timing. The cross-sectional analysis exploits the fact that the construction of Switzerland's railway was carried out in three waves (see Figure 2): Between 1847 and 1864 the main trunk lines were established, including the east-west connection linking Geneva (westernmost city), Bern (capital), Zurich (largest city), and St. Gallen (easternmost city). During the second wave, 1869 to 1882, further inter-city lines were completed and the first north-south route through the Alps was opened. After 1882, the ramification advanced and mostly small branch lines were added. The focus of the analysis lies on the first wave, i.e. w=1847–1864, and the second wave, i.e. w=1869–1882. Equations (1) and (2) are estimated separately for both waves, and five decades of annual population growth available, i.e. t=1850–60; 1860–70; 1880–90; 1890–1900. When the second wave of railway constructions is analysed, all municipalities with access prior to 1869 are excluded from the sample.

Two assumptions are needed in order to allow for a causal interpretation of $\hat{\beta}_2$: First, the instrumental variable and the treatment have to be correlated (i.e. $\beta_1 \neq 0$), which can be tested formally based on the first stage correlation. Second, the exclusion restriction must hold, implying that the instrument needs to be as good as randomly assigned conditional on control variables, and may affect the outcome only through the first stage (e.g. Angrist and Pischke, 2009, 117). While our large and highly statistically significant estimates for β_1 verify the first assumption, the exclusion restriction could be violated if locations along the least-cost path are correlated with municipality characteristics due to history or geography. In order to justify the exclusion restrictions, we include a number of control variables, which are briefly motivated hereafter (further information on the controls are presented in the Appendix, A.1).

By construction, municipalities nearby nodes are more likely to lie on a least-cost path than municipalities farther away. If proximity to a city or major traffic junction is correlated with population growth, the exclusion restriction would be violated. We therefore include the *log distances* of each municipality to its closest *town node* and to its closest *Stephenson-Swinburne node* as controls in our regressions.

The least-cost paths reflect direct routes between main nodes that avoid steep slopes and unnecessary river crossings. Location along these paths could be correlated with the economic structure of municipalities since they potentially coincide with historical trade routes that affected business prior to adoption of the railway technology. To account for this issue, we include a *road access* variable that measures whether a municipality is passed through by a major inter-cantonal road (source: GIS-Dufour, Egli et al., 2005). Before railway became available, these paved roads constituted the main inter-regional transport routes within Switzerland, and therefore should pick up possible confounding effects due to the potential correlation between historical trade routes and our instrument. Additionally, we include an indicator for *medieval town privileges* (source: Guyer, 1960), which were – amongst others – given to municipalities of trade strategic importance, and therefore may be correlated with both the likelihood of a municipality being crossed by a least-cost path and its population growth.

Naturally, our least-cost path algorithm tends to favour riversides, lake fronts, and low altitudes, as such terrain is often characterized by low gradients. A concern could be, that these places are also advantageous to economic development: Water turbines along rivers, for instance, were an important energy source in 19th century Switzerland, shipping on lakes was a regionally important complement to overland transport, while low altitudes pose favourable climatic conditions compared to higher elevations. Therefore, we include measures for *hydro power potential*, *adjacency to lakes*, and the *log of elevation* in our regressions.

A last set of controls is supposed to account for growth effects of *subsequent railway access*, and pre-determined population dynamics, namely *annual population growth prior to railway access*, the *log of population size in 1850*, as well as a municipality's *log area* in square kilometres.

Despite this broad set of control variables, it may still be possible that unobserved characteristics are correlated with both our instrument and the growth potential of municipalities, which would confound our estimate of β_2. We therefore follow an approach recently suggested in a similar setting by Hornung (2015), and complement our cross-sectional analysis with panel-models that take care of time-invariant unobserved heterogeneity by including municipality fixed effects, π_i. We regress the annual population growth rate of municipality i in decade t, APG_{ict}, on the instrumented dummy variable indicating railway access in the previous decade, RA_{ict-1}. The first and second stage IV panel-regressions are specified as

$$RA_{ict} = \pi_{3i} + \beta_3 LCP_{ict} + \lambda_{3t} + \lambda_{3t} \cdot \kappa_{3c} + \xi_{ict}, \text{ and} \quad (3)$$

$$APG_{ict} = \pi_{4i} + \beta_4 \widehat{RA}_{ict-1} + \lambda_{4t} + \lambda_{4t} \cdot \kappa_{4c} + \varepsilon_{ict} \tag{4}$$

where time fixed effects, λ_t, control for population growth cycles on the national level, and cantonal-time fixed effects, $\lambda_t \cdot \kappa_c$, account for cycles on the regional level.[23]

While the advantage of this approach is the elimination of potentially unobserved time-constant confounders, it washes out a lot of variance in the variables of interest and identifies the effect of railway access based on within-municipality variation only. Since the Swiss census was conducted with a periodicity of ten years, the timing of treatment and effect is rather imprecise in our setting: To eliminate concerns of reverse causality and because main lines were mostly built in the second half of the 1850s and 1870s, we use the first lag of railway access in our preferred panel specification, e.g. railway access between 1851 and 1860 affects population growth during the decade 1860 to 1870 and onwards. The following section reports and discusses the estimation results for both the cross-sectional and the panel-data analysis.

5 Results on Railway Access and Regional Development

Suggestive evidence for the impact of railway access on population growth is presented in Table 4, which compares the mean population growth rates for municipalities gaining railway access during the earliest wave of railway construction (1847–1864) to the growth rates of municipalities bypassed by these railway lines. While a two-sided T-test of differences in means (see column 4) suggests that population growth rates were not statistically different in the two groups during the pre-railway period, growth rates significantly diverged with the construction of the earliest railway lines during the 1850s and subsequent decades. Overall, this simple comparison in means suggest that municipalities with railway access grew on average 0.25 to 0.55 percentage points faster per year than unconnected municipalities.

In order to identify the causal impact of railway access on population growth rates, we now turn to our econometric analysis which is discussed in four subsections. The main evaluation concerns annual population growth at the municipal level, which is presented first. Discussing results on cross-section (section 5.1) and panel data (section 5.2) regressions, we complement the advantages of both approaches. In section 5.3 we attempt to get a clearer grasp of the heterogeneity of effects. The obvious question that arises is whether the construction of the railway infrastructure benefited all connected communes equally or led to a concentration of economic activity and divergence in the municipalities' growth rates. Furthermore, we analyse displacement effects of railway access on nearby municipalities. Finally, section 5.4 completes the municipality analysis by evaluating the robustness of results for population growth at the district level, and examining whether

[23] Map A.4 in the appendix depicts the time-variation in our instrument.

Table 4: Annual Population Growth Rates by Railway Access Status in 1864

	Pre-Railway Sample[a]				Whole Switzerland[a]				Nodes[b]	
		Rail	No Rail			Rail	No Rail			
	Obs.	Mean	Mean	Diff.	Obs.	Mean	Mean	Diff.	Obs.	Mean
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1800-1837	903	0.89	0.92	−0.03						
		(0.49)	(0.48)	(0.04)						
1837-1850	903	0.60	0.66	−0.07						
		(0.71)	(0.89)	(0.08)						
1850-1860	903	0.13	−0.017	0.30**	2811	0.57	0.02	0.55***	33	1.63
		(0.87)	(1.06)	(0.09)		(1.26)	(1.14)	(0.06)		(1.32)
1860-1870	903	0.59	0.20	0.39***	2827	0.47	0.22	0.25***	33	1.60
		(0.88)	(1.26)	(0.09)		(1.25)	(1.04)	(0.06)		(1.16)
1870-1880	898	0.46	−0.06	0.52***	2788	0.45	−0.02	0.47***	33	1.34
		(0.96)	(1.03)	(0.09)		(1.11)	(1.09)	(0.06)		(1.04)

Notes: Means and comparison of means for the first wave of railway construction (1847-1864). Columns (4) and (8) present a two-sided T-test of the difference in means of municipalities with railway access to those without railway access. ***a:*** Sample excludes nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). ***b:*** Sample includes all 20 largest towns nodes and Stephenson & Swinburne nodes. Standard deviations in parentheses in columns (2), (3), (6), (7), and (10). Standard errors in parentheses in columns (4) and (8). + $p<0.10$, * $p<0.05$, ** $p<0.01$ *** $p<0.001$.

the railway induced population growth is due to migration or birth surpluses. It also presents evidence of railway access accelerating structural change and increasing the body height of conscripts.

5.1 Cross-Sectional Analysis: Population Growth in Municipalities

The cross-sectional analysis focusing on railway lines constructed between 1847 and 1864 is presented first, followed by a discussion on the second wave of railway development that lasted from 1869 to 1882. Our benchmark results are based on a sample including all the municipalities of Switzerland, except for the 33 main transport nodes and municipalities that experienced extraordinary demographic volatility due to railway construction work.

Table 5 presents the findings for the *first wave* of railway expansion (1847–1864), illustrated in Figure 3. The first column reports results for a placebo test based on the pre-railway period between 1800 and 1850. Both the OLS and IV coefficients for the pretreatment period are close to zero and statistically insignificant. This indicates that conditional on our control variables, population growth rates in treated and untreated municipalities were similar previous to the railway era. This changed following the construction of the railway network. Column (2) captures the effects of railway lines on long-term population growth between 1850 and 1900. Municipalities that were connected to the railway network between 1847 and 1864 experienced a significant increase in population growth during the second half of the 19th century.

The IV estimates, shown in the middle panel of Table 5, imply an additional annual

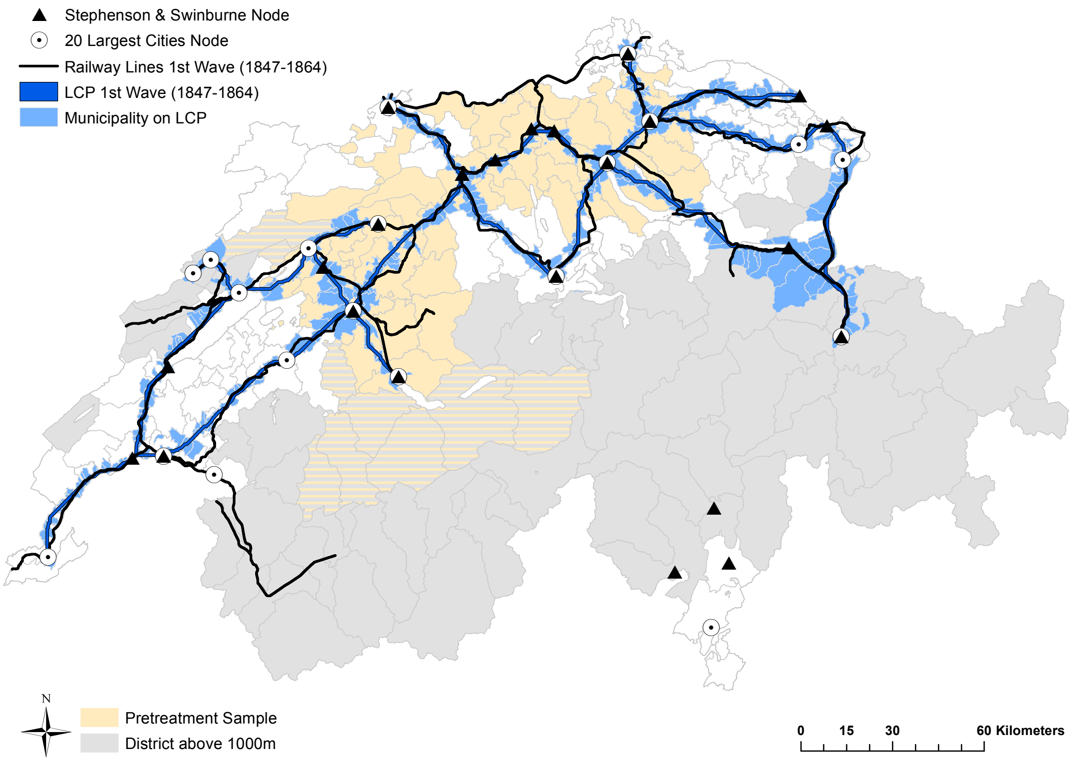


Figure 3: Railway Lines and Least-Cost Paths, 1st Wave

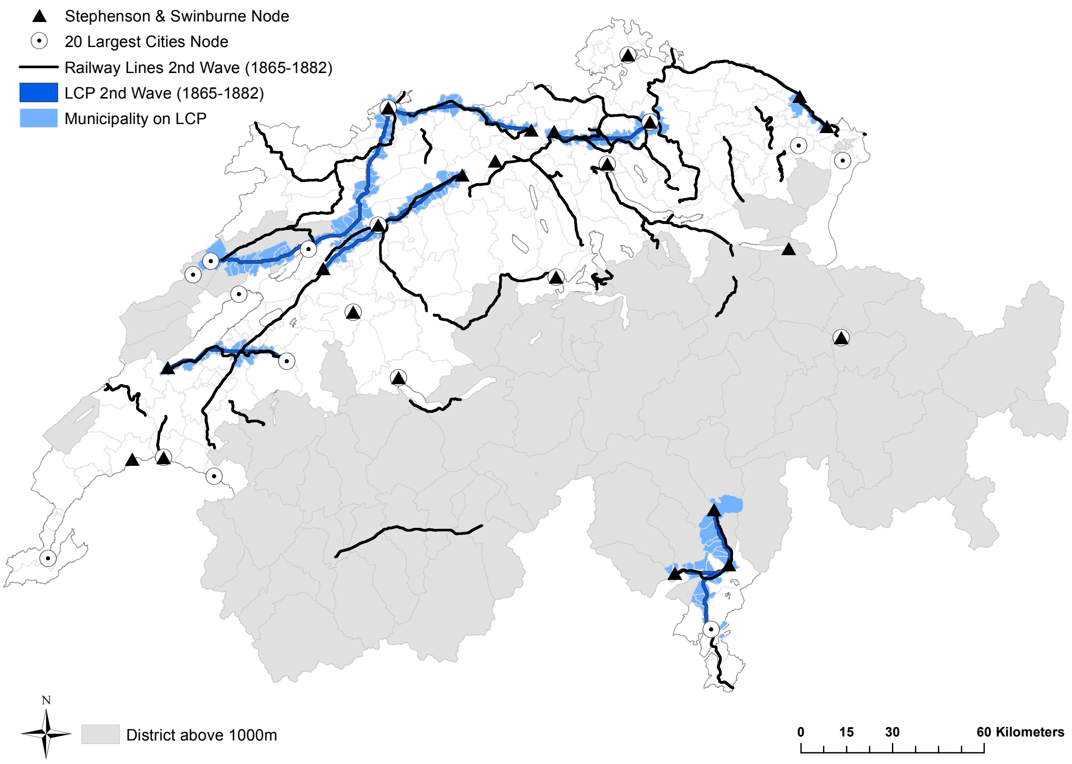


Figure 4: Railway Lines and Least-Cost Paths, 2nd Wave

Table 5: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates at the Municipal Level

	Long Run		10 Year Periods				
	1800–50[a]	1850–1900	1850–60	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.00	0.41***	0.31***	0.26***	0.36***	0.34***	0.56***
	(0.04)	(0.04)	(0.06)	(0.07)	(0.06)	(0.06)	(0.08)
R^2	0.26	0.28	0.17	0.07	0.11	0.11	0.12
Observations	903	2770	2791	2790	2748	2743	2769
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.15	0.39***	–0.06	0.31*	0.58**	0.32+	0.47*
	(0.15)	(0.10)	(0.15)	(0.15)	(0.18)	(0.18)	(0.22)
Observations	903	2770	2791	2790	2748	2743	2769
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths							
LCP 1847–64	0.25***	0.33***	0.41***	0.40***	0.35***	0.34***	0.33***
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
R^2	0.29	0.39	0.33	0.33	0.37	0.37	0.39
Observations	903	2770	2791	2790	2748	2743	2769

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects. ***Sample:*** All municipalities of Switzerland, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). ***a*:** Pre-railway sample available for four cantons (ZH, BE, SO, AG). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table 6: The Impact of Railway Access (1869–82) on Annual Population Growth Rates, Cross-Sectional Estimates at the Municipal Level

	Long Run		10 Year Periods				
	1850–70[a]	1870–1900	1850–60[a]	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1869–82	0.24***	0.36***	0.24***	0.19**	0.32***	0.23***	0.42***
	(0.05)	(0.04)	(0.07)	(0.06)	(0.06)	(0.07)	(0.08)
R^2	0.15	0.22	0.15	0.07	0.09	0.11	0.11
Observations	2344	2344	2365	2364	2324	2320	2344
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1869–82	–0.08	0.51**	0.01	–0.19	0.37	0.60*	0.49
	(0.19)	(0.18)	(0.27)	(0.23)	(0.29)	(0.26)	(0.35)
Observations	2344	2344	2365	2364	2324	2320	2344
IV, First Stage: Actual Railway Access 1869–82 and Least-Cost Paths							
LCP 1869–82	0.36***	0.36***	0.37***	0.37***	0.35***	0.36***	0.36***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
R^2	0.32	0.32	0.29	0.29	0.27	0.28	0.32
Observations	2344	2344	2365	2364	2324	2320	2344

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), cantonal fixed effects, and population growth 1850–1860 (except for columns ***a***, where district population growth 1800–1850 is used). ***Sample:*** All municipalities, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

growth of 0.39 percentage points, which translates into a relative population increase of over 20% within 50 years. An average municipality with early railway access and 750 inhabitants in 1850 would therefore have gained around 160 additional inhabitants by 1900 compared to an identical municipality without railway access. Note that the first stage, which is presented in the table's bottom panel, yields a strong and highly significant correlation between the instrument and the railway access variable. This alleviates concerns related to weak instruments.

Looking at every decade individually, we obtain fairly stable coefficients. According to our preferred IV estimates in columns (4) to (7), municipalities with railway access experienced additional annual growth of 0.31 to 0.58 percentage points compared to municipalities without a railway connection. This effect is significant at the 10% level or higher, except for the first decade of railway construction from 1850 to 1860 suggesting that railway access impacted population growth with a time lag. The OLS and IV coefficients are similar in magnitude, which substantiates the claim that early railway companies prioritised direct connections between large cities, and did not necessarily target fast growing municipalities along the way.

The results for the *second wave* of railway construction (1869–1882), which expanded the network by another 1 500 km of tracks, are presented in Table 6. Municipalities that gained railway access by 1864 were excluded from these regressions. Again, the first stage results for the IV models yield large and highly significant correlations between our instrument and railway access.

Columns (1), (3), and (4) display placebo tests based on an analysis of population growth rates from 1850 to 1870 and railway access obtained between 1869 and 1882. The OLS regressions produce a positive and statistically significant correlation, indicating that municipalities with a higher population growth rate in this pre-treatment period were more likely to receive railway access between 1869 to 1882. The IV approach seems to mitigate this issue, with coefficients being close to zero or negative and statistically insignificant in both the short (1850–60; 1860–70) and long run perspective (1850–70).

While pre-treatment annual growth rates are not correlated with the instrumented railway access indicator, we obtain strong correlations for the post-treatment period. Estimates for the long run effect spanning 30 years from 1870 to 1900 are displayed in the second column and show a positive and highly significant effect of railway access on population growth, with the IV estimate amounting to 0.51. Columns (5) to (7) report the analogous results for each decade separately, which display positive effects of railway access across all specifications, while in two cases the coefficients are insignificant with t-values between 1.3 and 1.4. The effects of railway access on population growth rates vary between 0.37 and 0.6 percentage points. As for the results on the first wave of railway expansion, the post-treatment IV estimates are not statistically different from the OLS estimates in this second set of cross-sectional regressions.

Tables B.2 and B.3 in the appendix (section B.1) present the same set of results for municipalities belonging to districts with a mean elevation below 1 000 m.a.s.l. Although population growth dynamics might be different in the barren alpine regions, the main estimates are not substantially affected by this robustness exercise.

Taken together, the results for both waves of railway construction suggest that railway access caused an increase in annual population growth rates, with the average effect lying between 0.39 and 0.51 percentage points for our preferred long run IV specifications. The following section analyses the impact of railway access on population growth based on panel data techniques.

5.2 Panel Data Analysis: Population Growth in Municipalities

The cross-section estimations include various control variables that account for municipality specific characteristics. Nevertheless, unobserved characteristics may still influence the particular growth potential of a municipality. The fixed effect estimation allows us to base inference on within municipality variation, which eliminates biases from time-invariant unobserved characteristics. Table 7 presents our preferred panel estimations that use the lag of railway access as main explanatory variable.

Table 7: The Impact of Railway Access on Annual Population Growth Rates, Panel Estimates at the Municipal Level

	Whole Switzerland[a]		Below 1 000 m[b]		Pre-Treatment Sample[c]	
	OLS FE	IV FE	OLS FE	IV FE	OLS FE	IV FE
	(1)	(2)	(3)	(4)	(5)	(6)
Annual Population Growth Rates in Decade t and Railway Access in Decade $t-1$						
Lag Railway Access	0.08*	0.42**	0.13**	0.41**	0.29***	0.44*
	(0.04)	(0.13)	(0.04)	(0.13)	(0.06)	(0.18)
R^2	0.05	–	0.05	–	0.17	–
Municipalities	2731	2731	2020	2020	821	821
Observations	13651	13651	10100	10100	4926	4926
Municpality FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Canton Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The dependent variable is annual population growth rate in percent. Full sample, ***a:*** All municipalities of Switzerland, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). Below 1 000 m sample, ***b:*** All municipalities of districts with mean elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (see Rey, 2003, 147-149). ***c:*** This estimation additionally includes the pre-treatment period 1837–1850, but is restricted to a smaller sample of municipalities for which pre-railway population data is available (four cantons: ZH, BE, SO, AG), excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

We provide results for OLS and IV fixed effects estimations for three different samples. The first sample includes all the municipalities in Switzerland (see column 1 & 2). The second sample excludes municipalities where the mean district elevation is higher than 1 000 m.a.s.l. in order to remove the barren alpine region (see column 2 & 3). The third sample is restricted to municipalities for which pre-railway population data is available, so that the decade from 1840 to 1850 can be included in the estimation as well (see column 3 & 4). For all samples the main nodes and municipalities affected by railway construction work are excluded.

The IV coefficients in columns (2), (4) and (6) range between 0.41 to 0.44 for all three samples and are statistically significant at the 5% level or higher. Remarkably, they are also very close to the long run effects estimated in the cross section (first wave: 0.39, second wave: 0.51). Although this effect is less than half of the estimates reported for cities (see Hornung, 2015; Berger and Enflo, forthcoming), it is not negligible. A coefficient of 0.42 translates into an additional population count of 23% after 50 years for municipalities that got connected to the railway infrastructure compared to municipalities without railway access. In the next section, we explore local displacement effects of railway and impact heterogeneity across treated municipalities.

5.3 Displacement Effects and Heterogeneity across Municipalities

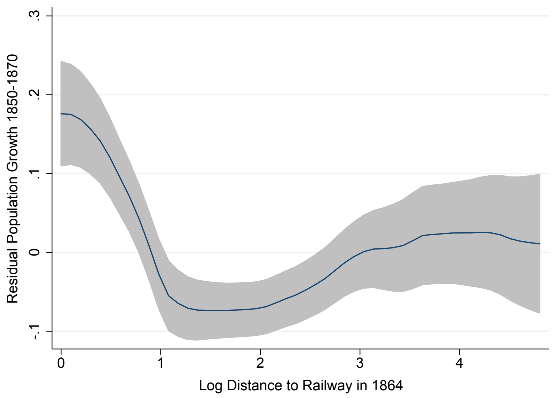
Compared to other studies that investigate the impact of railway infrastructure, the small size of Swiss municipalities allows for a detailed spatial evaluation of growth effects. For example, both Atack et al. (2010) and Donaldson and Hornbeck (forthcoming) use US counties as units of analysis, which have a median land area of 1 610 km^2 compared to less than 7 km^2 of a median-sized Swiss municipality.[24] Hornung (2015), on the other hand, uses Prussian cities as unit of analysis, and therefore provides no insights for railway effects in rural areas.

One important question that can be addressed based on the spatially small-scaled data relates to the local displacement effects of transportation infrastructure. For instance, Chandra and Thompson (2000) find that US highways led to a local shift of production from unconnected regions to neighbouring regions with highway access. If railway caused such local reorganisations, we would expect negative population growth effects in close proximity to the railway. Figure 5 shows two local polynomial regression of residual growth on the log distance to the railway in 1864, covering the periods from 1850 to 1870 and from 1850 to 1900. Both graphs are indeed hump-shaped, supporting the hypothesis of local displacement effects from nearby municipalities to those with direct railway access.

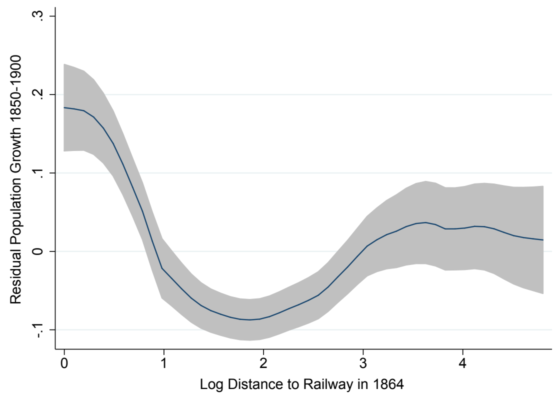
To further investigate this claim, Table B.8 in the appendix reconstructs our baseline cross-section results, yet provides a spatially disaggregated analysis by including a set of distance dummies. Distance to the railway is calculated as distance between a municipality's geographic centroid and the closest railway track, with each distance dummy covering a band with a width of 2 km.[25] Railway only had a positive growth impact on municipalities that either had direct access to the railway network, or were very close to the railway line. Reproducing the results from the local polynomial regressions, municipalities

[24]Information on the area of US counties is based on the US Census 2000 available at `http://factfinder.census.gov/`; the area of Swiss municipalities is based on our own calculations in GIS using the Swiss boundary files.

[25]We only present OLS results for this part, since instrumenting a series of distance dummies is beyond the power of our instrument. Considering the results in Tables 4 and 5 we are not too concerned about selection issues. Moreover, selection is probably even less likely for the set of municipalities that were close to the railway tracks but did not gain direct access. Indeed, the results in column (1) of Table B.8 do not point towards selection effects.



(a) Distance to Railway in 1864 and Population Growth from 1850 to 1870



(b) Distance to Railway in 1864 and Population Growth from 1850 to 1900

Figure 5: Distance to Railway and Population Growth, Local Polynomial with 95% Confidence Band. **Settings:** Kernel: Epanechnikov, Degree=0, Bandwith (a)=0.46 (b)=0.43, Pwidth (a)=0.7 (b)=0.64 **Residuals:** Calculated based on OLS regression of population growth (1850–1870; 1850–1900) on control variables, i.e. distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), and annual district population growth 1800–1850, and cantonal fixed effects.

located more than 2 km from the railway network experienced a slowdown in population growth with the negative effect peaking at 6 to 8 km. Taken together, this strongly points towards a local reorganisation of economic activity as municipalities in the direct vicinity of railway tracks (2 km–10 km) experienced slowing population growth, suggesting that people moved closer to the railway line after it went into service.

With regard to effect heterogeneity, it is interesting to investigate whether large municipalities benefited more from railway access in terms of population growth than small ones, as the *home-market channel* from economic geography models would suggest. In Table 8 we therefore add an interaction term of railway access with population size prior to the railway construction in 1850. Column (2) presents both OLS and IV estimates including that interaction term. The estimated coefficient turns out to be small and insignificant at conventional levels. Consequently, one may conclude that municipality size was not a key moderating factor for the impact of railway access, thus rejecting implications related to the home-market effect.

Urbanisation in Switzerland advanced quickly in the second half of the 19th century, as Figure 1a unambiguously illustrates. This may raise concerns that the effect of railway access was mainly driven by urbanisation forces. We therefore check whether the impact of railway access varies with distance to the urban centres. While distance to the 20 largest cities certainly has a strongly negative impact on population growth rates as seen in Table B.1 in the appendix, the interaction of distance to the 20 largest cities with railway access has no significant effect on the population growth rate. This alleviates concerns that the railway access dummy primarily picks up urbanisation effects, and suggests that railway access was equally beneficial in peripheral areas and in the direct vicinity of the main urban centres.

Table 8: The Impact of Railway Access (1847–64) and Interaction Terms on Annual Population Growth Rates, Cross-Sectional Estimates at the Municipal Level

	Long Run 1850–1900		
	(1)	(2)	(3)
OLS: Annual Population Growth and Railway Access			
Rail Access 1847–64	0.41***	0.40***	0.40***
	(0.04)	(0.04)	(0.04)
Rail Access 1847–64 x Population 1850		0.05	
		(0.04)	
Rail Access 1847–64 x Distance 20 Cities			–0.07
			(0.06)
R^2	0.28	0.28	0.28
Observations	2770	2770	2770
IV: Annual Population Growth and Railway Access			
Rail Access 1847-64	0.39***	0.35**	0.38***
	(0.10)	(0.12)	(0.10)
Rail Access 1847–64 x Population 1850		0.08	
		(0.10)	
Rail Access 1847–64 x Distance 20 Cities			–0.05
			(0.14)
Observations	2770	2770	2770
FS 1: F-statistic	146.87	81.99	86.01
FS 2: F-statistic	–	67.62	76.78

Notes: The dependent variable is the annual population growth rate in percent. The controls used are distance to the nearest town node(log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects. ***Sample:*** All municipalities of Switzerland, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Finally, we investigate the impact of railway access at different percentiles of the population growth distribution using quantile regressions. As Figure B.1 in the appendix reveals, railway access increased population growth across all percentiles evaluated, with somewhat stronger effects on faster growing municipalities.

Overall, our results at the municipal level show that railway moderately increased population growth in directly connected municipalities. This impact was fairly homogeneous across municipalities of different sizes, different geographical locations, and different percentiles of the growth distribution. However, our findings also suggest that unconnected municipalities in the close vicinity of railway lines experienced a slump in population growth rates, probably due to displacement effects, as reported for highways by Chandra and Thompson (2000) for instance.

5.4 District Level: Population Growth, Migration, Sectoral Work Shares, and Body Height

This section reports and discusses the estimation results based on district data. While studying the municipal level provides a cleaner setup for identification, district data allows for a number of extensions. *First*, the previously discussed results raise the question of whether railway had a positive net impact on local population growth, or simply led to a local zero-sum-shift from municipalities without railway access to municipalities with railway access. District level data can shed light on this question, as one would expect a positive impact of railway access on district population growth in the first scenario only. *Second*, Swiss municipality data does not reveal whether changes in the population count are driven by changes in migration, birth surpluses, or both. Census data including district birth and death statistics can be used to examine the two channels separately. *Third*, one may test the hypothesis that railway access promoted regional economic development based on further indicators alongside population growth. District statistics on sectoral work shares and the body height of conscripts allow us to gain insights into the impact of railway on structural change and the biological well-being of the Swiss population. This last step may also provide answers to the question why railway expansion affected population dynamics, since shifts in labour demand and altered living conditions are potential drivers of migrations flows.

We use the population weighted share of municipalities directly connected to the railway network as our main explanatory variable on the district level. Reflecting the three waves of railway constructions in 19th century Switzerland, we define three measures that indicate the *additional* railway access gained by districts in each period, i.e. $RASHR^{1847-64}$, $RASHR^{1865-82}$, and $RASHR^{1883-99}$.[26] These three railway variables are used as main explanatory variables in our OLS regressions of the form

$$Y_{ic}^{t} = \alpha_5 + \gamma_1 RASHR_{ic}^{47-64} + \gamma_2 RASHR_{ic}^{65-82} + \gamma_3 RASHR_{ic}^{83-99} + \varphi_5 D_{ic}^{1850} + \kappa_{5c} + \vartheta_{ic}, \quad (5)$$

where Y_{ic} stands for the outcome of interest in period t, κ_c denotes cantonal fixed effects, and D_{ic}^{1850} is a vector of district control variables, including the population weighted log distance to the nearest city, population weighted access to a main road, log mean district elevation, log population in 1850, and population growth between 1800 and 1850. We do not report the results for the IV equivalent of equation (5), since a test for weak instruments along Stock and Yogo (2005) suggests that instrumenting $RASHR_{ic}^{47-64}$ and $RASHR_{ic}^{65-82}$ would be unreliable due to low first stage correlations.

We complement the cross-sectional analysis with OLS and IV district fixed effects panel estimations, the latter being specified as

$$RASHR_{ict} = \pi_{6i} + \beta_6 LCPSHR_{ict} + \lambda_{6t} + \lambda_{6t} \cdot \kappa_{6c} + \xi_{ict}, \text{ and} \quad (6)$$

[26] We calculate the population weighted share of municipalities with railway access for each year and district. $RASHR_i^{1847-64}$ stands for district's i population weighted share of municipalities with railway access in 1864. $RASHR_i^{1865-82}$ gives district's i population weighted share of municipalities with railway access in 1882 minus its population weighted share of municipalities with railway access in 1864. Finally, $RASHR_i^{1883-99}$ is district's i population weighted share of municipalities with railway access in 1899 minus its population weighted share of municipalities with railway access in 1882.

$$Y_{ict} = \pi_{7i} + \beta_7 \widehat{RASHR}_{ict-1} + \lambda_{7t} + \lambda_{7t} \cdot \kappa_{7c} + \varepsilon_{ict} \quad (7)$$

where time fixed effects, λ_t, control for population growth cycles on the national level, and cantonal-time fixed effects, $\lambda_t \cdot \kappa_c$, account for cycles on the regional level. $LCPSHR_{ict}$ serves as instrument, which is defined as the population weighted share of municipalities in district i and decade t that lie on the least-cost path explained in section 4.2.

Table 9 shows the district level distribution of railway access. During the first wave of railway construction 84 of the 178 Swiss districts were connected to the railway network, and by 1900 this number increased to 158. The districts' average share of people living in a municipality with railway access climbed to 26% by 1864, and reached 55% by the end of the century. With respect to our main explanatory variable $RASHR^w$, this translates into district averages of 26% for the first wave, 19% for the second wave, and 10% for the third wave. These numbers are used in the remainder of this study for back-of-the-envelope calculations of impact magnitudes for districts with average railway access compared to identical districts without a railway connection.

Table 9: Share of Population with RW-Access, District Level Distribution

w	Mean across Districts Marginal[a]	Cumulative	Number of Districts with No Access (=0)	Full Access (=1)
1847–64	0.26	0.26	84	3
1865–82	0.19	0.45	34	8
1883–99	0.10	0.55	20	10

Notes: *a* This column shows the mean across the explanatory variable $RASHR^t$.

Did these railway improvements affect *population growth* at the district level, as observed for municipalities? The results in Table 10 indeed suggest that railway access had a positive net-impact on district population growth, and did not simply lead to a local zero-sum-shift from municipalities without railway access to municipalities with railway access. A district that was fully connected to the railway network experienced an average increase in the annual population growth rate of 0.4 to 0.8 percentage points compared to districts without railway access, which is slightly larger than the effects found at the municipal level. The panel-IV coefficient is rather imprecisely estimated, however, and is insignificantly different from our preferred municipality estimates, which range from 0.4 to 0.5. Furthermore, the equivalent coefficient for the sub-sample of districts with mean elevation below 1 000 m.a.s.l. is 0.63 (see Table C.1 in the appendix), and therefore halves the gap to the municipality estimates. While we find significant and robust correlations between railway access and population growth across different models and sub-samples, a placebo test based on district population growth prior to the railway era in column (1) does not yield significant coefficients for the railway access variables.

The previous findings unequivocally suggest that gaining railway access increased population growth. In a next step, we explore whether the additional growth is driven by larger

Table 10: The Impact of Railway Access on Annual Population Growth Rates, Cross-Sectional and Panel Estimates at the District Level

	Cross Section			Panel FE	Panel IV FE	IV FS
	1800–50	1850–1900		1850–1900	1850–1900	1850–1900
	(1)	(2)		(3)	(4)	(5)
RASHR 1847–64	0.18	0.52^{***}	Lag RASHR	0.41^{**}	0.84^{+}	
	(0.12)	(0.15)		(0.15)	(0.43)	
RASHR 1865–82	0.14	0.70^{***}	LCPSHR			0.43^{***}
	(0.13)	(0.17)				(0.09)
RASHR 1883–99	0.05	0.61^{**}				
	(0.12)	(0.22)				
R^2	0.58	0.49	R^2 (within)	0.33	–	0.73
Observations	136	126	Observations	600	600	600
			Districts	120	120	120

Notes: The dependent variable is the annual population growth rate in percent. *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. The controls used are distance to the nearest node (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), and population growth 1800–1850. The sample comprises all districts, except for districts including one of the 33 nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. The first stage regression is shown in the last column. *LCPSHR* is the population weighted share of municipalities in a district that lie on the least-cost path. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + $p<0.10$, * $p<0.05$, ** $p<0.01$ *** $p<0.001$.

birth surpluses or the *migration balance.* Based on the districts' birth and death statistics as reported in the Swiss census since 1870, we calculate the birth surplus as well as the migration balance for each decade and district as a share of the districts' populations. The cross-sectional and panel OLS regressions presented in Table 11 yield a positive correlation between railway access and the migration balance as well as the excess of birth over death counts. Comparing a district without railway infrastructure to an identical district with average railway access, the cross sectional estimates in column (1) translate into a railway induced increase in the net migration rate of 2.1% of the initial population within 10 years.[27] The panel estimates in column (3) are quantitatively similar to the cross-sectional results and suggest that connecting 55% of a district's population to the railway network would cause an increase in the net migration balance of 2.8 percentage points in the following decade. Turning to the second measure, average railway access is associated with an increase in the district's birth surplus of 0.5% to 1% of its initial population depending on the regression model used.[28]

As both dependent variables are measured in terms of a district's population, these results indicate that railway access had a considerably larger impact on the migration balance than on the birth surplus. Having said this, it should be noted that the migration balance was negative for three out of four districts between 1870 and 1900. Hence, improved railway access had a positive impact of population growth rates because it cushioned the outflow of people to urban centres rather than causing a net inflow. In summary, one may conclude that railway access had a weakly positive impact on the birth surplus and at the same time significantly improved the migration balance by attenuating the net

[27] Based on the cross-sectional results, the ten-year effect of railway access on the migration balance of an average district is calculated based on Table 9 and 11 as follows: $(0.26\cdot10.18+0.19\cdot15.44+0.1\cdot7.26)/3 = 2.1$.

[28] Based on the cross-sectional results, the ten-year effect of railway access on the birth surplus of an average district is calculated based on Table 9 and 11: $(0.26 \cdot 3.52 + 0.19 \cdot 3.68 + 0.1 \cdot 0.83)/3 = 0.5$.

Table 11: The Impact of Railway Access on Migration and Birth Surplus, Cross-Sectional and Panel Estimates at the District Level

	Cross Section (1870–1900)			Panel FE (1870–1900)	
	Migration[a]	Birth Surplus[b]		Migration[a]	Birth Surplus[b]
	(1)	(2)		(3)	(4)
RASHR 1847–64	10.18+	3.52**	Lag RASHR	5.06*	1.79*
	(5.82)	(1.22)		(2.02)	(0.84)
RASHR 1865–82	15.44*	3.68**			
	(6.36)	(1.32)			
RASHR 1883–99	7.26	0.83			
	(5.90)	(2.08)			
R^2	0.54	0.63	R^2 (within)	0.30	0.32
Observations	112	112	Observations	327	327
			Districts	109	109

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable, ***a***: A district's net balance of migration flow, indicates inflow - outflow. ***b***: A district's birth surplus as a share of average population. Railway access is measured by the share of the population that has access (municipalities with railway line) to the railway network. The sample comprises all districts, except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The controls used in the cross-section estimation are distance to the nearest city (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), and population growth 1800–1850. Cross-section estimations include cantonal fixed effects. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

outflow of people. Overall, these two effects translate on average into an additional annual population growth rate of 0.4 to 0.8 percentage points caused by full railway access.

In a last step, we complement the analysis of population growth by examining the impact of railway infrastructure on the *sectoral composition* and the *biological standard of living*. These two variables allow us to evaluate whether the conclusions derived from the population statistics are robust to the use of other proxies of regional economic development. Furthermore, we may learn why railway expansion affected population dynamics; railway induced changes in labour demand and living conditions could have been two potential factors shaping Switzerland's domestic migration flows.

While historians have discussed various channels through which railway infrastructure potentially accelerated structural change, to our knowledge no study has so far aimed to quantify these effects in the Swiss context. One important consequence of railway expansion in Switzerland was the shift in agricultural production from grain to dairy products, as explained in section 2. Frey and Vogel (e.g. 1997, chapter 8) point out that international demand for dairy products and the availability of cheap grain from abroad made dairy farming financially more attractive. Since milk is highly perishable, quick and reliable transport from producers to the processing industry was crucial, making accessible regions better suited to this type of farming.[29] At the same time animal husbandry was less labour intensive than grain cultivation, meaning that the shift to dairy farming led to stagnating or even decreasing agricultural workforce numbers. On top of that, employees in the agricultural sector traditionally supplemented their income with home-based manu-

[29] Consider the first condensed milk producer in Switzerland as an illustrative example. It started operating in Cham, 20 km south of Zurich, two years after being connected to the railway network in 1864. In around 1880, it was supplied by 1350 farmers, absorbing more milk than Switzerland's largest city Zurich (Frey and Vogel, 1997, 279).

Table 12: The Impact of Railway Access on Sectoral Work Shares, Panel Estimates at the District Level

	Panel FE (1860–1900)			Panel IV FE (1860–1900)		
	Agriculture	Manufact.	Services	Agriculture	Manufact.	Services
	(1)	(2)	(3)	(1)	(2)	(3)
Lag RASHR	-7.74^{***}	6.26^{***}	1.48	-9.69^{+}	9.14^{+}	0.55
	(1.72)	(1.36)	(0.99)	(5.16)	(4.72)	(1.59)
R^2 (within)	0.54	0.48	0.51	–	–	–
Districts	117	117	117	117	117	117
Observations	550	550	550	550	550	550

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable: A district's sectoral work share in percent (agriculture, manufacturing, services). The sample comprises all districts, except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

facturing work. With the advance of industrial mechanisation, driven among other things by large-scale coal imports via rail, this source of supplemental income began to vanish continuously. This process made farming jobs less attractive, and therefore potentially accelerated the decline in agricultural workforce numbers. On the other hand, railway access arguably offered opportunities in the manufacturing sector and service industry. For instance, the availability of cheap coal not only accelerated mechanisation, but also cleared the way for energy-intensive sectors such as steel works, salterns, and cement production (see section 2). Furthermore, railway infrastructure allowed industrial entrepreneurs to relocate to areas that offered cheap land and labour, without being penalised by uncompetitively high transport costs. The quintupling of freight volumes from 1870 to 1900 and the more than 350 privately owned – typically very short – interchange rail tracks illustrate how heavily manufacturers relied on this new means of transport.[30] Regarding services, the railway expansion coincided with a growing popularity of tourism and leisure activities. Early travel books such as "Baedeker's Schweiz" provide detailed accounts of train connections, documenting their attractiveness for (wealthy) tourists.[31] It is certainly no coincidence that nowadays well-known alpine sights like the "Rigi" (1 795 m.a.s.l.) at the Lake of Lucerne or the "Jungfraujoch" (3 466 m.a.s.l.) in Grindelwald were connected by rack railways from as early as 1871 and 1912.

We measure sectoral composition based on work shares of the agricultural, manufacturing, and service sector. The cross-sectional regressions aim to explain the percentage point change in sectoral work shares between 1860 to 1900 using our period specific district level measures for railway access along a set of controls. In the panel data models, the sectoral work shares for each decade are regressed on the lagged value of the time-variant

[30] Statistics on freight and privately owned interchange tracks were obtained from the *Schweizerische Eisenbahnstatik* (SPE, 1900), which is partly accessible online from `http://www.bahndaten.ch/` (last access: 01.02.2016).

[31] Baedeker's Schweiz, which appeared in 31 revised editions between 1840 and 1905, began offering descriptions of localities and recommended routes with detailed travel directions, typically information on train connections such as train operator, journey time, fares, and interchange facilities. It also included a map of Switzerland's railway network, as well as a general section on traveling by train with information on fares, circular tickets, and Switzerland's official railway guide.

railway access indicator, or its first-stage prediction in the IV setup.

The cross-sectional regressions (see Table 13) and the panel models (see Table 12) reveal an unambiguous pattern. Improvements in the railway access of districts are associated with a shift from the agricultural sector to the manufacturing and services industries. The estimated coefficients imply that in districts with average railway access the agricultural work share declined by an additional 4.6 to 8.3 percentage points between 1860 and 1900 compared to districts without a railway connection.[32] At least two-thirds of this railway induced drop in agricultural employment were absorbed by an increase in the industrial workforce, while employment gains in the service sector compensated for one-third or less. Considering that the average drop in the agricultural work share was 9.2 percentage points in the same period, the drop explained by railway infrastructure improvements at the district level is substantial.

Although very few sources document industry-specific wages paid during the 19th century in Switzerland, the available records suggest that wages in the secondary sector were higher than in the primary sector.[33] Since better connected localities experienced on average a faster shift from agricultural employment to better paid manufacturing jobs, railway related sectoral change may explain why districts with well-developed railway infrastructure experienced higher population growth than districts with poor railway access. This notion also reflects a common narrative within the agrarian community at the time, which claimed that employment opportunities in the manufacturing sector and the promise of higher living standards in the city were responsible for the rural exodus, thus jeopardising the traditional social order (Gruner, 1987, 1404).

While fragmentary income data makes it impossible to investigate these claims further, the body height data of conscripts allow us to directly compare improvements in *living standards* across Switzerland. Since the 1970s, interdisciplinary research – known as new anthropometric history – established body height and other anthropometric measures as indicators for the biological standard of living.[34] The adult height of a population serves as a measure of the population's nutritional status from birth through adolescence. Early childhood and the adolescent growth spurt are considered sensitive periods, during which a person's stature is most keenly affected by nutritional abundance or scarcity (Steckel, 2009, 8). A broad list of factors influencing nutritional status and physical growth have been

[32] Based on the cross-sectional results, the 40 year effect of railway access on the agricultural work share of an average district is calculated based on Table 9 and 13: $0.26 \cdot (-14.6) + 0.19 \cdot (-17.2) + 0.1 \cdot (-12.2) = -8.3$.

[33] The database *Historical Statistics of Switzerland Online* (`www.fsw.uzh.ch/histstat/`) compiles all industry specific income statistics available for the 19th century, its main sources being Brugger (1978) for the primary sector and Gruner (1987) for the secondary sector. While the database is relatively comprehensive for manufacturing jobs, wages paid in the agricultural sector are only available for the cantons of Geneva and Thurgau. A comparison of average incomes earned in various occupations and regions yields wage differences between the primary and secondary sector ranging from -20% (construction worker vs. senior farm labourer) to +250% (worker in horology industry vs. herdsman). By far most of these comparisons suggest that manufacturing jobs were better paid, even though we did not discount wages in the primary sector for the very poor employment opportunities during the winter months.

[34] Steckel (1995) reviews 145 articles on body height and human welfare written between the late 1970s and 1994, while Steckel (2009) covers 326 studies on this topic published between 1995 and 2008.

Table 13: The Impact of Railway Access on Sectoral Work Shares and Body Height, Cross-Sectional Estimates at the District Level

	Sectoral Shares (1860–1900)[a]				Body Height[b]
	Agriculture	Manufacturing	Services		1890–1910
	(1)	(2)	(3)		(4)
RASHR 1847–64	−14.56**	9.16**	4.89*		
	(4.48)	(3.44)	(2.32)		
RASHR 1865–82	−17.20***	12.35***	4.25*	RASHR 1847–82	0.17
	(4.65)	(3.61)	(2.14)		(0.29)
RASHR 1883–99	−12.22*	2.46	8.82*	RASHR 1882–99	0.93**
	(5.83)	(3.46)	(4.16)		(0.29)
R^2	0.49	0.54	0.39	R^2	0.73
Observations	123	123	123	Observations	125

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable, ***a:*** Percentage point change in a district's sectoral work share (agriculture, manufacturing, services). ***b:*** Centimeter change in a district's conscripts average body height between 1884/91 and 1908/12. The controls used are distance to the nearest city (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), population growth 1800–1850, and cantonal fixed effects. Additionally, models in columns ***a*** control for the district's sectoral work share in 1860 (agric., indust., services), while column ***b*** includes the district's average body height for the 1884/91 conscription. The sample comprises all districts, except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

studied, including social class (e.g. Schoch, Staub and Pfister, 2012), business cycles (e.g. Sunder and Woitek, 2005), industrialisation (e.g. Steckel and Floud, 1997) and public infrastructure, such as sanitary and electric facilities (e.g. Thomas and Strauss, 1992) or road access (e.g. Gibson and Rozelle, 2003). These studies find that economically favourable conditions and well-developed infrastructure are positively correlated with nutrition intake and body height. The study closest to our analysis of body height is Solakoglu (2007), who evaluates the effect of railway on nutritional intake in the US postbellum period. Her findings suggest that railway infrastructure increased nutritional intake significantly. Relating her estimates to findings on calorie intake and body height by Craig and Weiss (1998), she computes a railway-induced average stature growth of an additional 1.1 cm between 1867 and 1906.

Railway access may have an impact on body height through various channels, including the price and availability of nutrition and medical treatment, the quantity and physical nature of labour during adolescence, as well as the dissemination of infectious diseases. To quantify the net impact of railway infrastructure on body height, we study body height data from two conscription periods (source: Staub, 2010). The first cross-section comprises the body height of men physically examined between 1884 and 1891, with their year of birth ranging from 1865 to 1872. The second cross-section includes the body height of men physically examined between 1908 and 1912, with their year of birth ranging from 1889 to 1893.[35] We intend to explain the change in body height of recruits between these two periods using the change in district railway access and a set of controls (Figure C.1 in the appendix illustrates the timing for this test). Since we use the change in body

[35] Although the Swiss military authorities surveyed conscripts' body measurements every year, regional averages were computed and documented by the statistical office for multi-year periods only. The data from the years 1884 to 1891 and 1908 to 1912 are the earliest records available that can be used in a district comparison; see Staub (2010, 101–102) for details.

height between two conscription periods and control for the initial body height of recruits, one would expect that only the third wave of railway constructions, i.e. between 1883 to 1899, has explanatory value. On one hand, recruits registered in the first military survey available (1884 to 1891) were at least 11 years old by the time the earliest of these railway lines went into service so that possible railway induced improvements in their nutritional status were hardly sufficient to translate into body height gains. On the other hand, men recruited in the second period (1908 to 1912) were at most 10 years old when the last third-wave lines entered into operation, which allowed their stature to be affected by the benefits of improved railway access during childhood and the adolescent growth spurt.

The last column of Table 13 shows the results for the regression of body height changes in centimetres on railway access at the district level. As hypothesised, railway access prior to 1883 is not significantly correlated with changes in the districts' average body height between the two conscription rounds, while railway improvements between 1883 to 1899 are associated with a highly statistically significant growth effect. According to the coefficient for *RASHR 1883–99*, the average body height of young men increased by an additional 9.3 mm if they were domiciled in a district that gained full railway access between 1883 and 1899 compared to contemporaries living in a district without improvements in railway access.[36] This implies an additional gain in the conscripts' average body height of 1 mm for districts with average railway improvements between 1883 and 1899 relative to districts without additional railway connections in the same period. Compared to the average increase in body height across districts in the same period, which is 2.2 cm, these railway induced gains in body height were only marginal, however.

In summary, the regression results for all indicators of regional economic development analysed in this section indicate that railway improvements had a positive and statistically significant impact. In comparison to districts without any railway connections, those districts with average railway access experienced a moderate increase in population growth per year (around 0.2 to 0.4 percentage points), a substantially accelerated structural change in the economy (additional 4.6 to 8.3 percentage point shift in work shares from the primary to the secondary/tertiary sector), and a minor gain in biological well-being. Hence, the results for both the municipal and district levels support the hypothesis that railway access promoted regional economic development.

6 Conclusion

This paper investigates how railway infrastructure affects regional development by studying railway expansion and population growth in Switzerland during the second half of the 19th century. We find that the annual population growth rates of municipalities with access to the railway network were about 0.4 percentage points higher than annual the

[36] Restricting the sample to districts with a mean elevation of less than 1 000 m.a.s.l. (see column 4 in Table C.3 in the appendix) yields almost identical results.

growth rates of municipalities without a railway connection. This result proves to be very robust to adjustments in the econometric framework (*cross-section* and *panel IV*), changes in the sample (*whole of Switzerland* and *lowlands*), examinations of different construction periods (*1847–1864* and *1869–1882*), as well as adaptations in the spatial units considered (*municipalities* and *districts*). The positive effect of railway access on population growth was markedly localised, however, as we find strong evidence for displacement effects: Municipalities in the vicinity of railway tracks but without direct access experienced the lowest population growth, suggesting that people moved closer to the railway line after it went into service. The district analysis of birth, death, and migration statistics confirm that railway primarily had an impact on population growth via the local migration balance.

We supplement the analysis on population growth with an evaluation of two potential drivers behind migration flows, namely industrialisation inferred from sectoral work shares and improved living conditions measured via the body height of conscripts. Our estimates consistently show that the share of agricultural labour decreased substantially faster in districts with above-average railway access, while the same districts experienced an accelerated growth in manufacturing employment. Concerning body height, our estimations based on recruitment data yield a weakly positive but highly statistically significant effect of railway improvements between two conscription rounds and the gain in the recruits' average body height per district during that period. These findings signify that railway facilitated industrialisation and improved living conditions. Both factors – themselves indicators of regional development – likely drove migration towards better connected localities, as highlighted both by our municipality and district results on population growth.

Adding to the well-established findings on railway access and city growth, our study of Switzerland complements the recent literature on the impact of early railway lines in western countries. We show that not only urban centres but also small rural municipalities along the main lines benefited from railway access. While the estimated effects in rural areas are less than half that reported for cities, our findings do not strictly support the home-market hypothesis, as we find no evidence pointing towards a growth slowdown in peripheral municipalities after they received access to the railway network.

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A Data Appendix

A.1 Control Variables

Table A.1: Variable Description & Data Sources

Municipal Level		
Annual Population Growth	$100 \cdot (log(POP_{i,t2}) - log(POP_{i,t1}))/(t2 - t1)$	Census (1850, 60, 70, 80, 88, 1900), Schuler and Schluchter (in progress)
Treatment Variable		
Railway Access	Binary indicator. Equals one if railway intersects a municipality's boundary.	GIS-Dufour (Egli et al., 2005)
Control Variables		
Distance to Town Node	Natural logarithm of the distance between a municipality's centroid and the closest town node's centroid in kilometers. Town nodes are defined as Switzerland's 20 largest towns in 1850.	Swisstopo (2007)
Distance to Stephenson-Swinburne Node	Natural logarithm of the distance between a municipality's centroid and the closest Stephenson-Swinburne node in kilometers. If the closest Stephenson-Swinburne node is also a town node, we compute the distance based on the second closest Stephenson-Swinburne node.	Swisstopo (2007)
Access to Main Road in 1850	Binary indicator. Equals one if road of primary importance intersects a municipality's boundary, see A.1.1.	GIS-Dufour (Egli et al., 2005)
Access to Navigable Water	Binary indicator. Equals one if municipality adjoins navigable water.	Swisstopo (2007)
Elevation	Natural logarithm of the mean elevation (in 100m) calculated based on a 25 m x 25 m height model.	Swisstopo (2004)
Water Power Potential	Binary indicator. Equals one if a river with a water flow of at least 1 m^3/s crosses a municipality and – in doing so – overcomes a height difference of 10m or more, see A.1.2.	Swisstopo (2007), Pfaundler and Schönenberger (2013)
Town Privilege	Binary indicator. Equals one if municipality holds the historical town status.	Guyer (1960)
Population in 1850	Natural logarithm of a municipality's population in 1850.	Census (1850)
Municipal Area	Natural logarithm of municipal area in square kilometers.	Swisstopo (2007)
District Pop. Growth 1800–50	$100 \cdot (log(POP_{d,t2}) - log(POP_{d,t1}))/50$	Schluchter (1988), Census
District Level		
Annual Population Growth	$100 \cdot (log(POP_{d,t2}) - log(POP_{d,t1}))/(t2 - t1)$	Census (1850, 60, 70, 80, 88, 1900)
Migration Balance	$100 \cdot (POP_{d,t2} - POP_{d,t1} - Birthsurplus_{d,t1-2})/(POP_{d,t1})$	Census (since 1870)
Birth Surplus	$100 \cdot (\#Births_{d,t1-2} - \#Deaths_{d,t1-2})/(\frac{1}{2}POP_{d,t1} + \frac{1}{2}POP_{d,t2})$	Census (since 1870)
Work Share: Agriculture	*Cross-Section*: Percentage point change in work share of agric. sector 1860–1900; *Panel*: Work share in agric. sector	Census (since 1860)
Work Share: Manufacturing	*Cross-Section*: Percentage point change in work share of industrial sector 1860–1900; *Panel*: Work share in industrial sector	Census (since 1860)
Work Share: Services	*Cross-Section*: Percentage point change in work share of service industry 1860–1900; *Panel*: Work share in service industry	Census (since 1860)
Change in Body Height of Conscripts	Centimeter change in a district's conscripts average body height between 1884/91 and 1908/12	Staub (2010)
Treatment Variable		
Pop. Share with Railway Access	Population (as per 1850) weighted share of municipalities that had direct access to the railway network	GIS-Dufour (Egli et al., 2005)
Standard Control Variables		
Mean Distance to Town Node	Population weighted (as per 1850) minimal distances from a district's municipalities to the nearest city-node.	Swisstopo (2007), Census
Pop. Share with Road Access	Share of population (as per 1850) with direct access to road of primary importance.	GIS-Dufour (Egli et al., 2005)
Elevation	Mean elevation (in 100m) of district calculated based on a 25 m x 25 m height model.	Swisstopo (2004)
Population in 1850	Natural logarithm of a district's population in 1850.	Census (1850)
District Pop. Growth 1800–50	$100 \cdot (log(POP_{d,t2}) - log(POP_{d,t1}))/50$	Schluchter (1988), Census
Additional Control Variables		
Work Share in 1860	A district's work share in agriculture/industry/services in 1860	Census (since 1860)
Body Height of Conscripts in 1884/91	A district's conscripts average body height as measured between 1884–91.	Staub (2010)

Table A.2: Descriptive Statistics

Municipal Level	Observations	Mean	Std. Dev.	Min.	Max.
Annual Population Growth, 1850–1900 (cross-section)	2844	0.15	0.66	−2.43	5.90
Annual Population Growth, 1850–1900 (pooled)	14 330	0.15	1.27	−16.05	22.23
Treatment Variable					
Railway Access, 1850–1900 (pooled)	17 322	0.22	-	0	1
Control Variables					
LN(Distance to Town Node)	2854	2.90	0.63	0.68	4.44
LN(Distance to Stephenson-Swinburne Node)	2854	3.08	0.74	0.21	4.64
Access to Main Road in 1850	2887	0.38	-	0	1
Access to Navigable Water	2887	0.06	-	0	1
LN(Elevation in 100m)	2887	1.97	0.49	0.78	3.40
Water Power Potential	2887	0.42	-	0	1
Town Privilege	2887	0.04	-	0	1
LN(Population) in 1850	2847	6.25	0.92	3.56	10.64
LN(Municipal Area)	2887	2.00	1.04	−1.14	5.64
District Level	Observations	Mean	Std. Dev.	Min.	Max.
Annual Population Growth, 1850–1900 (cross-section)	178	0.35	0.48	−6.00	2.36
Annual Population Growth, 1850–1900 (pooled)	944	0.51	1.85	−4.50	51.10
Migration Balance, 1870–1900 (cross-section)	143	−12.11	16.39	−44.83	40.12
Migration Balance, 1870–1900 (pooled)	429	−4.09	6.59	−29.30	24.60
Birth Surplus, 1870–1900 (cross-section)	143	7.40	3.40	−9.60	15.59
Birth Surplus, 1870–1900 (pooled)	429	7.40	3.72	−13.42	20.02
Δ Work Share: Agricult., 1860–1900 (cross-section)	161	−9.17	9.70	−36.22	14.97
Work Share: Agricult., 1860–1900 (pooled)	784	51.27	19.23	2.18	96.24
Δ Work Share: Manuf., 1860–1900 (cross-section)	161	4.09	8.49	−16.34	29.04
Work Share: Manuf., 1860–1900 (pooled)	784	36.32	17.15	2.43	84.12
Δ Work Share: Services, 1860-1900 (cross-section)	161	5.07	4.00	−2.28	26.96
Work Share: Services, 1860–1900 (pooled)	784	12.41	6.59	1.33	50.17
Δ Body Height of Conscripts, 1884/91–1908/12	176	2.16	0.99	0.00	6.00
Treatment Variable					
Pop. Share with Railway Access, 1850–1900 (pooled)	1068	0.35	0.34	0	1
Standard Control Variables					
LN(Mean Distance to Town Node) in 1850	158	3.00	0.57	1.59	4.27
Pop. Share with Road Access in 1850	178	0.76	0.21	0	1
LN(Elevation in 100m)	178	2.12	0.52	1.20	3.26
LN(Population) in 1850	178	9.32	0.62	7.30	11.07
Annual Population Growth, 1800–1850 (cross-section)	175	0.69	0.31	−0.30	1.49
Additional Control Variables					
Work Share: Agriculture in 1860	149	55.06	17.57	7.85	92.84
Work Share: Manufacturing in 1860	149	35.45	15.95	4.64	76.58
Work Share: Services in 1860	149	9.49	4.72	2.52	32.39
Body Height of Conscripts in 1884/91	176	163.40	1.47	159.4	166.9

A.1.1 Road Network

We use information on the development of the road network in the 18th and 19th century from the GIS-Dufour project (Egli et al., 2005). GIS-Dufour documents all roads and their classification according to the cantonal road laws. The road laws were enacted in most cantons in the years 1830–1840 and they differ from canton to canton. However, most cantonal laws include at least a classification on roads of primary importance, i.e. class 1 roads. To control for road accessibility we use information on the class 1 road network, and identify municipalities with access to a class 1 road. Figure A.2 shows the first class road network in the year 1850.

A.1.2 Potential for Water Power Generation

Early Swiss industrial development used hydropower as an important source to run industrial machines. Since Switzerland itself had no coal deposits, wood was a limited power source and there was no high-capacity means of transportation for fossil fuels, water was the main source of power for industrial development prior to the railway era (Schnitter, 1992). By the year 1876 Switzerland had hydroelectric power plants installed with a capacity of 70 350 horse power (Weissenbach, 1876). For each municipality we define a potential for hydroelectric power based on existing hydropower technologies. The main parameters determining the potential for hydropower are the water cumulative flows and the gradient that the water falls. The Francis Turbine was invented in the year 1849 by James B. Francis and the most advanced technology at the beginning of the railway era in Switzerland. Taking the technical constraints of the Francis Turbine into account, we define a simplified indicator for hydro power potential based on two conditions: First, the water flow has to reach a minimum of at least 1 m^3/s. Second, the height difference between the point of entry and exit of a river flowing through a municipality has to be at least 10 m. If a watercourse satisfying both conditions runs through a municipality, it is assigned value 1, and otherwise 0. We construct this variable based on detailed information on water drain measured for each water body in Switzerland combined with data on larger river water flows measured by metering stations.[37] Using GIS we determine for every water body the point of entry and exit for each municipality and the height difference between entry and exit point. We then code municipalities as having the potential for industrial hydropower generation using the parameters mentioned above.

[37] Data on water drain is available at http://www.bafu.admin.ch/wasser/13462/13496/15016/index.html?lang=de (Pfaundler and Schönenberger, 2013); data from metering stations along larger Swiss rivers is available at http://www.hydrodaten.admin.ch/de/stationen-und-daten.html.

A.2 Maps

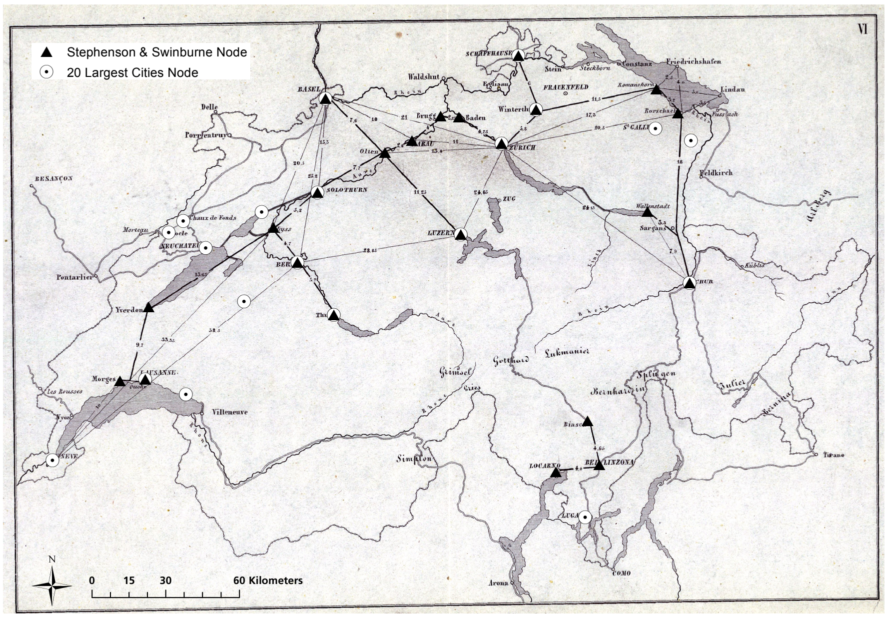

Figure A.1: Original Stephenson & Swinburne Plan with Main Nodes

Notes: The figure displays the original Stephenson & Swinburne railway plan and the selected main nodes. The selection of nodes is based on the proposed traffic hubs of Stephenson & Swinburne and the 20 largest municipalities in the year 1850 that had the town privilege. Some towns were both a hub in the original Stephenson & Swinburne plan and belonged to the 20 largest cities in 1850.

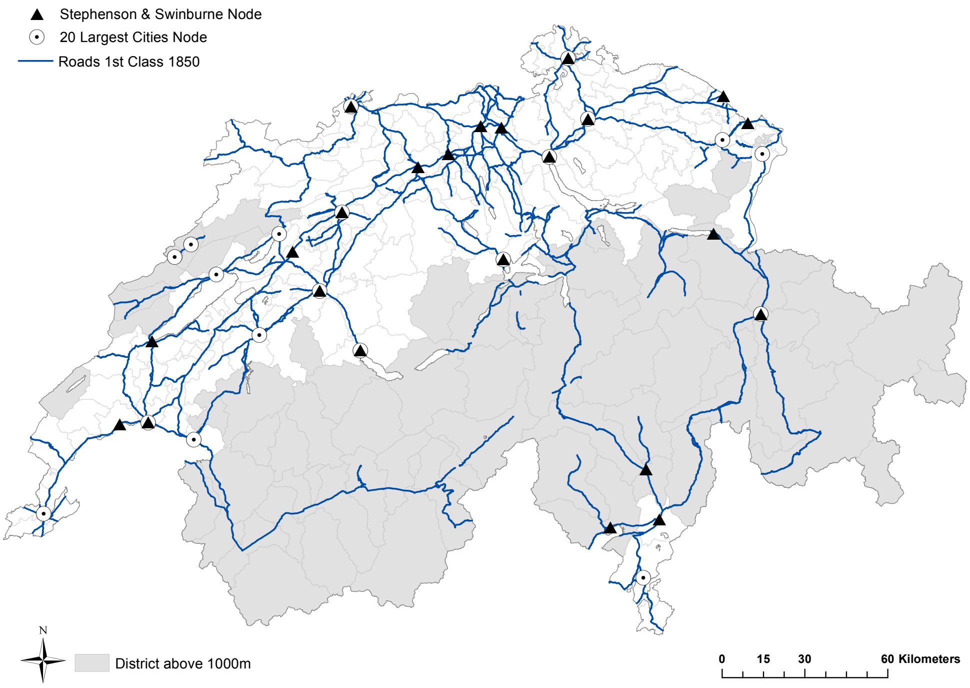

Figure A.2: Roads of Primary Importance in 1850

Notes: Road network displaying roads with a classification 1 according to the cantonal road laws in 1850, based on the GIS-Dufour project (Egli et al., 2005).

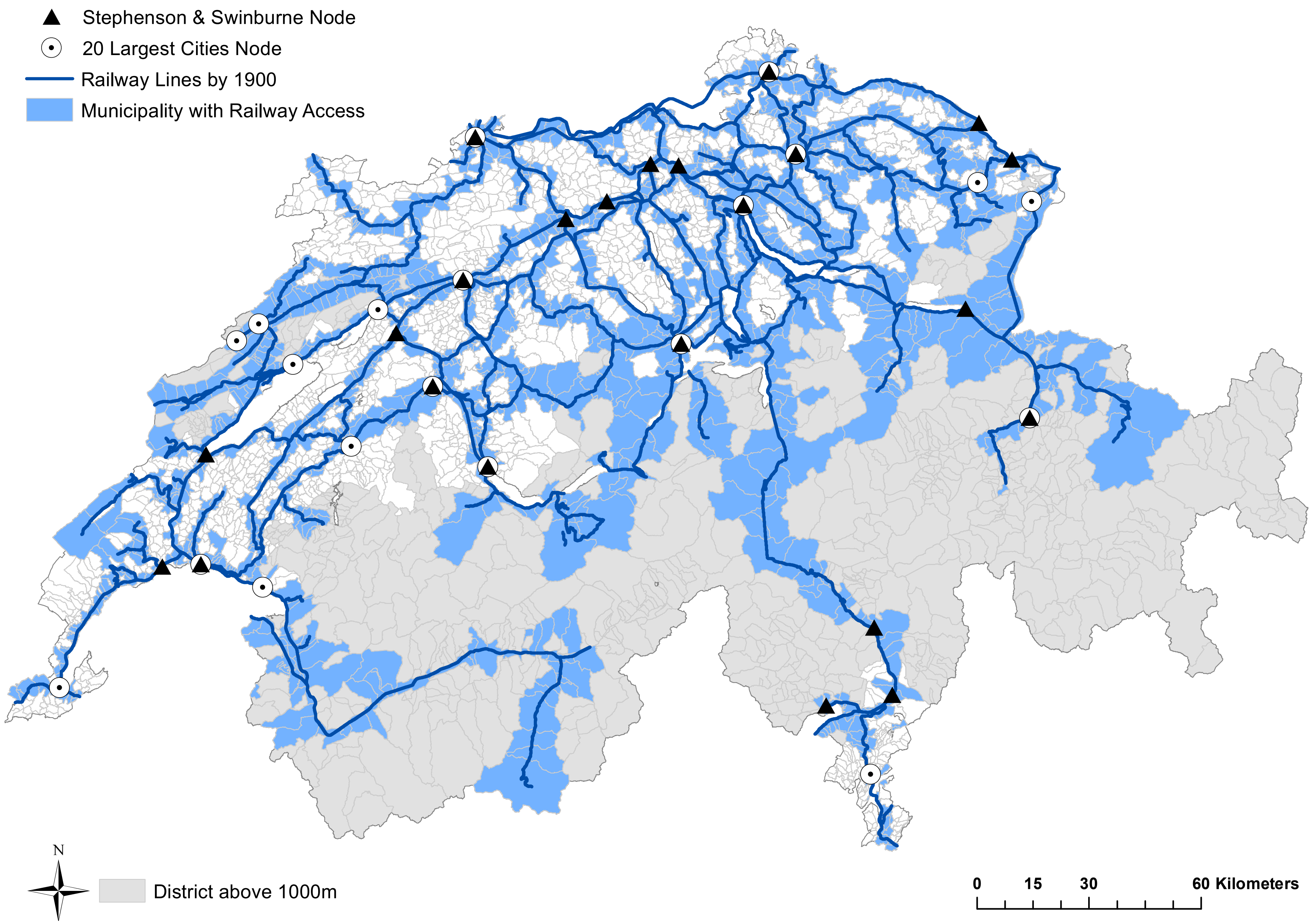

Figure A.3: Swiss Railway Network by 1900

Notes: The map shows the Swiss railway network as completed by 1900. The source of digitized railway lines is the project "GIS-Dufour" (Egli et al., 2005).

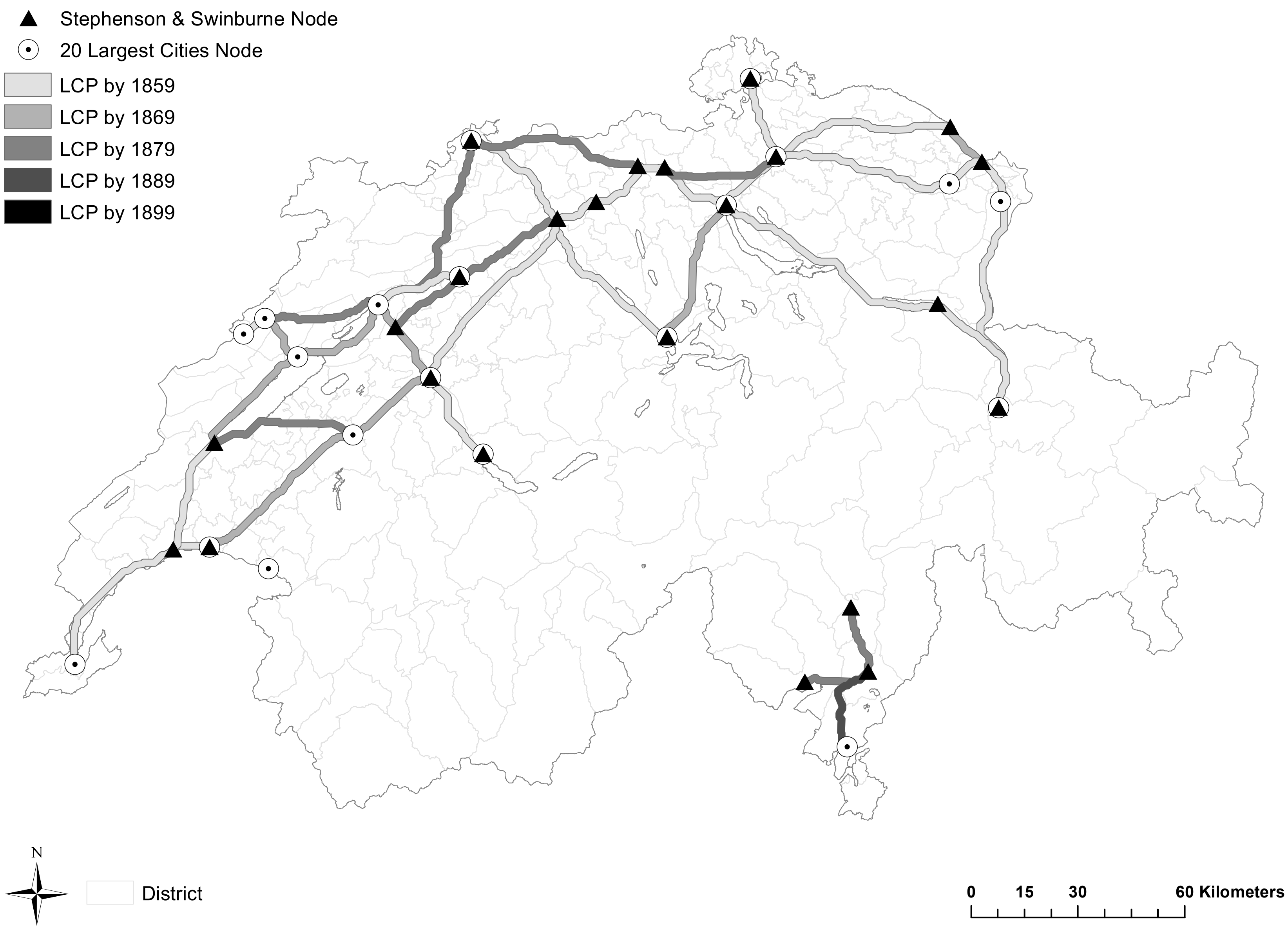

Figure A.4: Least-Cost Paths for Main Lines by Decade of Their Opening

Notes: Least-cost paths, which represent a virtual cost-efficient railway line computed with GIS-software. For better readability least-cost paths are displayed with a width of 2km.

A.3 Sample of Districts

Table A.3: Sample of Districts across Different Dependent Variables

ID	District	ID	District	ID	District	ID	District
Canton Zurich		**Canton of Schwyz**		**Canton of St. Gallen**		**Canton of Ticino**	
101	Affoltern	501	Einsiedeln	1701	St. Gallen^{n,s,b}	2101	Bellinzona^{n,c}
102	Andelfingen	502	Gersau	1702	Rorschach^{n}	2102	Blenio
103	Bülach	503	Höfe	1703	Unterrheintal	2103	Leventina^{c}
104	Dielsdorf^{s,b}	504	Küsnacht	1704	Oberrheintal^{n}	2104	Locarno^{n,c}
105	Hinwil	505	March	1705	Werdenberg	2105	Lugano^{n,c}
106	Horgen	506	Schwyz^{c,b}	1706	Sargans^{n}	2106	Mendrisio
107	Meilen	**Canton of Obwalden**		1707	Gaster	2107	Riviera^{n,c}
108	Pfäffikon	600	Obwalden	1708	See	2108	Vallemaggia
109	Uster	**Canton of Nidwalden**		1709	Obertoggenburg	**Canton of Vaud**	
110	Winterthur^{n,b}	700	Nidwalden	1710	Neutoggenburg	2201	Aigle
111	Zürich^{n,s,b}	**Canton of Glarus**		1711	Alttoggenburg	2202	Aubonne
Canton of Bern		800	Glarus	1712	Untertoggenburg	2203	Avenches
201	Aarberg^{n}	**Canton of Zug**		1713	Wil	2204	Cossonay
202	Aarwangen^{s,b}	900	Zug^{c}	1714	Gossau^{n,s,b}	2205	Echallens
203	Bern^{n,b}	**Canton of Fribourg**		**Canton of Grisons**		2206	Grandson
204	Biel^{n,s,b}	1001	Broye	1801	Albula^{c}	2207	Lausanne^{n,b}
205	Büren	1002	Glane	1802	Bernina	2208	Lavaux
206	Burgdorf	1003	Gruyere	1803	Glenner^{c,s}	2209	Morges^{n}
207	Courtelary	1004	Saane^{n}	1804	Heinzenberg^{c}	2210	Moudon^{n,b}
208	Delemont^{b}	1005	See	1805	Hinterrhein^{c}	2211	Nyon
209	Erlach	1006	Sense	1806	Imboden^{c,s}	2212	Orbe
210	Franches-Montagne	1007	Veveyse	1807	Inn	2213	Oron
211	Fraubrunnen	**Canton of Solothurn**		1808	Maloja^{c}	2214	Payerne
212	Frutigen^{c}	1101	Balsthal	1809	Moesa	2215	Enhaut
213	Interlaken	1102	Bucheggb.-Kriegst.	1810	Müstair	2216	Rolle
214	Konolfingen^{s}	1103	Dorneck-Thierstein	1811	Oberlandquart	2217	Vallée
215	Laufen	1104	Olten-Goesgen^{n}	1812	Plessur^{n}	2218	Vevey^{n}
216	Laupen	1105	Solothurn-Lebern^{n}	1813	Unterlandquart^{c}	2219	Yverdon^{n}
217	Moutier	**Canton of Basel-Stadt**		1814	Vorderrhein^{s}	**Canton of Valais**	
218	La Neuveville	1200	Basel^{n,b}	**Canton of Aargau**		2301	Brig^{c}
219	Nidau^{s,b}	**Canton of Basel-Land**		1901	Aarau^{n}	2302	Conthey
220	Oberhasli	1301	Arlesheim^{b}	1902	Baden^{n}	2303	Entremont
221	Porrentruy	1302	Liestal	1903	Bremgarten	2304	Goms
222	Saanen	1303	Sissach	1904	Brugg^{n}	2305	Hérens
223	Schwarzenburg	1304	Waldenburg	1905	Kulm	2306	Leuk
224	Seftigen	**Canton of Schaffhausen**		1906	Laufenburg^{s}	2307	Martigny
225	Signau	1401	Oberklettgau^{s}	1907	Lenzburg^{c}	2308	Monthey
226	Simmental, Nieder-^{c}	1402	Reiat^{s}	1908	Muri^{c}	2309	Raron^{c}
227	Simmental, Ober-	1403	Schaffhausen^{n,s}	1909	Rheinfelden	2310	Saint-Maurice
228	Thun^{n,s,b}	1404	Schleitheim	1910	Zofingen	2311	Sierre
229	Trachselwald	1405	Stein	1911	Zurzach^{s}	2312	Sion
230	Wangen^{s,b}	1406	Unterklettgau^{s}	**Canton of Thurgau**		2313	Visp
Canton of Lucerne		**Canton of Appenzell (AR)**		2001	Arbon^{n,s}	**Canton of Neuchatel**	
301	Entlebuch^{s,b}	1501	Hinterland^{p}	2002	Bischofszell^{p,s,b,h}	2401	Boudry^{s}
302	Hochdorf	1502	Mittelland^{p}	2003	Diessenhofen	2402	Chaux-de-Fonds^{n}
303	Luzern^{n,b}	1503	Vorderland^{p}	2004	Frauenfeld^{p,s,b,h}	2403	Locle^{n}
304	Sursee^{s,b}	**Canton of Appenzell (AI)**		2005	Kreuzlingen^{p,s,b,h}	2404	Neuchatel^{n}
305	Willisau	1600	Appenzell	2006	Münchwilen^{p}	2405	Val-de-Ruz^{s}
Canton of Uri				2007	Steckborn^{p,s,b,h}	2406	Val-de-Travers
400	Uri^{c}			2008	Weinfelden^{p,s,b,h}	**Canton of Geneva**	
						2500	Geneva^{n,b}

Notes: ***n:*** Districts including one of the 33 main nodes. Excluded in all regression models. ***c:*** Districts that were affected by railway construction work in a given decade (see Rey, 2003, 147–149). Observation is excluded in all regressions covering the concerned period. ***p:*** Population data for 1800 cannot be merged reliably for these districts. Observation is excluded in all cross-section regressions. ***s:*** The employment data cannot be merged reliably for these districts, at least in certain decades. Observation is excluded in regressions with sectoral composition as dependent variable covering the concerned period. ***b:*** The birth and death statistics cannot be merged reliably for these districts, at least in certain decades. Observation is excluded in regressions with migration or birth surplus as dependent variable covering the concerned period. ***h:*** The body height data cannot be merged reliably for these districts, at least in certain decades. Observation is excluded in regressions with body height as dependent variable covering the concerned period.

B Empirical Appendix: Municipal Level

Table B.1: The Impact of Railway Access (1847–64) on Annual Population Growth Rates (1850–1900), Cross-Sectional Estimates at the Municipal Level

	OLS (1)	IV (2)	IV, First Stage (3)
Railway Access 1847–64	0.41***	0.39***	
	(0.04)	(0.10)	
LCP 1847–64			0.33***
			(0.03)
Road Access 1850	0.05*	0.06+	0.16***
	(0.02)	(0.03)	(0.01)
Water Access	0.07	0.07	0.13***
	(0.06)	(0.06)	(0.03)
Log Elevation	−0.25***	−0.25***	−0.07**
	(0.05)	(0.05)	(0.02)
Water Power Potential	0.09***	0.09***	0.04**
	(0.03)	(0.03)	(0.01)
Log Distance to Town Node	−0.24***	−0.24***	−0.02
	(0.03)	(0.03)	(0.01)
Log Distance to Steph.-Swinb. Node	0.04+	0.04+	−0.01
	(0.02)	(0.02)	(0.01)
Log Population 1850	−0.05	−0.05	0.07***
	(0.03)	(0.03)	(0.01)
Log Area	0.12***	0.12***	−0.01
	(0.03)	(0.03)	(0.01)
Town Privilege	0.36***	0.36***	0.07+
	(0.07)	(0.07)	(0.04)
Subsequent Railway Access	0.29***	0.28***	−0.23***
	(0.03)	(0.04)	(0.01)
District Pop. Growth 1800–50	−1.58	−1.58	1.41
	(7.45)	(7.41)	(2.62)
R^2	0.28	–	0.39
Observations	2770	2770	2770

Notes: The dependent variable is annual population growth in percent. ***Sample:*** All municipalities, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

B.1 Robustness: Municipalities in Districts below 1 000 Meters

Table B.2: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Mean District Elevation below 1 000 m.a.s.l.)

	Long Run		10 Year Periods				
	1800–50[a]	1850–1900	1850–60	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	–0.02	0.42***	0.37***	0.21**	0.45***	0.37***	0.56***
	(0.04)	(0.04)	(0.07)	(0.08)	(0.07)	(0.07)	(0.08)
R^2	0.27	0.30	0.12	0.07	0.14	0.14	0.17
Observations	826	2018	2018	2018	2000	2000	2018
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.13	0.42***	0.12	0.34*	0.62**	0.38+	0.38
	(0.16)	(0.12)	(0.17)	(0.16)	(0.21)	(0.20)	(0.25)
Observations	826	2018	2018	2018	2000	2000	2018
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths							
LCP 1847–64	0.24***	0.31***	0.39***	0.39***	0.33***	0.32***	0.31***
	(0.05)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
R^2	0.29	0.37	0.31	0.31	0.35	0.36	0.37
Observations	826	2018	2018	2018	2000	2000	2018

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects. ***Sample:*** Municipalities of districts with a mean elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). ***a***: Pre-railway sample available for 4 cantons. The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.3: The Impact of Railway Access (1869–82) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Mean District Elevation below 1 000 m.a.s.l.)

	Long Run		10 Year Periods				
	1850–70[a]	1870–1900	1850–60[a]	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1869–82	0.19***	0.38***	0.17*	0.18**	0.35***	0.28***	0.43***
	(0.05)	(0.05)	(0.07)	(0.06)	(0.07)	(0.07)	(0.08)
R^2	0.12	0.27	0.11	0.07	0.10	0.13	0.17
Observations	1669	1669	1669	1669	1653	1653	1669
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1869–82	–0.38*	0.43*	–0.31	–0.45+	0.23	0.56*	0.48
	(0.19)	(0.17)	(0.25)	(0.24)	(0.29)	(0.26)	(0.32)
Observations	1669	1669	1669	1669	1653	1653	1669
IV, First Stage: Actual Railway Access 1869-82 and Least-Cost Paths							
LCP 1869-82	0.38***	0.38***	0.38***	0.39***	0.37***	0.37***	0.38***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
R^2	0.33	0.33	0.30	0.30	0.29	0.30	0.33
Observations	1669	1669	1669	1669	1653	1653	1669

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), cantonal fixed effects, and population growth 1850–1860 (except for columns ***a***, where district population growth 1800–1850 is used). ***Sample:*** Municipalities of districts with mean elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

B.2 Robustness: Pre-Treatment Sample

Table B.4: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Municipalities with Pre-Railway Data Available)

	Pre-Treatment			Post-Treatment
	1800–37[a]	1837–50[b]	1800–50[a]	1850–1900[c]
	(1)	(2)	(3)	(4)
OLS: Annual Population Growth Rates and Railway Access				
Rail Access 1847–64	0.03	−0.11	0.00	0.56***
	(0.04)	(0.07)	(0.04)	(0.06)
R^2	0.21	0.10	0.26	0.29
Observations	903	903	903	900
IV, Second Stage: Annual Population Growth Rates and Railway Access				
Rail Access 1847–64	0.13	0.24	0.15	0.95***
	(0.17)	(0.30)	(0.15)	(0.24)
Observations	903	903	903	900
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths				
LCC 1847–64	0.25***	0.25***	0.25***	0.25***
	(0.04)	(0.04)	(0.04)	(0.04)
R^2	0.29	0.29	0.29	0.29
Observations	903	903	903	900

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest city (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), area in km^2 (log), and cantonal fixed effects. Additional controls, ***a***: population in 1800 (log); ***b***: population in 1837 (log); ***c***: population in 1850 (log) and annual population growth 1800–1850. ***Sample:*** Municipalities for which population data is available for the pre-railway period (four cantons: ZH, BE, SO, AG), excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.5: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Municipalities with Pre-Railway Data Available and Mean District Elevation below 1 000 m.a.s.l.)

	Pre-Treatment			Post-Treatment
	1800–37[a]	1837–50[b]	1800–50[a]	1850–1900[c]
	(1)	(2)	(3)	(4)
OLS: Annual Population Growth Rates and Railway Access				
Rail Access 1847–64	0.02	−0.13+	−0.02	0.54***
	(0.04)	(0.08)	(0.04)	(0.06)
R^2	0.22	0.11	0.27	0.29
Observations	826	826	826	826
IV, Second Stage: Annual Population Growth Rates and Railway Access				
Rail Access 1847–64	0.08	0.28	0.13	0.88***
	(0.18)	(0.32)	(0.16)	(0.26)
Observations	826	826	826	826
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths				
LCC 1847–64	0.24***	0.24***	0.24***	0.24***
	(0.05)	(0.05)	(0.05)	(0.05)
R^2	0.29	0.29	0.29	0.29
Observations	826	826	826	826

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest city (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), area in km^2 (log), and cantonal fixed effects. Additional controls, ***a***: population in 1800 (log); ***b***: population in 1837 (log); ***c***: population in 1850 (log) and annual population growth 1800–1850. ***Sample:*** Municipalities for which population data is available for the pre-railway period (four cantons: ZH, BE, SO, AG) and with mean district elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.6: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Municipalities with Pre-Railway Data Available)

	Long Run		10 Year Periods				
	1800–50[a]	1850–1900	1850–60	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.00	0.56***	0.24**	0.43***	0.51***	0.42***	0.76***
	(0.04)	(0.06)	(0.09)	(0.11)	(0.09)	(0.10)	(0.12)
R^2	0.26	0.29	0.07	0.11	0.18	0.14	0.17
Observations	903	900	903	903	898	898	900
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.15	0.95***	0.33	0.57*	0.70+	0.68+	1.28**
	(0.15)	(0.24)	(0.28)	(0.26)	(0.36)	(0.35)	(0.49)
Observations	903	900	903	903	898	898	900
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths							
LCC 1847–64	0.25***	0.25***	0.33***	0.33***	0.27***	0.27***	0.25***
	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)
R^2	0.29	0.29	0.21	0.22	0.26	0.27	0.29
Observations	903	900	903	903	898	898	900

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest city (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), population in 1850 (log), annual population growth 1800–1850, and cantonal fixed effects. Other controls, ***a***: population in 1800 (log) instead of 1850, and without annual population growth 1800-1850. ***Sample:*** Excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses.. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.7: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates, (Sample: Municipalities with Pre-Railway Data Available and Mean District Elevation below 1 000 m.a.s.l.)

	Long Run		10 Year Periods				
	1800–50[a]	1850–1900	1850–60	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	−0.02	0.54***	0.28**	0.43***	0.50***	0.42***	0.74***
	(0.04)	(0.06)	(0.09)	(0.11)	(0.09)	(0.10)	(0.12)
R^2	0.27	0.29	0.07	0.11	0.19	0.13	0.19
Observations	826	826	826	826	821	821	826
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.13	0.88***	0.47	0.52+	0.61	0.70+	1.06*
	(0.16)	(0.26)	(0.29)	(0.27)	(0.38)	(0.37)	(0.51)
Observations	826	826	826	826	821	821	826
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths							
LCC 1847–64	0.24***	0.24***	0.33***	0.32***	0.26***	0.26***	0.24***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
R^2	0.29	0.29	0.20	0.21	0.25	0.26	0.29
Observations	826	826	826	826	821	821	826

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest city (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), population in 1850 (log), annual population growth 1800–1850, and cantonal fixed effects. Other controls, ***a***: population in 1800 (log) instead of 1850, and without annual population growth 1800–1850. ***Sample:*** Municipalities of districts with a mean elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (see Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses.. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

B.3 Additional Results: Displacement Effects and Heterogeneity

Table B.8: Distance to Railway (1847–64) and Annual Population Growth Rates, Cross-Sectional OLS Estimates at the Municipal Level

	Pre-Treatment Sample[a]			Whole Switzerland	
	1800–50	1850–70	1850–1900	1850–70	1850–1900
	(1)	(2)	(3)	(4)	(5)
Rail Access 1847–64	0.04	0.12	0.39***	0.21***	0.34***
	(0.06)	(0.11)	(0.08)	(0.06)	(0.04)
Distance to Railway 0–2 km	−0.01	−0.05	0.00	0.14+	0.16**
	(0.07)	(0.12)	(0.10)	(0.07)	(0.06)
Distance to Railway 2–4 km	0.00	−0.28**	−0.17*	−0.11*	−0.08*
	(0.05)	(0.10)	(0.07)	(0.05)	(0.04)
Distance to Railway 4–6 km	0.07	−0.26**	−0.20**	−0.15**	−0.14***
	(0.05)	(0.10)	(0.07)	(0.05)	(0.04)
Distance to Railway 6–8 km	0.11*	−0.31**	−0.26***	−0.15**	−0.19***
	(0.06)	(0.10)	(0.07)	(0.05)	(0.04)
Distance to Railway 8–10 km	0.10*	−0.13	−0.19*	0.02	−0.09*
	(0.05)	(0.12)	(0.08)	(0.06)	(0.04)
R^2	0.27	0.13	0.30	0.18	0.29
Observations	903	903	903	2810	2790

Notes: The dependent variable is annual population growth in percent. The municipalities with railway access are always excluded from the groups of distance dummies. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects. Distance dummies are exclusive, municipalities with direct railway access are not in the group of municipalities with a distance of 0–2km. The reference group are municipalities with a distance from the railway line larger than 10 km. ***Sample:*** All municipalities of Switzerland, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). ***a***: pre-railway sample available for 4 cantons. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

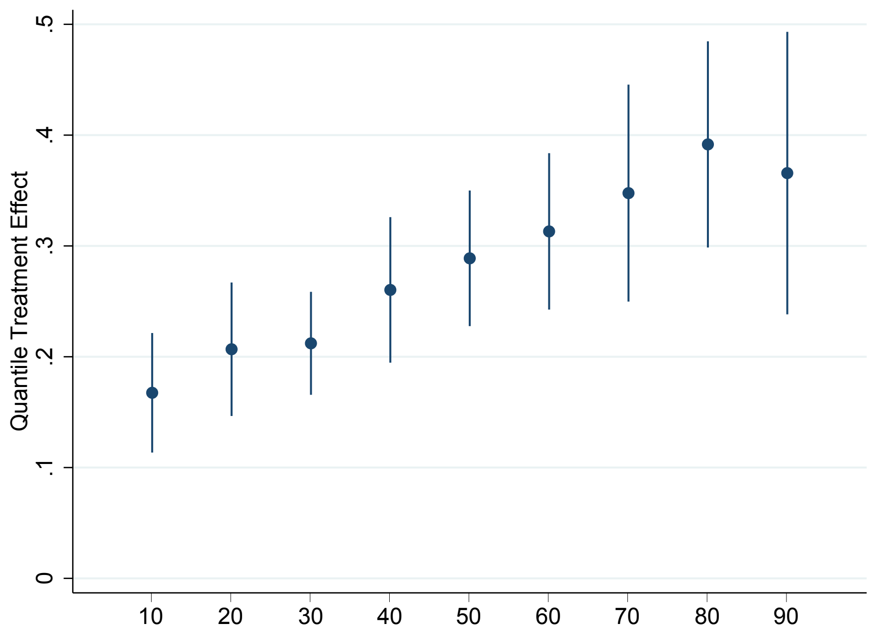

Figure B.1: Quantile Treatment Effects of Railway Access (1847–64) on Annual Population Growth (1850–1900), 10th to 90th Percentile.
Controls: Distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects.

C Empirical Appendix: District Level

C.1 Robustness: Districts with Mean Elevation below 1 000 Meters

Table C.1: The Impact of Railway Access on Annual Population Growth Rates, Cross-Sectional and Panel Estimates (Sample: Districts with a Mean Elevat. below 1 000 m.a.s.l.)

	Cross Section			Panel FE	Panel IV FE	IV FS
	1800–50	1850–1900		1850–1900	1850–1900	1850–1900
	(1)	(2)		(3)	(4)	(5)
RASHR 1847–64	–0.06	0.47^{*}	Lag RASHR	0.44^{**}	0.63^{+}	
	(0.21)	(0.18)		(0.15)	(0.39)	
RASHR 1865–82	–0.10	0.82^{***}	LCPSHR			0.48^{***}
	(0.22)	(0.21)				(0.09)
RASHR 1883–99	–0.28	0.41^{*}				
	(0.23)	(0.21)				
R^2	0.48	0.58	R^2 (within)	0.39	–	0.77
Observations	80	80	Observations	400	400	400
			Districts	80	80	80

Notes: Dependent variable is the annual population growth rate in percent. *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. The controls used are distance to the nearest node (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), and population growth 1800–1850. The sample comprises all districts with a mean elevation below 1 000 m.a.s.l., except for districts including one of the 33 nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. The first stage regression is shown in the last column. *LCPSHR* is the population weighted share of municipalities in a district that lie on the least-cost path. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table C.2: The Impact of Railway Access on Migration and Birth Surplus, Cross-Sectional and Panel Estimates (Sample: Districts with a Mean Elevation below 1 000 m.a.s.l.)

	Cross Section (1870–1900)			Panel FE (1870–1900)	
	Migration[a]	Birth Surplus[b]		Migration[a]	Birth Surplus[b]
	(1)	(2)		(3)	(4)
RASHR 1847–64	16.24^{+}	1.38	Lag RASHR	4.95^{**}	1.88^{+}
	(9.06)	(1.47)		(1.85)	(0.99)
RASHR 1865–82	25.63^{**}	1.51			
	(9.17)	(1.33)			
RASHR 1883–99	17.03^{+}	–3.69			
	(8.91)	(2.93)			
R^2	0.61	0.70	R^2 (within)	0.42	0.36
Observations	72	72	Observations	215	215
			Districts	72	72

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable, ***a***: A district's net balance of migration flow, indicates inflow - outflow. ***b***: A district's birth surplus as a share of average population. Railway access is measured by the share of the population that has access (municipalities with railway line) to the railway network. The sample comprises all districts with a mean elevation below 1 000 m.a.s.l., except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The controls used in the cross-section estimation are distance to the nearest city (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), and population growth 1800–1850. Cross-section estimations include cantonal fixed effects. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table C.3: The Impact of Railway Access on Sectoral Work Shares and Body Height, Cross-Sectional Estimates (Sample: Districts with a Mean Elevation below 1 000 m.a.s.l.)

	Sectoral Shares (1860–1900)[a]				Body Height[b]
	Agriculture	Manufacturing	Services		1890–1910
	(1)	(2)	(3)		(4)
RASHR 1847–64	−16.87**	11.80*	4.67**		
	(5.73)	(5.31)	(1.66)		
RASHR 1865–82	−22.95***	18.96**	3.91*	RASHR 1847–82	0.59
	(6.14)	(5.53)	(1.58)		(0.39)
RASHR 1883–99	−12.04*	5.65	6.45***	RASHR 1882–99	1.08*
	(5.02)	(4.63)	(1.39)		(0.53)
R^2	0.62	0.65	0.47	R^2	0.77
Observations	77	77	77	Observations	79

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable, ***a:*** Percentage point change in a district's sectoral work share (agriculture, manufacturing, services). ***b:*** Centimeter change in a district's conscripts average body height between 1884/91 and 1908/12. The controls used are distance to the nearest city (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), population growth 1800–1850, and cantonal fixed effects. Additionally, models in columns ***a*** control for the district's sectoral work share in 1860 (agric., indust., services), while column ***b*** includes the district's average body height for the 1884/91 conscription. The sample comprises all districts with a mean elevation below 1 000 m.a.s.l., except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table C.4: The Impact of Railway Access on Sectoral Work Shares, Panel Estimates (Sample: Districts with a Mean Elevation below 1 000 m.a.s.l.)

	Panel FE (1860–1900)			Panel IV FE (1860–1900)		
	Agriculture	Manufact.	Services	Agriculture	Manufact.	Services
	(1)	(2)	(3)	(1)	(2)	(3)
Lag RASHR	−6.74***	7.09***	−0.35	−11.10*	8.33	2.76+
	(1.61)	(1.47)	(0.50)	(5.53)	(5.09)	(1.52)
R^2 (within)	0.62	0.57	0.61	–	–	–
Districts	77	77	77	77	77	77
Observations	357	357	357	357	357	357

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable: A district's sectoral work share in percent (agriculture, manufacturing, services). The sample comprises all districts with a mean elevation below 1 000 m.a.s.l., except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

C.2 Impact of Railway Access on Body Height: Timing

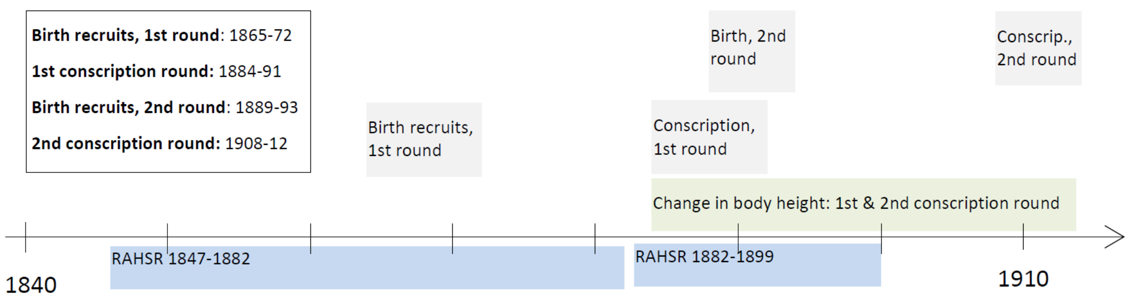

Figure C.1: Impact of Railway Access on Body Height, Timing.

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