# Fiscal Capacity, Railway Federalism, and German Railway Development 1835-1885

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**Abstract**

19th century governments understood the benefits of railroads but were constrained when supporting network construction; not only by their budgets, but also by their willingness to relinquish control to private capital. This paper analyzes the relationship between fiscal capacity and railroad development in Germany, whose states' fiscal development differed from both each other and from the European norm. I estimate how fiscal capacity's evolution across Germany influenced the states' decisions to grant concessions to private companies or expand public firms. I construct new fiscal capacity and railroad ownership datasets and find that increases in government revenues led to a significant switch away from public construction towards a concession based system without changing the overall rate of construction.

## Introduction

Fiscal capacity was an important determinant of early economic development.[1] In one channel, fiscal capacity allows governments to subsidize, guarantee the returns of, or directly invest in private companies providing infrastructure.[2] However, there are other potential

[1]For general discussion of the role of fiscal capacity, see (Besley and Persson 2011; Besley, Ilzetzki, and Persson 2013; Dincecco 2011; Dincecco and Prado 2012; Johnson and Koyama 2017).

[2]For studies connecting fiscal capacity to railroad expansion, see Bignon, Esteves, and Herranz-Loncán (2015) (Latin America), Dincecco and Katz (2016) (Europe), and Bogart and Chaudhary (2012) (India).

impacts. For example, fiscal capacity could also be used to expand public enterprise, either by nationalization of existing lines or investing in public construction.

Much research has focused on fiscal capacity in Europe, with its many states and long history. Fiscal capacity was growing across all of Europe in the 19th century, and states were presented with a choice of how best to utilize this capacity. Germany is interesting, as there was no cohesive central planning of the railroad network. Each German state (e.g., Prussia, Bavaria, Saxony) made their own railroad policies; even after unification in 1871, there was no central railroad authority and attempts to impose one all failed miserably until the first world war. Each state faced its own incentives and constraints that were tied to their political cultures, locations on trade routes, and endowments of key resources that could be exploited in the rapidly globalizing economy.

The common view (e.g, Millward (2004)) that Germany opted for public ownership hides a substantial amount of regional variation in early railroad policy. While it was true in 1910 that 94% percent of railroads were publically owned in Germany (the highest among all states studied in Bogart (2010)), there was little indication that public firms would end up playing such a large role when the first railroad line between Nuremberg and Fürth was laid by the private *Ludwigs-Eisenbahn Gesellschaft* in 1835. Prussia, Saxony, and many of the smaller states had entirely private networks until the late 1840s. In fact, the first year that the German states would lay more miles of track than private firms would not be until 1850, and private construction outpaced public construction in 37 out of the 51 years between 1835 and 1885 observed in this study.

By tracking what percentage of railroad miles within each state were owned by that state over time, one can see different state ownership policies for railroad construction. The full range of percentages exists in all periods, and while the percentage was increasing over time for most states, it decreased for others. This paper is the first to explore how fiscal capacity may have been a key determinant of ownership policy, and lays the groundwork for more detailed analysis on how that policy may have influenced network efficiency and development in a wider sense.[3]

This paper focuses on a state-level analysis of the effect of fiscal capacity on railroad construction, and crucially it allows private and state railway networks to react differently. By matching entries in primary sources that list which companies constructed each rail line in Germany to existing GIS data of rail line locations, I construct a new dataset that tracks the state ownership policies of the different states over time. Combining this with data on nationalizations and privatizations, it is possible to calculate how many miles of railroads in any state were publicaly or privately owned in any given year.

Through panel regressions based on a partial adjustment model (and an instrumental variable strategy based on GMM-like dynamic panel approaches) I estimate the effect of increased state capacity on the expansion rate of the public and private railroad networks within nine major German states. The findings suggest that increases in government revenues are associated with reduction in public construction and corresponding increase in private construction. However, these changes cancel each other out and do not result in any increase to the overall railroad network growth rate. One possible explanation for this puzzling result that fiscal capacity had no effect on total construction that only looking at government revenues paints an incomplete picture of fiscal capacity. To consider other forms of capacity, I also explore the effects of an increased capacity to issue debt. I find that issuing new debt is strongly associated with increased public construction. Finally, I find that as state railroads became more profitable, they grew at accelerating rates. This stands in stark contrast to the large body of research which focuses on tax revenues per capita as a measure of fiscal capacity.

Because this paper examines the role of public finance and fiscal capacity as determinants of railroad construction, it also builds on Dincecco and Katz (2016), who found that the adoption of fiscal centralization and increased state capacity lead to increased railroad

[3] The consequences of such policy for construction costs and operating efficiency in Britain are well explored by Foreman-Peck (1987), but Germany lacks a comparable analysis. Appendix 1 provides an extremely preliminary view.

construction. Because constitutional reform is insufficient as an explanatory variable in the wider German context[4], this paper's methodology for exploring the role of state capacity is instead closer to that of Bignon, Esteves, and Herranz-Loncán (2015). They emphasize the need for state financial support to initiate railway construction, while recognizing the feedback effect between government revenues and larger networks. However, it is not immediately clear whether one should expect the same relationships to hold in the German context. For one, the scale of subsidization in the early 19th century in Germany is not well established. Subsidies certainly existed, but the role of government financing is often obscured by many states' tendencies to make direct investment into private companies through the purchase of stock. Furthermore, the German states had a wider variety of revenue sources than the Latin American states studied by Bignon et al. and tariff revenues were distributed within the *Zollverein* according to the population distribution, rather than according to distribution of the origin or destination of traded goods. Finally, as highlighted by Fremdling (1980a)[5], state railway revenues were used as a substitute for taxation. The channels between railroad construction and revenues are clearly different and more complicated to identify in Germany's case.

The German context is also different because there is little evidence to suggest that a lack of access to funding (either to directly construct state rail or subsidize private rail) was ever a serious constraint on construction. Earlier scholars like Fremdling (1983) argue that demand for transportation was sufficient for private investment, and the only real constraint was the hesitancy of the states to grant concessions. Mitchell (2000) emphasizes the fact that railway construction began at a much faster rate in Germany than in France and argues that state intervention was just as likely to have spurred investment as to have constrained

[4]Prussia, the only German state examined by Dincecco and Katz, is one of only two states in this paper's sample which undergoes a lasting institutional change of this type, the other being Oldenburg. Every other state had already adopted a constitution by 1835, with the exception of Mecklenburg-Schwerin, which repealed its constitution only a year after adopting it in 1850.

[5]Fremdling finds strong evidence to support Prussia's use of railroad revenues in this way, but the evidence is less conclusive for other states. Appendix 2 shows Prussia was certainly an outlier in this regard, although railroad profit's share of government revenues may have been increasing in some other states as well.

the private sector. The outcome of interest, then, may not simply be the total length of track laid or the density of the network if one believes that the pace of construction was near optimal given the relative lack of binding financial constraints.[6]

To understand better, state and private actors may have very different motivations for laying miles of track. For example, it is generally accepted that the development of state railroads in Eastern Prussian was motivated by military concerns and that the state was required to intervene because even with subsidies the lines would not have been profitable enough to entice private investment. Consequently, it is not immediately obvious in all cases whether state and private miles are complements or substitutes. The general trend in the historical literature is to say that private companies focused on constructing lines on established trade routes where high demand was easy to see, whereas public railways followed more strategic routes (e.g., military, trade diversion, or infant industry support). While this may have been broadly true, the fact that some states chose not to allow private construction even along high-demand lines in favor of a totally public railway system challenges the generalization.

Sections 2 discusses the selection of which German states to include the sample. Sections 3 and 4 provide background information on the historical development of the German states' railroad networks and fiscal capacity. Sections 5 and 6 discuss the empirical specification and data. Section 7 reports results and section 8 concludes.

# Sample Selection

The existing literature does not provide a satisfactory explanation for the varying degrees of state involvement in the railway industry. While it is possible that such decisions were largely the result of idiosyncratic ideological differences, this view has been refuted by Millward (2013) who emphasizes the role of geopolitics and the desires of states to develop their

[6]State interventions may actually have led to an *overbuilding* of the network, as neighboring states competed to build lines that would attract traffic to routes through their own states and not neighbors. Analyzing the potential costs of this overbuilding and competition is beyond the scope of this paper.

capacity and control of key industries. Millward also considers the importance of expanding the state's participation in business to raise revenues, similar to Fremdling (1980a), but suffers from the same problem of basing those conclusions entirely on Prussian data (as discussed in the previous section). Furthermore, the literature does not agree on whether the net effect of intervention was typically to facilitate or delay railroad construction.[7]

To better understand how state intervention and state capacity influenced the development of the German railroad network, it is necessary to broaden the usual scope of study, which generally focuses primarily on Prussia, and only occasionally includes Baden, Wuerttemberg, Bavaria, and Saxony (the largest and most influential of the states in the "Third Germany" that divided Prussia and Austria). However, it is also important to establish some criteria for noteworthiness; most of the 44 observed states were insignificant, and many were so insignificant that they would be annexed before ever constructing a single mile of railroad. Therefore I use a simple cutoff: the state must construct at least 150 miles of railroad during the observation period of 1835 to 1885. This gives 11 states: Baden, Bayern, Braunschweig, Hanover, Hessen-Darmstadt, Mecklenburg-Schwerin, Oldenburg, Preussen, Sachsen, Sachsen-Weimar-Eisenach, and Wuerttemberg, whose area makes up 96.4% of the total area of Germany, as shown in Figure @ref(fig:SampleCoverage).[8]

[7]Fremdling (1983) argues that there was more than enough demand for railroads, and the influence of state intervention was purely to slow construction. On the other hand, Mayntz and Hughes (1988) believe that, at least in the earliest years, raising funding was difficult for both state and private actors. Mitchell (2000) takes a middle position, and argues that the effect of state intervention was ambiguous and could have gone other way depending on the context. Millward (2004) takes a positive view of state intervention, arguing that it occurred in cases when the German states were impatient with the slow pace of private investment. None of these arguments are based on a systematic evaluation of empirical evidence.

[8]Of these, data has been collected for 8: Baden, Bavaria, Brunswick, Prussia, Saxony, Sachsen-Weimar-Eisenach, and Wuerttemberg. Results in this draft are based on the 8 state sample. This sample covers 84% of Germany from 1835-1865, then 94% after Hanover is annexed by Prussia.

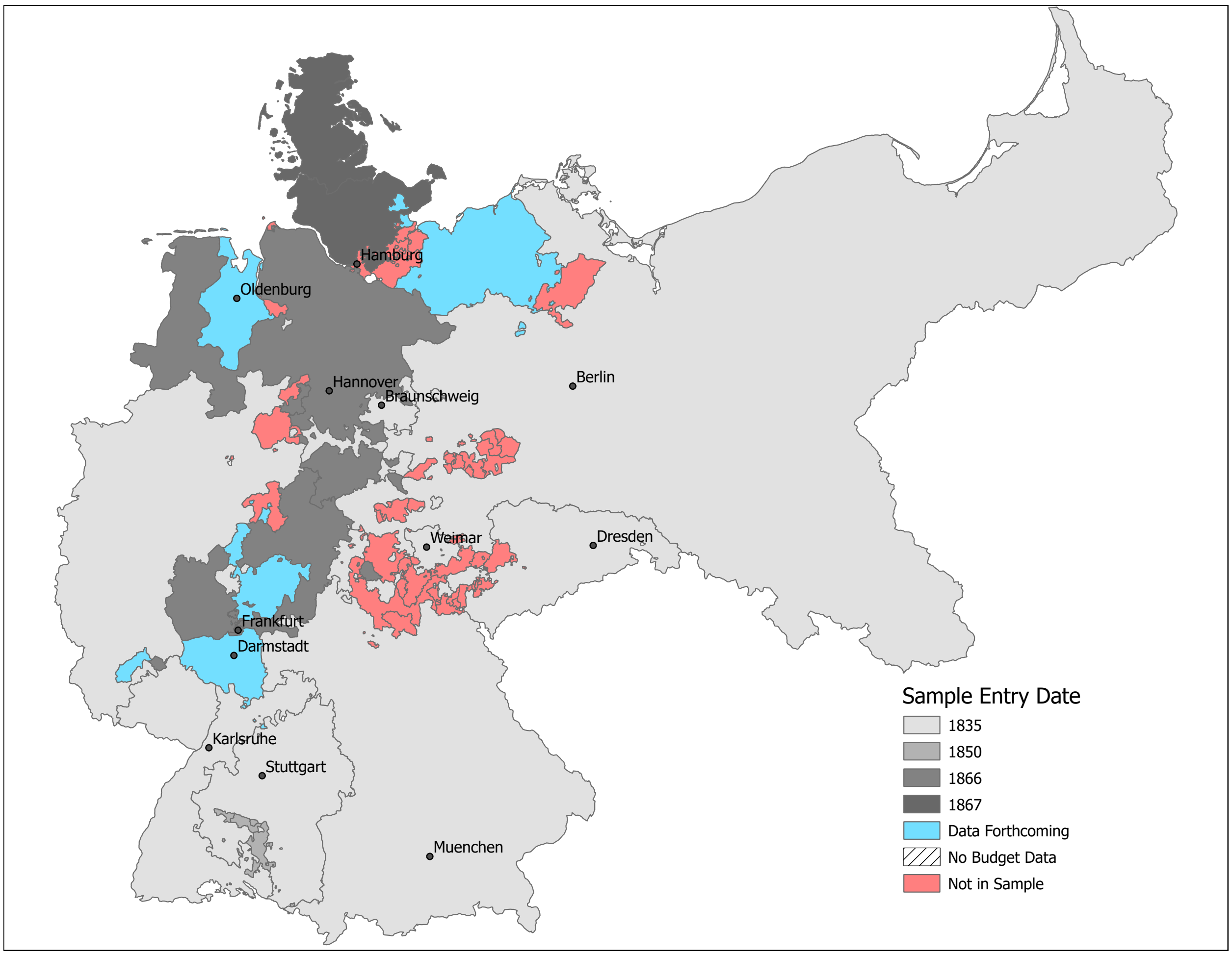



Figure 1: Sample Coverage. Late entry occurs when smaller states are annexed by Prussia.

# Early German Railroad Development

## Stylized Facts

The development of the German railroad network is illustrated in Figure @ref(fig:NetworkDevelopment). The first 3.6 miles of track were laid in 1835 between Nuremberg and Fürth by the *Ludwigs-Eisenbahn Gesellschaft.* In the next decade, over 1000 miles of track would be laid, primarily in Prussia, Baden, Saxony. Construction rapidly accelerated, with over 7000 miles built between 1846 and 1865. It has frequently been stated that the initial phase of railroad construction did not lead to any significant new connections, but simply intensified existing trade along major routes.[9] By the end of this period, we can see that the major trunk lines had been constructed, but densification had only begun in the Ruhr.

Most trunk lines that needed to cross state borders were not built until the end of this period, as the construction of East-West lines was significantly delayed by particularism and the fear of trade diversion.[10] This was exacerbated by the challenges associated with negotiating the treaties required for a railroad to cross a border.[11] Negotiations often took many years and most were not finalized until the 1860s and 70s. It is likely that the proliferation of private firms was in some part due to the fact that joint investment by states was a workable solution when both parties wanted to retain some degree of sovereignty and control; in fact, over 70% of border crossings were opened by private firms. These points highlight the role of federalism in the development of German railways.

Accelerating densification and a reduction in particularism following Prussia's territorial expansion in the aftermath of the Austro-Prussian War and German Unification massively increased the rate of construction in the next decade. Between 1866 and 1875, over 8000 miles were built, doubling the size of the network. In Prussia, densification of the Ruhr network proceeded at pace, and massive trunk lines connected Berlin and East Prussia. Densification

[9] Fremdling (1983), Mayntz and Hughes (1988).

[10] Described by Mitchell (2000), Hoffman (1969), and Fremdling (1983).

[11] Hoffman (1969) is the definitive source here.

also began in earnest in the southern states. Another 5000 miles were built between 1876 and 1885, mostly increasing density in the remote northern and eastern regions, as well as politically fragmented Thuringia.

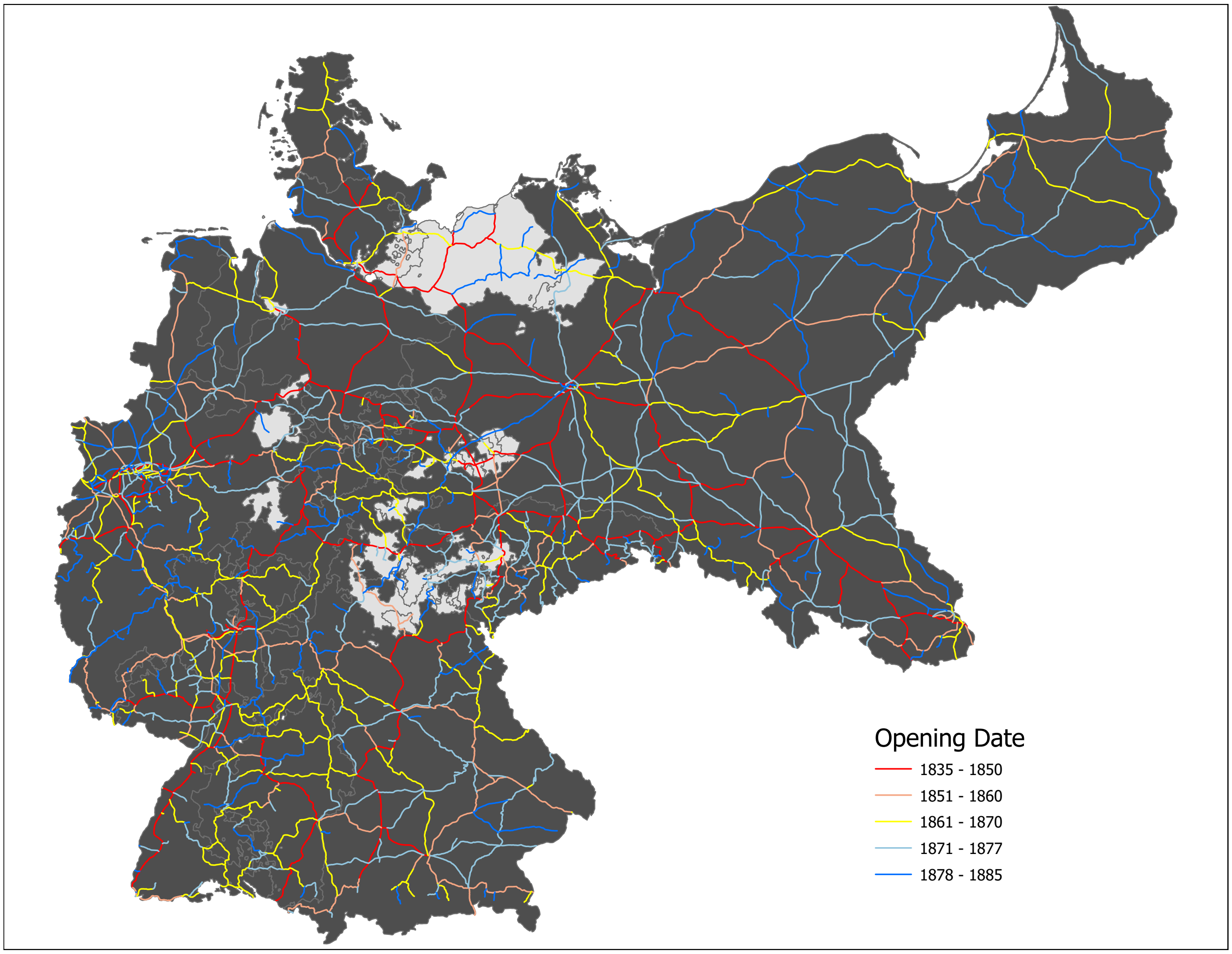



Figure 2: Timing of Railway Construction. Shapefiles: Kunz & Zipf 2008. Graphic by author.

Table 1 presents the size and density of the ten largest state railway networks in 1885. One can see that, although the absolute size of the networks varies substantially, the density measures all fall within a reasonable distance of each other. This is not to say that all states achieved the same level of density; whether measuring density by area or per capita, the most dense network is roughly twice as dense as the least dense and the remainder fall relatively evenly between these two extremes.

| State | Miles | Rank | Per Capitax1000 | Rank | per square mile | Rank |
|---|---|---|---|---|---|---|
| Prussia | 12994 | 1 | .46 | 8 | .10 | 8 |
| Bavaria | 2817 | 2 | .54 | 4 | .10 | 7 |
| Saxony | 1118 | 3 | .35 | 10 | .19 | 1 |
| Wuerttenberg | 840 | 4 | .42 | 9 | .11 | 5 |
| Baden | 751 | 5 | .47 | 7 | .13 | 4 |
| Hessen-Darmstadt | 475 | 6 | .50 | 6 | .16 | 2 |
| Mecklinburg-Schwerin | 374 | 7 | .65 | 1 | .08 | 10 |
| Oldenburg | 219 | 9 | .64 | 2 | .09 | 9 |
| Brunswick | 214 | 10 | .58 | 3 | .15 | 3 |
| Saxony-Weimar-Eisenach | 156 | 11 | .50 | 5 | .11 | 6 |

## Public and Private Railways

To analyze how ownership policies varied across Germany and within states it was necessary to construct a new dataset. Before describing the construction of that dataset and the stylized facts that emerge, it is important to clarify how railroad mileage is divided into different categories. Contemporary sources such as Vereins Deutscher Eisenbahn-Verwaltungen (1868) and Kühn (1882) divided firms into three types: First were the *Staatsbahnen*, or state railroads, which would later become known as the *Länderbahnen*. These were fully incorporated into the bureaucracy of the state; administration was handled by the state and profits were treated as state revenues. Second were the *Privatbahnen*, or private railways. These are further subdivided into those administered by a state bureaucracy (which typically fluctuated around 10% of total railway mileage), and those which were administered privately. To my knowledge, there is no strict definition of "state administration", but we can understand through an example:

The *Bergisch-Märkische Eisenbahn-Gesellschaft* was founded in 1843 as a private railway, with a quarter of the founding capital provided by the Prussian government. In 1849, the railway failed to repay a government loan, and the Prussian government would not agree to provide further loans unless the company agreed to turn over operations to the Prussian state ("Bergisch-Märkische Eisenbahn-Gesellschaft" 2023). From then on, the state handled operation of the railway, and presumably profits were distributed to shareholders through dividends; there is no evidence that profits from this firm were treated as part of the state's budget in the way that state owned firms were. Unfortunately, I have also not found any evidence to suggest whether operating expenses were borne by the state or if the state was compensated as if it were a contractor.

For my analyses, I do not retain the distinction between publicly and privately administered private railways to emphasize two points: First, granting a concession to a private company implies a need for finance beyond what the state itself is willing to invest. Second, the budget of a private firm is at arms length from the state it is located in, even when it is publicly administered. Because there is no data on the shares of stock owned by each state, it is impossible to know precisely how the performance of private firms would have influenced state budgets.[12]

In the empirical analysis, it is important to recognize to recognize that state-owned companies also operated in other states. For simplicity, I use "State" miles to refer to *state owned* railways operating *within that state* (e.g., the Bavarian State Railway constructing miles within Bavaria). In contrast, "Other" miles refer to state railways operating in some *other* state (e.g., a Prussian state railway operating within Oldenburg). Thus, the ownership of rail lines fits into one of three categories: State, Private, and Other.

The railway GIS data used to classify mileage by type begins with shapefiles from Kunz and Zipf (2008). The railroad shape files within do not contain any qualitative data about

[12]The complexity of untangling the flow of funds between governments and JSCs is highlighted by an example that can be found in Fremdling and Knieps (1993). Prussia purchased about 15% of the outstanding stock of the Cologne-Minden railway in 1843, while also guaranteeing a minimum dividend to the other investors in exchange for a share of excess profits (among other privileges). The complexity of the relationship and lack of accounting data make it impossible to determine the direction of the net flow of capital between the state and the company.

individual line segments besides the year of opening. Thus, it is necessary to match these segments to a different source with qualitative information. The primary source is Dumjahn (1984), which notes the company responsible for construction of the segment, the length of the segment, and, if the segment was nationalized, by which state and in what year. Matching was successful in nearly all cases, and the remainder were matched using Kühn (1882). It is important to note that the methods used by Kunz and Zipf (2008) to simplify the drawing of the rail network introduce minor inaccuracies. For example, no distinction is made between different stations of most cities (with the exceptions of Berlin and some major industrial cities on the Rhine). The effect of the measured length of track is negligible, but this does ignore the important costs of trans-shipment from one company's station to another that often existed before the construction of smaller connecting lines as the number of companies fell. Furthermore, Kunz generally omits small lines connecting city centers to ports, as well as all of the narrow gauge track (roughly 300km) which was utilized primarily used for short haul industrial purposes (typically under 20km).

It is also important to note that Dumjahn does not record privatizations or mergers. Mergers or sales of lines from one private firm to another are not coded, but it is important to note privatizations. Kleeberg (1990) provides data on the timing of the privatization of the Brunswick state railways and eventual sale to the Prussian state railways. Reliable information on the privatization and renationalization of railways in Mecklenburg-Schwerin is harder to find, and not all sources agree on the timing. I follow the timing given by Fremdling and Kunz (2011). I am not aware of any other privatizations.

Figure @ref(fig:OriginalOwnership) presents which types of firms constructed the railroads in each state. Because policies varied from state to state, an individual treatment is necessary to explain contextual factors; this is presented in Appendix 2. However, some broad patterns do emerge. State construction was much more widespread in the South, which likely contributed to the delay in East-West lines connecting the southern states. These were the states whose administrations were most intensely particularistic and least

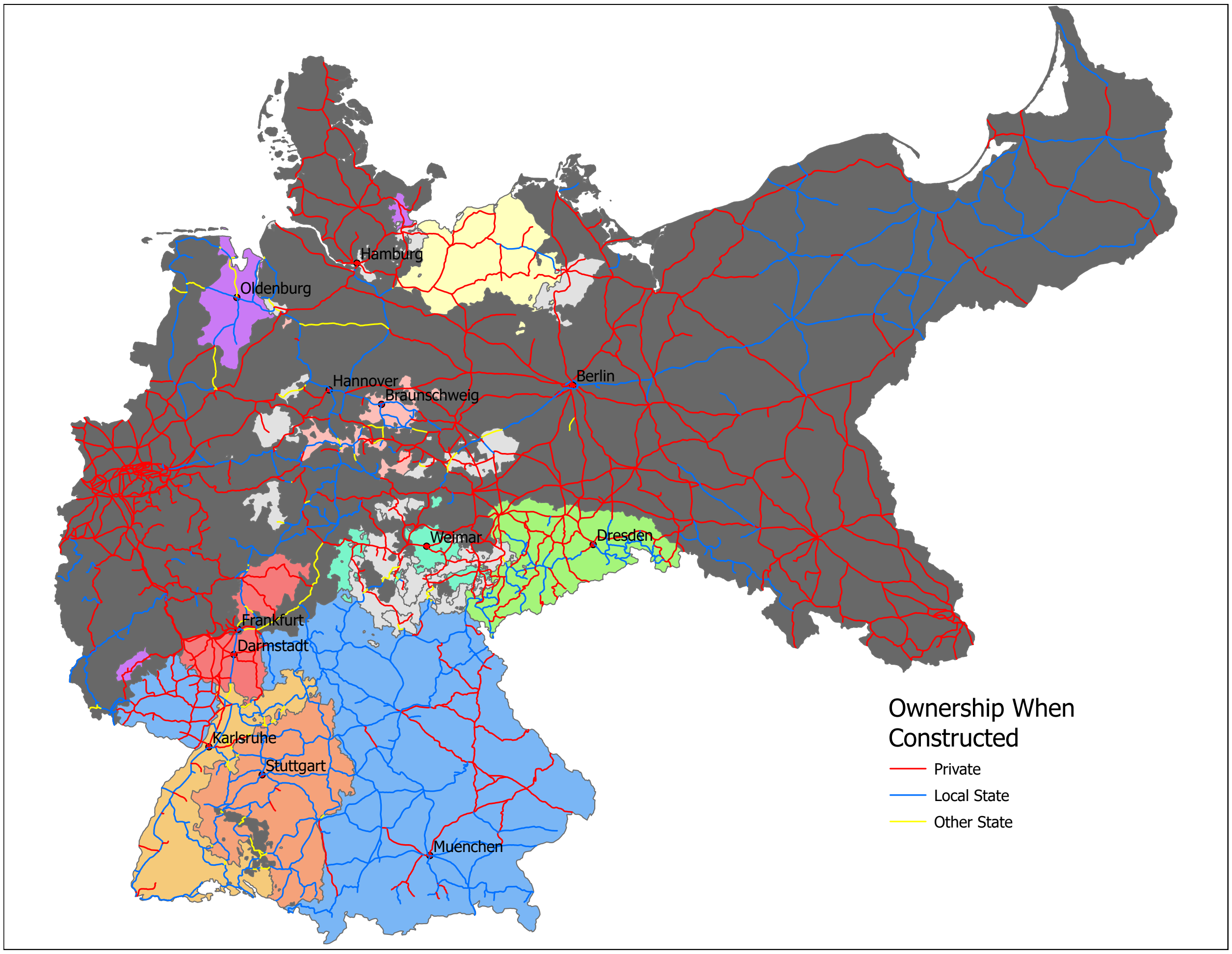



Figure 3: Ownership of railway at the time it was opened. Sources: Shapefiles for state borders and railroad lines from Kunz and Zipf (2008). Ownership classifications by author based on Dumjahn (1984).

willing to make any concessions that could be considered ceding sovereignty. It is harder to make generalizations about the connection between industrial regions and state construction from a purely visual inspection. While Prussian state intervention was common in the Saar and Silesia, railroads in the Ruhr were constructed almost entirely by private firms. Discontiguous territory, however, appears to be highly correlated with favoring private firms. With the exception of the Saar, and some connections with Hannover, railroad construction in the Rhineland and West Prussia is dominated by private firms. Hessen-Darmstadt's territory was also divided in two, and her network was primarily constructed by private firms as well. Bavaria and Oldenburg preferred state construction in their core territory, but left construction in their exclaves exclusively to private firms.

Despite these observable trends under specific circumstances, and in particular because a "one size fits all" explanation that state railways emerged in regions with infant industries does not match our observations, a substantial amount of variation in state railroad construction within and across states remains unexplained. Explaining how a portion of that variation is explained by fiscal capacity is the main focus of this paper, and is discussed further in Section @ref(results).

A digression on nationalizations is also necessary, as nationalizations may play an important role in determining state railway profitability. It has been shown by Bogart (2010) that state intervention though nationalizations had differing effects from state intervention by construction. The effect of nationalization is somewhat difficult to account for in this study for two reasons. First, most nationalizations occurred very close to the end of the observed period of railroad construction from 1835-1885, as shown in Figure @ref(fig:nationalizations). The early nationalizations in Bavaria and Saxony initiated state involvement, but only led to the wider development of state firms rather than general policies of nationalization. Second, nationalizations were largely a reaction to exogenous political pressure. Prussian attempts to create a national railway administration were complete failures and led to fears among the smaller states that Prussia would create a national administration indirectly by purchasing

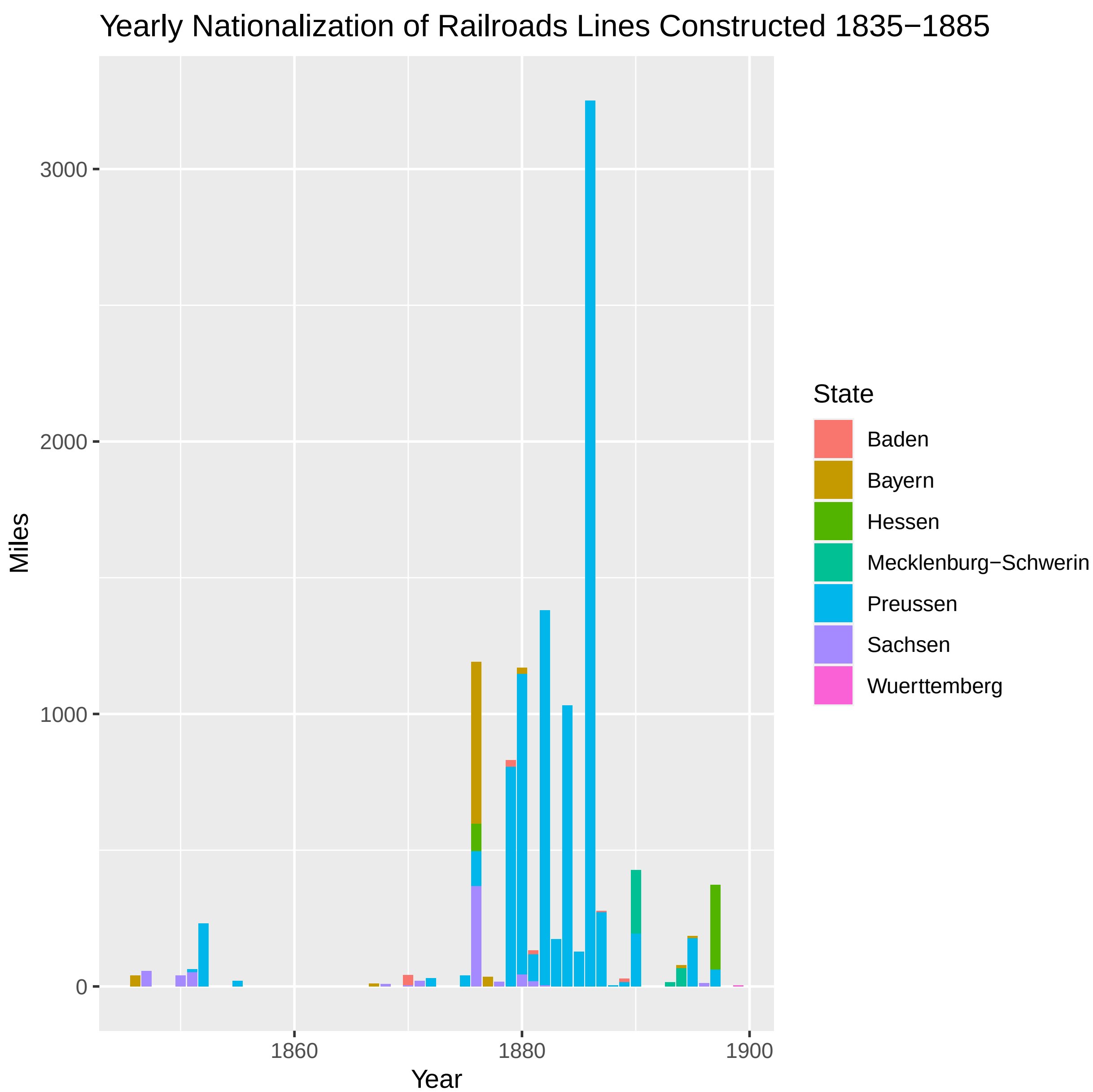



Figure 4: Nationalizations by State and Year. Source: Calculated by author from Kunz and Zipf (2008) and Dumjahn (1984)

the remaining private railways and absorbing them into the Prussian State Railways (as would occur in Brunswick). To preempt this possibility, the south German states nationalized most of the remaining private firms within their borders in 1876. In the coming years, Prussia would begin a massive nationalization campaign to bring nearly all of its existing mileage under state ownership. After a few late nationalizations, (Mecklenburg-Schwerin in 1890, Hessen-Darmstadt in 1897, and the Bavarian Palatinate in 1908), the State Railways would control nearly all mileage in the Empire until they were finally united under the *Deutsche Reichsbahn* in 1920.

For the purposes of this paper, nationalizations are only considered to the extent that they adjust the percentage of railroad mileage owned by the state in a given year in the descriptive results. Future research may consider why the first wave of nationalizations in the 1840s and 1850s occurred instead of states simply granting financial support in the form of subsidies; this is a particularly interesting question since it may have been the catalyst for the expansion of state owned railroad systems in Prussia, Bavaria, and Saxony. The second wave of nationalizations, being exogenously determined by political factors (at least in Bavaria, Hessen, and Saxony), may prove useful as a natural experiment for studying the efficiency of state administrations.

# Fiscal History[13]

## New Data

Though some qualititative histories about the development of public finance in Germany exist, comprehensive quantitative data has heretofore been sparse. Andic and Veverka (1963) only collected data on the expense side. The first effort to compile state income was made by Mauersberg (1988), who made no attempt to ensure the consistency of variable definitions across observations or time and simply reported the given figures in the regular budgets.

[13]See section 6 for details on how new data on fiscal histories was collected.

Thus, Mauersberg's data is biased by changes in reporting from Net to Gross revenues, the occasional inclusion of fees and fines within direct taxation, and the definition of the "regular" budget, among other idiosyncrasies. Furthermore, Mauersberg does not discuss his choice of sources, leaving it up to the reader to determine which figures are projections and which are based on draft proposals rather than approved laws. Most importantly, Mauersberg did not exhaust available sources and only included a limited sample of states and years, severely hampering the data's usefulness for a quantitative study.

In my dataset, I do my best to remedy these flaws, though as we will see, limited documentation surrounding the primary sources presents a challenge. The first problem confronting the researcher interested in compiling 19th-century budget data is one of scale. There is an over-abundance of data; the tables and appendices to a "*Finanzgesetz*" (the law establishing the budget for a financial period) frequently number in the hundreds of pages. To create a complete panel of all income and expenditure would be a herculean effort. Thus, the first step is to decide on a limited number of "high-level" categories that can be consistently measured across space and time. A brief review of how these categories were defined follows. In the final draft, much of this information and more will be contained in a forthcoming data appendix.

For the current iteration of this project, I collect data on Total Income and three major categories: Direct Tax, Indirect Tax, and Railroads.[14] Where possible, I also collect data on the associated operating expenses, which allows gross income figures to be converted to net and vice versa. When income is disaggregated, the remainder is made up of income from royal properties (such as forests), state enterprises and monopolies (such as salt mines and the post), administrative fees, legal fines, transfers from state coffers (i.e., liquidation of assets), and other miscellaneous sources such as reparations.

Generally, contemporary definitions of direct and indirect taxations are consistent with

[14] An important omitted category is debt, which is unfortunately beyond the current scope of the project. While debt servicing expenses are typically reported consistently and simply as a line item, there is little consistency in the reporting of debt issuances. Consequently, the consideration of debt as an income source needs to be left to a future draft.

modern expectations. Direct taxation is primarily made up of property, poll, income, and capital taxes whereas indirect taxation is primarily made up of customs, stamp taxes, and taxes on luxury goods. While direct taxation figures can usually be taken as given, there are two main challenges to constructing the indirect taxation figures. The first is that while indirect taxation was administered by the states, they were often remitted to a central administration to be redistributed (first the *Zollverein*, then the *Norddeutscher Bund*, and finally the *Reich*). The reporting surrounding these redistributions is opaque and it is not always clear whether the reported figures represent the pre- or post-redistribution figures. Second, there was a tendency to report fines and penalties as indirect tax revenue. While this is arguably appropriate for customs violations, it is less clear whether fines for illegal activity fit the modern conception of indirect taxation. However, because it is generally impossible to exclusively remove civil and criminal fines only, these costs remain in indirect taxation.[15]

Defining railroad income faces similar challenges. First, I make a judgment to include all railroad related income, exclusive of specifically labeled direct "railroad taxes". Thus, railroad income includes not just profits from state enterprise, but also other miscellaneous income generated by the ministry governing railroads. This includes income from direct investments, privatization, and other general fees. The remaining challenge regarding railroad income is related to the lack of standardized reporting for the issuance of bonds. Because bond issuance is often unreported in the regular budget, this significantly overestimates net income from railroads, as debt repayment related to those bonds is folded into the general debt servicing line item. As I broaden the scope of sources used, I hope to gather more data on debt.

The first choice of primary sources for budget information are the *Gesetzsammlungen* (Law Collections) or *Gesetzblätter* (Law Gazettes). These were the official communication channels of the states to notify citizens of new laws. The budgets presented here are preferred,

[15]The exception here is Prussia, where fines were only reported as indirect taxation for small subsample of years. To keep the definition internally consistent, the value of fees was removed from those select years. However, future drafts will instead add fees to all years to make the definition more consistent with other states.

since they represent a fully approved law which is no longer subject to any further debate or amendment. However, it is important to note that these were still projected figures rather than an accurate accounting of real income. An additional drawback is that many states only reported abridged budgets in these public-facing documents. For example, in Bavaria's case, between 1820 and 1871, the *Gesetzblätter* only report net income, giving an incomplete picture of state fiscal capacity.

In such cases, the next choice is to examine parliamentary proceedings. Budgets submitted for parliamentary approval typically contain far more information but are of reduced value because the figures are still subject to approval and amendments. If neither gazettes nor parliamentary proceedings are available, then secondary sources are used. Appendix 3 describes the sources used for each state. I convert all currency units to Marks, using the 1871 exchange rates of 1 thaler = 3 mark and 1 gulden = 12/7 mark (Deutsche Bundesbank, n.d.).

## Stylized Facts

The 19th century saw a massive increase in the fiscal capacity of German states (Figure @ref(fig:GRPC)). After the collapse of the Holy Roman Empire, the importation of French institutions following the Napoleonic wars, and the massive consolidation of territory that followed the *Reichsdeputationshauptschluss,* German administrations were forced to undergo massive reforms in the early 19th century. As feudalism and absolutism gave way to constitutionalism, taxation became more regular and took new forms, leading to large increases in tax revenues per capita (Figure @ref(fig:TRPC)). Spoerer (2010) summarizes these changes to the direct tax regimes: The southern German states tended to follow the French model most closely, with an emphasis on direct taxation of impersonal wealth (land, buildings, and business). Prussia's tax system was more personal. Prior to 1851, a head tax called the *klassensteuer* was levied based on social standing or occupation. As the bureaucracy became more sophisticated, this was transformed into a proper income tax. Saxony and Baden introduced income taxes in 1878 and 1884 respectively, and Prussia expanded the income tax again in 1891. Although approaches to direct taxation differed between the North and South, direct taxation tended to account for a similar share of overall taxes across states in 1830, with divergence only occurring in the late 1860s (See Figure @ref(fig:DirectTaxShare)).

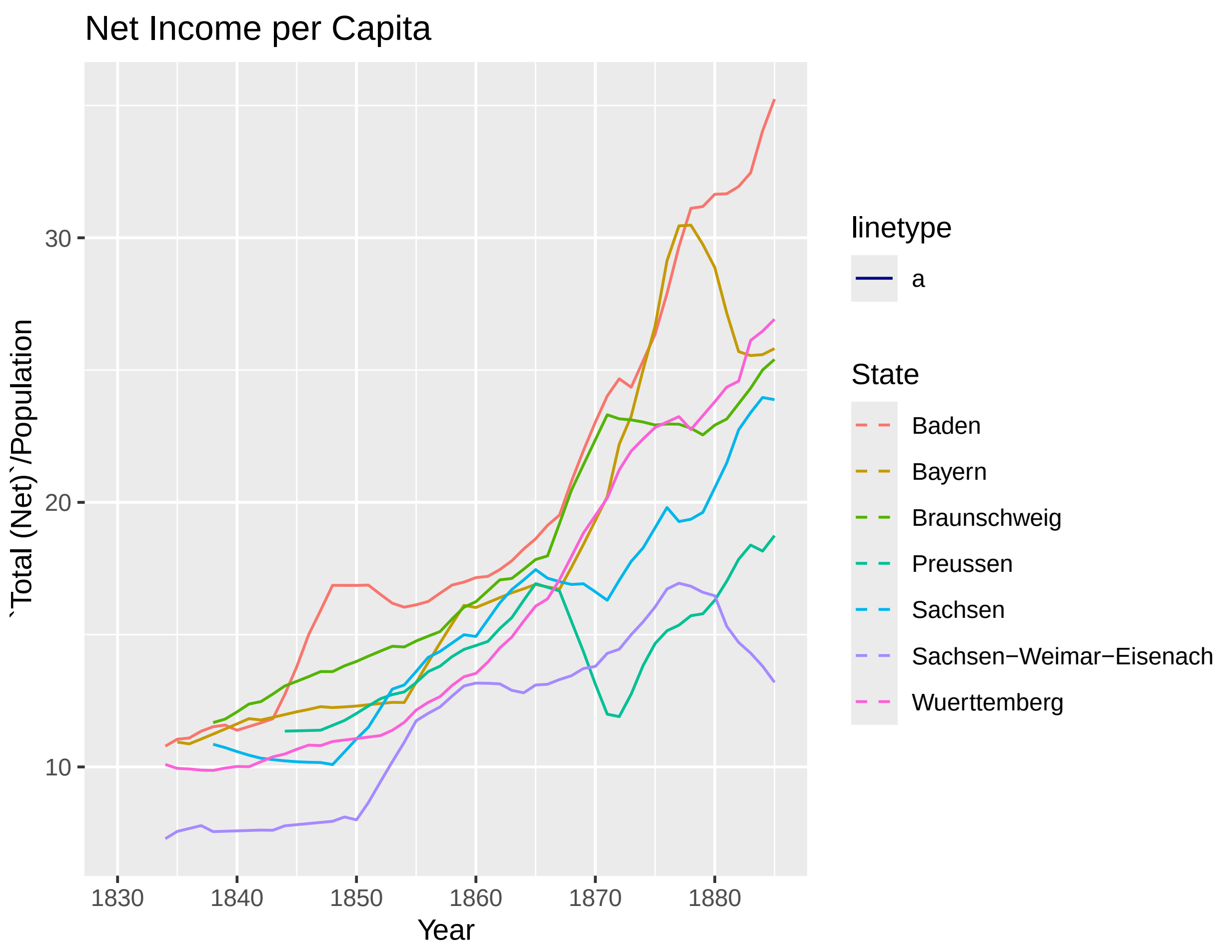



Figure 5: Source: See Text.

Indirect taxation in Germany has a much more complicated history. The earliest forms were taxes levied on goods entering and exiting city gates, but with the near extinction of the free cities this was no longer relevant. Because of the administrative costs involved, consumption taxes were rare, and only Prussia continued to levy indirect taxes on milling and butchery in its cities (Spoerer 2010). Because of the administrative costs involved, indirect

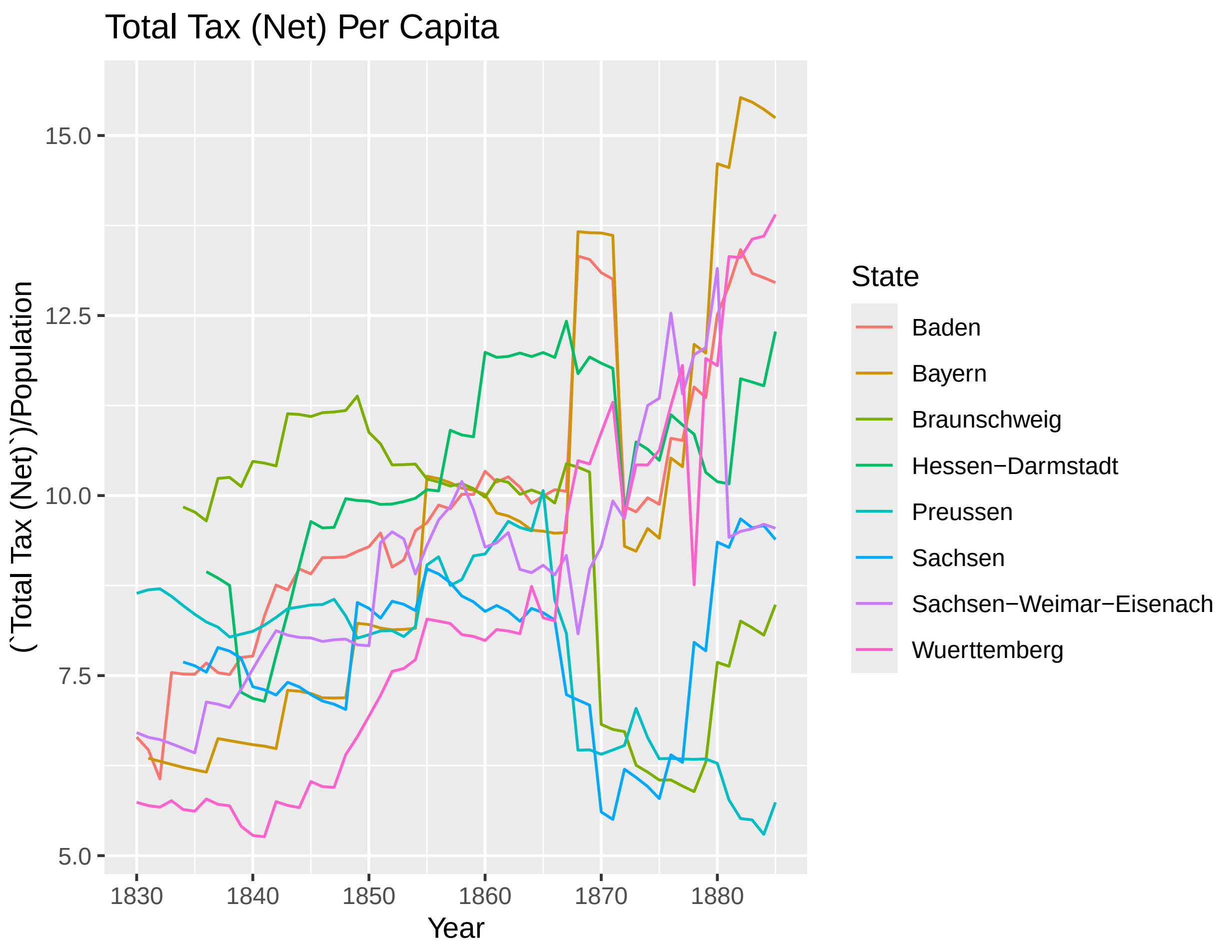



Figure 6: Source:See Text. Observed years noted with thick dots.

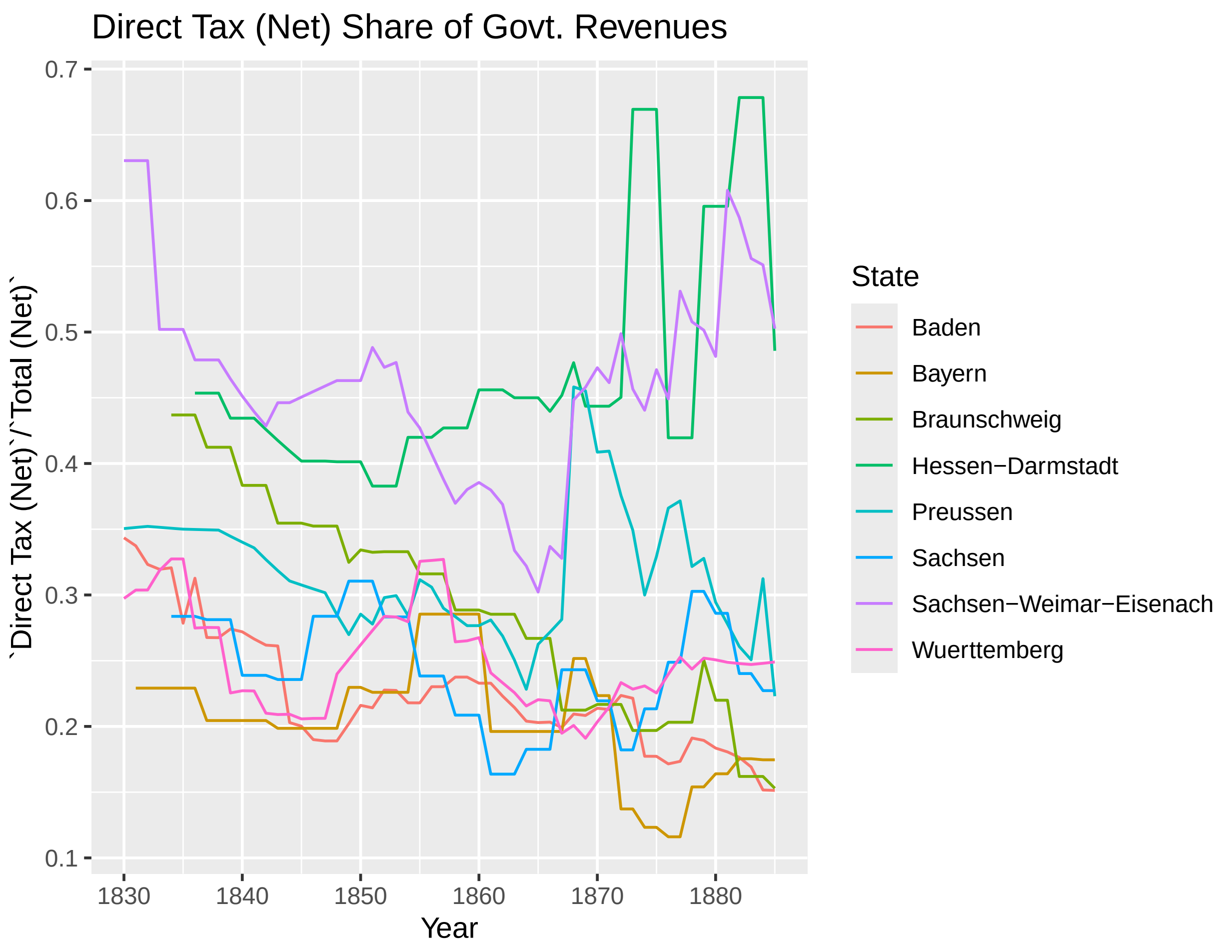



Figure 7: Direct Tax Revenues as a share of Total Tax Revenues. Source: See Text.

taxes were mostly levied at borders as customs duties and tariffs.[16]

Consequently, indirect taxation is one of the few policies administered by a central authority in Germany. By 1842, nearly all of the German states had joined the *Zollverein*, which eliminated customs borders between participating states. Tariffs were set and could only be changed by the unanimous consent of all members (Dumke 1976). The arrangement was relatively liberal, with low duties compared to contemporary tariffs, and no restrictive quotas. The majority of revenues came from duties on luxuries (Millward 2013). Most interesting about the *Zollverein* in the context of state fiscal capacity is how revenues were distributed: after members were compensated for the costs of customs administration at their borders, the remainder was shared on a per capita basis (Ploeckl 2010). Incidentally, the need to properly allocate revenues was the impetus for regular census-taking in many parts of Germany (Gehrmann 2009). This system is generally considered to have favored East Prussian agrarian interests over artisans and south Germany in general. On the other hand, the revenue distribution system led to lower revenues for the Prussian state, since its population was proportionately low with respect to its volume of trade. Another counterintuitive result of this system was that the smallest states with the least fiscal and administrative capacity became the most dependent on indirect tax revenue.

The *Zollverein* became obsolete after German unification in 1871, but indirect taxes generally remained the purview of central authorities. The new Imperial constitution respected the federal rights of the states to levy direct taxes, but customs and stamp duties as well as most luxury consumption taxes were reserved for the *Reich* (Millward 2013; Spoerer 2010). One would expect this to lead to a decrease in indirect direct tax revenues, since what was formerly being remitted according to population was now being allocated to the *Reich*. The states, however, were wary of this result. When tariffs began to rise in the 1870s, the states became increasingly aware of just how much revenue was being lost to the central government. In response, they passed in Franckenstein claue in 1879 which set a limit on

[16] Transit taxes were the exception, as access to rivers and railroads was relatively easy to monitor.

central indirect tax revenues. All revenues from tariffs and tobacco taxes above 130m *marks* would be redistributed to the states (Hefeker 2001). Furthermore, as administrative capacity developed, indirect taxation on non-luxury goods became more feasible.

Taxation, however, is only half of the story. Prior to the development of regular taxation, the fiscal bureaucracy of the German states in the 18th and early 19th centuries was primarily concerned with effective management of domain properties, such as forests[17] and mines.[18] The traditional models of fiscal development, from Schumpeter (1918) to Ormrod, Bonney, and Bonney (1999) have predicted that as fiscal capacity develops, the "tax state" will emerge from the "domain state". As Spoerer (2008) points out, this was not the case in Prussia, Bavaria, or Saxony, and we can see tax's share of government revenues was decreasing across all of the major German states in the 19th century (see Figure @ref(fig:TaxShare)). However, this does not mean that German states were stagnant or failing to develop more sophisticated revenue streams. Beyond the tax reforms discussed above, the German states were becoming increasingly involved in public enterprise.

The most important public enterprise, of course, was the state railway. Fremdling (1980b) shaped all future discussion when he convincingly argued that the Prussian government used railway revenues as a substitute for taxation, or, as Spoerer (2004) terms it, "indirect indirect taxation". One historian even referred to this as the emergence of the "railway state" (Thier 2000). Figure @ref(fig:RailroadShare) shows clearly how revenues related to railroads were rapidly increasing in importance across GermanyS. It is evident that the "railway state" phenomenon was not unique to Prussia.

Unfortunately, there is little to say about the remaining sources of government revenues, namely non-rail enterprise, investments, and debt. Data on non-rail public enterprises is either sparse or yet to be compiled. Similarly, the role of debt and public investment are understudied for any state besides Prussia, and collection of state debt data faces unique

[17] Lowood (2020) discusses how the "cameral sciences" emerged out of the need to manage forests.

[18] See Cantoni, Mohr, and Weigand (2021) for a discussion of how the emergence of cameralism and scientific management principles influenced the growth of early German states.

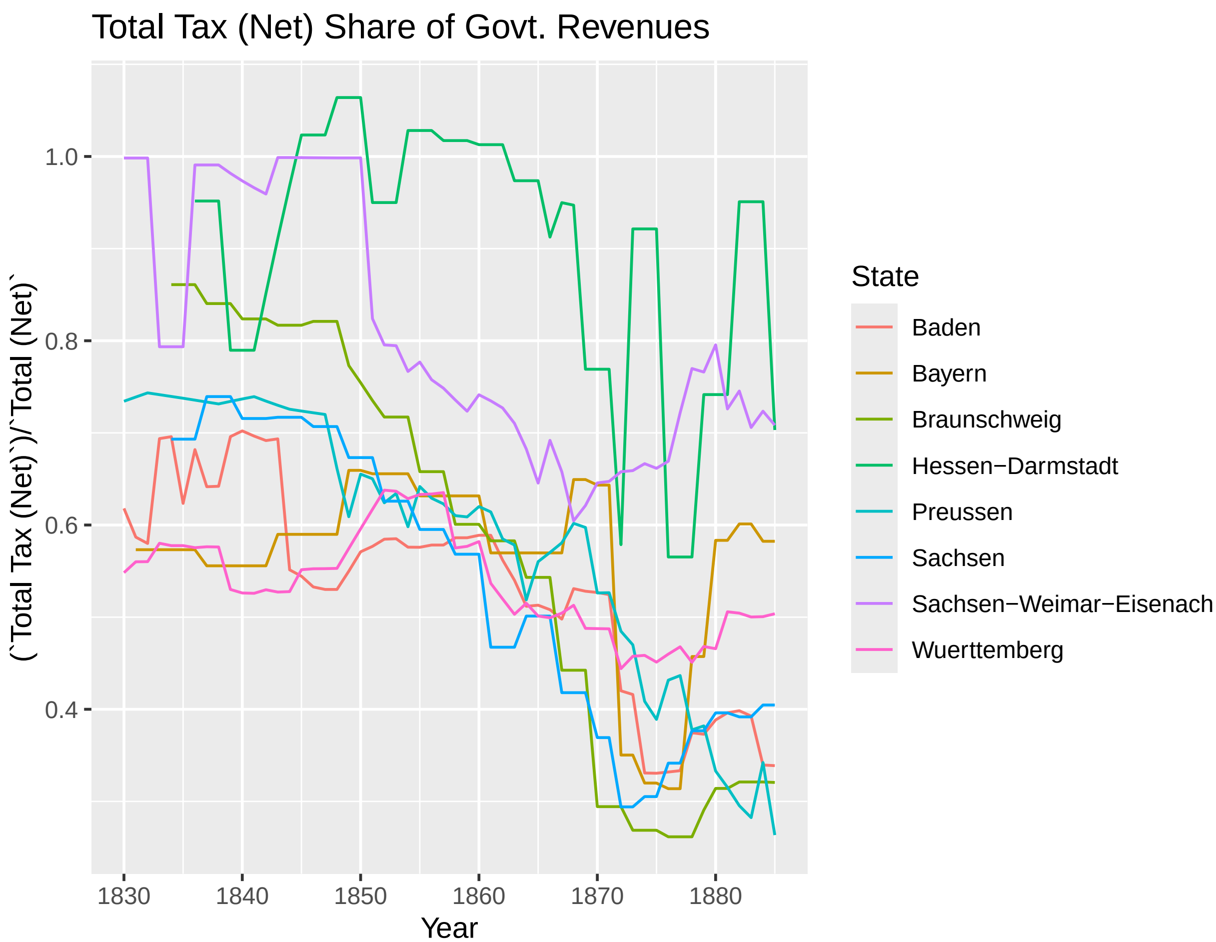



Figure 8: Tax's Share of Government Revenues. Source:See text.

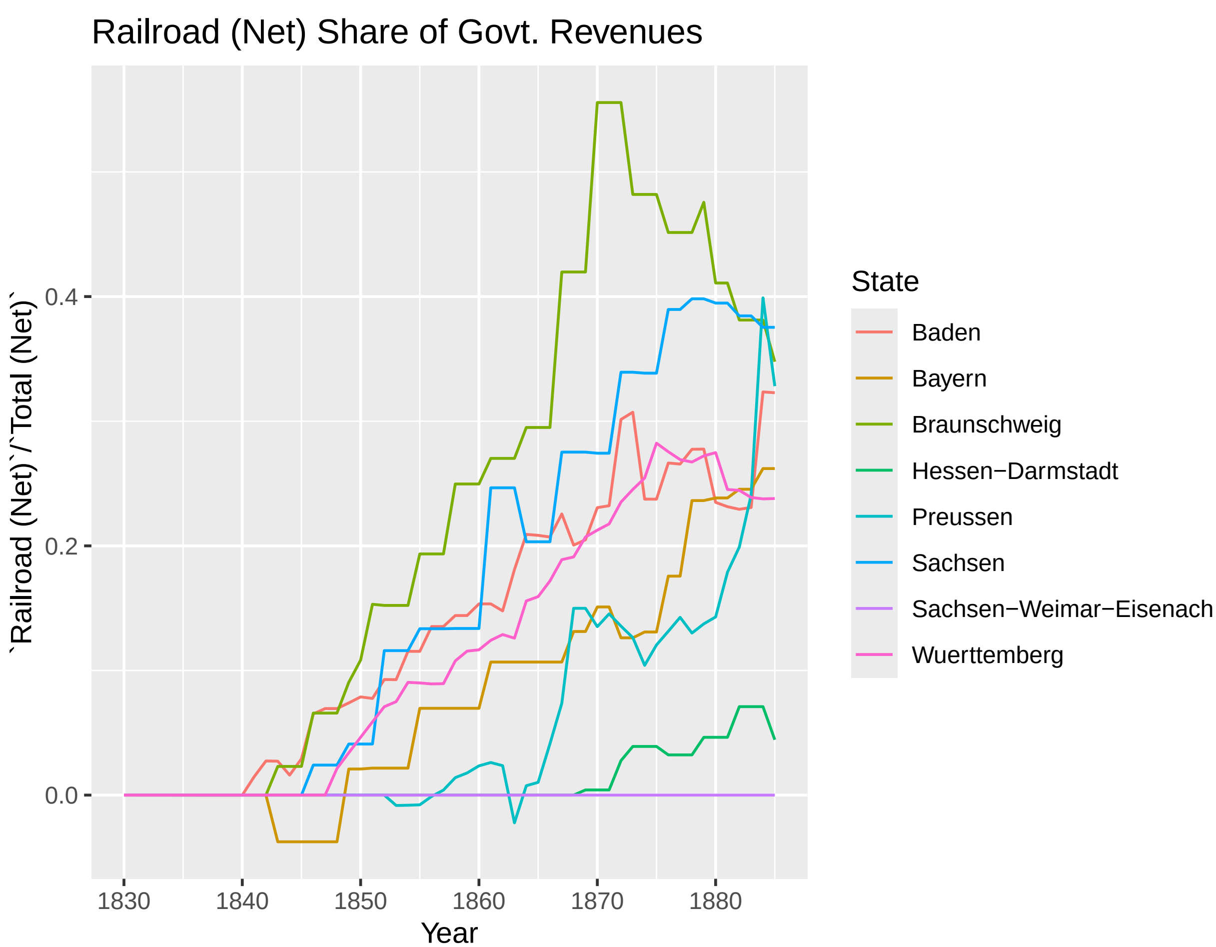



Figure 9: State Railroad Profit's Share of Government Revenues. Source: See Text.

hurdles.

In summary, the 19th century saw a great expansion and sophistication of the German states' fiscal apparatuses. The old tax system relied on unpredictable and impersonal extraordinary taxes. New, modern institutions, as well as an expanding bureaucracy facilitated regular taxation that was increasingly tied to actual economic activity. Along with increased taxes, governments increasingly applied their skills managing domain assets to the expansion of public enterprise. Most important among these public enterprises by far was the railroad, which contributed directly and significantly to most states' budgets.

## Empirical Strategy

My theoretical framework begins with the assumption that railroad construction follows a partial adjustment model.[19] In this framework, the state acts as a planner who observes the current state of the economy then decides what the optimal railword network size is. The state also has final say of how many railroad miles may be built. Private actors are able to make proposals, but ultimately the existence of all lines must be approved by the state. Thus, the evolution of the network is described by a single primitive function:

$$R^*_{i,t} = \beta_0 + BX_{i,t} + \alpha_i + \nu_t + \epsilon_{i,t}$$

However, because proposing and constructing new lines is time consuming and furthermore there may not be sufficient capital to construct all the desired lines, the state does not instantly move to its preferred number of railroad miles $R^*_{i,t}$. Instead, the network will partially adjust with speed $\delta$ according to the following relationship:

$$R_{i,t} - R_{i,t-1} = \delta(R^*_{i,t} - R_{i,t-1})$$

Substitution results in the standard estimating equation for partial adjustment models

[19] My approach is similar to the model used in Bignon, Esteves, and Herranz-Loncán (2015) .

(which is typically then log transformed):

$$R_{i,t} - R_{i,t-1} = \delta\beta_0 - \delta R_{i,t-1} + \delta BX_{i,t} + \delta\alpha_i + \delta\nu_t + \delta\epsilon_{i,t}$$

Recall that so far I have classified railroad miles as “(local) State”,”Other (State)“, and”Private”, according to their ownership and whether they were located in the state that owned them. To emphasize that states must make a decision to either construct miles through their own enterprises or grant concessions to outside actors, I group “Other” and “Private” into “Non-State”. To model this decision to assign desired miles to State or Non-state lines I approximate the log-differenced partial adjustment model with a growth rate that can be disaggregated without changing the interpretation across models:[20]

$$log(R_{i,t}) - log(R_{i,t-1}) \approx \frac{NewMiles^Y_{i,t}}{R^{Total}_{i,t-1}}$$

Where $NewMiles^Y_{i,t}$ is the number of miles constructed during year $t$ by $Y \in \{Total, State, NonState\}$ firms. It is important to note that this measure only captures changes due to construction of new lines. Nationalizations are not considered new state miles. This is a deliberate choice, since the majority of nationalizations prior to 1885 were due to exogenous political shocks and not revenue concerns (as discussed above). Thus, we can write the baseline specification being estimated as follows:

$$\frac{NewMiles^Y_{i,t}}{R^{Total}_{i,t-1}} = \delta\beta_0 - \delta R_{i,t-1} + \delta\beta_1 Govt.Rev_{i,t-1} + \delta\beta_2 Population_{i,t-1} + \delta\alpha_i + \delta\nu_t + \delta\epsilon_{i,t}$$

The variable of interest across specifications is $Govt.Rev_{i,t-1}$, which is measured either as the sum of all government revenues less collection costs, or a disaggregated measure that separately estimates the effect of profits from state railroad enterprises.

To ensure that the LHS accurately approximates the log-differences and to limit the

[20] That is to say, $ln(A+B) - ln(C) \neq ln(A) - ln(C) + ln(B) - ln(C)$ whereas $\frac{a+b}{c} = \frac{a}{c} + \frac{b}{c}$.

influence of outliers, we do not want to include years where $\frac{NewMiles_{i,t}^{Total}}{R_{i,t-1}^{Total}} > 1$, as relatively small amounts of construction can lead to abnormally large expansion rates in the early years of construction. We also do not want values from these years to be used as instruments, so the final sample begins with the fifth year after the last year with a growth rate greater than one. The median number of years dropped is 13 and the max is 16. Less than 8% of total mileage was constructed in the omitted years. It is also more believable that $\delta$ had a consistent value over this shortened period.

# Summary Statistics

[Note: These tables are from an older draft that did not include budget data from Hessen-Darmstadt or data on debt and need to be updated. They should also be adjusted so that both summarize the final sample, and not the data before dropping early years. I apologize for the inconvenience.]

## Railroad Ownership

The construction of the original dataset used to track how the development of public and private railroad networks differed is detailed in Section @ref(public-and-private-railways). With this data, I construct a panel of railroad miles constructed by each company in each state, as well as a running measure of what percentage of existing mileage is owned by each set of actors in any given year. This running measure of mileage is adjusted to account for nationalizations, privatizations, and annexations so that $Miles_t - Miles_{t-1}$ can be different from $NewMiles_t$ which only measures construction. Summary statistics for the total construction and the expansion rates ($\frac{NewMiles_{i,t}^{Y}}{Miles_{i,t-1}^{Total}}$) before dropping any years to remove abnormally high values are displayed in Table 2. Summary statistics for individual states are included in Appendix 2.

Table 1: Summary Statistics: Railroad Construction

| Statistic | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| NewMiles_JSC | 291 | 35.89 | 91.58 | 0.00 | 659.08 |
| NewMiles_LB | 291 | 22.08 | 46.90 | 0.00 | 405.72 |
| NewMiles_O | 291 | 1.25 | 6.21 | 0.00 | 74.21 |
| NewMiles_Total | 291 | 59.22 | 117.73 | 0.00 | 810.44 |
| TotalRate | 291 | 0.07 | 0.11 | 0.00 | 0.65 |
| StateRate | 291 | 0.03 | 0.08 | 0.00 | 0.45 |
| NonStateRate | 291 | 0.04 | 0.09 | 0.00 | 0.65 |

## Public Finance

The public finance data panel is generally balanced, with a few exceptions. In the sample period from 1835 to 1885, only 23/357 rows are missing total net income data. Because there is generally no reason not to, I interpolate the missing values. This is most likely generally harmless, although there is likely some upward bias from interpolating the often missing budgets of 1848-1849. Summary statistics for the unbalanced data after interpolation and after dropping early outlier years are presented in Table 3.

Table 2: Summary Statistics: Public Finance and Economic Activity

| Statistic | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| Direct.Tax..Net. | 291 | 21,063,864 | 34,774,119 | 959,907 | 151,563,350 |
| Indirect.Tax..Net. | 291 | 18,184,597 | 24,208,239 | 297,745 | 104,063,607 |
| Railroad..Net. | 291 | 9,707,915 | 21,159,754 | −6,978,822 | 202,458,916 |
| Total..Net. | 291 | 78,216,366 | 114,004,757 | 2,072,883 | 617,007,982 |
| Population | 291 | 4,769,998 | 7,283,822 | 258,500 | 28,318,470 |

Sources: Population from Kunz and Zipf (2008)
See text for Public finance statistics

It is also important to include controls that account for the general level of economic and commercial activity, since these influence both the supply and demand for railroads, as well as the size of the tax base. I code a dummy variable for the common shocks of war. The war dummy variable is based on Clodfelter (2017), who mentions specifically the major participants in 19th century wars in Western Europe. The state of the economy is simply proxied by state population from Kunz and Zipf (2008).[21] Extensions use data on industrial production from the same source.

## Time Series Properties

[Need to change this to a footnote or appendix]

Preliminary tests using the Im-Pesaran-Shin test show that none of the main variables have a unit root when measured in logs except for debt service payments. However, after differencing the debt service series is also stationary.

## Identification Strategy

Because of the obvious feedback effects between railroads, the economy, and government revenues, OLS regression results are immediately suspect. To address the endogeneity problems, I adapt IV strategies from the dynamic panel modeling literature (the most common treatment of these methods can be found in Wooldridge (n.d.)). The identifying assumption is that the x variables are "sequentially exogenous", that is:

$$E(y_{i,t}|x_{i,t}, x_{i,t-1}, ..., x_{i,1}) = E(y_{i,t}|x_{i,t})$$

Put simply, this means that the history of x is irrelevant and y is fully determined by the current value of x. In my model of railroad construction, this means that the state does not care about past values of income and only cares about projected revenues in the year that construction is occurring. This assumption is violated in years with budget surpluses, but surpluses are in fact quite rare.

Because historical values of endogenous variables do not determine current values of y, but are good predictors of the current values of endogenous variables, this makes them valid

[21] Kunz also includes data on production of a subset of industrial goods, however, the limited sample of goods included leads to significant bias when trying to include this data, limiting its value in this application. Lack of good data on state level productivity remains a significant bottleneck for this project.

and appropriate instruments. The typical approach here is to use the so called Arellano and Bond estimator which maximizes the number of lagged values of endogenous variables. Due to the nature of my panel (N groups $<$ T years) this leads to an overidentification issue. Instead, I use only the values of endogenous variables from $t-3$ and $t-4$. Wald tests show that this is enough instruments to avoid a weak instrument problem while Sargan tests show that there are few enough to avoid overidentification.

# Results

## Baseline

Table 3 presents the baseline results when all government revenue sources are pooled. First, note that the coefficient on $TotalMiles_{i,t-1}$, which is the $\delta$ coefficient measuring the speed of convergence gives a very reasonable value. Each year, the network gets roughly 20% closer to its conditionally optimal size. The slight majority of this convergence is due to NonState construction, which is appropriate since private firms constructed slightly more than half of all miles constructed between 1835 and 1885.

Population does not seem to be a consistent driver of within-state variation in railroad construction in either direction, though this is perhaps unsurprising since population growth tended to be stable across Germany in this period, except in Prussia which experienced a major population shock after annexing Hanover and other states following the 1866 Austro-Prussian War.

Interestingly, government revenues do not have a significant relationship with overall railroad network growth rates. Even more surprisingly, the IV specification suggests a slightly negative relationship. One possibility is that a major driver of railroad construction was the need to raise government revenues. It is possible that as revenues increased this demand fell proportionally, since the constitutional structure of many German states tended to limit revenue generation to only what was needed to cover planned expenses.

The more interesting result appears in columns 3-6, which show how construction was allocated to state or nonstate actors. The results are highly significant and show that revenue increases led to a reduction in state construction and corresponding increase in nonstate construction. It appears that as government revenues increased, regular budget spending on state railroad firms was reduced in favor of granting subsidies or other support to private firms.

However, this is not the only explanation. Another explanation could be that as revenues increased, so did the ability of the state to raise debt. This idea is explored more in the next section. First, I consider what happens when disaggregating revenue into rail and non-rail sources.

We can see in Table 4 that disaggregating revenue tells a consistent but slightly more nuanced story. Nonrail incomes still seem to lead a switch from state to nonstate construction, further supporting the hypothesis that regular revenues were more easily used on subsidies or interest rate guarantees to support private construction than transferred to state firms. Rail incomes, unsurprisingly, predict increased state construction. The more profitable the state enterprise was, the more it expanded.

## Extension: Debt

Since railroad projects were exceptionally capital intensive projects, it is unreasonable to think that marginal year-to-year increases in the regular budgets of any German state would be sufficient to fund new railroad lines. Thus, any complete study of railroad construction should also account for the issuance of railroad debt, typically in the form of bonds.

Unfortunately, data on the debt of German states is limited. Laws for the sale of particular bonds were idiosyncratic, which makes data difficult to collect. Furthermore, none of the states here studied published figures for outstanding debt in their budget reports (although data for some years can be found in British statistical abstracts). The only consistent time series data available is data on debt servicing payments.

Table 3: Baseline Results

| Dependent Variables: | TotalRate | | StateRate | | NonStateRate | |
|---|---|---|---|---|---|---|
| | OLS | IV | OLS | IV | OLS | IV |
| Model: | (1) | (2) | (3) | (4) | (5) | (6) |
| *Variables* | | | | | | |
| $TotalMiles_{i,t-1}$ | -0.1991*** | -0.2346*** | -0.0742** | -0.1119*** | -0.1249*** | -0.1227** |
| | (0.0420) | (0.0505) | (0.0304) | (0.0282) | (0.0390) | (0.0463) |
| $Population_{i,t-1}$ | 0.0440 | 0.0200 | 0.0339 | 0.0242 | 0.0101 | -0.0042 |
| | (0.0697) | (0.0756) | (0.0426) | (0.0500) | (0.0538) | (0.0546) |
| $Govt.Rev_{i,t-1}$ | -0.0046 | -0.0217 | -0.0573*** | -0.0957*** | 0.0527** | 0.0740* |
| | (0.0382) | (0.0525) | (0.0206) | (0.0284) | (0.0260) | (0.0391) |
| War | -0.0295 | -0.0380 | -0.0053 | -0.0120 | -0.0242 | -0.0260 |
| | (0.0270) | (0.0298) | (0.0194) | (0.0190) | (0.0157) | (0.0193) |
| *Fixed-effects* | | | | | | |
| State | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| *Fit statistics* | | | | | | |
| Observations | 298 | 298 | 298 | 298 | 298 | 298 |
| $R^2$ | 0.43936 | 0.43551 | 0.25452 | 0.23810 | 0.51789 | 0.51683 |
| Within $R^2$ | 0.14527 | 0.13940 | 0.06478 | 0.04419 | 0.10486 | 0.10290 |

*Driscoll-Kraay (L=2) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*
Note: Italicized variables have been asinh transformed.

Table 4: Baseline Results - Disaggregated Income

| Dependent Variables: | TotalRate | | StateRate | | NonStateRate | |
|---|---|---|---|---|---|---|
| | OLS | IV | OLS | IV | OLS | IV |
| Model: | (1) | (2) | (3) | (4) | (5) | (6) |
| *Variables* | | | | | | |
| $TotalMiles_{i,t-1}$ | -0.2065*** | -0.2651*** | -0.0763** | -0.1408*** | -0.1302*** | -0.1243** |
| | (0.0492) | (0.0537) | (0.0285) | (0.0313) | (0.0428) | (0.0505) |
| $Population_{i,t-1}$ | 0.0365 | -0.0006 | 0.0103 | -0.0284 | 0.0262 | 0.0279 |
| | (0.0741) | (0.0929) | (0.0351) | (0.0596) | (0.0675) | (0.0659) |
| $NonRailIncome_{i,t-1}$ | 0.0113 | 0.0284 | -0.0336 | -0.0428 | 0.0449* | 0.0711* |
| | (0.0384) | (0.0679) | (0.0249) | (0.0477) | (0.0243) | (0.0412) |
| $RailIncome_{i,t-1}$ | 0.0008 | 0.0027 | 0.0004 | 0.0030*** | 0.0004 | -0.0003 |
| | (0.0016) | (0.0021) | (0.0009) | (0.0011) | (0.0014) | (0.0020) |
| War | -0.0234 | -0.0191 | -0.0076 | 0.0014 | -0.0158 | -0.0206 |
| | (0.0241) | (0.0328) | (0.0221) | (0.0290) | (0.0179) | (0.0254) |
| *Fixed-effects* | | | | | | |
| State | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| *Fit statistics* | | | | | | |
| Observations | 298 | 298 | 298 | 298 | 298 | 298 |
| $R^2$ | 0.44007 | 0.43219 | 0.24596 | 0.21584 | 0.51637 | 0.51399 |
| Within $R^2$ | 0.14636 | 0.13433 | 0.05405 | 0.01626 | 0.10204 | 0.09762 |

*Driscoll-Kraay (L=2) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*
Note: Italicized variables have been asinh transformed.

Including debt service payment data lead to additional empirical issues. To remain consistent with the baseline models and identification strategy, it would be necessary to include debt service payments in levels. However, this series has a unit root. Taking first differences resolves this problem, but introduces a weak instrument problem since lagged levels of the other variables in the system do not predict debt service differences.

Consequently, the only statistically valid approach is to treat differenced debt service payments as exogenous. Fortunately, this is not as strong an assumption as it might seem at first glance. There are many arguments in the literature that the main determinant of early modern states' ability to issue debt was institutional. That is, politics and institutions constraining the state and demonstrating a commitment to repay debt may have been more important for determining the ability to issue debt than actual revenue streams. Furthermore, debt is much more dependent on the state of international financial markets. Barring any serious deficit crisis, the decision to issue new bonds might therefore be plausibly exogenous and determined more by the political will of the government to issue debt and its perceived credibility to not default. Regressions based on this assumption are presented in Tables 5 and 6.

Again, the results suggest that as government revenues increased, there was a shift away from state construction towards nonstate construction. The magnitude of these estimates is similar to those in Tables 3 and 4.

The coefficient on $\Delta Debt$ is positive and significant. If bonds were being issued faster than they were being paid off, this predicts an increase in state railroads. Of course, since a large proportion of the increase in state debt service payments was the issuance of bonds specifically to fund railroad construction, this relationship is largely mechanical.

The results here are still preliminary, and a more detailed exploration of the relationship between government revenues and debt is required.

Table 5: Exogenous Debt Results

| Dependent Variables: | TotalRate | | StateRate | | NonStateRate | |
|---|---|---|---|---|---|---|
| | OLS | IV | OLS | IV | OLS | IV |
| Model: | (1) | (2) | (3) | (4) | (5) | (6) |
| *Variables* | | | | | | |
| $TotalMiles_{i,t-1}$ | -0.1999*** | -0.2335*** | -0.0756** | -0.1114*** | -0.1243*** | -0.1221** |
| | (0.0419) | (0.0504) | (0.0303) | (0.0285) | (0.0391) | (0.0463) |
| $Population_{i,t-1}$ | 0.0439 | 0.0211 | 0.0337 | 0.0254 | 0.0102 | -0.0043 |
| | (0.0699) | (0.0758) | (0.0429) | (0.0500) | (0.0539) | (0.0549) |
| $Govt.Rev_{i,t-1}$ | -0.0050 | -0.0251 | -0.0579*** | -0.1003*** | 0.0529* | 0.0752* |
| | (0.0378) | (0.0509) | (0.0197) | (0.0278) | (0.0264) | (0.0405) |
| $\Delta Debt_{i,t}$ | 0.0135 | 0.0169 | 0.0232 | 0.0273* | -0.0097 | -0.0104 |
| | (0.0174) | (0.0176) | (0.0138) | (0.0141) | (0.0197) | (0.0188) |
| War | -0.0303 | -0.0383 | -0.0066 | -0.0127 | -0.0237 | -0.0255 |
| | (0.0267) | (0.0294) | (0.0193) | (0.0189) | (0.0156) | (0.0194) |
| *Fixed-effects* | | | | | | |
| State | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| *Fit statistics* | | | | | | |
| Observations | 298 | 298 | 298 | 298 | 298 | 298 |
| $R^2$ | 0.43968 | 0.43599 | 0.25707 | 0.24028 | 0.51811 | 0.51697 |
| Within $R^2$ | 0.14575 | 0.14014 | 0.06798 | 0.04693 | 0.10527 | 0.10315 |

*Driscoll-Kraay (L=2) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Note: Italicized variables have been asinh transformed.

Table 6: Exogenous Debt Results - Disaggregated Income

| Dependent Variables: | TotalRate | | StateRate | | NonStateRate | |
|---|---|---|---|---|---|---|
| | OLS | IV | OLS | IV | OLS | IV |
| Model: | (1) | (2) | (3) | (4) | (5) | (6) |
| *Variables* | | | | | | |
| $TotalMiles_{i,t-1}$ | -0.2073*** | -0.2622*** | -0.0778*** | -0.1384*** | -0.1296*** | -0.1239** |
| | (0.0490) | (0.0541) | (0.0284) | (0.0313) | (0.0429) | (0.0503) |
| $Population_{i,t-1}$ | 0.0360 | -0.0002 | 0.0094 | -0.0290 | 0.0266 | 0.0288 |
| | (0.0738) | (0.0917) | (0.0362) | (0.0593) | (0.0678) | (0.0668) |
| $NonRailIncome_{i,t-1}$ | 0.0104 | 0.0241 | -0.0352 | -0.0502 | 0.0456* | 0.0743* |
| | (0.0379) | (0.0662) | (0.0236) | (0.0452) | (0.0248) | (0.0425) |
| $RailIncome_{i,t-1}$ | 0.0008 | 0.0026 | 0.0004 | 0.0029*** | 0.0004 | -0.0003 |
| | (0.0016) | (0.0021) | (0.0009) | (0.0011) | (0.0014) | (0.0020) |
| $\Delta Debt_{i,t}$ | 0.0131 | 0.0163 | 0.0242* | 0.0297* | -0.0111 | -0.0134 |
| | (0.0169) | (0.0172) | (0.0144) | (0.0152) | (0.0207) | (0.0188) |
| War | -0.0241 | -0.0204 | -0.0089 | -0.0007 | -0.0152 | -0.0197 |
| | (0.0239) | (0.0325) | (0.0223) | (0.0294) | (0.0181) | (0.0255) |
| *Fixed-effects* | | | | | | |
| State | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| *Fit statistics* | | | | | | |
| Observations | 298 | 298 | 298 | 298 | 298 | 298 |
| $R^2$ | 0.44037 | 0.43348 | 0.24873 | 0.22080 | 0.51666 | 0.51401 |
| Within $R^2$ | 0.14681 | 0.13630 | 0.05752 | 0.02249 | 0.10258 | 0.09765 |

*Driscoll-Kraay (L=2) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*
Note: Italicized variables have been asinh transformed.

## Extension: Alternate Economy Measures

Section Forthcoming.

Population is only a rough proxy of economy growth, and one that becomes increasingly inappropriate over the 19th century due to the widening gap in labor productivity between industry and agriculture. Unfortunately, GDP measures are not available at the state level for any state besides Prussia. The only extant data tracks the output of certain key industrial metals and minerals, but does not cover any manufacturing, and is thus a biased measure of economic growth.

A second possibility is to construct a gravity model based on the exposure of the different states to Germany's main trading partner: the UK.

## Robustness Check: Leave One Out Regressions

Section Forthcoming.

Because the panel is low N (only 8 states), there is a significant risk of the results being driven by outliers. Leave one out regressions show that magnitudes are somewhat sensitive, but signs do not change.

## Conclusion

Regular government revenues did not seem to be an important factor in determining the growth rate of railroads in German states (except perhaps through their effect on states' ability to borrow, which requires more study). However, revenue shocks do have the effect of making contemporaneous construction more private. I hypothesize that this is because revenue shocks were not large enough to fund new state owned railroad projects, but did allow the states to increase subsidies enticing private investment. Further study should explore how much private capital a subsidy can attract compared to the amount of debt service an equally sized revenue stream could support.

# Appendix 1: Comparing Public and Private Railway Performance

The firms for which there is at least one year of data in Fremdling and Kunz (2011) were responsible for building 75% of the railway mileage constructed between 1835 and 1885. The missing performance data is mostly in the band of Prussia between Schleswig-Holstein and Silesia. There are also significant sections of Saxony and the Bavarian Palatinate missing.

First, this appendix demonstrates that return on invested capital (ROIC) of state railways was significantly lower than private ones, as Figure 8 suggests. Table 12 shows that for each mark of capital invested in a state railway, two fewer marks of revenues would have been generated than by the same investment in a private railway. Note that ROIC says more about operational efficiency than on return on investment, since no data is available on subsidies or dividends.

Table 7: Firm Performance by Ownership

| Dependent Variable: | ROIC |
|---|---|
| Model: | (1) |
| *Variables* | |
| OwnershipLaenderbahnen | -1.972** |
| | (0.8650) |
| *Fixed-effects* | |
| Year | Yes |
| *Fit statistics* | |
| Observations | 1,813 |
| $R^2$ | 0.35332 |
| Within $R^2$ | 0.02545 |

*Clustered (Firm) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Efficiency can also be measured by looking at shipping revenues per ton-kilometer and passenger revenues per passenger-kilometer. These measures also tell us the average prices

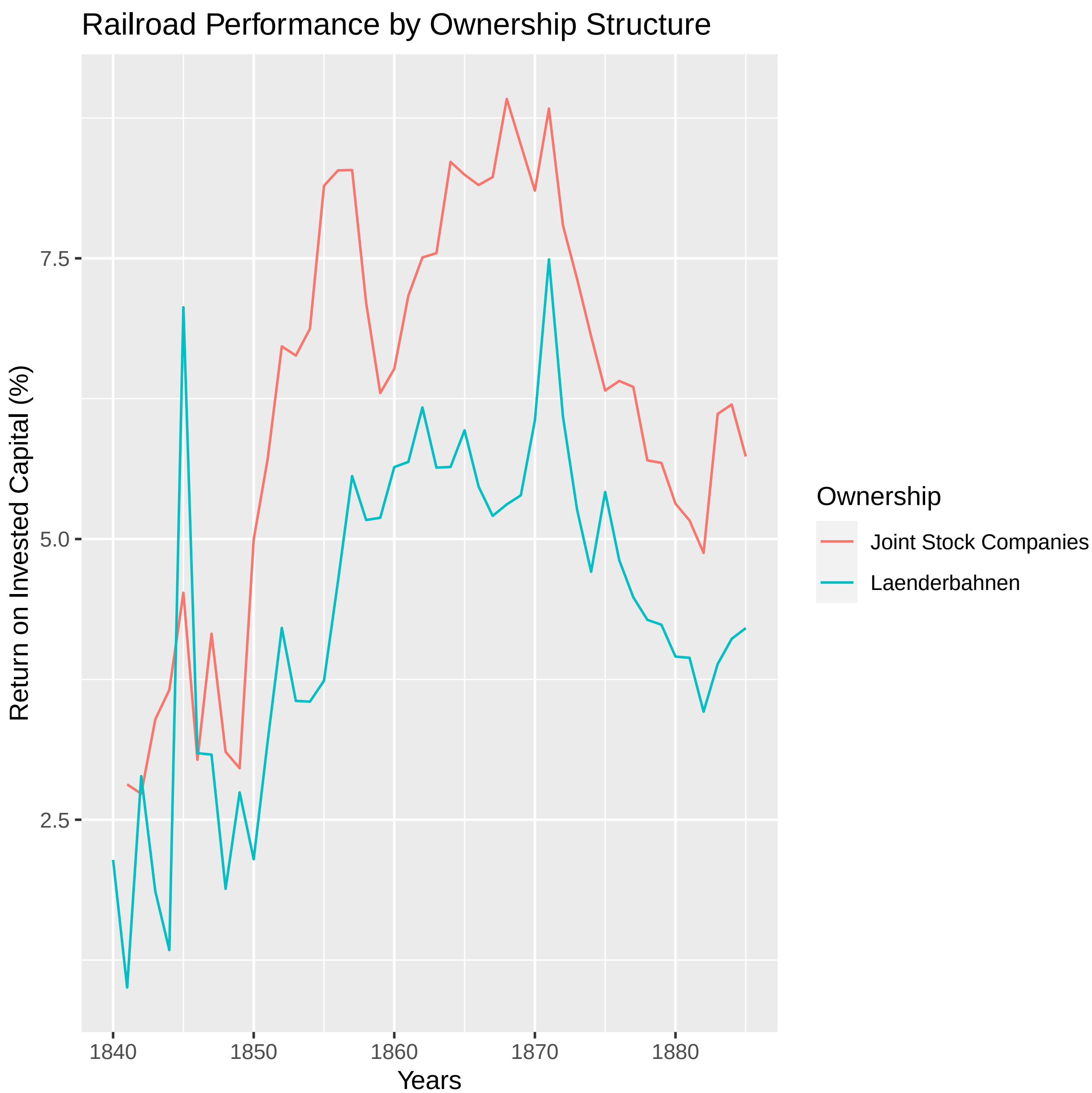
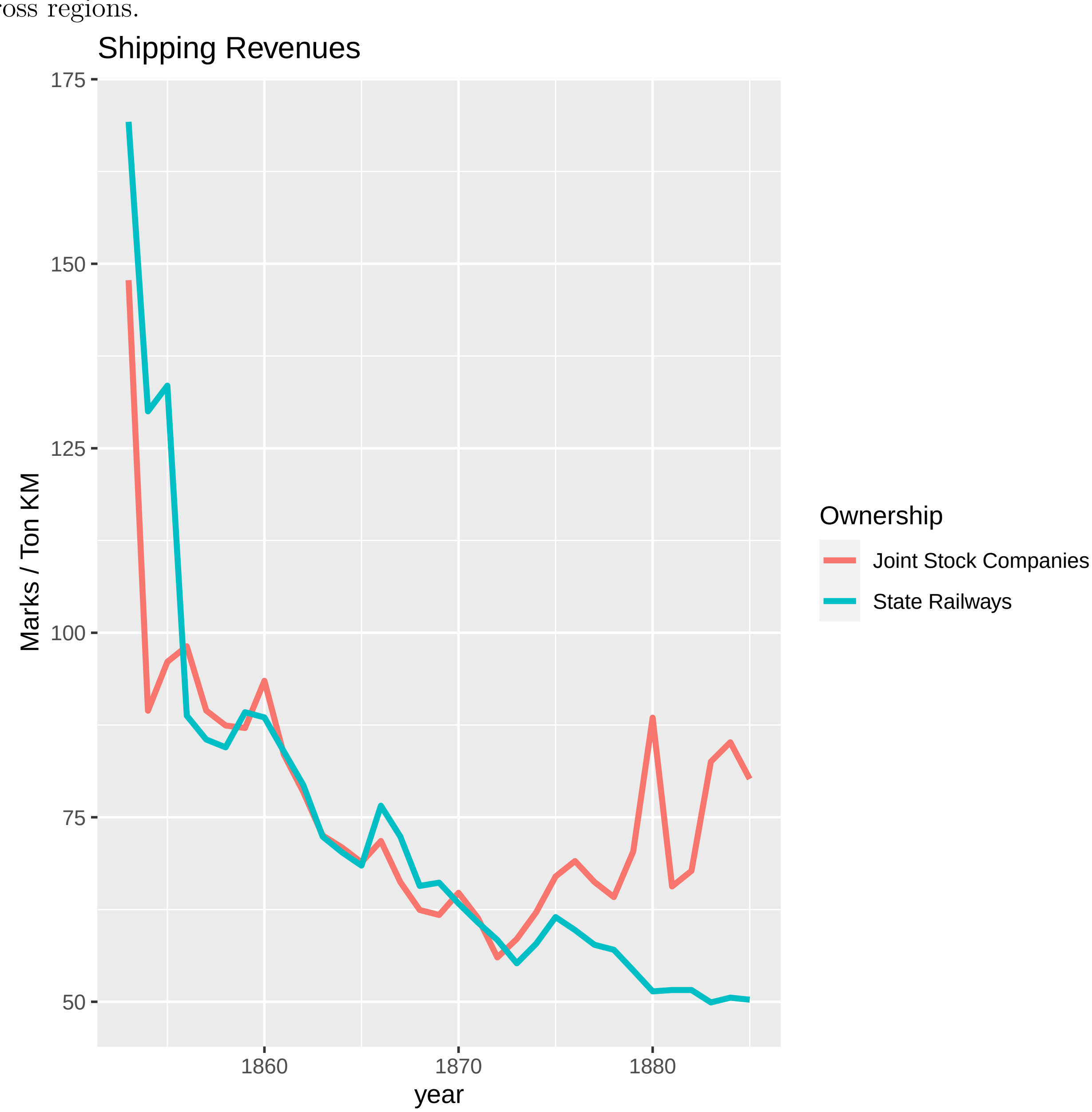
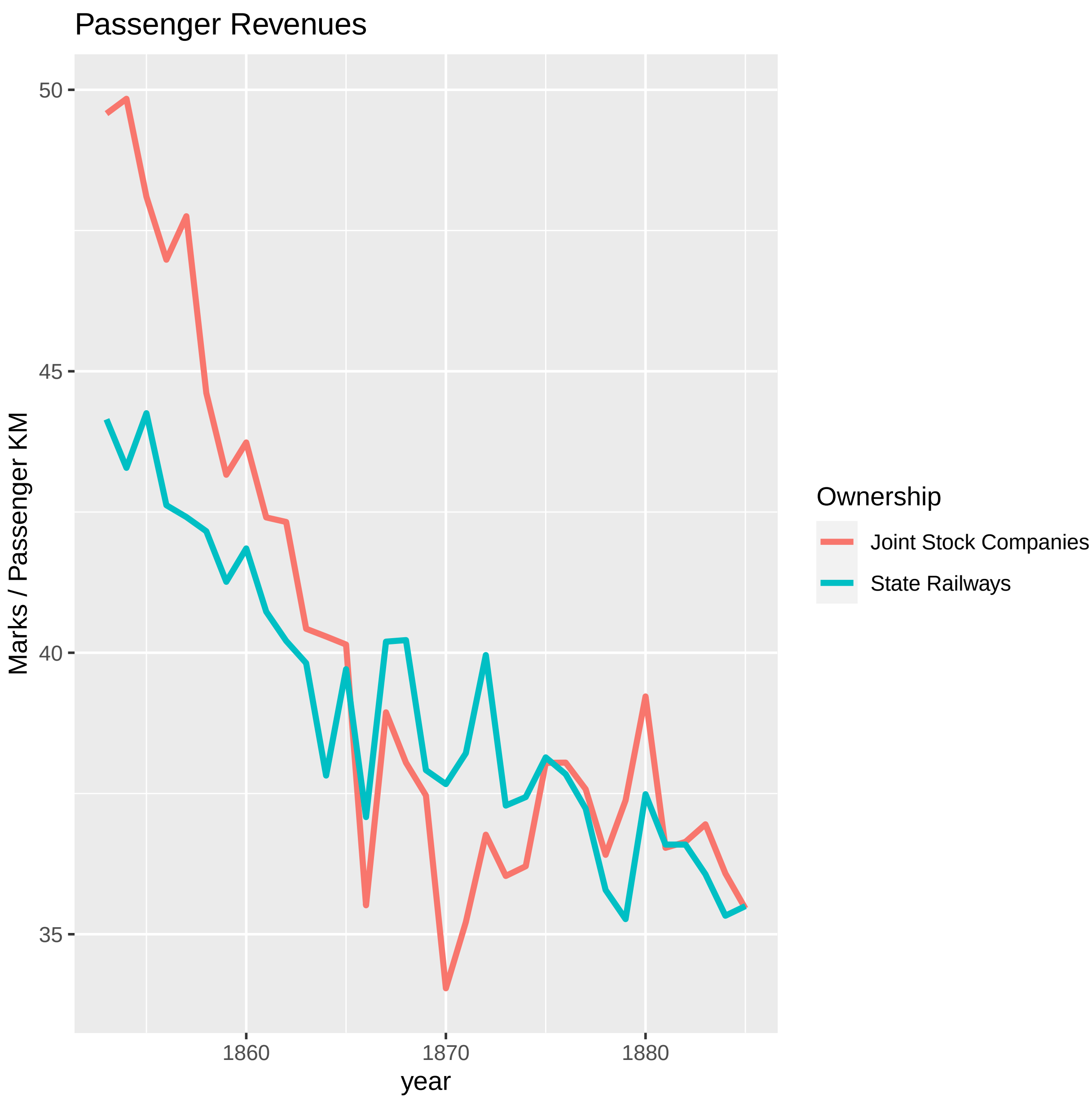



Figure 10: Comparison of the return on invested capital of public and private railroad companies. Source: See text.

customers would have faced when using the railways. Shipping revenues for state and private firms track each other closely, both falling steadily until the early 1870s, when the measure begins to increase private firms. This divergence increases as nationalizations occur, so the higher revenues may be due to the location of the few remaining private firms.

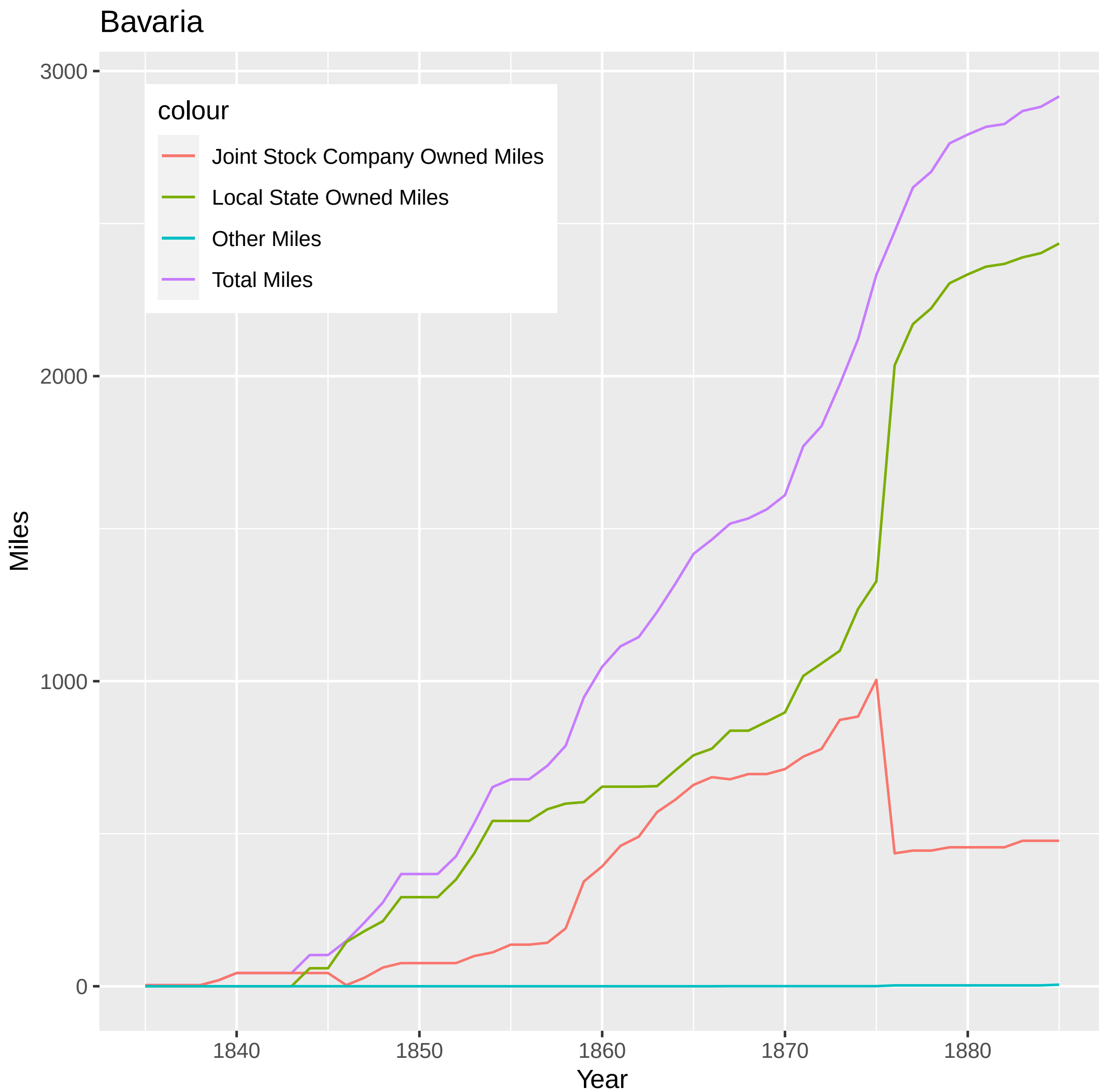
Gaps for passenger revenues are largest initially, but the absolute size of the gap is small: only about 5 marks per passenger-kilometer. By the 1860s this gap has vanished. This suggests that passenger travel rates were more competitive, or perhaps simply more similar across regions.




Passenger Revenues
50
45
40
35
Marks / Passenger KM
1860
1870
1880
year
Ownership
Joint Stock Companies
State Railways

# Appendix 2: Individual State Trajectories

## Bavaria




The Nuremberg-Fürth railway, the first German railroad, was built by (and remained for a long time) a private company. After 10 more years of mainly private construction, nearly all construction between 1845 and 1860 would be done by the state. From the late 1850s to 1875, there would be a resurgence in private construction in the eastern borderlands, the Palatinate, and Franconia while public construction remained dominant along the borders with Wuerttemberg. That the approach towards Franconia was similar to the approach to the Palatinate, despite its geographic proximity and contiguity with Bavaria, is interesting, and highlights the difficulties faced in integrating these regions highlighted by Segal (2019). 1875 would see the nationalization of all rail in Bavaria except the Palatine, which would remain the largest Private railway until 1909 when it was also nationalized.

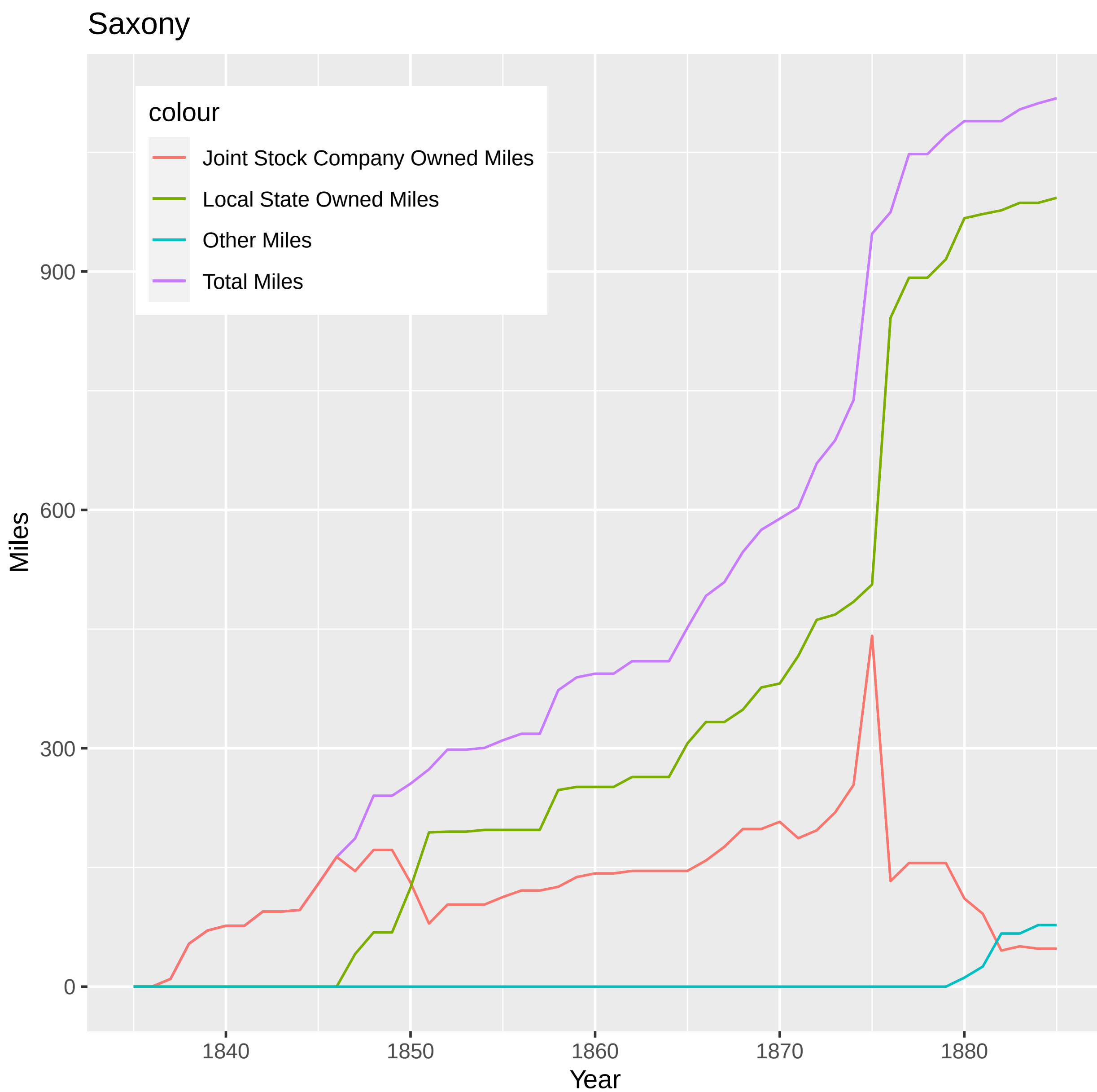
Independent railway management was perhaps more important to Bavaria than any other state. They refused to sign the constitution of the German Empire unless guaranteed "special priviliges", and one of the demands was the continued sovereignty of the Bavarian State Railway.

Table 8: Expansion Rates: Bavaria

| Statistic | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| lag5NonStateRate | 51 | Inf.00 | | 0.00 | Inf.00 |
| lag6NonStateRate | 51 | Inf.00 | | 0.00 | Inf.00 |
| lag1NetTaxRev | 55 | 45,704,556.00 | 16,835,583.00 | 26,439,396.00 | 82,788,498.00 |

Sources: Derived by author from Kunz and Zipf (2008) and Dumjahn (1984).

## Saxony




After 10 years of exclusively private construction, Saxony nationalized the Saxon-Bavarian and Saxon-Silesian railway companies due to their financial insolvency. Public and private construction would continue at similar rates until total nationalization in 1876.

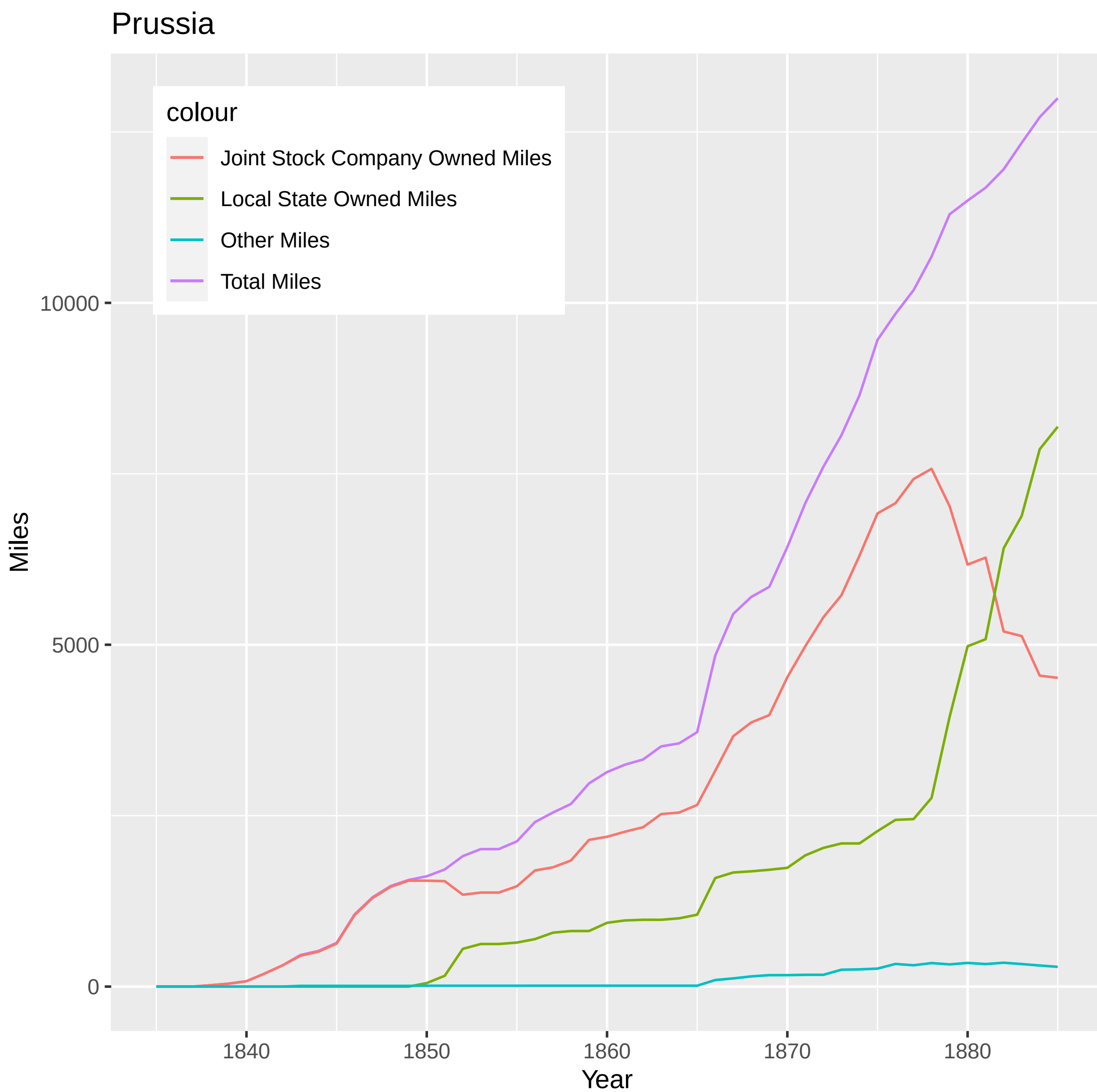
The Saxon case is of particular interest, because even though the first rail was built in Bavaria, Saxon planners and financiers were heavily involved in most early railroad plans (Beyer 1978).

Table 9: Expansion Rates: Saxony

| Statistic | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| lag5NonStateRate | 49 | Inf.00 | | 0.00 | Inf.00 |
| lag6NonStateRate | 49 | Inf.00 | | 0.00 | Inf.00 |
| lag1NetTaxRev | 52 | 17,637,833.00 | 4,963,823.00 | 12,269,020 | 29,879,823 |

Sources: Derived by author from Kunz and Zipf (2008) and Dumjahn (1984).

## Prussia




Mitchell (2000) emphasizes that Prussia was much more committed to liberalism than any of the other German states, and this is why the first 1000 miles of railroad would all be by private firms. There were no public railroads until 1850, when Prussia stepped in to manage railroads in the Saarland and the connections to the Palatinate. In 1851, public railroad construction would begin at a much larger scale in East Prussia. The first nationalization would be in 1852, of the Lower Silesian railway.

The pattern that emerges is that public railroads initially emerged in areas with significant strategic concern, as well as significant exports. Interestingly, even in the Rhineland, where JSCs dominated, the state railways managed the connections into Hesse and Hannover. This is a contrast to the connections through smaller states in central Germany and Thuringia, which tended to be handled by JSCs based in Prussia. Despite this increase in public construction, JSCs still dominated and their rate of growth was faster into the 1870s.

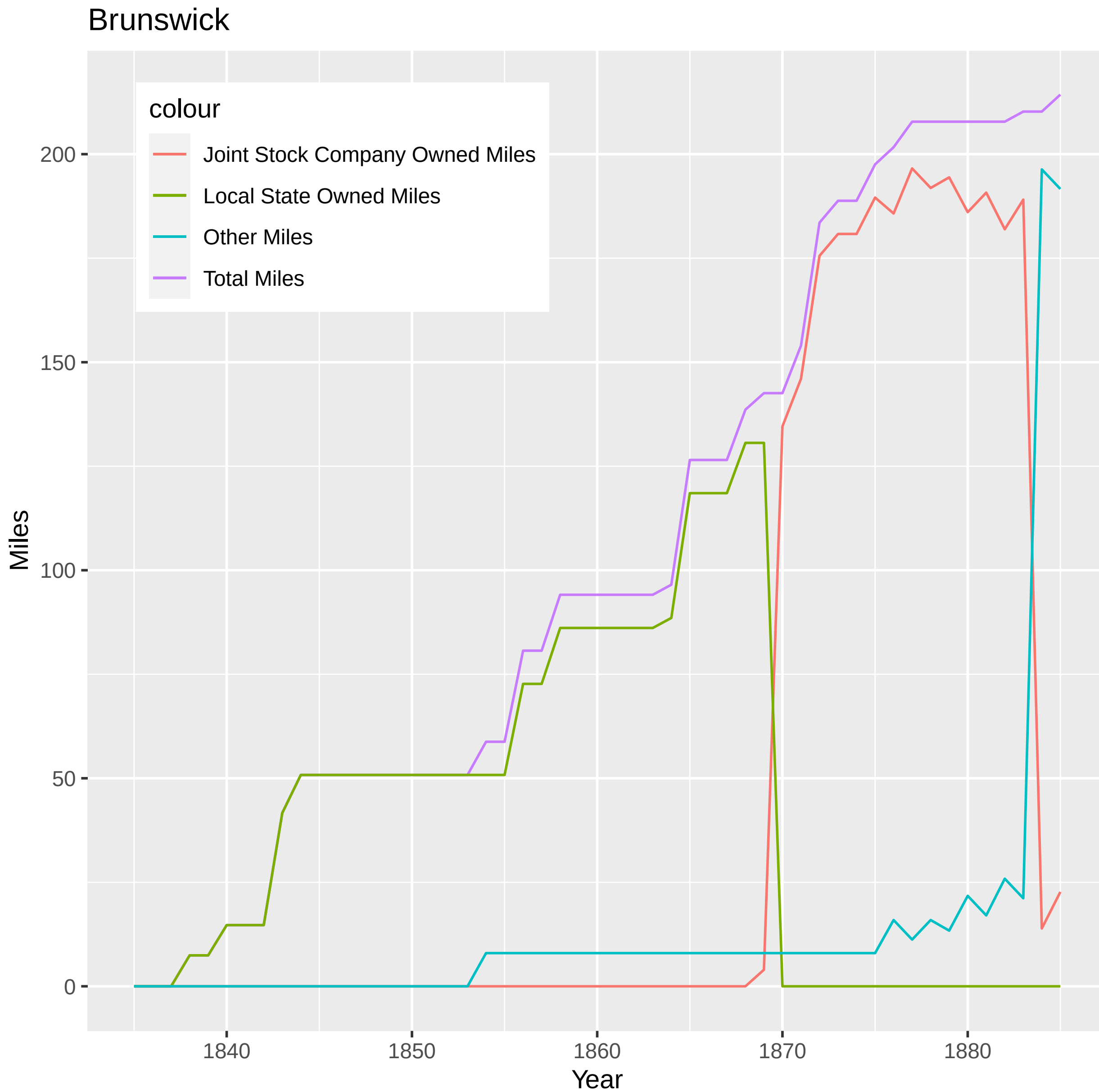
Nationalizations begin in 1875, and by 1879 JSCs are being nationalized faster than they can expand. Nationalization continues to accelerate until 1886, when nearly all remaining lines are nationalized; over 3000 miles were nationalized in one year.

Table 10: Expansion Rates: Prussia

| Statistic | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| lag5NonStateRate | 48 | Inf.00 | | 0.00 | Inf.00 |
| lag6NonStateRate | 48 | Inf.00 | | 0.00 | Inf.00 |
| lag1NetTaxRev | 65 | 143,182,545.00 | 25,878,625.00 | 107,573,550.00 | 195,824,640.00 |

Sources: Derived by author from Kunz and Zipf (2008) and Dumjahn (1984).

## Brunswick




100% state operated until the 1850s, when a small portion of mileage owned and operated by Hannover is allowed. All remaining construction is by the Brunswick State railway until the late 1860s, when some JSC activity occurs.

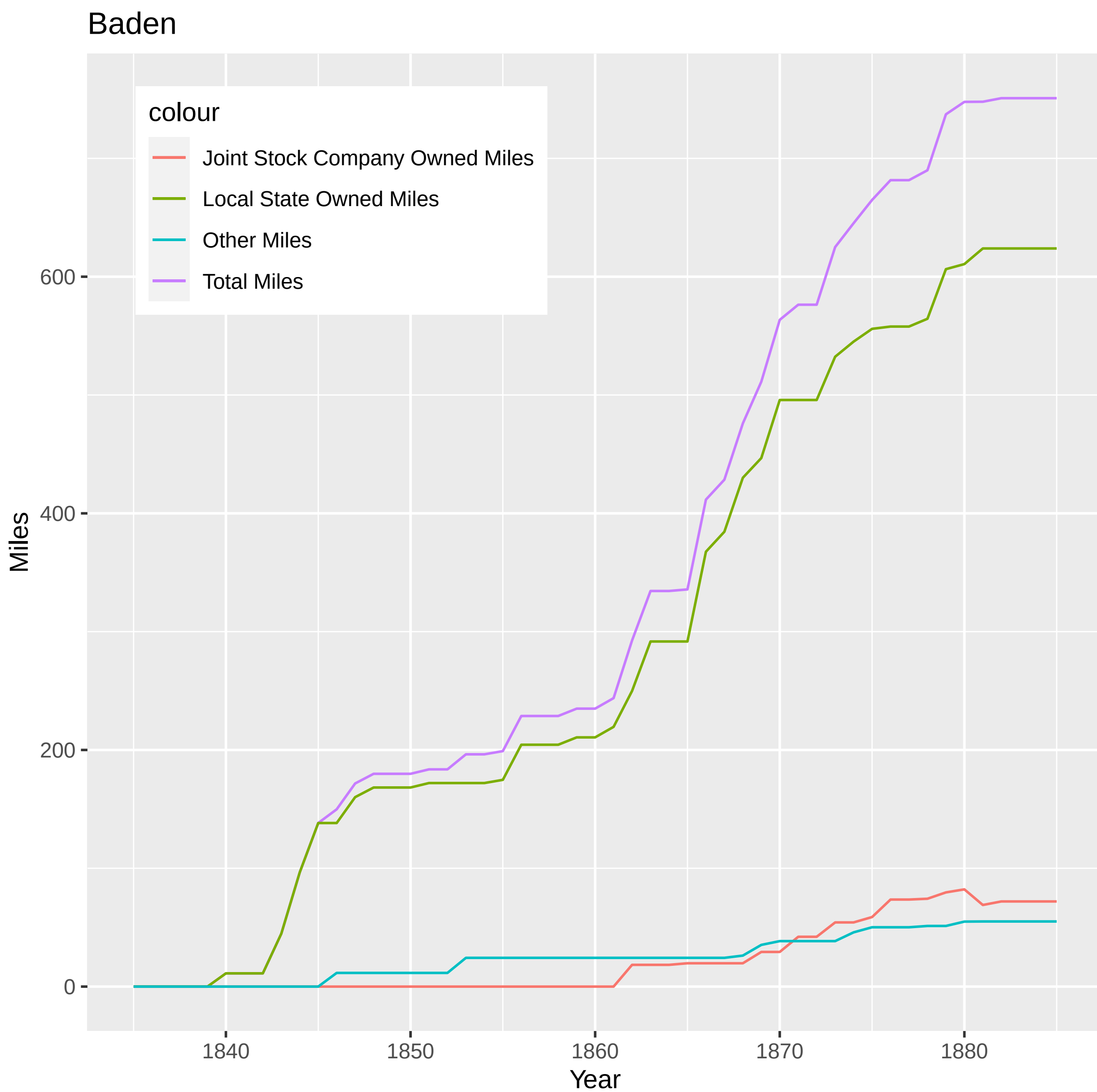
The Brunswick State Railway was privatized in 1870 (see Kleeberg (1990) for reasoning), then purchased by Prussia in 1884.

Table 11: Expansion Rates: Brunswick

| Statistic | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| lag5NonStateRate | 47 | 0.01 | 0.04 | 0.00 | 0.19 |
| lag6NonStateRate | 47 | 0.01 | 0.04 | 0.00 | 0.19 |
| lag1NetTaxRev | 54 | 2,717,574.00 | 364,418.70 | 1,981,192 | 3,162,000 |

Sources: Derived by author from Kunz and Zipf (2008) and Dumjahn (1984).

## Baden



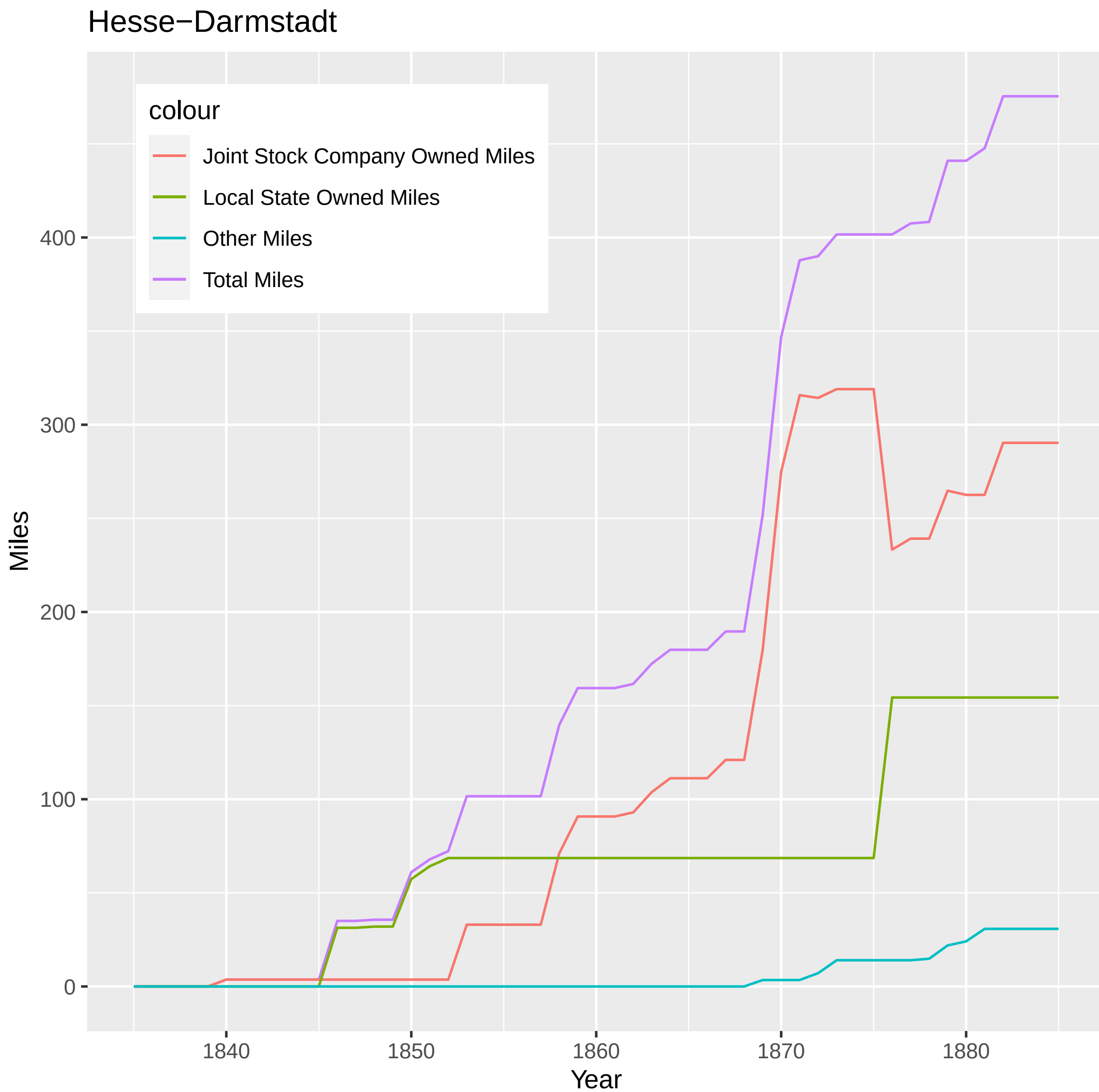

First 150 miles were all constructed by the Baden State Railway, and nearly all subsequent miles were as well. Baden does have an above average amount of municipal railways (Karlsruhe, Mannheim, Freiburg & Altbreisach, and Waldkirch). Baden is also noteworthy for being the only state to initially adopt a non-standard gauge, but did eventually switch to conform to the rest of Germany.

Table 12: Expansion Rates: Baden

| Statistic | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| lag5NonStateRate | 45 | 0.01 | 0.02 | 0.00 | 0.08 |
| lag6NonStateRate | 45 | 0.01 | 0.02 | 0.00 | 0.08 |
| lag1NetTaxRev | 66 | 12,903,344.00 | 4,074,955.00 | 7,119,943.00 | 21,195,067.00 |

Sources: Derived by author from Kunz and Zipf (2008) and Dumjahn (1984).

## Hesse-Darmstadt




One of the few cases where JSCs dominated. First miles were JSC, and except for a short stint from 1845-1857, JSCs owned the majority of railway miles. Even after the nationalization of the Upper Hessian company, JSCs remained the major player.

Caveat: I treat the Main-Neckar railway as being one of the state railways of Hessen-Darmstadt, however this is not entirely true. It was grouped with state railways by contemporaries (*Deutsche Eisenbahn Statistik Für Das Betriebs-Jahr 1850* 1851), but the headquarters was placed in Hessen-Cassel, although there is a note that it was jointly administered by Hessen-Cassel, Hessen-Darmstadt, and Frankfurt. However, Dumjahn (1984) does not mention the Main-Neckar company by name, and instead treats it as a state railway, noting only whether particular lines were constructed by “Hessen”, “Hessen and Frankfurt”, or “Hessen und Kurhessen”[22] Because none of the lines attributed solely to Hesse-Cassel lay within Hessen-Darmstadt, treating remainder as the state rail of Hessen-Darmstadt seems accurate, except to the extent that Frankfurt was involved.

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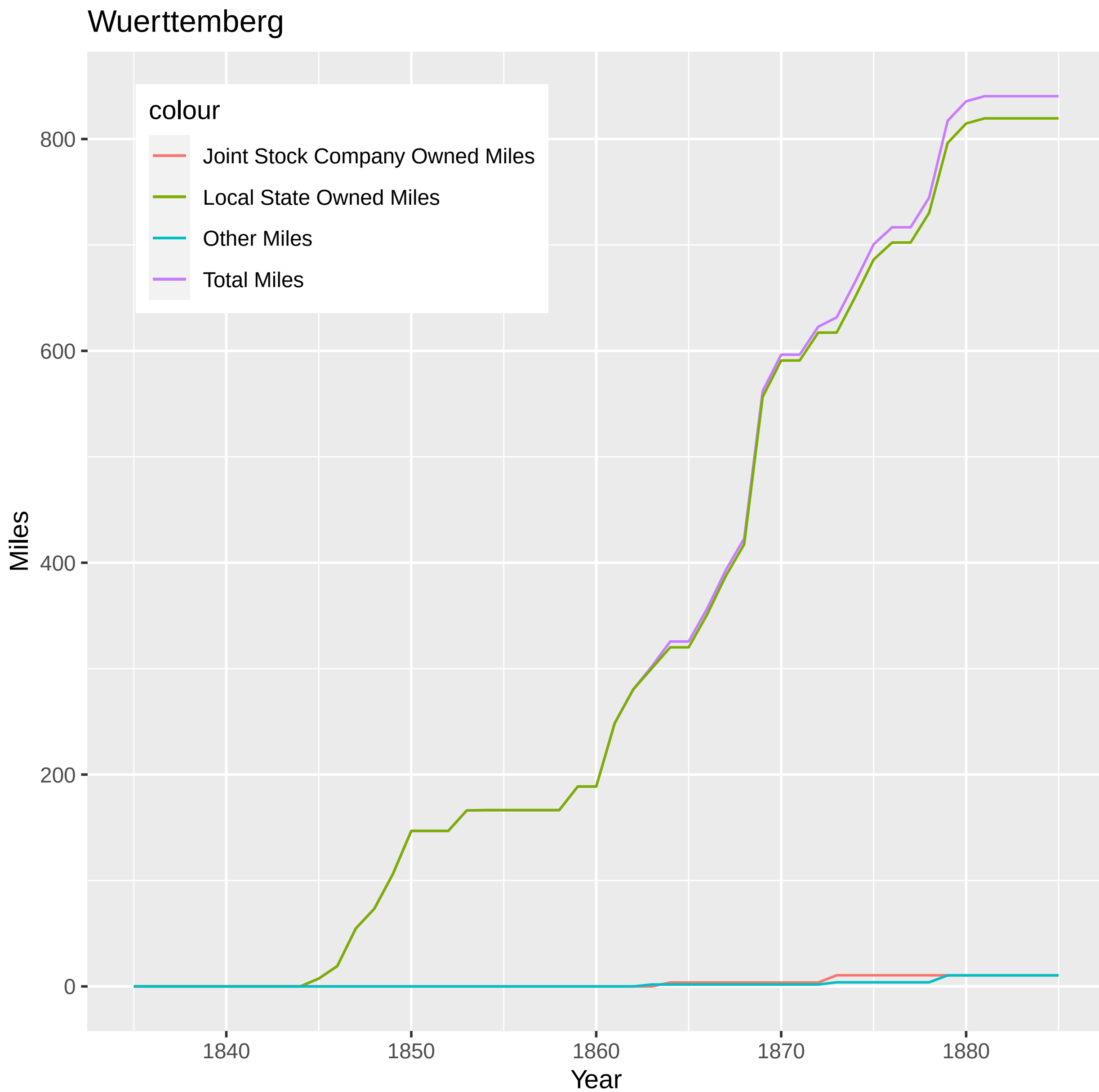
[22] In this context, Hessen refers to Hesse-Darmstadt and Kurhessen to Hesse-Cassel.

## Wuerrtemberg



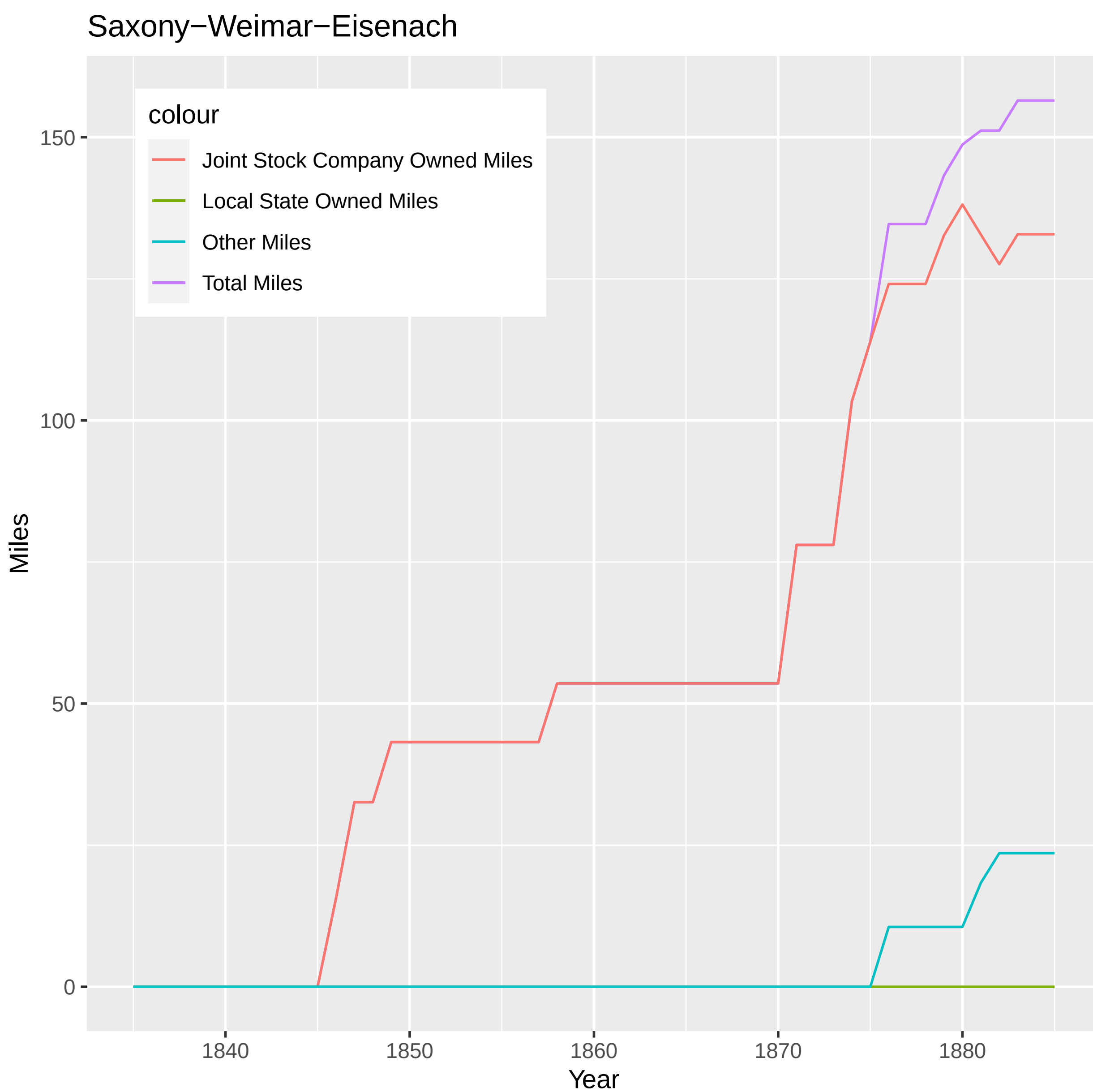

The purest example of a state system. Only two short lines operated by JSCs, and the “Other” miles are rounding errors from border crossings. Hoffman (1969) explains why.

Table 13: Expansion Rates: Wuerttemberg

| Statistic | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| lag5NonStateRate | 40 | 0.001 | 0.003 | 0.00 | 0.01 |
| lag6NonStateRate | 40 | 0.001 | 0.003 | 0.00 | 0.01 |
| lag1NetTaxRev | 57 | 15,152,691.00 | 5,848,095.00 | 8,697,646.00 | 27,857,865.00 |

Sources: Derived by author from Kunz and Zipf (2008) and Dumjahn (1984).

## Saxony-Weimar-Eisenach



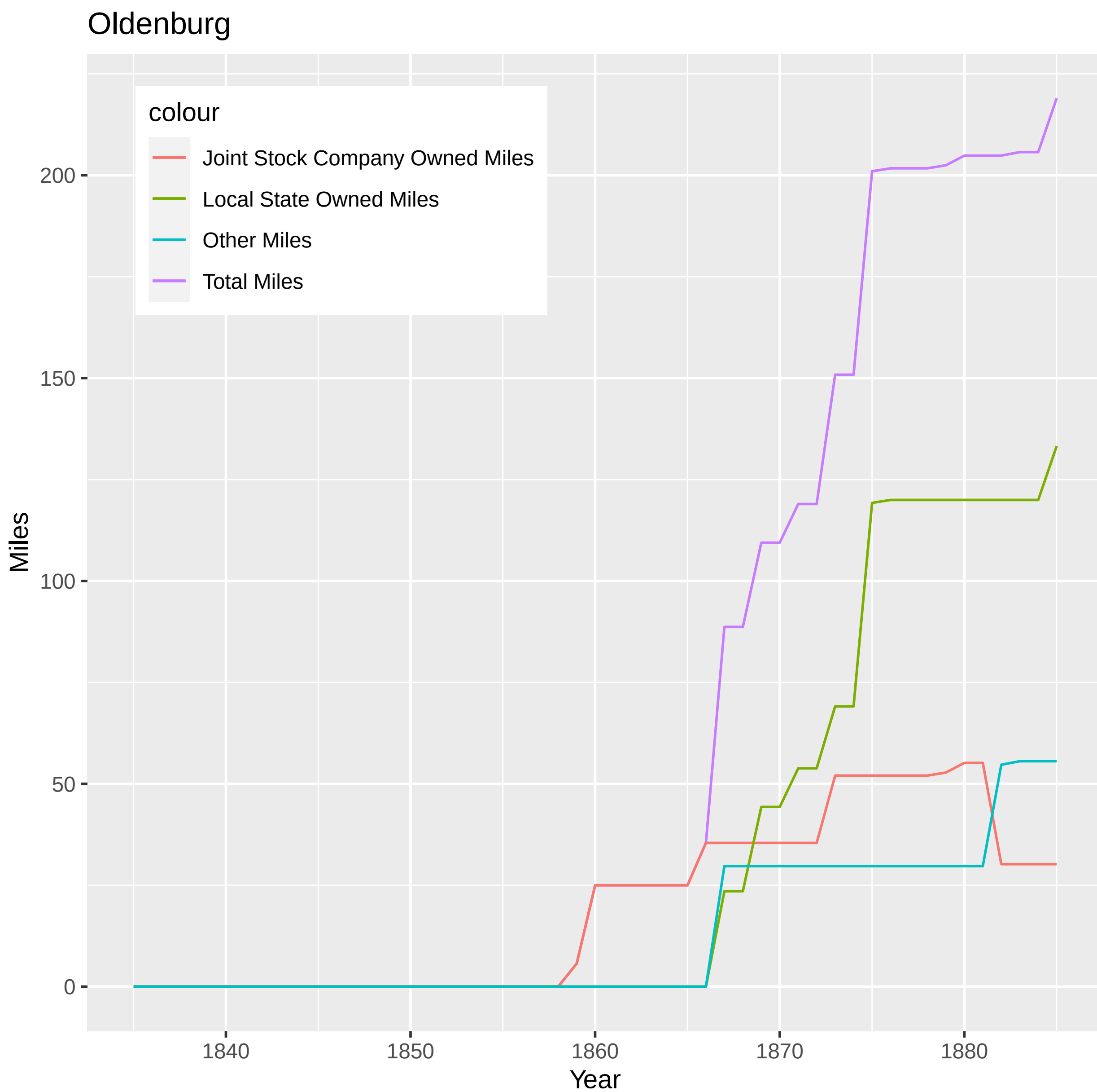

The only state in the sample which seems to have never operated its own railway. Almost all construction is by JSCs, except for a small section operated by the neighboring state of Schwarzburg-Sondershausen.

Table 14: Expansion Rates: Saxony-Weimar-Eisenach

| Statistic | N | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| lag5NonStateRate | 40 | Inf.00 | | 0.00 | Inf.00 |
| lag6NonStateRate | 40 | Inf.00 | | 0.00 | Inf.00 |
| lag1NetTaxRev | 56 | 2,460,080.00 | 610,453.90 | 1,545,906.00 | 4,072,381.00 |

Sources: Derived by author from Kunz and Zipf (2008) and Dumjahn (1984).

## Oldenburg




By far the latest state in the sample to construct a railroad, likely as much due to its economic backwardness as its easy access to inland waterways and the North Sea. The first constructions are by JSCs in the exclaves of Birkenfeld (1859, 1860 by the Rhein-Nahe Eisenbahn Gesellschaft) and Eutin (1866, Altona Kieler Eisenbahn Gesellschaft), mirroring the Bavarian decision not to manage a state railway in the Palatinate. Railway construction in the heartland is delayed by Hannover's refusal to allow a connection (Fremdling and Kunz

2011). There was desire to build south towards Westphalia, but the first routes ended up connecting the capital the ports at Wilhelmshaven (1867), Bremen (1867), and Leer (1869) , though the route to Wilhelmshaven was owned by Prussia. In the 1880s, the railways in exclaves were purchased and nationalized by Prussia.

% Error: Data frame must have at least one row and one column.

# Appendix 3

Unformatted sources are legal gazzettes. Parliamentary proceedings are in bold, and secondary sources are in italics.

Baden

1820-1844: Großherzoglich Badisches Staats- und Regierungsblatt

1845-1868: Großherzoglich Badisches Regierungsblatt

1869-1885: Gesetzes- und Verordnungs-Blatt für das Großherzogthum Baden

Bavaria

**1831-1837: Verhandlungen der Zweyten Kammer der Ständeversammlung des Königreichs Bayern**

**1837-1848: Verhandlungen der Kammer der Abgeordneten des Königreichs Bayern**

**1849-1871: Verhandlungen der Kammer der Abgeordneten des Bayerischen Landtages**

1872-1873: Gesetzblatt für das Königreich Bayern

1874-1885: Gesetz- und Verordnungsblatt für den Freistaat Bayern

Brunswick*

1832-1885: Gesetz- und Verordnungssammlung für die Herzoglich-Braunschweigischen Lande

Hssen-Darmstadt*

**1835-1885: Verhandlungen der Zweiten Kammer der Landstände des Großherzogthums Hessen**

Oldenburg*

1853-1885: Gesetzblatt für das Herzogtum Oldenburg

Prussia

1821-1885: Gesetzsammlung für die Königlich-Preußischen Staaten

Saxony

1835-1885: Löbe (1889)

Sachsen-Weimar-Eisenach

**1830-1850: Verhandlungen des Landtags und der Gebietsvertretung von Sachsen-Weimar-Eisenach**

1851-1885: Boelcke (1906)

Württemberg

1820-1823: Königlich-Württembergisches Staats- und Regierungsblatt

1824-1885: Regierungsblatt für das Königreich Württemberg

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