Online Appendix

Appendix 1 Württemberg in the German Empire

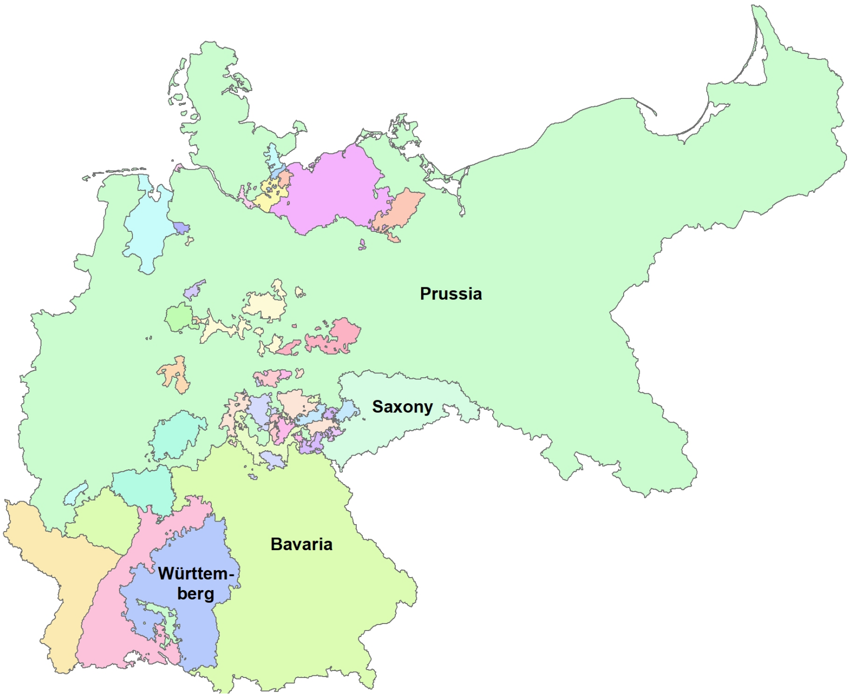

Figure A-1: The German Empire in 1871

Notes: The figure shows the German Empire in its 1871 borders. Labels mark the four Kingdoms that were part of the German Empire (namely, the Kingdoms of Bavaria, Prussia, Saxony and Württemberg).
Source: Max Planck Institute for Demographic Research (MPIDR) and Chair for Geodesy and Geoinformatics, University of Rostock (CGG) (2011). Authors' design.

Appendix 2 Network development stages in the Kingdom of Württemberg 1845–1910

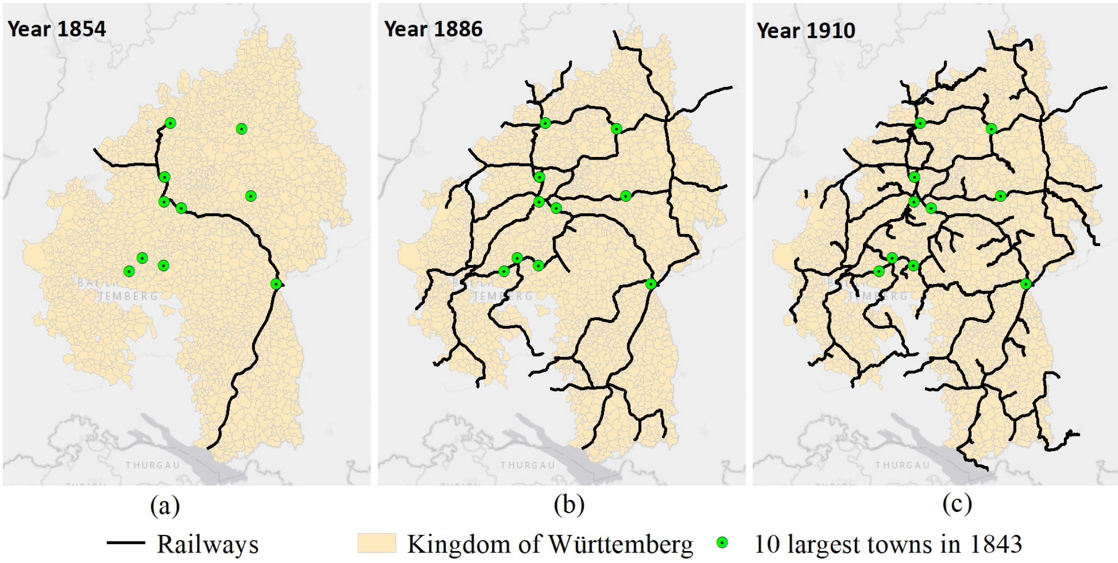

Figure A-2: Network development stages in the Kingdom of Württemberg 1845–1910

Notes: Panels (a), (b), and (c) show the railway network at the end of the construction phases in 1854, 1886, and 1910, respectively.

Sources: Kunz and Zipf (2008), Dumjahn (1984), Kommission für geschichtliche Landeskunde in Baden-Württemberg and Landesvermessungsamt Baden-Württemberg (1972), and Esri HERE Delorme, MapmyIndia, OpenStreetMap© contributors, and the GIS map user community. Authors' design.

Appendix 3 Regional economic development in Württemberg

Table A-1: Development indicators of Württemberg's districts

	National income per capita (in % of average)		Agricultural employment share (in %)	Urbanization rate (in %)
	1849	1907/13	1907	1910
Neckarkreis	111.2	113.3	30.0	53.9
Schwarzwaldkreis	96.8	85.5	44.8	32.4
Jagstkreis	88.0	72.6	52.9	23.1
Donaukreis	96.6	85.7	45.3	32.6
Württemberg			41.3	38.7
German Empire	100	100	32.7	44.3

Notes: The urbanization rate measures the percent of the total population living in urban municipalities of 2,000 or more inhabitants.

Source: Data on national income per capita is taken from Frank (1993), data on agricultural employment is from Kaiserliches Statistisches Amt (1910, 1913), and data on urbanization from Kaiserliches Statistisches Amt (1915).

Appendix 4 The planning process for the central line

This section outlines the planning process for the central line (*Zentralbahn*), the first railway line constructed in Württemberg. The central line was destined to connect the capital Stuttgart with Ludwigsburg in the north and with Cannstatt and Esslingen in the east.

On behalf of the government, building officer Georg von Bühler and engineer Carl von Seeger worked out the first detailed plan of the central line in 1836–39 (Mühl and Seidel 1980). Figure A-3 sketches their proposed route (thin red dashed line), along with three later proposals that we discuss below. Von Bühler and von Seeger's route mostly follows the river Neckar. Beginning in Ludwigsburg, the route heads east and then follows the western shore of the river. The route from Cannstatt to Stuttgart branches of the main line. By following the flat shore of the river, von Bühler and von Seeger's proposal reduced height differences and kept the railway gradient below a threshold of 1:100 (Etzel et al. 1985). The expected construction costs for the central line amounted to 3,390,430 *Gulden* (von Reden 1846).

In 1839, Württemberg's parliament asked for another expert to inspect the existing railway plans. Alois Negrelli, a chief engineer at the Emperor Ferdinand Northern Railway in Vienna (*Kaiser Ferdinands-Nordbahn*), approved the plans of von Bühler and von Seeger in 1843 and recommended only minor changes (Mühl and Seidel 1980). His proposal is delineated by the thin red dash-dotted line in Figure A-3.

After Negrelli's report, the parliament was largely convinced of the feasibility of a railway network and asked the government to appoint a railway commission to elaborate on the technical aspects. The commission entrusted engineers Charles Vignoles (eponym of the Vignoles rail), Ludwig Klein, Karl Etzel, and Michael Knoll with examining various railway lines (Mühl and Seidel 1980).

Figure A-3 illustrates the routes proposed for the central line by Vignoles in 1843 (bold

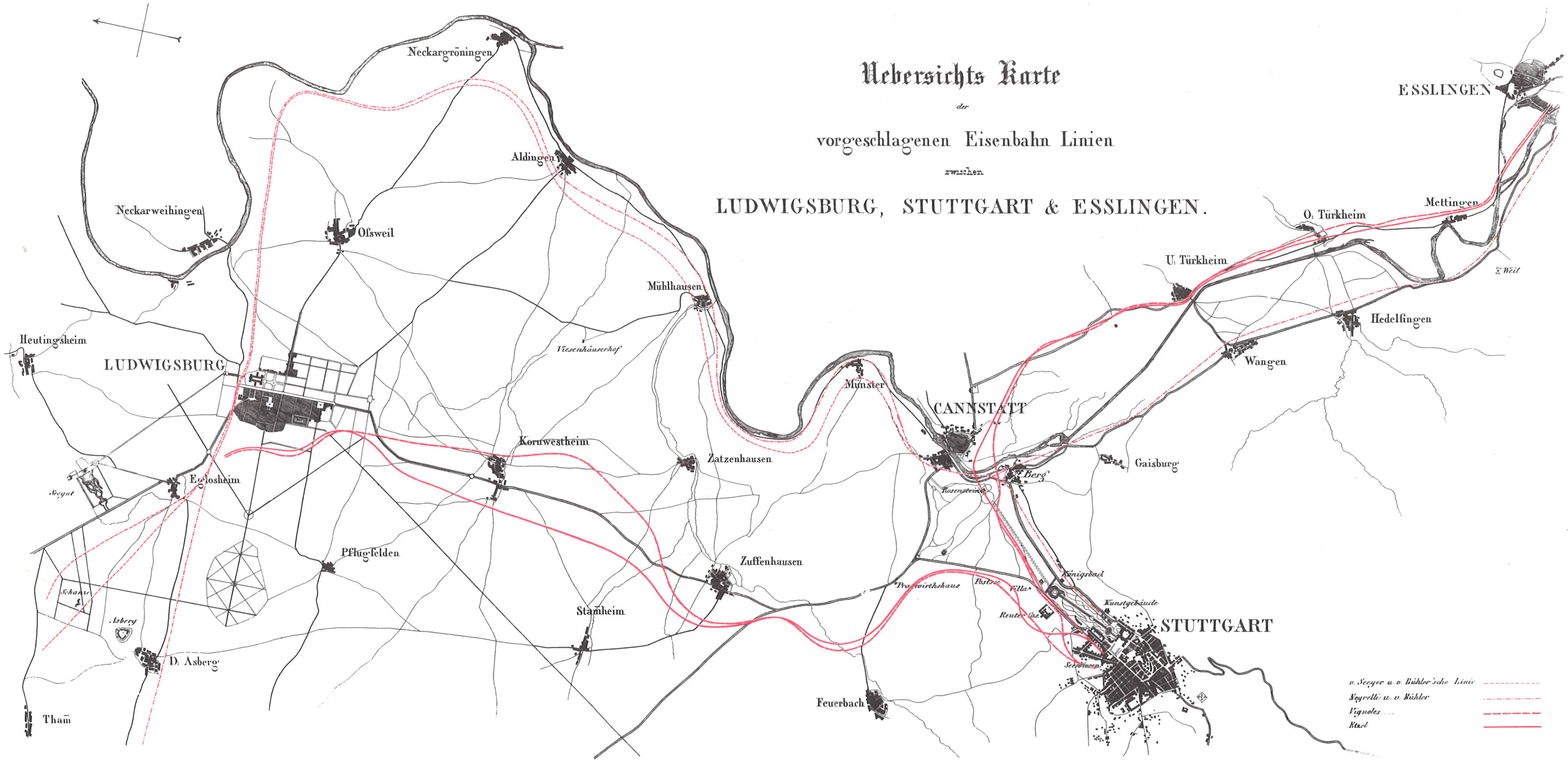

Figure A-3: Route proposals for the central line (*Zentralbahn*) in 1844

Notes: The figure shows the four different routes of the central line proposed during the planning process by von Bühler and von Seeger in 1839 (thin red dashed line), Negrelli in 1843 (thin red dashed-dotted line), Vignoles in 1843 (bold red dashed line), and Etzel in 1844 (bold red solid line).

Source: Etzel et al. (1985).

red dashed line) and Etzel in 1844 (bold red solid line). Both proposals significantly changed the initial plans by recommending two separate lines that both start in Stuttgart. The first line connects Stuttgart to Ludwigsburg on a shorter route, which does not follow the Neckar but requires a tunnel near Feuerbach. The second line crosses the Neckar near Cannstatt and then follows the eastern shore of the river to Esslingen. The additional tunnel (and inflation) increased the estimated construction costs for Etzel's proposal to 3,732,380 *Gulden* (von Reden 1846).

The railway commission finally asked engineer Ludwig Klein to re-evaluate all existing proposals. Klein argued in his report that expected traffic–and thus the catchment area of a line–determines the turnover of a railway but that costs–and thus technical aspects of the line–drive profits (Etzel et al. 1985). Consequently, Klein's report compares the proposals mainly under technical aspects.

In particular, Klein compared proposals I. by von Bühler and von Seeger (including Negrelli's refinement), II. by Vignoles, and III. by Etzel based on their overall length, curvature, height difference, gradient, and weighted length (which accounts for curvature and gradient). Panel A of Table A-2 shows the results of this comparison for the line between Stuttgart and Esslingen. Route I. has the shortest length, both unweighted (44,600 feet) and weighted (49,100 feet). However, it also has the highest maximum gradient (1:100) and the lowest minimum curve radius (800 feet). Klein thus recommended route III., which dominates route II. in all aspects (Etzel et al. 1985).

Panel B of Table A-2 shows the corresponding values for the three alternative routes of the line Stuttgart-Ludwigsburg. Again, Klein recommended route III. to the government. Route III. is the shortest of all three alternatives, both in terms of unweighted and weighted length. It also has the largest minimum curve radius and the lowest maximum gradient. The government followed Klein's recommendations and choose proposal III. for both lines. Construction works

Table A-2: Comparison of alternatives for the central line by Klein in 1844

Route	Length	Length of		Smallest	Height	Maximum	Weighted
		Straight lines	Curves	curve radius	difference	gradient	length
	(feet)	(feet)	(feet)	(feet)	(feet)		(feet)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Stuttgart to Esslingen							
I.	44,600	33,100	11,500	800	119.3	1:100	49,100
II.	50,200	26,000	24,200	1,000	161.0	1:115	60,960
III.	49,260	30,875	18,385	1,200	144.0	1:125	56,600
Panel B: Stuttgart to Ludwigsburg							
I.	79,000	46,690	32,310	800	273.2	1:100	96,865
II.	54,105	26,085	28,020	1,500	228.7	1:125	64,619
III.	51,988	22,840	29,148	1,600	234.3	1:125	63,261

Notes: The table compares different routes for the line from Stuttgart to Esslingen (Panel A) and Stuttgart to Ludwigsburg (Panel B) proposed by von Bühler and von Seeger (I.), Vignoles (II.), and Etzel (III.) based on the length in total (Column(2)), of straight lines (Column (3)) and of curves (Column(4)). The table also shows the smallest curve radius (Column (5)), the height difference (Column (6)), the maximum gradient (Column (7)), and the weighted length (Column (8)), in other words, total length plus a penalty for curves and gradient. Distances in Württemberg feet, with 1,000 feet = 286.49 meters.

Source: Based on Tables XVI and XVIII from the report of Klein (1844) (Etzel et al. 1985, pages 71 and 76).

began in June 1844. The first segment between Stuttgart and Esslingen was finished in November 1845, and the central line was completed in October 1846.

Our empirical analysis defines Obertürkheim as winning parish on the line Stuttgart-Esslingen and Feuerbach, Kornwestheim, Zuffenhausen as winning parishes on the line Stuttgart-Ludwigsburg. These parishes were only connected to the railway because the eventually built route followed Etzel's proposal and not von Bühler and von Seeger's earlier plans. Losing parishes are those that would have been connected to the railway under Bühler and von Seeger's plans but not under Etzel's (see Table A-4 for a list of winning and losing parishes by railway line).

Appendix 5 Density of Württemberg's railway network in comparison

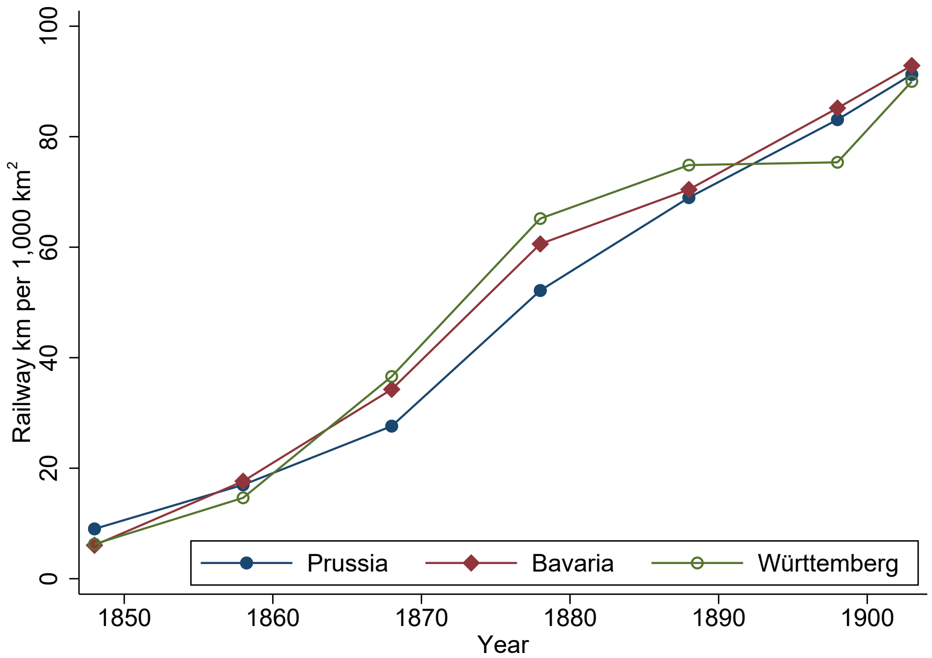

Figure A-4: Density of railway network in Bavaria, Prussia, and Württemberg, 1848–1903

Notes: The figure shows the density of the railway network in Bavaria, Prussia, and Württemberg from 1848 to 1903. Density is measured as the total length of the railway network (in km) over the land area of a state (in 1000 km^2).
Sources: The length of the railway network is from Lenschau (1906) and area is from Kaiserliches Statistisches Amt (1903). Authors' design.

Appendix 6 Annual revenue and transport statistics of Württemberg's public railway

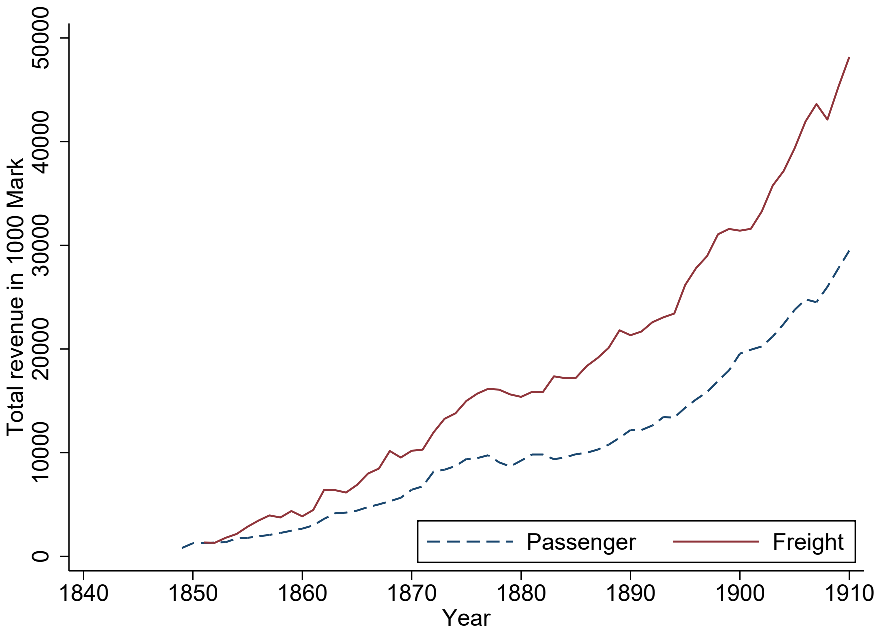

Figure A-5: Annual revenue of the public railway by passengers and freight, 1853–1910

Notes: The figure shows the total revenue of the public railway company in Württemberg 1853–1910 by passengers and freight in 1,000 *Mark*.

Source: Fremdling, Federspiel, and Kunz (1995). Authors' design.

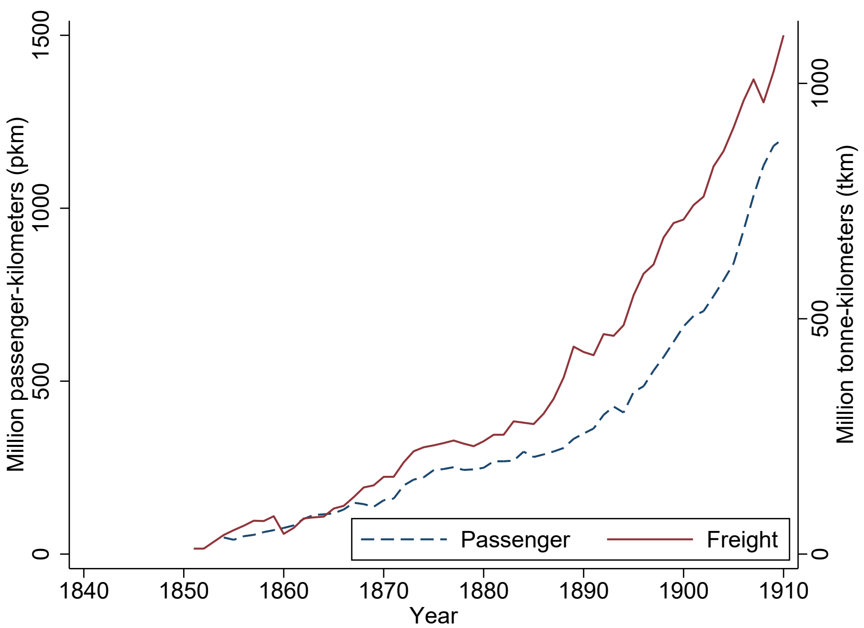

Figure A-6: Annual transport statistics of the public railway by passengers and freight, 1853–1910

Notes: The figure shows annual transport statistics of the public railway company in Württemberg 1853–1910 for passengers and goods. The dashed line shows million passenger-kilometers and the solid line million tonne-kilometers.

Source: Fremdling, Federspiel, and Kunz (1995). Authors' design.

Appendix 7 Political representation, lobbying, and railway access

By contemporary standards, Württemberg's parliament exercised unusually strong control over the executive. Manned by business interest, it supported and maintained the power of local communities, guilds, and cartels (Ogilvie, Küpker, and Maegraith 2009; Ogilvie and Carus 2014). We might thus expect that lobbying and political pressure had profound effects also on the routing of the railway. If so, winning and losing parishes might systematically differ, insofar as the former were more successful in their lobbying efforts. This might also explain why winners tended to be smaller and less industrialized than runners-up (see Table 1). As less dynamic places, they might have been better for political connections.

It is beyond the scope of this paper to comprehensively assess the influence that local special interest group–through lobbying and political pressure–had on the routing of the railway. We nevertheless think that any such influence was presumably small, at least in the first stage of the railway expansion. There are several reasons for this assessment.

First, the decision as to where to build rested primarily with the government, not the parliament (Mann 2006). This was because local communities naturally had conflicting interests, which made decision-making in the parliament difficult. Parliamentary representatives did not agree on whether to build a railway in the first place (Mühl and Seidel 1980; Supper 1895). Some argued that Württemberg, as an agrarian country, did not need a railway. Others pointed to the disastrous consequences of the railway for carters and other trades, and to the burden imposed by state railways on taxpayers in remote areas without railway access. After long-lasting debates, the majority nevertheless agreed to the railway bill of 1843, which legislated the first stage of Württemberg's railway expansion (see the "Background" section for details).

Naturally, conflicts also arose over the exact routes of the lines, stated in the railway bill. A key debate in the first construction phase was over the route of the *Ostbahn* from Cannstatt to Ulm. The first, and eventually realized, route ran via Göppingen through the Fills Valley (so-called *Filstalbahn*). The alternative route ran via Aalen through the valleys of Neckar, Rems and Brenz (so-called *Remsbahn*). While the Remsbahn bypassed the Swabian Alb, it was considerably longer than the *Filsbahn* and ran partly over Bavarian territory (Figure 2 in the main text maps the proposed alternatives). Therefore, Alois Negrelli, the first external expert commissioned to inspect Württemberg's railway plans, strongly advocated the *Filstalbahn.* His strong rejection of the *Remsbahn* prompted local interest groups to commission a counter assessment, which, however, was eventually refuted by the second external expert, Ludwig Klein.

Second, the important role played by external experts arguably limited the influence of local special interest groups (see, for example, Mühl and Seidel 1980; von Morlok 1890; Supper 1895, for detailed descriptions of the reports written by these experts and their influence on the decision process). Importantly, Alois Negrelli and Ludwig Klein both came from outside Württemberg. Negrelli oversaw the construction of railways in the Austrian Empire and Switzerland, and also advised the Kingdom of Saxony. Klein came from Vienna to Württemberg, and had previously worked in Russia and the US. His influential report of 1843, approved by the railway commission and the ministry, explicitly states that "circumstances of local nature" must not be considered in his scientific evaluation of existing proposals (von Morlok 1890, p. 24). Instead, Klein argues that the expected traffic and costs of a line should be the only two decision criteria. His report is also explicitly written on the premise that no economic or political obstacles stand in the way of any of the proposed lines.

Third, the railway bill of 1843 limited the scope of towns to lobby for a railway access in the first construction phase, as it determined both the general direction and destination of Württemberg's main lines.[1] An exception was the western line, for which the bill did not specify a destination due to the pending negotiations with Baden. However, the route of the western

[1] In contrast, Mühl and Seidel (1980) discuss a number of examples where towns tried to influence the direction of railway lines in the second and third expansion stage.

line was mainly determined in direct negotiations between Baden and Württemberg.[2]

Fourth, we find no empirical evidence that parishes with direct connections to representatives in either the parliament or the advisory privy council (*Geheimer Rat*) were more likely to gain access to the railway in the first construction phase.[3] We construct two measures for political connections. The first indicates whether at least one representative of the nobility in the privy council or parliamentary estates owned land in a parish. The second indicates whether at least one of the elected representatives of the parliament had his place of work in a parish. Information on the names of representatives and their workplaces as well as the landholdings of the nobility refer to 1843 and come from Königliches Statistisches Landesamt (1843).

Table A-3 report OLS regression estimates of the effect of political connections on the probability of gaining railway access in 1845–54, both for the winners versus runners-up sample

[2]While Württemberg had approached Baden already in 1838 for negotiations about the connection of their networks, Baden initially focused on the connection of its railway with Switzerland (in an attempt to exclude Württemberg from this trade route). However, Württemberg finished its main line, and thus the connection to Lake Constance and Switzerland, already in June 1850, and thus earlier than Baden. Only then was Baden interested in connecting its network to Württemberg's, also to redirect trade flows between the Netherlands and Austria-Hungary from more northern trade routes. Württemberg preferred a connection in the north between Heidelberg and Heilbronn, while Baden preferred a line between Durlach and Bietigheim in the south. Both countries favored the connection that kept the trains as long on their territories as possible. On December 4, 1850, they agreed to connect both networks between Bruchsal in Baden and Bietigheim in Württemberg, which is in the middle of their initial proposals.

[3]The constitution of September 1819 turned Württemberg into Germany's first constitutional monarchy. The legislature was organized into two chambers. Members of the first chamber (*Ständekammer*) were the princes of the House of Württemberg, representatives of the nobility, and nominees of the King. Member of the second chamber (*Abgeordnetenkammer*) were 70 elected representatives of the administrative districts (Oberämter) and largest towns as well as 23 'privileged representatives' (namely, representatives of the knightly nobility, the churches, and the chancellor of the University of Tübingen). The re-established privy council acted as a link between the parliamentary estates and the King. As the highest state bureaucracy, the council was directly subordinate to the King. It consisted of the ministers and additional members appointed by the King.

Table A-3: OLS estimates of the effect of political connections on railway access

	Dependent variable: Railway access 1845–1854 (0/1)			
	(1)	(2)	(3)	(4)
Panel A: Winners vs. runners-up				
Noble landholder (0/1)	0.062	0.021		
	(0.084)	(0.093)		
Place of work (0/1)			-0.152	-0.086
			(0.145)	(0.135)
Control variables	No	Yes	No	Yes
Observations	156	156	156	156
Panel B: Full sample				
Noble landholder (0/1)	-0.004	-0.006		
	(0.009)	(0.009)		
Place of work (0/1)			0.017	-0.021
			(0.035)	(0.040)
Control variables	No	Yes	No	Yes
Observations	1,846	1,846	1,846	1,846

Notes: The table shows OLS regression estimates of the effect of political connections on the probability of gaining railway access in 1845–54. Regressions in Panel A are estimated for the winners versus runners-up sample, regressions in Panel B for the complete sample excluding railway nodes. Regressions in Columns (1) and (2) measure political connections with a dummy indicating whether at least one representative of the nobility in the privy council or parliamentary estates owned land in a parish. Regressions in Columns (3) and (4) measure political connections with a dummy indicating whether at least one of the elected representatives of the parliament had his place of work in a parish. Regressions in Columns (2) and (4) include as control variables log population and log population density in 1834, the share of protestants in 1821, a dummy for having a manufactory in 1832, industry employment per 100 persons in 1829, elevation, dummies for access to a navigable river in 1845 and to a road in 1848, and case dummies. Robust standard errors are in parentheses. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.
Sources: The names of representatives and their workplaces as well as the landholdings of the nobility are from Königliches Statistisches Landesamt (1843).

(Panel A) and the full sample (Panel B). Columns (1) and (3) show unconditional estimates, whereas Columns (2) and (4) condition on our usual control variables. None of the specifications indicates a statistically significant effect of political connections on railway access. Of course, our measures of political connections are at best imperfect proxies. The empirical results in Table A-3 should thus not be taken as definite evidence against the importance of lobbying and political pressure for the routing of the railway. Nevertheless, they are consistent with our general assessment that any such influence was presumably small.

Appendix 8 List of winning and losing parishes

Table A-4 shows the list of winning and losing parishes by case and railway line. We exclude railway nodes and parishes that would have been connected to the railway under all alternative proposals from the list.

Table A-4: Winning and losing parishes by case

Case	Line	Winning parishes	Losing parishes
(1)	(2)	(3)	(4)
1	Stuttgart - Ulm	Altbach, Altenstadt, Amstetten, Beimerstetten, Ebersbach an der Fils, Faurndau, Gingen an der Fils, Göppingen, Großeislingen, Jungingen, Kuchen, Lonsee, Oberesslingen, Obertürkheim, Reichenbach an der Fils, Salach, Uhingen, Westerstetten, Zell am Neckar	Aalen, Aufhausen, Beinstein, Bergenweiler, Beutelsbach, Bolheim, Bopfingen, Endersbach, Essingen, Fellbach, Geradstetten, Giengen an der Brenz, Großdeinbach, Grunbach, Heidenheim a.d. Brenz, Herbrechtingen, Herlikofen, Hermaringen, Königsbronn, Langenau, Lauchheim, Lorch, Mergelstetten, Mögglingen, Niederstotzingen, Oberkochen, Oberurbach, Pflaumloch, Plüderhausen, Rammingen, Rommelshausen, Röttingen, Schorndorf, Schwäbisch Gmünd, Sontheim an der Brenz, Stetten im Remstal, Trochtelfingen, Unterböbingen, Unterkochen, Waiblingen, Waldhausen, Wasseralfingen, Weiler (Rems), Westhausen, Winterbach

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Table A-4 – *Continued from previous page*

Case	Line	Winning parishes	Losing parishes
(1)	(2)	(3)	(4)
2	Stuttgart - Esslingen	Obertürkheim	Hedelfingen
3	Bad Cannstatt - Ludwigsburg	Feuerbach, Kornwestheim, Zuffenhausen	Aldingen am Neckar, Mühlhausen, Münster, Neckargröningen, Neckarrems
4	Biberach - Ulm	Achstetten, Einsingen, Erbach, Grimmelfingen, Langenschemmern, Laupheim, Rißtissen, Schemmerberg, Schweinhausen, Ummendorf, Unteressendorf, Warthausen, Wolpertswende	Allmendingen, Bad Buchau, Berkach, Blaubeuren, Dettingen, Ehingen (Donau), Ehrenstein, Gerhausen, Herrlingen, Klingenstein, Munderkingen, Reichenbach bei Schussenried, Rottenacker, Schelklingen, Schmiechen
5	Ravensburg - Biberach	Aulendorf, Bad Schussenried, Reute, Schweinhausen, Ummendorf, Unteressendorf, Wolpertswende	Bad Waldsee, Hochdorf, Michelwinnaden, Rißegg, Steinach, Winterstettenstadt

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Table A-4 – *Continued from previous page*

Case	Line	Winning parishes	Losing parishes
(1)	(2)	(3)	(4)
6	Bietigheim - Bretten	Dürrmenz/Mühlacker, Ensingen, Großsachsenheim, Illingen, Maulbronn, Ötisheim, Sersheim	Aurich, Bissingen an der Enz, Ditzingen, Enzberg, Enzweihingen, Friolzheim, Gündelbach, Horrheim, Knittlingen, Markgröningen, Oberriexingen, Roßwag, Zaisersweiher
7	Bietigheim - Heilbronn	Besigheim, Böckingen, Kirchheim am Neckar, Klingenberg, Lauffen am Neckar, Nordheim, Walheim	Auenstein, Beihingen am Neckar, Beilstein, Großbottwar, Hof und Lembach, Ilsfeld, Kleinbottwar, Marbach am Neckar, Murr, Oberstenfeld, Schozach, Sontheim, Steinheim an der Murr, Talheim

Appendix 9 Semi-parametric models

This section provides technical details on IPW and IPWRA models (see Imbens and Wooldridge (2009) and Wooldridge (2010) for a thorough discussion), which we estimate using Stata's 16.1 command `teffects`.

Average treatment effect on the treated (ATT). The parameter γ in models (1) and (2) can be interpreted as the ATT, provided that the linearity assumption inherent in these models holds. Let $y^{\tau}_{ijt}(d)$ denote the potential outcome at time $t+\tau$ of parish i of case j whose winning line was opened in t. Here, $d \in \{0,1\}$ indicates railway access, so that $y^{\tau}_{ijt}(1)$ denotes the potential outcome with railway access and $y^{\tau}_{ijt}(0)$ the potential outcome without railway access. We furthermore define the potential outcome growth between periods $t-4$ and $t+\tau$ as $\Delta y^{\tau}_{ijt}(d) = y^{\tau}_{ijt}(d) - y_{ijt-4}$. The causal effect of railway access at time t on the outcome of interest after τ periods is

$$\gamma_{att,\tau} \equiv \mathbb{E}\left[\Delta y^{\tau}_{ijt}(1) - \Delta y^{\tau}_{ijt}(0) \mid D_{ij,1855} = 1\right]. \tag{A-1}$$

As in the event study analysis, we again express population relative to a baseline four periods before the treatment. Assumption 2 then applies to the difference rather than the level in potential outcomes, i.e., $(\Delta y^{\tau}_{ijt}(1), \Delta y^{\tau}_{ijt}(0)) \perp D_{ij,1855} \mid \boldsymbol{X}_i$.

Inverse probability weighting. IPW estimates the ATT by comparing *weighted* outcome means of parishes with and without railway access, placing more weight on observations in the control group that–given their covariates–had a high probability of being treated in the first place. More specifically, IPW first uses a probit model to estimate the propensity score–or probability–of being in the treatment group (in other words, of $D_{ij,1855} = 1$) conditional on covariates $\boldsymbol{X}_i$. We then use the predicted propensity score $\hat{P}_i$ to re-weight the outcome variable, applying the efficient weights $\hat{w}_i$ of Hirano, Imbens, and Ridder (2003):

$$\hat{w}_i = \begin{cases} 1/\hat{\mathbb{E}}\left[D_{ij,1855}\right] \text{ if } D_{ij,1855} = 1, \\ -\hat{P}_i/\left[\hat{\mathbb{E}}[D_{ij,1855}](1-\hat{P}_i)\right] \text{ if } D_{ij,1855} = 0, \end{cases} \tag{A-2}$$

where $\hat{\mathbb{E}}[X \mid S]$ denotes the sample average of X for all observations in a set S. $\hat{\mathbb{E}}[D_{ij,1855}]$ in equation (A-2), for instance, is simply the fraction of parishes in the sample that are part of the treatment group. Finally, we obtain the IPW estimate of the effect of railway access on the change in outcome from four periods before the line opened to τ periods thereafter by comparing means of the re-weighted data: $\hat{\gamma}_{att,\tau,IPW} = \hat{\mathbb{E}}[\hat{w}_i \cdot \Delta y^{\tau}_{ijt}]$. Here, $\Delta y^{\tau}_{ijt} = y^{t+\tau}_{ijt} - y^{t-4}_{ijt}$ is the change in outcome y between period $t-4$ and $t+\tau$ for a parish i. As before, τ are the time periods since the (case-specific) railway line's opening year t. We compute estimates $\hat{\gamma}_{att,\tau,IPW}$ for $\tau = -3, ..., 13$ with $\tau = 0$ corresponding to the year of railway access.

Inverse probability weighting regression adjustment. The IPWRA model uses $\hat{w}_i$ from equation (A-2) to run weighted regressions of Δy^{τ}_{ijt} on our set of covariates. These regressions are estimated separately for treated and control parishes. Specifically, we estimate parameters (α_0, ω_0) and (α_1, ω_1) by solving the following weighted least squares problems:

$$\min_{\alpha_0,\omega_0} (1 - D_{ij,1855})\hat{w}_i(\Delta y^{\tau}_{ijt} - \alpha_0 - \omega_0 \boldsymbol{X}_i)^2,$$

$$\min_{\alpha_1,\omega_1} D_{ij,1855}\hat{w}_i(\Delta y^{\tau}_{ijt} - \alpha_1 - \omega_1 \boldsymbol{X}_i)^2.$$

The IPWRA estimate is then given by the average of the difference in predicted values, as evaluated for the sub-population of parishes with railway access:

$$\hat{\tau}_{att,\tau,IPWRA} = \hat{\mathbb{E}}\left[(\hat{\alpha}_1 - \hat{\omega}_1 \boldsymbol{X}_i) - \hat{\alpha}_0 - \hat{\omega}_0 \boldsymbol{X}_i) \mid D_{ij,1855} = 1\right].$$

Appendix 10 Overlap assumption

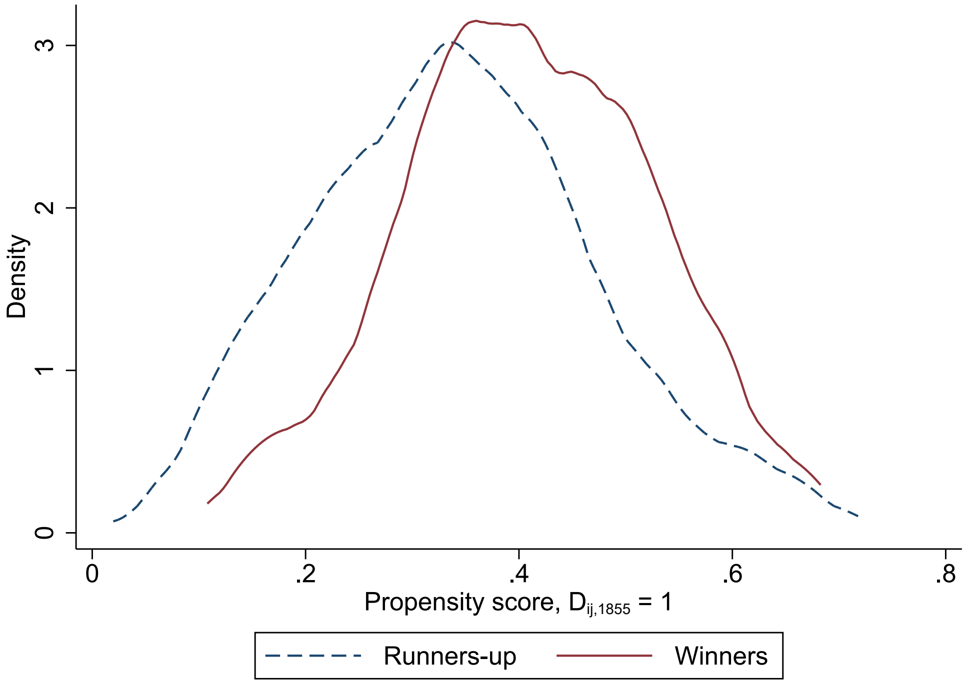

Figure A-7: Smoothed density for the estimated propensity for railway access in the first construction stage

Notes: The figure shows smoothed densities of the estimated propensities for railway access in the first construction stage both for winners (solid line) and runners-up (dashed line). The explanatory variables are log population and log population density in 1834, the share of protestants in 1821, a dummy for having a manufactory in 1832, industry employment per 100 persons in 1829, elevation, dummies for access to a navigable river in 1845 and to a road in 1848, and case dummies. We smooth the densities using an Epanechnikov kernel.

Source: Authors' calculations.

Appendix 11 Semi-parametric estimates for population growth, winner versus runners-up sample

Figure A-8 shows the results from semi-parametric IPW and IPWRA of the effect of railway access on population growth for the winner versus runners-up sample. The dependent variable is the change in log population between period $t-4$ and period $t+\tau$ where t is the time when a case's winning line was opened. The effect of railway access on the change in log population is thus normalized to zero for $\tau = -4$.

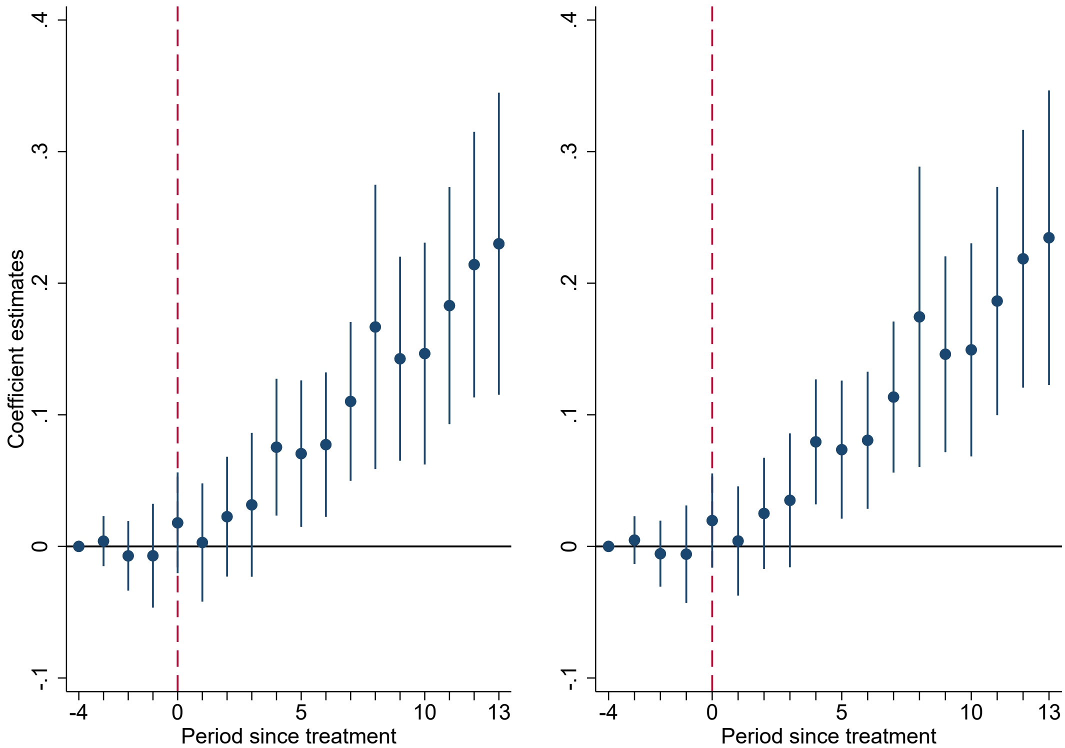

Figure A-8: Semi-parametric estimates of the effect of railway access on log population

Notes: This figure plots semi-parametric estimates of the effect of railway access in 1845–54 on log population. The dependent variable is the change in log population since the fourth period before the treatment. The left panel shows estimates from inverse probability weighting (IPW), the right panel from inverse probability weighting regression adjustment (IPWRA). Point estimates are marked by a dot. The vertical bands indicate the 95 percent confidence interval of each estimate. The red dashed vertical line indicates the treatment period.
Sources: Data on Population are from Statistisches Landesamt Baden-Württemberg (2008).

The figure depicts estimates for $\tau = -4, -3, ..., 13$. Dots mark the point estimates, vertical bands the corresponding 95 percent confidence intervals. Reassuringly, we see no differential population trends between winner and runner-up parishes before the arrival of the railway. Thereafter, log population gradually increases in winner parishes in both IPW and IPWRA estimations. After thirteen periods, the cumulative effect of railway access on population reaches 0.229 and 0.234 log points in the IPW and IPWRA estimation, respectively. Semi-parametric estimates are thus very similar to our event study results in the Subsection "Population growth". Figure A-9 additionally compares the event study results from Figure 3 in the main text to cross-sectional IPWRA estimates, which use the population *level* rather than the *change in population* relative to the baseline period as outcome variable. Both models again yield very similar results for the over-time effect of railway access on population.

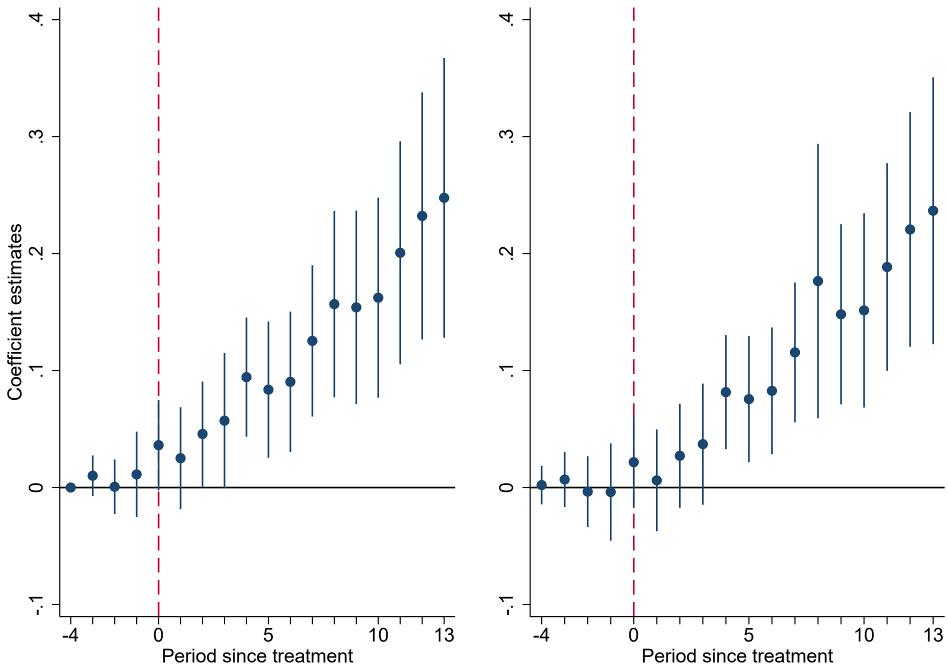

Figure A-9: Event study and cross sectional IPWRA estimates

Notes: The graph depicts differences in log population between winner and runner-up parishes. The left panel replicates Figure 3, that is, the difference in log population for pre- and post-treatment periods, as estimated in an event study regression. Differences are expressed relative to the baseline differences four periods before the treatment. The right panel shows cross sectional estimates from inverse probability weighting regression adjustment (IPWRA) with log population as dependent variable. Each point estimate shows the difference in log population for a cross section in pre- and post-treatment periods τ = -4,-3,...,13. Point estimates are marked by a dot. The vertical bands indicate the 95 percent confidence interval of each estimate. The red dashed vertical line indicates the treatment period.

Sources: Data on population are from Statistisches Landesamt Baden-Württemberg (2008).

Appendix 12 Event study and semi-parametric estimates for population growth, full sample

Event-study and semi-parametric estimates for the winners versus runners-up sample in Subsection "Population growth" shows that much of the positive effect of railway access on population growth materializes decades after the treatment. This Appendix shows that we reach similar conclusion for the full sample as well.

Appendix Figure A-10 compares over time differences in population between railway and non-railway parishes for the full sample, based on panel fixed effects regression. The 'period since treatment' is not defined for non-railway parishes that were not runners-up for a railway line. We thus instead compare differences between railway and non-railway parishes over time, taking 1834 as the baseline year. Consequently, results for the full sample are not directly comparable to those for the winner versus runners-up sample reported in Subsection "Population growth". They nevertheless show a similar picture, with population differences gradually growing over time. In fact, Figure A-10 shows that the widening of the population gap between railway and non-railway parishes accelerated in the 1890s and 1900s, long after parishes first got access to the railway. Semi-parametric IPW and IPWRA estimates yield very similar conclusions (see Figure A-11).

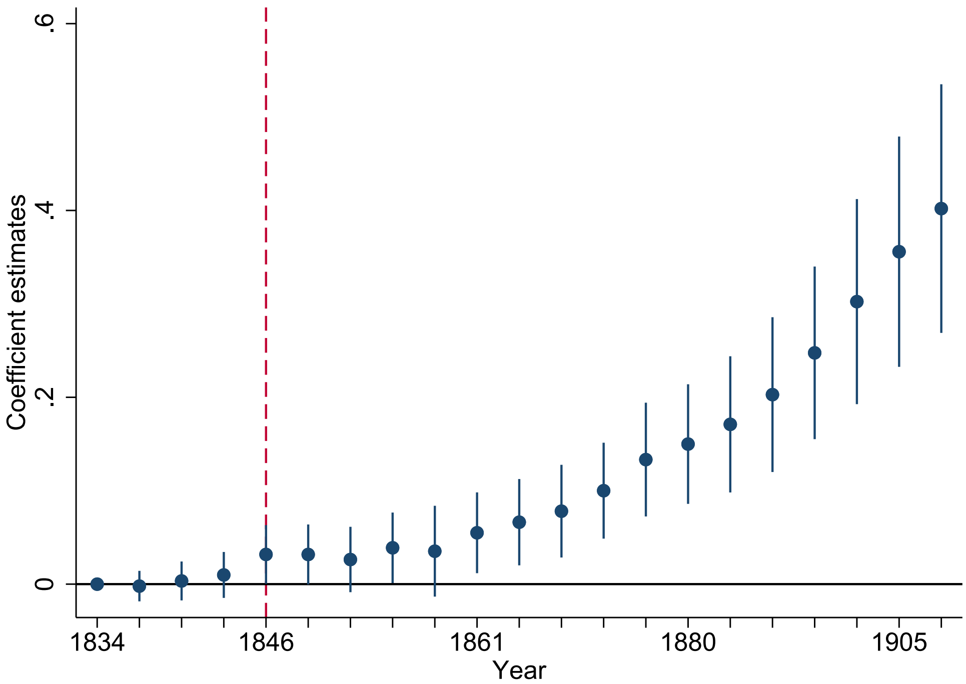

Figure A-10: Event study estimates, full sample

Notes: The graph depicts differences in log population between railway and non-railway parishes in 1837–1910, as estimated in a panel regression with parish fixed effects. 1834 serves as baseline period. Point estimates are marked by a dot. The vertical bands indicate the 95 percent confidence interval of each estimate. The red dashed vertical line indicates the treatment period.

Sources: Data on population are from Statistisches Landesamt Baden-Württemberg (2008).

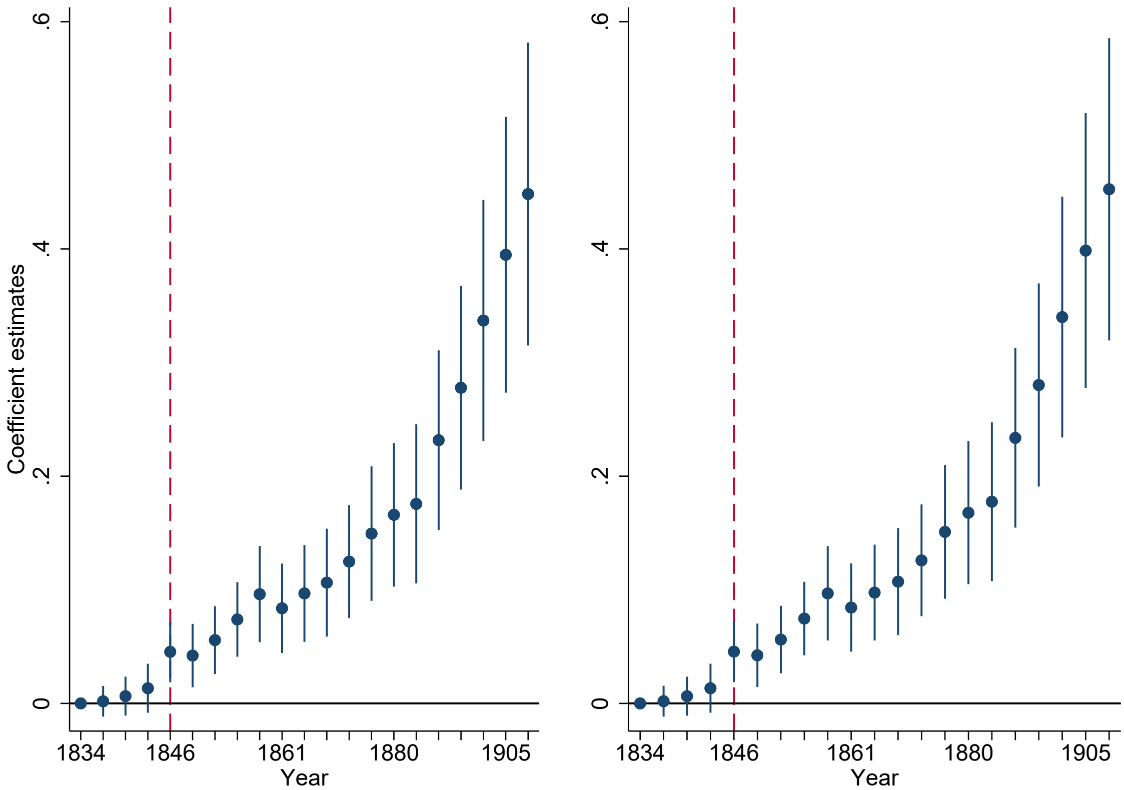

Figure A-11: Semi-parametric estimates of the over time effect of railway access on log population, full sample

Notes: This figure plots semi-parametric estimates of the effect of railway access in 1845–54 on log population. The dependent variable is the change in log population since 1834. The left panel shows estimates from inverse probability weighting (IPW), the right panel from inverse probability weighting regression adjustment (IPWRA). Point estimates are marked by a dot. The vertical bands indicate the 95 percent confidence interval of each estimate. The red dashed vertical line indicates the treatment period.

Sources: Data on population are from Statistisches Landesamt Baden-Württemberg (2008).

Appendix 13 Natural population growth versus immigration

We have established in the main text that railway access had a sizable and lasting positive effect on parish level population. Such population increase could be driven by immigration and/or changes in the rate of natural population increase (in other words, an increasing birth rate and/or a decreasing death rate). Census data for 1871, 1895 and 1900 tentatively suggest that railway access indeed induced immigration to winner parishes. For all three years, we regress the share of inhabitants born outside of a parish (hereafter: foreign-born) on the treatment group dummy and our usual set of control variables (we cannot run panel regressions as we do not have pre-treatment information on the share of foreign-born). IPW and IPWRA estimations suggest that railway access increased the population share of foreign-born inhabitants by 5.8 percentage points in 1871 (from a baseline of 24.5 percent), by 6.3 percentage points in 1895 (from a baseline of 28.9 percent), and by 6.0 percentage points in 1900 (from a baseline of 30.9 percent). OLS regressions yield virtually identical results (see again Table A-5 for details).

Data for 1871 additionally distinguishes between foreign-born who were born a) in a different parish in Württemberg, b) in a member state of the German Customs Union (except Württemberg), and c) abroad. Much of the differences in the share of the foreign-born between winner and runner-up parishes is driven by migration within Württemberg: the (unconditional) population share of foreign-born who are originally from another parish in Württemberg is 28.1 percent in winning parishes but only 23.0 percent in losing parishes. Population growth in winner parishes was thus–at least in part–due to relocation within Württemberg. Migration across state borders was much less important: Only 0.5 percent of individuals in our winners versus runners-up sample were born abroad in 1871. Yet, the average population share of migrants born abroad is three times higher in winning parishes (0.6 percent) compared to losing parishes (0.2 percent)–and such differences might have become more important over time.[4]

[4] Data on immigration is not consistent over time, as the different censuses use very different definitions. The

Table A-5: The effect of railway access on the share of foreign-born and the rate of natural population increase

	Share of foreign born			Fertility rate	Mortality rate	Rate of nat. increase
	1871	1895	1900	1871–1910	1871–1910	1871–1910
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: IPW						
Treatment effect	0.059***	0.063***	0.060***	-0.303	-0.174	-0.129
	(0.016)	(0.015)	(0.018)	(0.983)	(0.788)	(0.899)
Panel B: IPWRA						
Treatment effect	0.057***	0.062***	0.059***	-0.172	-0.180	0.008
	(0.016)	(0.015)	(0.017)	(0.942)	(0.792)	(0.892)
Panel C: OLS						
Treatment effect	0.059***	0.066***	0.065***	-0.072	-0.548	0.475
	(0.015)	(0.015)	(0.017)	(0.976)	(0.673)	(0.805)
Observations	156	156	156	152	152	152
Control mean	0.245	0.289	0.309	37.65	26.26	11.39

Notes: The table shows regression estimates of the effect of railway access in 1845–54 on the share of inhabitants born outside a parish in 1871 (Column (1)), 1895 (Column (2)) and 1900 (Column (3)), and on the annual number of birth (Column (4)), death (Column (5)) and natural population increase (Column (6)) per 1,000 inhabitants, averaged for 1871–1910. The regressions in Panel A are estimated by IPW, regressions in Panel B by IPWRA and regressions in Panel C by OLS. All regressions include as control variables log population and log population density in 1834, the share of protestants in 1821, a dummy for having a manufactory in 1832, industry employment per 100 persons in 1829, elevation, dummies for access to a navigable river in 1845 and to a road in 1848, and case dummies. Robust standard errors are in parentheses. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.
Sources: Data are from Statistisches Landesamt Baden-Württemberg (2008).

We also use annual data on the number of births and deaths between 1871 and 1910 to estimate OLS and semi-parametric models with the average annual birth rate, death rate and rate of natural population increase as dependent variables. The results indicate that there is no statistically significant difference in fertility and mortality rates between winners and runners-up in 1871–1910 (see Table A-5 for details). Finally, we also use the vital statistics to calculate the hypothetical average annual parish level population growth in 1871–1910 had population only changed through net migration (in other words, average annual population growth net of natural population increase). Appendix Figure A-12 shows this hypothetical growth rate,

last census in our sample from 1910 recorded the number of individuals without German citizenship. The average share is 1.4 percent in winning parishes and 0.8 percent in losing parishes.

along with Württemberg's railway network in 1855. The figure indicates that migration-induced population growth was indeed higher in parishes along the railway network.[5] We thus conclude that the positive effect of the railway on population growth in winner parishes is mainly driven by immigration, in line with spatial equilibrium models.

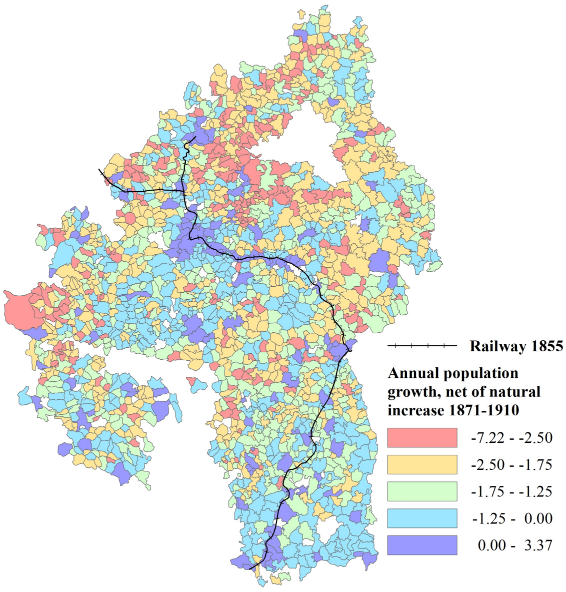

Figure A-12: Average annual population growth in 1871–1910, net of natural population increases

Notes: The figure shows the hypothetical average annual parish level population growth in 1871–1910 had population only changed through net migration (in other words, average annual population growth net of natural population increase). The solid black line depicts the railway network in 1855. Data on vital statistics are missing for the district of Hall and a few other parishes.

Sources: Kunz and Zipf (2008), Dumjahn (1984), Kommission für geschichtliche Landeskunde in Baden-Württemberg and Landesvermessungsamt Baden-Württemberg (1972). Authors' design.

[5]The figure suggests that net emigration rates were highest in the northwest of the country. Most historical accounts explain this pattern with the poor soil quality in the northwest of Württemberg (von Hippel 1984). Moreover, the cultivation of potatoes and wine in the north-west of Württemberg was more susceptible to crop failures than the traditional grain cultivation in the east. This led to higher emigration during hunger crises.

Appendix 14 The effect of gaining railway access in later construction stages

As it is common in the literature (see, for example, Berger and Enflo 2017; Hornung 2015), our analysis focuses on *early* railway connections. In particular, we focus on the effect of gaining access to the railway in the first construction stage from 1845 to 1854. However, a significant number of parishes that did not get access to the railway in the first construction stage did get access in the second stage from 1857 to 1886. In fact, the second stage was of major importance for Württemberg's railway network: It expanded its length from 290 to 1,560 kilometers and increased the number of parishes with railway access from 73 to 350. Figure A-13 shows the share of winners, runners-up, and 'non-railway' parishes with access to the railway over time. This subsection studies whether gaining railway access in later construction stages had similar effects on population as those that we document for the first stage.

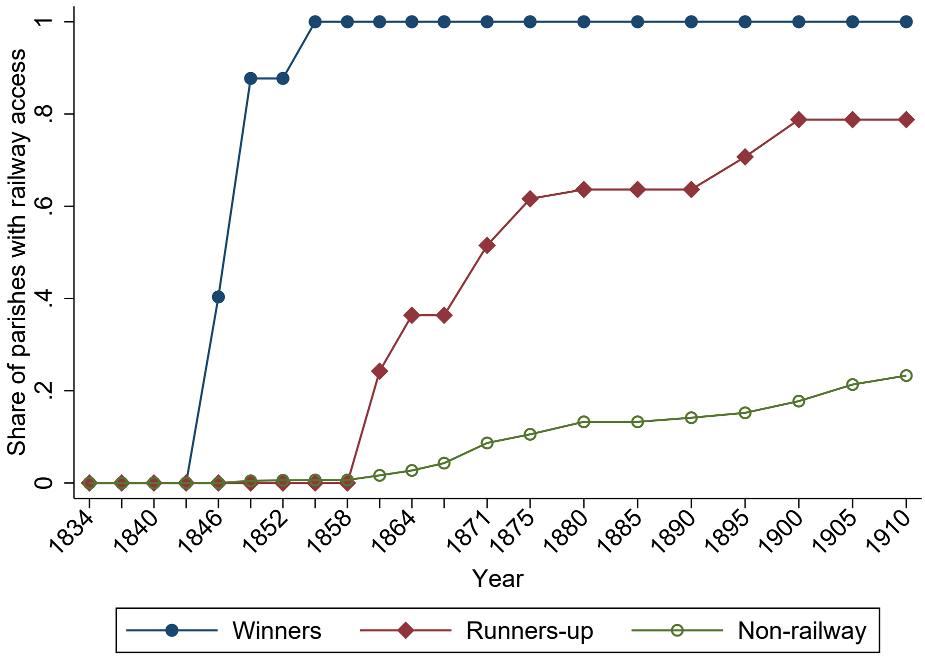

Figure A-13: Share of parishes with railway access by winners, runners-up, and non-railway parishes, 1834–1910

Notes: The figure shows the share of parishes with railway access for winners, runners-up, and non-railway parishes by year.
Sources: Dumjahn (1984), Wolff and Menges (1995), Königliches Statistisches Landesamt (1911). Authors' design.

Table A-6 replicates the results from our baseline specifications (from Table 2 in the main text), adding a separate treatment indicator for the second construction stage to equation (1).[6] Columns (1) and (2) restrict the sample to winner and runner-up parishes. Of the 99 runner-up parishes, 61 parishes–or 62 percent–gained access to the railway in the second construction phase (see Appendix Figure A-13). Our estimates suggest, however, that these parishes did not grow faster than parishes that remained without access by 1886.[7] This also implies that runner-up parishes did not catch up to the winner parishes even if they later gained access to the railway themselves.

Table A-6: Panel estimates of the effect of early and late railway access on population

	Winners vs. runners-up		Full sample		
	(1)	(2)	(3)	(4)	(5)
Railway access 1845–54	0.106***	0.116***	0.180***	0.142***	0.143***
	(0.030)	(0.028)	(0.024)	(0.023)	(0.023)
Railway access 1857–86	-0.029	-0.059*	0.095***	0.112***	0.113***
	(0.034)	(0.035)	(0.011)	(0.010)	(0.010)
Railway access 1887–1910					0.054***
					(0.020)
Observations	3,276	3,276	38,766	38,766	38,766
Parish FE	Yes	Yes	Yes	Yes	Yes
Year × Case/County FE	No	Yes	No	Yes	Yes

Notes: The table shows panel regression estimates of the effect of railway access in the first, second, and third construction phase (1845–54, 1857–86 and 1887–1910) on log population. Regressions (1) and (2) are estimated for the winners versus runners-up sample, regressions (3) to (5) for the complete sample excluding railway nodes. All regressions include a full set of year and parish dummies. Regression (2) additionally includes year-by-case fixed effects and regressions (4) and (5) include year-by-county fixed effects. Standard errors clustered at the parish level are in parentheses. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.

Sources: Population data are from Statistisches Landesamt Baden-Württemberg (2008).

[6] Let $D_{i,1886}$ be a binary treatment indicator that indicates whether parish i was connected to the railway between 1857 and 1886 (and not earlier, later or never), and let $1(\kappa \geq 0)_{it}$ be a dummy that indicates whether parish i had railway access at time t. The treatment indicator for the second construction stage is $D_{i,1886} \times 1(\kappa \geq 0)_{it}$.

[7] An important shortcoming of these regressions is that runner-up parishes that did not gain railway access by 1886 are likely to be a selected group of all runner-up parishes. In fact, runner-up parishes that did not get access in the second stage were statistically significantly smaller in 1855 than runner-up parishes that gained access in 1857–86 (difference in log population is 0.28 with a s.e. of 0.14). This selection should, however, bias the estimated impact of later rail connections upward and can thus not explain our 'no effect finding'.

The fact that later railway access did not boost population in the winner vs. runner-up sample may seem surprising. After all, the second construction stage connected major towns to the network, such as Reutlingen or Tübingen, which had remained without access after the first stage. However, our winners versus runners-up sample does not capture the most important new lines that were added to the network in 1857–86 (such as the railway line connecting Plochingen with Reutlingen and Tübingen). This is because the runner-up parishes are located along alternative routes between major towns, which had already been connected in the first construction stage. Building these initially unrealized 'alternative routes' later did not boost population along the way, probably precisely because the winning lines were already in operation.

This interpretation is strengthened by our findings for the full sample, reported in Columns (3) and (4) of Table A-6. Of the 1,786 parishes that did not get railway access in the first construction stage, 277 did so in 1857–86. The estimates suggest that in the full sample, late railway access indeed increased population. The effect is sizable but somewhat smaller than for early railway access (0.095–0.112 compared to 0.142–0.180 log points). This is not surprising since the lines built in the first construction phase were arguably the most important ones, especially for transit passengers and freight. The estimated effect of early railway access on population is slightly larger in Table A-6 than in our baseline regressions in Table 2. This is because in later years, parishes that gained access in 1857–1886 are no longer in the control group in Table A-6 (and these parishes grew faster themselves). Yet, differences are small, as the majority of parishes remained without railway access by 1886.

In the full sample, we can also study the effect of the third construction stage from 1887 onwards, which connected mostly rural parishes via branch lines to the main network. Of the 1,509 parishes that did not get railway access until 1886, 173 did so in 1887–1910. Column (5) adds separate treatment indicators for the second and third construction stage to our full-fledged specification with parish and year-by-county fixed effects. The estimates suggest that the third construction stage still had a positive effect on population, but that the effect was considerably smaller than for the first two stages. The decreasing effect size presumably reflect the lower importance, in terms of passengers and freight, of the lines that were built later.

Appendix 15 Localized displacement

This subsection describes our results on localized displacement effects in greater detail. Following Büchel and Kyburz (2020), we estimate local polynomial regressions of residual outcomes on log distance (in meters) to the nearest railway parish in 1855. Under the assumption that railways had no effect on distant parishes, the resulting spatial pattern should be hump-shaped if railways indeed cause reorganization (see also Berger and Enflo 2017; Bogart et al. 2022). We use the full sample for this analysis since the winners vs. runners-up sample exhibits too little variation in the distance to railway parishes for the analysis to be meaningful.

Figure A-14 shows the results for six different outcome variables, namely for the population ratio 1843 to 1834 (Graph (a)), the population ratio 1910 to 1855 (Graph (b)), the average annual income in 1907 in *Mark* (Graph (c)), the building value in 1907 in *Mark* (Graph (d)), and the number of full-time employees in industry per 100 persons in 1829 and 1907 (Graphs (e) and (f)). Residuals come from OLS regressions of the outcome variables on log population and log population density in 1834, the share of protestants in 1821, a dummy for having a manufactory in 1832, industry employment per 100 persons in 1829 (except Graph (e)), elevation, dummies for access to a navigable river in 1845 and to a road in 1848, and district dummies. Reassuringly, the residuals for pre-treatment outcomes, the population ratio 1843 to 1834 and industry employment in 1829, are uncorrelated with the distance to railway parishes in 1855.

In line with our empirical analysis, Graph (b) of Figure A-14 shows that population growth in 1855–1910 was considerably stronger in parishes close to the railway than in those further away. However, population growth in parishes with railway access did not come only–or even predominantly–at the expense of nearby parishes. Our results for income, housing values, and industrial employment are broadly consistent with our results for population growth. While income and housing values show a small trough at medium distances, industry employment falls monotonically with distance to railway parishes. Overall, we find little evidence for localized

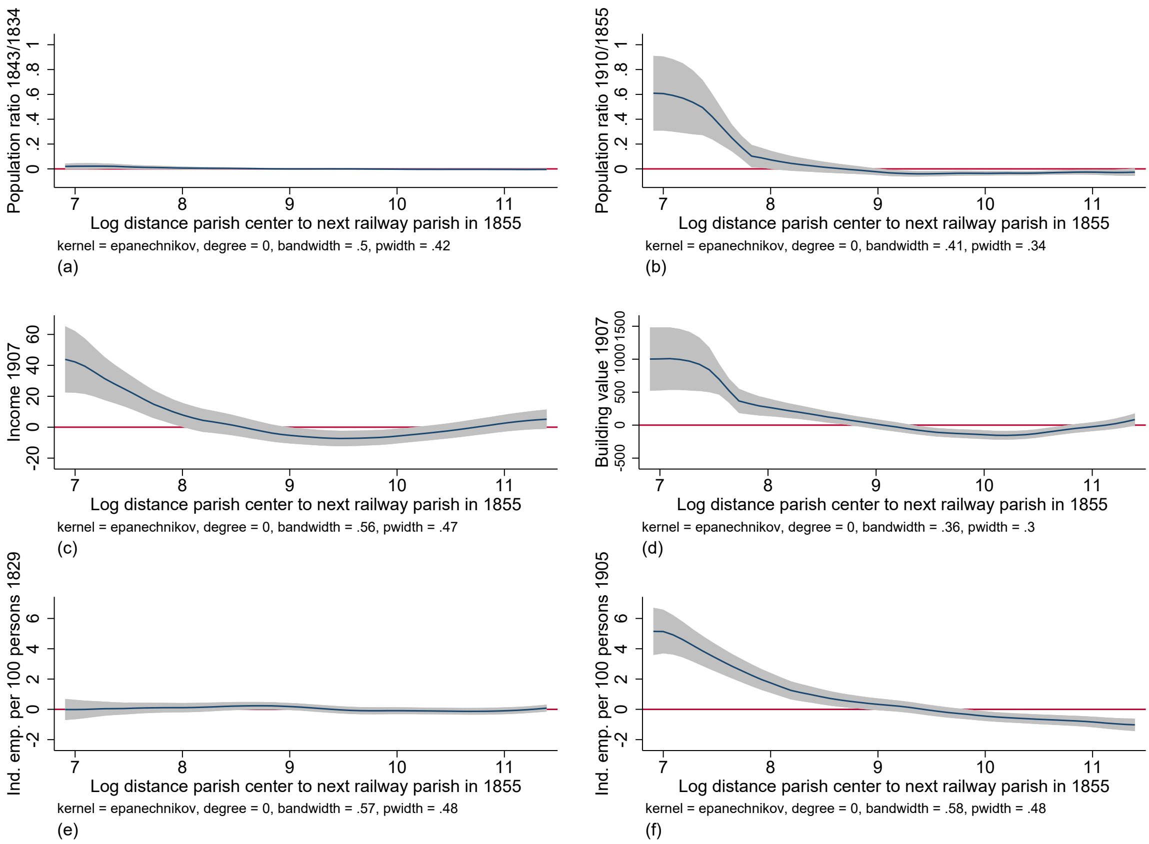

Figure A-14: Polynomial estimates, full sample

Notes: Each graph shows smooth values with 95 percent confidence band from kernel-weighted local polynomial regression of outcome residuals on log distance of parish centroids to the nearest railway parish in 1855. We add 1000 meters to all distances to avoid zero distances and smooth values close to zero. The outcome variables are the population ratio 1843 to 1834 (Graph (a)), the population ratio 1910 to 1855 (Graph (b)), the average annual income in 1907 in *Mark* (Graph (c)), the building value in 1907 in *Mark* (Graph (d)), and the number of full-time employees in industry per 100 persons in 1829 and in 1907 (Graphs (e) and (f)). We take the residuals from OLS regressions of outcome variables on log population and log population density in 1834, the share of protestants in 1821, a dummy for having a manufactory in 1832, industry employment per 100 persons in 1829 (except Graph (e)), elevation, dummies for access to a navigable river in 1845 and to a road in 1848, and district dummies as explanatory variables.

Sources: Population is from Statistisches Landesamt Baden-Württemberg (2008). Taxable income and building tax revenues in 1907 are from Königliches Statistisches Landesamt (1910). Employment data are from the occupation census of 1907 (Königliches Statistisches Landesamt 1900a, 1910) and the *Gewerbestatistik* of 1829 (various volumes of *Gewerbekataster*, Staatsarchiv Ludwigsburg E 258 VI).

displacement effects.

One potential explanation for the lack of displacement effects is that nearby parishes were not well integrated, possibly because of Württemberg's hilly topography or the restrictions placed on settlement rights until the 1860s (von Hippel 1992). Another explanation holds that the railway facilitated particularly the recruitment of workers from further afield. Ziegler (1996), for instance, argues that the movement of Polish workers to the Ruhr valley would not have been possible without the railway, in contrast to the immigration from nearby Westphalia. Positive spill-overs, as documented by Hornung (2015) for Prussia, might also have outweighed potential displacement effects. Unfortunately, our data do not allow us to distinguish between these explanations.

We also caution that the cross-sectional regressions in Figure A-14 will only be informative about the "pure" growth effects of railway infrastructure if far-away regions–or some "residual regions" more generally–are unaffected by the treatment (Redding and Turner 2015). This assumption might be questionable, especially in our context of a nation-wide infrastructure project. For instance, Subsection "Population growth" suggests that immigration from within Württemberg was important for the positive effect of railways on population growth in winner parishes. In this context, Graph (b) of Figure A-14 only clarifies that the relocation of population within Würrtemberg did not come solely at the expense of parishes in the immediate vicinity of the railway.

Appendix 16 Württemberg's location of iron and steel production 1834 and 1895

Appendix Figure A-15 shows parish-level employment in Württemberg's iron and steel production (per 100 persons) in 1834 and 1895. In 1834, 23 parishes reported positive employment levels in iron and steel production. Eight of them had at least one worker per 100 persons employed in the sector. Württemberg's iron and steel production clustered around the iron ore deposits in the black forest and the Swabian Alp. Railway construction initially increased demand for Württemberg's iron and steel (von Hippel 1992), and iron ore mining for the production of iron reached its peak in the late 1850s (Plumpe 1982).

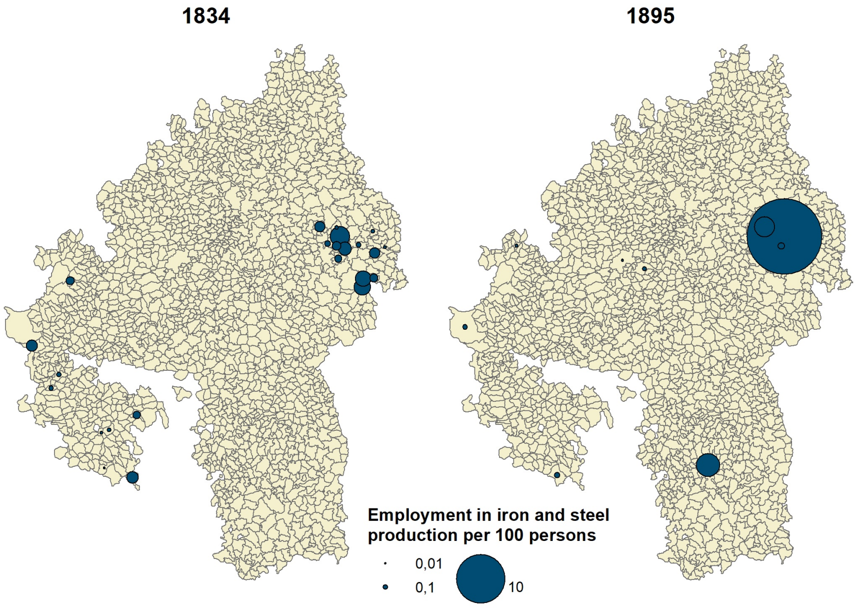

Figure A-15: Employment in iron and steel production, 1834 and 1895 (per 100 persons)

Notes: The figure shows parish-level employment per 100 persons in iron and steel production (*Herstellung von Eisen und Stahl, Frisch- und Streckwaren*)

Sources: Württemberg's *Gewerbestatistik* of 1829 (various volumes of *Gewerbekataster*, Staatsarchiv Ludwigsburg E 258 VI) and 1895 (Königliches Statistisches Landesamt 1900b). Authors' design.

However, Württemberg's charcoal pig iron could less and less compete with the cheaper coke pig iron produced in the Ruhr and Saar regions. The availability of wood, historically a significant locational advantage of Württemberg's iron producer, lost importance. Between 1870 and 1895, Württemberg's iron and steel production plummeted from 1% of Germany's overall production to just 0.2% (von Hippel 1992).[8] By 1895, only nine parishes still reported positive employment levels in iron and steel production, and only three of them had employment levels of one or more worker per 100 persons. The royal smelting works (*königliche Hüttenwerke*) Wasseralfingen gained a dominant position since the 1850s when it developed into a vertically integrated plant that combined iron ore mining, pig iron production, and iron processing. However, after production peaked in 1873, total output declined and Wasseralfingen's blast furnace finally closed in 1925 (Plumpe 1982).

Appendix 17 Effect heterogeneity by railway line

This subsection tests for effect heterogeneity by railway line, distinguishing between the northern line (Stuttgart-Bietigheim-Heilbronn/Bretten), the eastern line (Stuttgart-Esslingen-Ulm) and the southern line (Ulm-Friedrichshafen) (see Figure A-16). The eastern line formed arguably the core of the network. It connected the densely populated Neckar basin, where much of the important textile industry was concentrated already before the railway era (Feyer 1973), with Ulm, Württemberg's second largest town. It is thus not surprising that the eastern line was the busiest section of Württemberg's railway network, benefiting also from the transit traffic between Baden and Bavaria. The southern line from Ulm to Friedrichshafen, in contrast, was much less frequented as it served the sparsely populated and hardly industrialized south-east of Württemberg.[9] We thus expect that parishes along the eastern line benefited more from the

[8]Likewise, Plumpe (1982) reports that Württemberg's share in Germany's pig iron production fell from 1.0% in 1871 to 0.1% in 1894. At the same time, Prussia's share increased from 62% to 77%.

[9]Transport statistics from 1868/69 illustrate the difference between the lines (Königliches Statistisches Landesamt 1874). Looking at internal freight with origin and destination in Württemberg, railways transported 4,487,810 centners per mile per year on the eastern line but only 2,106,534 centners on the northern, and 1,903,806 centners on the southern line. Differences are even more striking if we consider freight with origin and/or destination outside Wüttemberg. Such freight amounted to 4,277,782 and 4,765,137 centners on the eastern and northern line, respectively, but to only 480,872 centners on the southern line.

railway than those along the southern line.

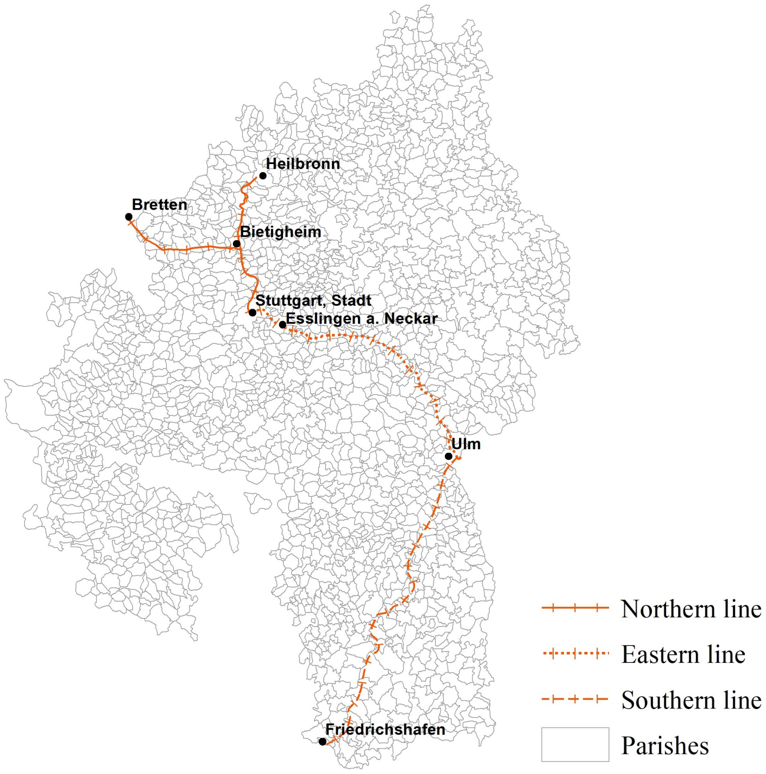

Figure A-16: Northern, eastern and southern line of the railway network in Württemberg 1855

Notes: The figure shows the northern (solid line), eastern (dotted line), and southern railway line (dashed line) of the railway network in Württemberg in 1855.
Sources: Kunz and Zipf (2008), Dumjahn (1984), Kommission für geschichtliche Landeskunde in Baden-Württemberg and Landesvermessungsamt Baden-Württemberg (1972), Statistisches Landesamt Baden-Württemberg (2008). Authors' design.

Table A-7: Heterogeneous effects of railway access by railway line

		Day laborer wage (*Pfennig*)		Taxable income (*Mark*)	Building value (*Mark*)	Fire insurance value (*Mark*)	Industry employment		Establishment size (logs)	Steam engine	
	Population	Female	Male							(0/1)	HP pc
	1834–1910	1909	1909	1907	1907	1908	1895	1907	1895	1869	1869
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Treatment dummy	0.009***	14.959***	26.236***	117.623***	2,207.0***	2,887.5***	9.745***	10.752***	0.842***	0.419***	20.916**
	(0.002)	(2.973)	(3.836)	(21.927)	(482.5)	(669.2)	(1.822)	(1.724)	(0.180)	(0.132)	(9.785)
Treatment dummy ×											
Northern line	-0.001	2.522	-5.130	-58.645*	-1,169.1*	-1,811.9**	-3.926	-4.586**	-0.382*	-0.210	-19.789**
	(0.002)	(4.704)	(8.272)	(29.985)	(695.9)	(835.4)	(2.439)	(2.186)	(0.221)	(0.174)	(9.811)
Southern line	- 0.006***	-16.598***	-23.651***	-103.051***	-1,664.3***	-2,220.6***	-7.492***	-6.834***	-0.697***	-0.333**	-20.468**
	(0.002)	(4.025)	(6.718)	(26.715)	(498.9)	(709.0)	(2.039)	(1.963)	(0.197)	(0.151)	(9.726)
Observations	38,766	1,843	1,843	1,843	1,843	1,843	3,692	3,686	3,318	3,692	3,692

Notes: The table shows regression estimates of the effect of railway access in 1845–54–and its interaction with location along the northern and southern line–on population (Column (1)), the average daily wage of female (Column (2)) and male (Column (3)) day laborers in 1909, on taxable income per capita in 1907 (Column (4)), the average value of buildings in 1907 (Column (5)), the average fire insurance value per building in 1908 (Column (6)), the number of full-time employees in industry per 100 persons in 1895 and 1907 (Columns (7) and (8)), establishment size in industry in 1895 (Column (9)), the probability of having installed at least one steam engine by 1869 (Column (10)), and steam horsepower per 1,000 persons in 1869 (Column (11)). Estimates in Columns (1) and (7) to (11) are from panel fixed effects regression that include parish and year-by-county fixed effects. Specification (1) assumes that the treatment effect is a linear time break. Estimates in Columns (2) to (6) are from cross-sectional OLS regressions. Control variables in these regressions include log population and log population density in 1834, the share of protestants in 1821, a dummy for having a manufactory in 1832, industry employment per 100 persons in 1829, elevation, dummies for access to a navigable river in 1845 and to a road in 1848, a dummy indicating whether population in the main location of residence in 1843 was above the treatment group median, and dummies for geographic location within Württemberg. Robust standard errors are in parentheses. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.

Sources: The average daily wage of day laborers in 1909, taxable income and building value in 1907, and the fire insurance value of buildings in 1908 are from Königliches Statistisches Landesamt (1910). Employment data are from the occupation censuses of 1895 and 1907 (Königliches Statistisches Landesamt 1900a, 1910) and the *Gewerbestatistik* of 1829 (various volumes of *Gewerbekataster*, Staatsarchiv Ludwigsburg E 258 VI) and 1895 (Königliches Statistisches Landesamt 1900b). Data on the location of steam engines are from archival records (Staatsarchiv Ludwigsburg E 170 Bü 272).

Consistent with our conjecture, estimates in Column (1) show that railway access increased population growth much more strongly along the eastern than along the southern line. Annual population growth increased by 0.9 percentage points in parishes along the eastern line but by only 0.3 percentage points in parishes along the southern line. The railway thus reinforced pre-existing population differences between Württemberg's densely populated Neckar basin and the sparsely populated southwest.

Columns (2) to (6) tests for heterogeneity in the effect of railway access on wages, income and housing values. We again find strong and precisely estimated differences between parishes located along the eastern and southern line. As a point in case, we find no statistically significant effect of railway access on wages of day laborers for parishes along the southern line. In contrast, access increased female and male day laborer wages along the eastern line by 14.96 and 26.24 *Pfennig*, respectively (or 9.0 and 10.6 percent relative to the control mean).

Finally, Columns (7) to (11) reveal that railway access also had strikingly different effects on industrial development. For instance, we find that by 1895, railway access had increased industry employment by 9.7 employees per 100 persons along the eastern but by only 2.3 employees along the southern line. Likewise, access increased the probability of adopting a steam engine by almost 42 percentage points along the eastern line but by only 8.6 points along the southern line. The railway thus increased disparities between Württemberg's more and less industrialized regions.

Appendix 18 Additional results for the winner versus runners-up sample

Table A-8: Panel estimates of the effect of railway access on population with Conley standard errors

	Winners vs. runners-up	
	(1)	(2)
Panel A: Distance cut off 10 km		
Treatment effect	0.117***	0.136***
	(0.014)	(0.012)
Panel B: Distance cut off 20 km		
Treatment effect	0.117***	0.136***
	(0.016)	(0.015)
Panel C: Distance cut off 50 km		
Treatment effect	0.117***	0.136***
	(0.021)	(0.018)
Observations	3,276	3,276
Parish FE	Yes	Yes
Year × Case FE	No	Yes

Notes: The table shows panel regression estimates of the effect of railway access in 1845–54 on log population estimated for the winners versus runners-up sample. All regressions include a full set of year and parish dummies. Regression (2) additionally includes year-by-case fixed effects. Conley standard errors are in parentheses. We use Stata command `reg2hdfespatial` to calculate the Conley standard errors (Conley 1999; Hsiang 2010). The distance cut off is 10 kilometers in Panel A, 20 kilometers in Panel B, and 50 kilometers in Panel C. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.

Sources: Population data are from Statistisches Landesamt Baden-Württemberg (2008).

Table A-9: The effect of railway access on the gender wage gap

	Gender wage gap		
	1884	1898	1909
	(1)	(2)	(3)
Panel A: IPW			
Treatment effect	-2.007**	-1.736*	-0.698
	(1.020)	(0.940)	(0.576)
Panel B: IPWRA			
Treatment effect	-2.163**	-1.791*	-0.727
	(1.086)	(0.952)	(0.597)
Panel C: OLS			
Treatment effect	-2.146**	-1.918**	-0.672
	(1.032)	(0.944)	(0.552)
Observations	155	156	156
Control mean	32.78	32.85	33.94

Notes: The table shows regression estimates of the effect of railway access in 1845–54 on the gender wage gap of day laborers in 1884 (Column (1)), 1898 (Column (2)) and 1909 (Column (3)). The regressions in Panel A are estimated by IPW, regressions in Panel B by IPWRA and regressions in Panel C by OLS. All regressions include as control variables log population and log population density in 1834, the share of protestants in 1821, a dummy for having a manufactory in 1832, industry employment per 100 persons in 1829, elevation, dummies for access to a navigable river in 1845 and to a road in 1848, and case dummies. Robust standard errors are in parentheses. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.

Sources: The average daily wage of day laborers in 1884, 1898, and 1909 are from Königliches Statistisches Landesamt (1898) and Königliches Statistisches Landesamt (1910).

Appendix 19 Additional results for the full sample

Table A-10: Comparison of pre-treatment characteristics for parishes on and off straight-line corridors and least cost paths

	Full sample						
	Nodes	On least cost path (500 m)	Off least cost path (500 m)	Difference (2) - (3)	On straight line (500 m)	Off straight line (500 m)	Difference (5) - (6)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Pop. 1834 (log)	8.379	6.549	6.393	0.156	6.572	6.393	0.179
	(1.464)	(0.676)	(0.705)	[0.065]	(0.684)	(0.704)	[0.069]
Pop. density 1834 (log)	5.628	4.337	4.280	0.057	4.341	4.280	0.061
	(0.753)	(0.665)	(0.602)	[0.056]	(0.701)	(0.600)	[0.060]
Protestants 1821 (share)	0.730	0.561	0.621	-0.059	0.577	0.619	-0.042
	(0.379)	(0.491)	(0.468)	[0.044]	(0.485)	(0.469)	[0.046]
Manufactory dummy 1832	0.583	0.048	0.054	-0.006	0.073	0.052	0.020
	(0.515)	(0.215)	(0.226)	[0.021]	(0.261)	(0.223)	[0.022]
Ind. employment per 100 persons 1829	12.953	8.313	7.726	0.588	8.354	7.728	0.626
	(4.087)	(3.062)	(4.375)	[0.400]	(3.254)	(4.357)	[0.423]
Average elevation (in m)	391.685	416.112	499.072	-82.960	421.476	498.063	-76.587
	(120.070)	(140.525)	(155.773)	[14.394]	(136.118)	(156.252)	[15.253]
River dummy	0.417	0.161	0.071	0.090	0.155	0.073	0.082
	(0.515)	(0.369)	(0.258)	[0.025]	(0.363)	(0.260)	[0.026]
Road dummy	0.917	0.694	0.477	0.217	0.700	0.478	0.222
	(0.289)	(0.463)	(0.500)	[0.046]	(0.460)	(0.500)	[0.049]
Observations	12	124	1,722		110	1,736	

Notes: The table shows average values of pre-treatment characteristics for nodes (Column (1)), parishes that are (Column (2)) and are not (Column (3)) within 500 meters of a least cost path between the nodes, and parishes that are (Column (5)) and are not (Column (6)) within 500 meters of a straight-line between the nodes (Column (5)). Column (4) shows the mean difference in pre-treatment characteristic between parishes on and off the least cost path and Column (7) the mean difference between parishes on and off the straight-line corridor. Nodes are defined as parishes that are either starting or end points of a railway segment or serve as network junctions. In the calculation of the least cost path we follow Keller and Shiue (2016) and approximate the gradient related track costs by the foregone freight hauling capacity of trains. In addition, we incorporate political costs and penalize the crossing of foreign territory. We set the cost of crossing foreign territory to equal a complete loss of freight. We calculate a weighted sum of the different costs and create a cost raster, which is used in the least-cost path calculations using Esri ArcGIS's least cost path module. Standard deviations are in parentheses (Columns (1)–(3) and (5)–(6)). Standard errors of a two-sided mean difference t-test are in brackets (Columns (4) and (7)).

Sources: Population in 1834 is from Statistisches Landesamt Baden-Württemberg (2008). The share of Protestants is from Königliches Statistisches Landesamt (1824). The location of manufactories in 1832 is from Memminger (1833). Industrial employment 1829 is from various volumes of *Gewerbekataster* (Staatsarchiv Ludwigsburg E 258 VI). Elevation is from Bundesamt für Kartographie und Geodäsie (2017). The locations of rivers navigable in 1845 and paved roads in 1848 are from Kunz and Zipf (2008).

Table A-11: IV estimates of the effect of railway access on population

	Population			
	(1)	(2)	(3)	(4)
Second stage:				
Treatment effect	0.267***	0.178***	0.246***	0.153**
	(0.054)	(0.062)	(0.053)	(0.060)
First stage: Dependent variable – $Line_{ijt}$				
Least cost path (500 m) (0/1)	0.327***	0.283***		
	(0.041)	(0.043)		
Straight line (500 m) (0/1)			0.345***	0.291***
			(0.044)	(0.046)
Observations	38,766	38,766	38,766	38,766
Kleibergen-Paap F-statistic	64.384	42.766	61.430	40.462
Parish FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Year × County FE	No	Yes	No	Yes

Notes: The table shows IV regression estimates of the effect of railway access in 1845–54 on log population for the full sample. Regressions (1) and (2) use least cost paths and regressions (3) and (4) straight lines between railway nodes to instrument for railway access. All regressions include a full set of year and parish dummies. Regressions (2) and (4) additionally include year-by-county (*Oberamt*) fixed effects. Standard errors clustered at the parish level are in parentheses. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.

Sources: Population data are from Statistisches Landesamt Baden-Württemberg (2008).

Table A-12: The effect of railway access on day laborer wages, taxable income, and building values, full sample

	Day laborer wage (*Pfennig*)						Taxable income (*Mark*)	Building value (*Mark*)	Fire insurance value (*Mark*)
	Female			Male					
	1884	1898	1909	1884	1898	1909	1907	1907	1908
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: IPW									
Treatment effect	11.409***	13.586***	11.654***	8.488***	10.219***	16.899***	68.774***	1,364.0***	1,565.7***
	(1.917)	(1.989)	(2.212)	(2.183)	(2.393)	(3.899)	(12.169)	(248.9)	(317.5)
Panel B: IPWRA									
Treatment effect	11.456***	13.404***	11.593***	8.718***	10.271***	17.039***	69.810***	1,372.5***	1,584.4***
	(1.980)	(1.986)	(2.205)	(2.210)	(2.373)	(3.851)	(12.136)	(247.2)	(316.4)
Panel C: OLS									
Treatment effect	11.542***	12.876***	12.098***	9.377***	10.995***	18.829***	71.443***	1,435.7***	1,687.8***
	(1.931)	(1.985)	(2.201)	(2.126)	(2.387)	(3.826)	(12.508)	(253.7)	(314.6)
Observations	1,830	1,846	1,843	1,832	1,846	1,843	1,843	1,843	1,843
Control mean	106.53	116.21	165.76	159.34	173.01	246.96	320.96	2,763.9	3,794.0

Notes: The table shows regression estimates of the effect of railway access in 1845–54 on the average daily wage of female (Columns (1) to (3)) and male (Columns (4) to (6)) day laborers in 1884, 1898, and 1909, on taxable income per capita in 1907 (Column (7)), the average value of buildings in 1907 (Column (8)), and the average fire insurance value per building in 1908 (Column (9)). Values in Columns (1) to (6) are in *Pfennig* and values in Columns (7) to (9) are in *Mark*, with 1 *Mark* = 100 *Pfennig*. Regressions in Panel A are estimated by IPW, regressions in Panel B by IPWRA and regressions in Panel C by OLS. All regressions include as control variables log population and log population density in 1834, the share of protestants in 1821, a dummy for having a manufactory in 1832, industry employment per 100 persons in 1829, elevation, dummies for access to a navigable river in 1845 and to a road in 1848. Robust standard errors are in parentheses. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.
Sources: The average daily wage of day laborers in 1884, 1898, and 1909, taxable income and building value in 1907, and the fire insurance value of buildings in 1908 are from Königliches Statistisches Landesamt (1898) and Königliches Statistisches Landesamt (1910).

Table A-13: The effect of railway access on industrial development, full sample

	Emplyoment				Establishment size (logs)	Steam engine	
	Industry		Agriculture			(0/1)	HP pc
	1895	1907	1895	1907	1895	1869	1869
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: IPW							
Treatment effect	4.771***	6.122***	-5.653***	-8.575***	0.382***	0.183***	9.12**
	(0.926)	(0.905)	(0.947)	(1.348)	(0.076)	(0.056)	(4.519)
Panel B: IPWRA							
Treatment effect	4.864***	6.208***	-5.785***	-8.787***	0.388***	0.186***	9.29**
	(0.939)	(0.927)	(0.975)	(1.322)	(0.076)	(0.056)	(4.516)
Observations	1,846	1,843	1,846	1,843	1,839	1,846	1,846
Panel C: Panel estimates							
Treatment effect	5.699***	6.738***	–	–	0.460***	0.263***	11.29**
	(0.901)	(0.827)			(0.082)	(0.060)	(4.484)
Observations	3,692	3,689			3,504	3,692	3,692
Control mean	9.629	11.06	31.50	36.84	0.478	0.073	1.002

Notes: The table shows estimates of the effect of railway access in 1845–54 on the number of full-time employees in industry (Columns (1) and (2)) and agriculture (Columns (3) and (4)) per 100 persons in 1895 and 1907, establishment size in industry in 1895 (Column (5)), the probability of having installed at least one steam engine by 1869 (Column (6)), and steam horsepower per 1,000 persons in 1869 (Column (7)). Establishment size is the average number of persons employed in a main plant (*Hauptbetrieb*). Panels A and B display IPW and IPWRA estimates, respectively. Regressions in Panels A and B include as control variables log population and log population density in 1834, the share of protestants in 1821, a dummy for having a manufactory in 1832, elevation, dummies for access to a navigable river in 1845 and to a road in 1848. Panel C displays estimates from panel fixed effects regression that include parish and year-by-county fixed effects. The pre-treatment period is 1829 in Columns (1) to (5) and 1846 in Columns (6) and (7). We cannot run panel fixed effects regression for agricultural employment, as we lack data on agricultural employment in the pre-treatment period. The control mean gives the mean value of the outcome for the control group in 1895 (Columns (1), (3), (5)) 1907 (Columns (2) and (4)) and 1869 (Columns (6) and (7)). Robust standard errors are in parentheses. Standard errors in Panel C are clustered at the parish level. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.

Sources: Employment data are from the occupation censuses of 1895 and 1907 (Königliches Statistisches Landesamt 1900a, 1910) and the *Gewerbestatistik* 1829 (various volumes of *Gewerbekataster*, Staatsarchiv Ludwigsburg E 258 VI) and 1895 (Königliches Statistisches Landesamt 1900b). Data on the location of steam engines are from archival records (Staatsarchiv Ludwigsburg E 170 Bü 272).

Table A-14: The effect of railway access on employment in key industrial sectors and specialization, full sample

	Employment in key industrial sectors					
		Coal, iron & steel	Machines & instruments			
	Textile		all	electrical	Chem-ical	Spec-ialization
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: IPW						
Treatment effect	2.381**	-0.004	0.301*	0.007	0.076	0.005
	(1.069)	(0.056)	(0.171)	(0.008)	(0.088)	(0.014)
Panel B: IPWRA						
Treatment effect	2.398**	-0.003	0.303*	0.007	0.075	0.005
	(1.069)	(0.055)	(0.171)	(0.008)	(0.088)	(0.014)
Observations	1,846	1,846	1,846	1,846	1,846	1,839
Panel C: Panel estimates						
Treatment effect	3.352***	0.038	0.418**	0.008	0.098	0.031**
	(0.991)	(0.037)	(0.176)	(0.007)	(0.098)	(0.015)
Observations	3,692	3,692	3,692	3,692	3,692	3,504
Control mean	0.848	0.015	0.046	0.001	0.027	0.171

Notes: The table shows estimates of the effect of railway access in 1845–54 on the number of full-time employees per 100 persons in different industries (Columns (1)–(5)) and specialization within industry (Column (6)) in 1895. We distinguish between employment in the textile industry (Column (1)), coal, iron, and steel industry (Column (2)), building of machines and instruments (Column (3)), building of electrical machines and instruments (Column (4)), and the chemical industry (Column (5)). Specialization is measured by the Hirschman-Herfindahl-Index (with $\alpha = 2$). Panels A and B display IPW and IPWRA estimates, respectively, using employment in 1895 as outcome variable. Regressions in Panels A and B include as control variables log population and log population density in 1834, industry employment per 100 persons in 1829, a dummy for having a manufactory in 1832, the share of protestants in 1821, elevation, dummies for access to a navigable river in 1845 and to a road in 1848. Panel C displays estimates from panel fixed effects regression that include parish and year-by-county fixed effects. The pre-treatment period is 1829. The control mean gives the mean value of the outcome for the control group in 1895. Standard errors in Panel C are clustered at the parish level. ***, **, and * denote statistical significance at the 1, 5, and 10 percent level, respectively.

Sources: Employment data are from *Gewerbestatistik* of 1829 (various volumes of *Gewerbekataster*, Staatsarchiv Ludwigsburg E 258 VI) and 1895 (Königliches Statistisches Landesamt 1900b).

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