Tariffs, Trains, and Trade: The Role of Institutions versus Technology in the Expansion of Markets*

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Abstract

We study the relative importance of technology and institutions as factors determining the effective size of markets. The setting of 19th century Europe presents a unique opportunity to address this issue, since it witnessed fundamental change in both dimensions. First, Germany went from around 1,800 customs borders to none through the Zollverein customs treaties. Second, it moved from a situation of monetary disorder to currency unification. And third, the 19th century saw the introduction of steam trains. As the key technology of the 19th century, railways revolutionized transportation between markets. Changes in market integration are studied in terms of the spatial dispersion of grain prices in 68 markets with more than 10,000 observations, located in five different countries and fifteen different German states. We find that the emergence of integrated commodity markets in 19th century Europe is in major part due to the transportation revolution in form of the railways. There is evidence that also customs liberalizations and, more so, currency agreements improved trade possibilities. However, the impact of trains was larger than the effect of these institutions: about three times larger over the long horizon, and around 50% larger for the relatively short time horizon of twenty-five years. These results suggest that as significant as institutional factors were for the expansion of markets, technology factors may have been even more important.

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1 Introduction

The growth of Europe, and indeed of the world, has been linked to the scope of market transactions. In fact, it has been said that economic development is the spread of the market economy.[1] What are the primary means in this process, and conversely, what are the main obstacles to the expansion of markets? Even though technology and institutions are frequently mentioned as major factors determining the effective size of markets, to date little is known on their relative importance. We examine the key institutional and technological factors in 19th century Europe in order to answer this question.

Germany started out with about 1,800 customs borders in the late 18th century.[2] Moreover, a vast number of different currencies existed, which raised the costs of trade. Fundamental change arrived in the 19th century. European growth coincided with a series of innovations in transportation as well as institutional changes in trade liberalization and monetary agreements. The main mechanism bringing down customs duties was an institution called the German Zollverein, the classic example of a customs union.[3] Starting in the year 1828, the Zollverein treaties successively liberalized trade by abolishing tariffs among some thirty-five member states that would later constitute Germany. The first half of the 19th century witnessed also another institutional change, the creation of the first major monetary arrangements in Germany.

The institutional framework provided by these laws governing commodity and foreign

[1] Braudel (1992, 225).
[2] Henderson (1959, 21).
[3] See Viner (1950, 97).

exchange transactions was a clear break from centuries of relatively chaotic conditions, and so one would expect their impact on trade to be fairly large. The question we ask is how the Zollverein liberalizations and monetary agreements stack up in their effect on market integration compared to that of the key technology of the 19th century, the steam train.

Market integration is studied in terms of the spatial dispersion of grain prices in 68 markets of Europe with more than 10,000 observations. These markets are located in five different countries and fifteen different German states, including Prussia. The area corresponds approximately to the location of today's Austria, Belgium, Czech Republic, France, Germany, Italy, the Netherlands, Poland, and Switzerland.

We find that the emergence of integrated commodity markets in 19th century Europe is in major part due to the transportation revolution in form of the railways. There is evidence that also customs liberalizations and, more so, currency agreements improved trade possibilities. However, the impact of trains was larger than those of customs liberalization and currency agreements, about three times larger over the long horizon of one hundred years, and around 50% larger for the relatively short time horizon of twenty-five years. These results suggest that technology factors were more important than institutional factors in creating integrated commodity markets.

There are two main contributions. First, while the trade effects of customs and currency agreements are of obvious importance and an immense literature has emerged on the subject, existing results are fairly mixed.[4] Our setting has several key advantages. For one, during

[4] In particular, Lopez-Cordova and Meissner (2003) as well as Estevadeordal, Frantz, and Taylor (2003) show that if both trade partners were signatories of a monetary agreement, the gold standard, this raised trade by 40% to 60% during the period of 1870 to 1939. Baier and Bergstrand (2007) find that membership

the sample period, the 19th century, the institutional and technological changes in question are not only observed frequently, but they are also observed for most of the economies. In contrast, research on the post-World War II period often faces the difficulty that major economies experience no change during the sample period.[5] The economies of 19th century Europe also proceeded at different speeds in the implementation of trade and currency agreements. This is crucial since one can correspondingly look for the expansion of markets at different times across economies.

While the historical account is interesting as such, it is crucial for the estimation. To the extent that agreements on trade and monetary issues are systematically related to underlying characteristics of the economies—they are endogenous– OLS estimation will yield inconsistent estimates. Indeed, strong evidence is presented that institutional and technological change in 19th century Europe was endogenous. We conduct an instrumental variable analysis that is compelling because it picks up on key facts that mattered in specific economies. This yields results that are substantively different from results treating the institutional and technological changes as exogenous.[6]

The second contribution of our paper is that it compares the impact of institutional and technological factors on the expansion of markets and trade. Transportation has long been

in a free trade agreement raised the volume of trade by about 100% in the post-World War II era. In contrast, the evidence that trade agreements lead to more trade in Rose (2004) is much weaker. Other contributions include Rose (2000), Frankel and Rose (2002), and Subramaniam and Wei (2006), who study contemporary periods, and Eichengreen and Irwin (1995), Flandreau and Maurel (2001), Ritschl and Wolf (2003) as well as Jacks (2005), who examine historical episodes.

[5] Most major industrial nations were members of the General Agreement on Tariffs and Trade (GATT) right from the start, for example.

[6] Other work in this area that has employed IV estimation before us includes Estevadeordal, Frantz, and Taylor (2003), Lopez-Cordova and Meissner (2003), Ritschl and Wolf (2003), and others. These papers differ from our work along the lines described in the text.

a focus in major studies of economic history, for example transatlantic shipping (Harley 1988, O'Rourke and Williamson 1999), or railways (Fogel 1964, Fishlow 1965, Fremdling 1977, and Williamson 1980). More recent work compares institutional and technological factors affecting trade (Estevadeordal, Frantz, and Taylor 2003), or even a much broader set of factors (Jacks 2005, 2006). However, the recent emphasis has generally been on non-transportation factors, and research that brings to bear rich information on changes in transportation technology is rare. Our analysis is unique in comparing causal effects from trade and currency agreements versus transportation technology using economy-specific information on all three mechanisms.

Technological change in transportation has long been viewed as a critical input in the growth of trade in the 19th and early 20th century. Recently, it has been documented that improvements in transportation, including air transport and declining costs of rapid shipments, have been a critical input in fostering integration during the latter part of the 20th century (Hummels 2007). Based on our results that transportation changes were of dominant importance during the 19th century, we expect to see more analysis for contemporary periods as well that employs explicit measures of transportation technology to examine its impact on trade and globalized production.

By examining the relative impact of institutions and technology on trade, our analysis also informs recent research on the relative importance of these mechanisms for economic performance, in particular how the onset of modern economic growth is related to the expansion of markets (Acemoglu, Johnson, and Robinson 2005, Shiue and Keller 2007). A distinctive feature of this paper is that it examines changes in both intra-national and inter-

national market integration during a period of nation formation. This should be useful for research on the timing of economic versus political unification.

The next section 2 presents some initial evidence and provides a historical background. Section 3 discusses the data we use, while the empirical results are shown in section 4. Section 5 provides some conclusions.

2 Price Convergence in 19th Century Europe: the Zollverein, Currency Agreements, and Steam Trains

Consider the European cities Berlin, Brussels, and Munster. The first was the capital of Prussia, and later, of the German Reich. The second is the capital of Belgium (founded in 1830), and Munster was the capital of the Prussian province of Westfalia. Figure 1 shows the location of all three cities on a map. Between Berlin and Munster, customs borders fell away in the year 1831, while between Berlin and Brussels, customs borders remained.[7] Does this customs liberalization explain why between 1830 and 1855, the Berlin-Munster relative price gap for wheat fell by 0.12, while for Berlin-Brussels it fell only by about 0.02?

A priori, it is plausible that customs liberalization did indeed play a role. However, the period 1830-55 witnessed not only customs liberalization, but also, in the year 1848, the

[7] Even though both Berlin and Munster are Prussian cities, and Prussia did away with internal customs borders in 1818, customs borders between the two cities only vanished in the year 1831, when the state of Hesse-Cassel joined the Prussian customs union. This is because Berlin and Munster were located in two disjoint parts of Prussia, with Hesse-Cassel in between them; see Figure 1. Also, note that the Zollverein as a whole had at times over the 19th century trade agreements with foreign nations, including a treaty with Belgium (1844). The customs liberalizations stipulated in these agreements tended to be less comprehensive than those among the Zollverein signatories, and moreover, the liberalization relative to foreign countries was often reversed after some time; see Henderson (1959) and Hahn (1984).

arrival of a steam train connection between Berlin and Munster, while a train connection between Berlin and Brussels was not available until 1859. Hence, it would be hard to argue that the difference in price gap reduction of 0.10 (0.12 minus 0.02) is due to customs liberalization alone.

There are also the German cities of Nurnberg, and Parchim. The former is a major city in Bavaria, while Parchim was a smaller town in the state of Mecklenburg-Schwerin, in Germany's far North (see Figure 1). Between Berlin and Nurnberg, it was possible to transport wheat on trains from the year 1851 on, while between Berlin and Parchim, such transport was possible only from the year 1880 on. Does this difference in the transport options explain why between 1830 and 1855, the Berlin-Nurnberg relative price gap for wheat fell by 0.18, while for Berlin-Parchim it fell only by about 0.01?

Trains may have brought down the Berlin-Nurnberg price gap faster than for Berlin-Parchim. However, Berlin and Nurnberg also became members of the Zollverein in 1834, while Parchim joined it only in 1867. Moreover, it is surely no accident that trains connected the relatively important cities of Berlin and Nurnberg three decades before it was possible to transport grain by steam train from Berlin to the less important town of Parchim. The marginal contribution from trains on relative price gaps may therefore be different than what these figures indicate.

As a first cut, then, the evidence is consistent with customs liberalization and train transport, and also with currency agreements to expand the geographic scope of markets. However, which barriers were the relatively most important? To answer this question, it is also instructive to review what is known about the views of people who lived in these areas

at the time.

It was recognized early on that internal trade in Germany was hampered by the multiple customs borders. The economist Friedrich List, head of the Union of Merchants (der Deutsche Handels- and Gewerbeverein), expressed this in a petition to the German parliament in the year 1819 as follows: the numerous customs barriers

> "cripple internal trade and produce the same effect as ligatures which prevent the free circulation of blood. The merchants trading between Hamburg and Austria, or Berlin and Switzerland must traverse ten states, must learn ten customs tariffs, must pay ten successive transit dues. Anyone who is unfortunate enough as to live on the boundary line between three or four states spends his days among hostile tax-gatherers and customs house officials. He is a man without country."[8]

The customs situation in Germany was also unfavorably compared with that in other major countries, such as France. In the words of List, the situation is

> "depressing for [German] men who want to act and trade. With envious eyes they look across the Rhine river, where a large nation, from the Canal to the Mediteranean Sea, from the Rhine to the Pyrenees, form the border with the Netherlands to Italy, engages in trade on open rivers and roads without ever encountering a single customs official."[9]

The support for a removal of customs borders was broad and went beyond merchants,

[8] The petition is printed in German in von Eisenhart Rothe and Ritthaler (1934, 320-324).
[9] Ibid.

agriculturalists and industrialists.[10] For example, Goethe emphasized both the importance of currency agreements as well as customs liberalization. He said in 1828 that he would look forward to a time in which

> "the German Thaler and Groschen will have the same value throughout the entire country and my luggage may pass unopened through all thirty-six German states."[11]

There were also some voices opposing economic liberalization in Germany, especially in the early 1800s. They included political progressives, who would however typically not oppose liberalization per se, but liberalization under the leadership of Prussia, which they considered as politically undesirable and relatively authoritarian.[12] These views waned somewhat over time, especially through the 1820s, with the increasing recognition that there was no other way to economic liberalization other than under Prussia's leadership.

Also the nobility leading the smaller and mid-sized German states was often hesitant about economic liberalization in Germany, mostly because they feared that it would lead to political changes that would result in a loss in their personal power. However, at times the economic imperatives were overwhelming. For example, Ludwig I, the king of Bavaria, strongly supported customs liberalizations with Prussia in the year 1833. He expected that the economic costs imposed by customs borders would fuel political unrest in the population,

[10] See Henderson (1959), Hahn (1984). This is not to say that merchants, agriculturalists and industrialists everywhere were in favor of customs liberalization. For example, industrial producers in the South German states of Baden, Bavaria, and Wurttemberg complained about the new competition from Prussian and Saxon products after the 1834 Zollverein treaty (Hahn 1984, 94). The producers in Prussia's Rhine-Ruhr area, as well as those in the Kingdom of Saxony were more advanced than their South German counterparts.

[11] Goethe in conversation with Eckermann; see Goethe (1828).

[12] Several of the Southern German states had by then adopted constitutions, which Prussia had not.

thereby leading to a revolution and his loss of legitimacy (Hahn 1984, 73-75).

There is, finally, no doubt that steam trains were considered to be a major factor in improving trade in Germany. In fact, the influence of this new means of transportation was often thought to be far greater than merely expanding the size of markets. To some, it was crucial to Germany's industrialization in the 19th century, and to others, transport improvements were central to Germany's economic development. Goethe, for example, stated in 1828 that he would not at all be concerned that Germany would not be unified. He saw the major contribution in this coming from improvements in transportation technology through the (future) adoption of steam trains.[13]

This actually foreshadowed the introduction of steam trains in Germany by a number of years. The following gives a brief overview of how customs and currency agreements as well as steam trains changed the economic landscape in 19th century Central Europe.

2.1 The Zollverein

The main economic impact of the Zollverein treaties was the abolishment of tariff barriers among member states, and the implementation of a single external tariff for non-members. As of 1815, Germany's political structure was divided into the thirty-nine states of the German Confederation (Deutscher Bund), see Figure 1.[14] The confederation consisted of sovereign states in which joint action depended upon unanimity. Austria was the most powerful of the German states, followed by Prussia. Individual states tended to be highly protectionist

[13] See Goethe (1828).

[14] For more details on the history of the Zollverein, see Hahn (1984) and Henderson (1959).

and the tariffs that were imposed were complicated. There is no reliable information on enforcement, but it was likely that it was costly especially for the many small states to each monitor its own borders.[15]

In the aftermath of debts from a decade of war, and new tariffs raised by Britain, Russia, Austria, France, the Netherlands, Prussia sought to negotiate treaties with her neighbors while reforming internal tariffs. This was particularly pressing because Prussia's territories were divided into two, an eastern portion consisting of seven provinces, and a western portion that included the Rhineland provinces and the Ruhr area. In the year 1818, the Prussian Customs Union was formed. With few exceptions, internal dues were abolished. Foreign raw material were admitted free of duty and by 1821, only a single tariff for the entire Kingdom was levied on consumption goods and transit dues on goods passing through Prussia were reduced. The importance of the Prussian Customs Union stems from the fact that it served as a model for most of the Zollverein treaties that followed.

Enclaves within Prussia were the first to develop agreements with Prussia on how its payment of duties were to be treated—with Prussia deciding to treat the enclaves as her own territory rather than as foreign states required to pay import duties. As all of the following treaties, these were based on the principle that states that adopted the Prussian system of tariff received a share of the joint revenue based on population size. Their rights as sovereign states were maintained.[16]

Hesse-Darmstadt was the first territorially separate state to join the Prussian Cus-

[15] Dumke (1976) presents some estimates on border control costs, p. 44.

[16] Throughout, Prussia reserved the right to negotiate with foreign countries such as France, Belgium, and England for itself.

toms Union in the year 1828. In the same year, as a defensive agreement not to join the Prussian/Hesse-Darmstadt union, Bavaria and Württemberg formed the South German Customs Union, while a number of central German states and cities formed the Middle German Commercial Union (see Figure 2).[17] The latter was not a customs union, but an agreement among members to commit to not joining either; the strategy was unsuccessful and the union lasted only five years. Hesse-Cassel became the next to join the Prussian Customs Union in 1831. This was significant because it meant that the East and West Prussian provinces were joined without a customs border for the first time. It also meant that British goods could not reach Frankfurt and Germany's south anymore without crossing the Prussian external tariff border; see Figure 1. In the year 1834, both the Thuringian states and the Kingdom of Saxony, together with the augmented Prussian Customs Union, became the German Zollverein on January 1st, 1834. At that point the Zollverein had an area of about 163,000 square miles and a population of about 23.5 million people.

By stages, other states entered. Three other German states joined the Zollverein between mid-1835 and early 1836: Baden, Nassau, and the Free City of Frankfurt. The entry of Baden was significant because it meant that the two separate areas of Bavaria were joined without custom borders. The entry of Frankfurt meant that trade was possible in manufacturing goods from Frankfurt up the Main River to Northern Bavaria in exchange for grain without paying customs duties. Later on, Brunswick became a member of the Zollverein in 1841, Hanover in 1851, Oldenburg in 1852, Mecklenburg and the Free City of Lübeck in 1867. Two

[17] Those states were Hanover, Saxony, Hesse-Cassel, Nassau, Brunswick, Oldenburg, Frankfurt, Bremen, the Saxon duchies, and a couple of smaller ones; Henderson (1959, 67).

states became members of the Zollverein only after Germany became politically unified in 1871, namely the Free Cities of Bremen and Hamburg in 1888. Thus, the process of customs union enlargement materialized over a large part of the century (the years 1828 to 1888). Austria-Hungary did not become member of the Zollverein.

There are a number of possible reasons for states wanting to join the Zollverein. Market access was certainly a major motive. First of all, generally the states located further in the South joined the Zollverein earlier. This is because not joining implied having to pay hefty tolls before reaching the Baltic or North Sea coast, to trade with the emerging industrial powers, in particular England.[18] Thus, the Southern states of Baden, Württemberg and Bavaria had all joined the Zollverein by 1834, whereas the Mecklenburg states, located directly on the Baltic coast, joined only in 1867, and the city states of Hamburg and Bremen, which were particularly strongly relying on international trade, joined only in 1888. Another major reason for joining the Zollverein, which was shared more equally among most states, was that it gave tariff-free access to the large market of Prussia, which included the leading industrial areas of Germany at this time.

Fiscal reasons may well have also been part of the calculus: for many of the relatively small states, it was prohibitively costly to establish and enforce tariff borders, and they preferred joining the Prussian-led customs union in exchange for a fraction of the joint tariff revenue (Dumke 1976, Chapter 1). At the same time, this cannot be the full explanation since there were several highly indebted and small states that joined the Zollverein relatively late. Some of the smaller and mid-sized German states may also have hesitated to join the

[18] Notwithstanding the British Corn Laws; they were repealed in 1846.

Zollverein because they preferred more trade protection than the external tariff preferred by Prussia provided. However, Prussia's tariffs on a range of goods, especially *Kolonialwaren* such as tobacco, tea, and sugar, were actually higher than the tariffs of other German states before they joined the Zollverein, so the desire for more protection can hardly be the main reason for not joining the Zollverein.[19] Other reasons for joining the Zollverein were idiosyncratic. For example, Hanover joined relatively late in part because it was governed in personal union with England, which had no interest in an all-inclusive Prussian led customs union in the center of Europe. Overall, the key motive for joining the Zollverein was likely market access. We will return to the determinants of Zollverein accession in the empirical analysis below.

Since the Zollverein was a customs union, joining it was not identical to a move towards multilateral free trade. Trade diversion was a possible outcome. However, most of trade of the German states at the time was with other German states, and a substantial share of imports were consumption goods that were hardly produced in Europe (such as tobacco, sugar, spices). Therefore, the trade diversion effect of the Zollverein was rather limited, and thus the basic character of the Zollverein was trade-liberalizing.[20].

2.2 Currency Agreements

In the first decades of the 19th century, Germany was replete with coins issued by its many different states. The diversity was immense, in sharp contrast to the unified monetary

[19] See Dumke (1976) for more details.
[20] See also Dumke (1976), Chapter 3.

conditions in Great Britain and France, for example.[21] In the Southern states, the currency was often called Gulden, as in the empire of Austria-Hungary, while in the Northern states the currency was typically called Thaler. Irrespective of the name, each state minted its own currency, and initially currencies did not have legal-tender status outside of a given state. The currencies were linked to silver by the currency unit expressed in equivalent to a certain quantity of silver weighted in Cologne Mark. Comparability of coins even of the same denomination, like Gulden, was difficult because the mints in different states had different coinage fees. This meant that the net silver weight of Gulden from different states would actually differ. During the 1820s, the state of Nassau for example went as far as to melt down high-silver content coins issued in Bavaria to produce its own low-silver content coins, and pocket the difference (Holtfrerich 1993). The dividing line between full-value specie money and debased coins was therefore fluid.

The South German states put an end to this through the Munich Coin Treaty of 1837.[22] It stipulated that the silver content of the Gulden should be the same (nine-tenth of face value), no matter which state minted it. This effectively meant the fixing of exchange rates among the Southern states' currencies from this date on. Importantly, Gulden coins minted in any of the Southern states would have legal-tender status in all signatory states. One year later, the Dresden Coin Convention in 1838 effectively led to fixed exchange rates between all Zollverein currencies by requiring that each state was obliged to mint coins according to the common metal-content specifications. However, the 1838 Dresden agreement did not give

[21] Holtfrerich (1989, 1993).

[22] These Southern states are Bavaria, Baden, Württemberg, Nassau, Hesse-Darmstadt, and the Free City of Frankfurt.

legal tender status to all currencies throughout the Zollverein. This created an important barrier to commercial exchange.[23] The Dresden agreement left the Northern Thaler bloc and the Southern Gulden bloc intact, even though currencies in both blocs were linked to the Cologne Mark at a fixed exchange rate of 1 Thaler = 1.75 Gulden.

It was recognized at the time that a generally accepted medium of exchange is important for facilitating trade between the Thaler and the Gulden blocs. The states agreed on the minting of a common coin worth 2 Thaler or 3.5 Gulden that would have full legal tender status throughout. In part because its denomination was too large for everyday small-scale business, the coin never played the role for which it was introduced.[24] Instead, the Prussian one-Thaler piece was increasingly used for commercial transactions after 1838, and even gained de facto acceptance in the Gulden states of Southern Germany. The need for a generally accepted medium of exchange was remedied only twenty years later, in the Vienna Coin Treaty of 1857, where all Zollverein currencies were given full legal tender status throughout the Zollverein (even retrospectively to those coins minted between 1838 and 1857). The states that remained outside the Vienna currency agreement of 1857 in our sample are Mecklenburg-Schwerin and the Free Cities of Bremen, Hamburg, and Lübeck (Willis 1896).

Monetary unification was achieved with political unification of Germany soon after the year 1871. The newly created Reichsmark had full legal tender status in all German states.

[23] This affected trade among Northern Zollverein states, and trade between a Northern and a Southern state, since the Southern states had agreed on full legal tender status among themselves in the 1837 Munich agreement.

[24] The signatories expected that by the year 1842, the *Vereinsthaler* would account for 1.2% of the total coin circulation in Germany. In fact, the *Vereinsthaler* circulation fell well short of this; Holtfrerich (1993).

Also, Germany moved from the silver to the gold standard after the year 1871, in line with the international trend at the time.[25]

2.3 The Introduction of Steam Trains

European economic growth from the 19th century on also coincided with a series of innovations in transportation.[26] These innovations included paved roads, improvements in waterways, railways, in materials such as iron and steel, and later on, steam power, but the rapid increase of railway construction was particularly important. In the 1840's British suppliers of locomotives dominated the market, and railway iron exports were an important iron export for Britain. Gradually, countries on the continent started to produce their own railway inputs. In Germany, for instance, first domestic locomotives began to be produced and substituted for British locomotives, and then iron processing plants using British technology were established, and by the 1850's German iron industries were supplying rolled rails, and eventually also exported rails. The effects of these innovations appeared as price differentials between regions (and sectors) in the European economy, and contributed to regional specialization and trade.

The first German railway was opened in December 1835. With only 4 miles of tracks, it was a short suburban line located in Bavaria, between Nurnberg and Fürth. The first longer route (70 miles) was built in Saxony in 1839, some 5 years after the initial Zollverein treaties came into effect. Thereafter, additional miles of rail were laid down swiftly. By 1847, there

[25] In our sample, the Netherlands was on the gold standard by 1875, while Belgium and France were on the gold standard by 1880 (Lopez-Cordova and Meissner 2003).

[26] A good survey is O'Brien (1983). On the debate concerning the contribution of railways, see Fogel (1964), Fishlow (1965), and Williamson (1980).

were over 2,000 miles of rail in Germany (Henderson 1959, 147), and almost all main railway lines were completed by 1877 (Milward and Saul 1977, 42). Government participation in railroads differed across states (Fremdling 1977). In some states, railroads were owned and run as a public enterprise. In Prussia and Saxony, railways were primarily privately owned, and the government had a dominant shareholder role or was guarantor of minimal returns.

Railway building in the five sample countries other than Germany, namely Austria-Hungary, Belgium, France, the Netherlands, and Switzerland, proceeded in quite different ways. In France, railway construction began as early as 1828 with 23 kilometers of track opened, but its pace fell behind that of Germany in part because of resistance to the new technology from owners of other means of transportation. It has also been argued that railway building in Germany has been particularly fast because the various politically independent states competed for transport routes through their territitories (Fremdling et al. 1995). At the same time, railway building in Belgium was also very swift. The Belgium railways were designed as a means of international transport from the beginning. This meant that negotiations among different states were necessary. In 1834, the Belgium Parliament planned for a network that allowed connections to Prussia, France, England, and the sea at Anvers, and later, an extension to Holland (Laffut 1983). In Switzerland, both the difficult geography as well as the highly federalistic (cantonal) system slowed down railway building. Also in Austria-Hungary, railway building proceeded at a moderate pace; major reasons for that include relatively little interest in the new technology among the empire's leaders, as well as empty state budgets and lost wars starting around the mid-19th century.

How important were railways as a means of transportation for grain? Generally, railways

were important for low value-to-weight ratio good such as coal, construction materials, metal goods, and also grain (O'Brien 1983, 1-2). At the same time, the importance of railroads for transporting grain varied greatly across the German states. While it was cheaper to transport grain by railroads than by other means of land transport, trains could not compete with transport by ship.[27] In the late 19th century, for example, sending one ton of grain from Posen (in East Prussia) to Cologne by train was at least three times as expensive as shipping it to Rotterdam or Antwerp and then up the Rhine river (Köttgen 1890, 64).

Consequently, long distance grain trade in the southeast direction, parallel to the major rivers (Elbe, Rhine, Danube), was hardly ever done by rail. At the same time, transportation of grain on railways was of utmost importance when it connected the drainage areas of the main rivers.[28] Grain transportation on railways was also of major significance whenever sea or river transport was not an option. For example, the great majority of all grain exported from Bavaria to Switzerland in the early 1850s was transported on railways (Seuffert 1857, Chapters 5, 6). The attractiveness of transporting grain on railways was not only affected by geographic features across Germany, i.e., whether or not ship transport was feasible. Also the freight rates per ton-kilometer mattered, and while we do not have fully detailed information on this, we know that differed both across states as well as over time (Hohorst and Fremdling 1979, 64-65). The existence of a train connection does therefore not say everything on the importance of a particular train track for grain trade. For the estimation this means that

[27] On the comparison between land transport and rail transport of grain, see Fremdling and Hohorst (1979, 64).

[28] For example, Fremdling and Hohorst note that the full opening of the Köln-Mindener railway in the year 1847 was crucial for transporting the relatively cheap Prussian grain to the emerging industrial areas of the Rhine-Ruhr (1979, 64).

we expect unobserved heterogeneity in terms of the significance of railways for grain trade between different market pairs.[29]

We now turn to a description of the data.

3 Data

This study employs the prices for wheat across markets in Europe to analyze market integration. We have compiled a data set consisting of sixty-eight market locations; Table 1 provides an overview. There are 16 markets outside of Germany, about 24% of the sample. These are located in Austria-Hungary, Belgium, France, the Netherlands, and Switzerland. The remaining 52 wheat price series are for markets located in fifteen different German states.[30] The prices are averages for an entire year, which is appropriate since we are interested in low-frequency changes of price gaps over an entire century. All prices are quoted in terms of Bavarian Gulden per Bavarian Scheffel (about 223 liter of wheat). To arrive at a comparable set of prices we have converted the many different quantity and monetary units that were used in 19th century Europe using the conversion rates given in Seuffert (1857) as well as in the original sources.

The overall sample period is 1800 to 1899, but data availability varies greatly across

[29] See also Kopsidis (2002, 1996) for a careful analysis of the impact of railways for agricultural development in 19th century Westphalia.

[30] These German states are (1) The Grand Duchy of Baden, (2) The Kingdom of Bavaria, (3) Duchy of Brunswick, (4) the Free City of Bremen, (5) the Free City of Frankfurt/Main, (6) the Free City of Hamburg, (7) the Free City of Lübeck, (8) the Kingdom of Hannover, (9) the Electorate of Hesse-Cassel, (10) the Grand Duchy of Hesse-Darmstadt, (11), the Duchy of Hesse-Nassau, (12) the Grand Duchy of Mecklenburg-Schwerin, (13) the Kingdom of Prussia, (14) the Kingdom of Saxony, and (15) the Kingdom of Württemberg. Some of these territories changed their name during the 19th century, for instance the Kingdom of Hannover, which was an Electorate until 1814. All of these territories became part of the German Reich after the year 1871.

the series. For example, there are all 100 annual price observations for the Belgian city of Brugge during the 19th century, while for the market in Wiesbaden (Hesse-Nassau), there is only one single observation. Since the goal is to rely on important time-series variation (before-after comparison), it is clear that more weight should be placed on markets where prices are observed for a long time. Table 1 reports the number of observations for each market as well as the year of the earliest price observation during the 19th century.

Grain prices in Europe at the time generally increased from South (the Black Sea area) and East (Eastern Prussia) to the Northwest (Northern Germany, the Canal region, and England). The average percentage price gap between two markets in our sample is about 0.18 over the entire 19th century. For the subset of price gaps for which we have information for the entire century, the average price gap in the first decade of the 19th century is about 0.32, while in the last decade of the 19th century it is less than one third of that (0.10). This decline reflects that dramatic extent of price convergence over the 19th century. We are trying to understand the roles of customs liberalization, currency agreements, and railways in this. The information on prices comes from work by Fremdling and Hohorst (1979), Gerhard and Kaufhold (1990), Hanauer (1878), Seuffert (1857), as well as Shiue and Keller (2007). In addition, we are using some data underlying Kopsidis (2002, 1996), while the information on the population of cities that we employ below comes from Bairoch et al. (1988) and de Vries (1984). Further details on the sources and the construction of these series are given in the Appendix.

The Zollverein was the most important element in the move towards trade liberalization in

19th century continental Europe.[31] For each city-market, we have recorded the year in which it became part of the Zollverein; this year is listed in Table 1. Important accession dates are 1834 and 1836, as well as the years 1841 (Brunswick), 1854 (Hanover), 1867 (Mecklenburg and Lübeck), and 1888 (Bremen and Hamburg). Generally, joining the Zollverein meant that barriers for grain trade between any two of its markets would be equal to zero. Unfortunately, there is no comprehensive information on the levels of tariffs on grain before liberalization. Some available figures suggest that the duties on wheat may have been on average the equivalent of about 10 percent ad valorem.[32] Instead of exploiting the size of the tariff change, we rely on the timing of the move towards zero trade barriers through Zollverein membership.[33]

Even though within states tariffs were generally abolished in the very early 1800s, there could still have been customs borders faced by agents trading within the same state. This is because the territory of several states consisted of several non-contiguous parts, such as the Eastern and Western provinces of Prussia, or the Bavarian Palatinate area that was separate from core Bavaria around Nurnberg and Munich. For each market pair in our sample, we have established using maps whether a direct trade route would involve passing any customs

[31] There have been other trade agreements, for example the customs union created between Bavaria and Württemberg in the year 1828. However, most of these were relatively short-lived. The Zollverein was the major development.

[32] At the time, mostly specific duties were charged, so that the ad valorem duty varied with the price of wheat. In the year 1831, the Prussia-Hesse Customs Union charged a specific duty equivalent to about 7% for wheat (Dumke 1976, Table 3.16). The ad valorem equivalents for "products of agriculture" before the formation of the Zollverein in 1834 were about 16% in Prussia, 9% in Bavaria and Wurttemberg, 8% in Baden, and 3% in Saxony (Dumke 1976, Table 3.17).

[33] In a few cases, the time of the Zollverein accession does not coincide with the year in which tariffs on grain were eliminated (for example, between the Bavaria-Wurttemberg and Prussia-Hesse-Darmstadt customs unions tariffs were eliminated in 1829, four years before the Zollverein treaty). We focus nevertheless on the Zollverein accession date, not least because this played the key role in terms of commitment.

borders. If the number of customs borders to be crossed is greater than or equal to one, CU_{ijt} is coded as 0, otherwise it is 1, for each market pair ij and year t. For any relationship between a German and a non-German market, or between two markets in different European countries, CU_{ijt} is equal to 0 for all years.[34] For example, Figure 3 shows the four cities Rostock, Munster, Cologne, and Munich in the year 1834. In this year, Bavaria and Prussia both formed part of the Zollverein, leading to the elimination of customs borders between the Bavarian city of Munich and the Prussian cities of Cologne and Muenster; so CU_{ijt} for the pair Munich-Cologne, for example, switches from 0 to 1 in the year 1834. In contrast, there remains at least one customs border between Munich and Rostock, since the latter, part of the state Mecklenburg-Schwerin, joined the Zollverein only in the year 1867.

Turning to monetary agreements, the major event in this area was that currencies were giving full legal tender status in other states. As discussed above, this occurred between the Southern states in 1837 with the Munich Coin Treaty. For all Zollverein currencies, full legal tender status was agreed upon with the Vienna Coin Treaty of 1857. Thus, for example, the variable LT_{ijt} for the pair of Munich (in Bavaria) and Stuttgart (Wurttemberg) up to the year 1837 is equal to 0 and 1 afterwards, for example. In contrast, the variable LT_{ijt} for the pair Berlin (Prussia) and Stuttgart is 0 up to the year 1857, and 1 afterwards. For relations between a German and a non-German market, LT_{ijt} is always 0.[35] Table 1 gives the year in

[34] The Zollverein, as well as many European countries, liberalized trade in parts of the 19th century, especially between about 1850 and 1875; see Bairoch (1989) for a general account of trade policies in Europe in the period 1815-1914, and Pahre (2008), who has compiled a database of trade agreements between 1815-1914. While detailed information on the extent of wheat trade liberalization is not available, the effects of these liberalizations are likely not comparable to those of the Zollverein treaties, both because of the former's temporary nature and more limited depth. In the appendix, we provide additional results that account for the most important of these temporary liberalizations, showing that this does not change our main results; see Tables A3 to A5.

[35] The two Alsatian cities of Mulhouse and Strassbourg are special cases, since they were part of France

which the currency used in a particular city had for the first time full legal tender status in another state.[36]

Finally, Table 1 gives also the year in which a particular city-market had its earliest bilateral rail connection in our sample. For example, the rail track between the Saxony cities of Dresden and Leipzig was completed in the year 1839, and since this was the earliest connection in the sample for both cities, Table 1 lists this year for Dresden and Leipzig. The trains variables TR_{ijt} for the Dresden-Leipzig pair is 0 until the year 1839, and 1 thereafter.

This coding is not based on when a particular city became part of the railway network by getting its railway station. Instead, we code the TR variable specific to bilateral connections in our sample. Moreover, since it clearly matters for competition between different modes of transport how circuitous the route between two markets is, we have set TR_{ijt} only equal to one once a direct and non-circuitous train connection existed. This has been determined by analyzing maps that give the precise geographic location of the historical train tracks (IEG 2007). For example, Figure 4 shows the train connections in the year 1850, as well as the four cities Strassbourg, Munich, Hamburg, and Cologne. In the following year, 1851, the North-South connection between Munich and Hamburg was established, and the variable TR_{ijt} switches from 0 to 1 in our analysis.

The TR variable also incorporates other relevant elements of Europe's topography, such

until 1871 and part of Germany from 1871 to 1918. Thus, the value of LT_{ijt} between Mulhouse and Toulouse, e.g., goes from 1 to zero after 1871. Moreover, we could in principle take into account the fact that the unified Germany and other countries in our sample went on the gold standard in the 1870s. We have not done so because being on the same commodity standard is not identical to mutually agreed upon legal tender status of currencies; in fact, all German states except Bremen for a short period were on a common standard throughout the 19th century, silver before 1871, and gold afterwards.

[36] We have also considered the effects of fixed exchange rates on the price gaps. Incorporating this into our analysis does not qualitatively change our findings.

as the existence of bridges across rivers. For example, the railway line between Cologne and Aachen was an early one in Europe, completed in the year 1841, and as early as 1843 this line connected internationally to the Belgian cities of Brussels and Brugge. Grain from the relatively low-price areas of Prussia could be shipped via Hanover to the emerging industrial areas of Cologne by the year 1847 via the Köln-Mindener line. But that was only the Cologne-Deutz part of Cologne, located on the east side of the Rhine—the railway bridge across the Rhine was completed only in the year 1859, and until then, Aachen as well as the Belgian markets could effectively not be supplied by rail with the relatively cheap Eastern European grain.[37]

We now turn to the empirical analysis.

4 Empirical Results

How important was institutional change– in the form of customs liberalization and currency agreements– relative to technological change through railways in bringing down price gaps between markets? Consider the following regression:

$$pdif_{ijt} = \beta_0 + \beta_1 CU_{ijt} + \gamma X' + \varepsilon_{ijt} \tag{1}$$

[37] We have also constructed a second railway variable that incorporates information on how much freight traffic was present on a given rail line in a given year, based on information in Fremdling et al. (1995). This has the advantage that we take into account differences in the relative relative importance of rail connections for freight traffic. Moreover, the actual freight traffic figures also factor in differences across rail lines and over time in terms of freight charges per ton-kilometer. This alternative railway variable leads to similar results.

which relates the bilateral price gap between markets i and j in year t to the dichotomous customs liberalization variable CU_{ijt} and a vector of control variables X. Our primary interest lies in consistently estimating β_1. The concern is that customs liberalizations were not exogenous, so that CU_{ijt} is correlated with ε_{ijt}, which would yield inconsistent OLS estimates. To address this, we adopt an instrumental variable (IV) approach:

$$\begin{aligned} pdif_{ijt} &= \beta_0 + \beta_1 CU_{ijt} + \gamma X' + \varepsilon_{ijt} \\ CU_{ijt} &= \delta_0 + \delta_1 Z_{1ij}^{CU} + \delta_2 Z_{2t}^{CU} + v_{ijt} \end{aligned} \tag{2}$$

where Z_{1ij}^{CU} and Z_{2t}^{CU} are two instruments for customs liberalization. The first is based on information on the distance of a market to the coast. Almost all of the customs liberalizations between cities in this sample were due to the enlargement of the Zollverein. Moreover, the date of a state's accession to the Zollverein is clearly related to the distance to the coast, with more distant markets joinint earlier. Not being a member of the Zollverein mattered more for the states in the south of Germany, since the external tariff of Zollverein prevented customs-free access to the coast, which gave relatively low-transport access to distant markets. Figure 5 shows the positive correlation of Zollverein accession with distance to the seaboard for the cross-section of 68 wheat markets. With an R^2 of 0.48, this is a strong relationship.

The bilateral variable Z_{1ij}^{CU} equals the minimum of the distance to the coast for market i and for market j. If at least one of the markets is located near the coast, customs between i and j would tend to be not liberalized. The sample correlation of the bilateral measures Z_{1ij}^{CU} and CU_{ijt} is 0.41. To gain precision, we add as a second instrument: the log of the Zollverein

population in that particular year (Z_{2t}^{CU}). A larger population means a larger customs-free internal market in the customs union, and thus the greater is the incentive to join. Note that this instrument varies over time while the distance-to-coast variable does not.

We adopt analogous IV approaches for the trains and the currency variables, with the following instruments. The size of the markets that the railway would connect was an important consideration. In Figure 6, we show the cross-sectional relationship between city population in the year 1800 and the earliest date at which a city-market had a railway connection for our 68 markets. The positive relationship indicates that on average, larger cities adopted railways earlier than smaller cities. The bilateral instrumental variable for TR is the average of the population sizes in city i and city j in the year 1800 (denoted Z_{1ij}^{TR}); the sample correlation of TR_{ijt} and Z_{1ij}^{TR} is 0.22.

We also employ another variable which is not based on population figures in the markets i and j themselves. It is given by the market potential of a particular location. For any market i, this is defined as the sum of the distance-weighted populations of all states and countries:

$$MP_{it} = \sum_{s \epsilon S} \frac{pop_{st}}{d_{is}}. \tag{3}$$

Here, $s = 1, ..., S$ is an index for one of the 20 sovereign states and countries in the sample, pop_{st} is the population of state s in year t, and d_{is} is the distance between city-market i and the capital of state s. The variable MP_{it} is large if market i is relatively close to large populations, and vice versa. The bilateral instrumental variable is the log average of the market potentials of city-markets i and j in year t (denoted by Z_{2ijt}^{TR}); its sample correlation

with TR_{ijt} is equal to 0.22 as well.

We construct also two instruments for the currency agreement variable. The first is based on the extent to which monetary systems imposed differential transactions costs for trade between market pairs. In the Southern German states, transactions costs were particularly high because coins from different states had highly varying silver contents even though they had the same face value, one Gulden.[38] The Southern Gulden states thus had relatively more to gain from currency agreements, and these states formed currency agreements before other German states did. The instrument for the bilateral LT_{ijt} variable is a dichotomous variable that is equal to one if both markets i and j belong to the Gulden area, and zero if at least one of the markets is not part of the Gulden area (the instrument is denoted by Z_{1ij}^{LT}). The Gulden area was formed about half a century before the sample period begins, in the year 1754. A second instrument for currency agreements is created as the log average population covered by giving reciprocally full legal tender status of the different currencies (denoted by Z_{2t}^{LT}).

Table 2 presents summary statistics of the data. We employ only a subset of the data in the empirical analysis, namely observations at five-year intervals (1800, 1805, ..., 1895). Since in the case of wheat, shocks to prices often affect the crop for several years, using all annual information would yield relatively little additional information while at the same time create serial correlation. The final row of Table 2 shows that the average number of observations per market-pair is about 12, or 60 years during the 19th century.[39] The average

[38] This difference in the monetary developments between the South and the Middle/Northern German states had its root in the different ways of how the states financed wars following the French revolution (see Rittmann 1975, 467-469). See also Holtfrerich (1993, 521).

[39] Typically, the price observations are available for consecutive years.

price gap in our sample is 0.18, with a standard deviation of 0.15. The table also shows that the fraction of observations where customs was liberalized is somewhat higher than the fraction where a train connection existed (22% versus 14%, respectively). This reflects the fact that the Zollverein liberalizations started in the late 1820s, which is at least a decade before the building of railway tracks gained momentum in Germany. Table 2 also shows that about 11% of the sample had the Gulden currency in the year 1754, and that the smaller distance to the coast of the two locations in a market-pair is on average 169 kilometers.

Table 3 presents instrumental-variable results for the effect of customs liberalizations, currency agreements, and train connections on bilateral price gaps.[40] Panel A shows the second-stage regression, Panel B the first-stage, and Panel C the corresponding OLS regression. All regressions include year- and state-pair fixed effects that control for common shocks and heterogeneity at the pair level. The regressions are also weighted by the number of bilateral price gap observations for a particular pair.[41] The table reports robust standard errors that are clustered at the state-pair level in parentheses.[42]

In column (1), the trains coefficient is estimated at about -0.35, consistent with a substantial price gap reducing effect. The first-stage results yield the expected positive coefficients

[40] We employ the 2-step efficient GMM two-stage least squares estimator. Because it has been shown that the limited-information maximum likelihood (LIML) estimator has sometimes better properties, we have also considered LIML estimators. In our context, they lead to similar results; see Tables A1 and A2 in the appendix.

[41] Giving relatively more weight to market pairs that are observed for a relatively long period of time is useful since identification results to a large extent from a before/after comparison. At the same time, unweighted regressions yield quite similar results, see the appendix.

[42] Clustering at the state-pair level is preferred since customs liberalizations typically occur at the state-pair level, so that trade barriers between any markets for a given state-pair fall away in the same year. The analogous is often the case for currency agreements as well. Also train connections were frequently established so that the opening of a particular train connection also connected other markets for the same pair of states.

on City Population in 1800 and Market Potential. The first-stage F-statistic is about 7, and the partial R-squared for the two excluded instruments is 0.8%. This suggests that the instruments are moderately powerful, and we will consider additional instruments in the estimation of relative effects in Tables 4 to 6 below.

As seen from Panel C, the OLS estimate for train connection is quite close to zero. The substantial difference between IV and OLS estimates provides strong evidence for endogeneity of the establishment of a train connection, and only the IV estimate is consistent (the Hausman test rejects the null of exogeneity at a 0.5% significance level). The last line in Table 1 reports the p-value of the Hansen J overidentification test. This asks whether the instruments, Market Potential and City Population in 1800, are orthogonal to the structural error. With a p-value of 0.67, the null of orthogonality cannot be rejected.

Why is the OLS effect of trains on price gaps small and larger (in absolute value) using IV estimation? If endogeneity of train adoption induces selection such that those market-pairs expecting large price gap reductions adopt trains before other market-pairs anticipating smaller reductions, the IV estimate would be smaller, not larger than the OLS estimate. However, this is not what we find. Instead, the results suggest that many of the late train-adopting market-pairs are smaller markets that would have experienced large reductions in price gaps if the date of train adoption would not be systematically related to market size. The IV estimation un-does the relation between timing of adoption and market size, and the relatively large effect of trains on shrinking price gaps becomes apparent.

Columns (2) and (3) in Table 3 show the results for the customs and currency variables. At about -1 and -0.8, respectively, they are also both consistent with a price gap-reducing

effect. While these point estimates suggest a quantitatively larger effect than for trains, also the corresponding standard errors are larger. Moreover, of central interest is which factor, technology or institutions, is more important once both are included in the same specification. We turn to this now.

Table 4 compares the impact of currency agreements and train connections on bilateral price gaps. In column (1), the train coefficient is about -0.21, while the currency coefficient is -0.04 but estimated imprecisely (s.e. of 0.14). Even though the instruments in the first-stage regression for the currency agreement indicator have the expected sign and are significant, the relatively low partial R^2 of 0.4 percent signals a possible weak-instruments problem. Therefore, in column (2) we include two of the four instruments, Z_{1ij}^{TR} and Z_{1ij}^{LT}, interacted with state dummies. This leads to the following specification

$$\begin{aligned} pdif_{ijt} &= \beta_0 + \beta_1 TR_{ijt} + \beta_2 LT_{ijt} + \gamma X' + \varepsilon_{ijt} \\ TR_{ijt} &= \pi_0 + \pi_{1s} Z_{1ij}^{TR} + \pi_2 Z_{2ijt}^{TR} + \pi_{3s} Z_{1ij}^{LT} + \pi_4 Z_{2t}^{LT} + \pi X' + u_{ijt} \\ LT_{ijt} &= \delta_0 + \delta_{1s} Z_{1ij}^{LT} + \delta_2 Z_{2t}^{LT} + \delta_{3s} Z_{1ij}^{TR} + \delta_4 Z_{2ijt}^{TR} + \delta X' + e_{ijt} \end{aligned} \tag{4}$$

This brings the number of excluded instruments up from 4 to 27 instruments.[43] As seen in the lower part of Table 4, the fit of the customs first-stage is improved, with a partial R^2 of 2.9 percent. Also the trains first-stage regression fit improves. The trains impact is

[43] With $S = 20$ states and countries, each reduced-form in equation (4) has potentially 42 instruments; for example, the trains first-stage equation has those associated with π_{1s} (up to 20), π_{3s} (up to 20), and with π_2 and π_4. Because of limited data availability, not all π's are estimated.

estimated at about -0.2, as before. In contrast, the currency effect is now larger in absolute value, at about -0.07. It is also more precisely estimated and significant at standard levels.

In column (3) we present estimates of the more short-run effects of trains and currency agreements. We restrict the analysis to a window of 25 years before and after the changes, for example around the year in which a train connection was established. Over this shorter horizon, we estimate that establishing a train connection reduces price gaps on average by about fourteen percentage points. Comparing the results from columns (2) and (3), this suggests that around two thirds of the total effect from trains comes to pass during the twenty-five years after train introduction, while about one third transpires later than twenty-five years after the change.

Currency agreements have significant effects on price gaps over this shorter horizon as well. Compared to trains, the customs effect is about one-third as large (-0.04 versus -0.14 in column (3) of Table 3). Overall, we find that the impact of trains on the expansion of markets is larger than that of currency agreements, in the order of 2 (and perhaps 3) to 1.

Table 5 compares the impact of customs liberalizations and train connections on bilateral price gaps. In column (1), the train coefficient is about -0.24, while the customs coefficient is insignificantly different from zero. Since there is also here some evidence that the instruments may be weak, in column (2) we include the four instruments of column (1) interacted with state dummies; this brings the number of excluded instruments up from 4 to 74 instruments.[44]

As seen in the lower part of Table 5, the fit of the customs first-stage is improved in

[44] Based on empirical fit, here all four instruments are interacted with state dummies, while earlier only two instruments were interacted. This has no major effect on the results; see Tables A1 and A2 in the appendix for analyses where the number of excluded instruments is held constant.

column (2), with a partial R^2 that is much larger than with the smaller set of instruments in column (1). At the same time, there is no qualitative change for the customs and trains effects on price gaps: the trains effect is around -0.2, while the customs effect is essentially zero (-0.015, with a standard error of 0.013).

Column (3) shows the results for trains versus customs liberalization over the shorter horizon of twenty-five years before and after a change. We estimate that establishing a train connection reduces price gaps on average by twelve percentage points. This suggests that around 55% of the total effect from trains comes to pass during the twenty-five years after train introduction. Also customs liberalizations have significant effects over this shorter horizon. Compared to trains, the customs effect is about 75% as large (-0.09 versus -0.12 in column (4) of Table 5). Overall, we find that the impact of trains on the expansion of markets is larger than that of customs liberalization. This is especially the case over the long horizon.

We are interested in analyzing the size of the trains effect relative to both that from currency agreements and from customs liberalizations. Unfortunately, it is difficult to estimate the customs and currency effect separately in the same regression, because customs liberalization and currency agreements went frequently hand in hand (the correlation of CU_{ijt} and LT_{ijt} is 0.75). In order to be able to compare the effect from trains relative to a broad institutions effect, we construct a new variable, $INST_{ijt}$ that incorporates both currency

and customs information:

$$INST_{ijt} = \begin{cases} 0 & if \quad CU_{ijt} = 0 \text{ and } LT_{ijt} = 0 \\ 1 & if \quad CU_{ijt} = 1 \text{ and } LT_{ijt} = 0 \quad \text{or} \quad CU_{ijt} = 0 \text{ and } LT_{ijt} = 1 \\ 2 & if \quad CU_{ijt} = 1 \text{ and } LT_{ijt} = 1 \end{cases} \tag{5}$$

Table 6 shows these results. In column (1), we employ four instruments; Market Potential, the Zollverein Population, the Gulden in 1754 indicator, and Distance to Coast. The train coefficient is estimated at about -0.17, and also the institutions variable $INST_{ijt}$ comes in negative, at -0.12. Even though the instruments enter significantly in the institutions first-stage regression, the partial R^2 is relatively low, and we interact all instruments with state dummies. This substantially improves the fit of the first-stage regressions (lower part of column (2)). The trains coefficient is estimated around -0.2, as before, while the institutions effect is much smaller, at about -0.01, albeit significantly different from zero.

For the twenty-five year window around changes, we estimate that trains lower the average price gap by about nine percentage points, while institutions in the form of customs or currency agreements reduce the average price gap by about six percentage points (coefficients of -0.09 and -0.06 in column (3), respectively). This short-run trains effect is somewhat smaller than either in Table 4 or Table 5, although the difference is barely significant. The short-run institutions effect lies right between the short-run effect of currency agreements (-0.038) and customs liberalizations (-0.093).

Overall, the analysis shows that the introduction of train transportation lowered price gaps by about ten percentage points within a window of twenty-five years, and by about

twenty percentage points in the long-run. Currency agreements reduce price gaps in the short-run by about four percentage points, and by twice that in the long-run. And customs liberalizations reduce price gaps in the short-run relatively strongly, by about nine percentage points, but in the long-run we do not estimate a significant effect from the removal of customs barriers.

Additional analysis in the Appendix confirms these findings. Across a wide number of alternative specifications, the trains effect over the entire century is estimated around -0.2, while the short-run trains effect is about half that. The currency agreement estimate is typically estimated at around -0.07 in the long- and about -0.04 in the short-run. The estimated impact from customs liberalization generally varies more across specifications. The long-run effect appears to be small or equal to zero, while the short-run effect may bring down the average price gap by about six percentage points (see the Appendix Tables A1 and A2).

It is also important to ask how large the estimated effects are relative to the observed reduction in price gaps. As noted earlier, the mean price gap falls from 0.32 during the first decade of the 19th century to 0.10 in the last decade, a 22 percentage points decline. The long-run trains coefficient is around -0.2, while the long-run currency effect is around -0.04. Thus, the combined trains and currency effect can account for most if not all of the observed decline in the price gaps during the 19th century.[45]

[45] Since our estimates are obtained conditional on a generalized time trend—the regressions include time fixed effects– the train, currency, and customs effects arguably account more than fully for the observed decline in price gaps. This suggests that the IV estimates are not only identified from the effects on the mean price gap, but also particularly from the effects on initially relatively large price gaps.

5 Conclusions

Do institutional and technological change affect the size of the market? To answer this question, we examined systematic deviations from the Law of One Price in Western and Central Europe over the 19th century. This setting is particularly interesting since at the time national and international markets were still only emerging. To examine systematic deviations from the Law of One Price, we focus on the market price of wheat in cities in large parts of Europe. The analysis embodies three determinants of trade and the size of the market: customs liberalizations, currency agreements, and train transportation. Admittedly, this list in incomplete. However, the analysis covers the Zollverein liberalizations, monetary unification in Germany, and transportation improvements in form of steam trains, which are a priori all of first-order importance for European economic development during this time. Our empirical results strikingly demonstrate that both institutional and technology change must figure prominently for any understanding of the expansion of markets and economic development.

It would have been impossible to arrive at these results without extensive data. To this end, we constructed a unique database on wheat prices, geographic, city, state, and country characteristics, customs and currency agreements, and train connections for 68 markets in a major part of Europe over the 1800-1899 period. This detailed data lets us address the reality that institutional as well as technological change are endogenous responses to economic conditions at the time. We find that accounting for this endogeneity gives vastly different results than not doing so.

Our main conclusions are as follows: (1) Over the long-run, the impact of new transportation technology on closing price gaps, or the size of the market, appears to be significantly larger than that of institutional change; we estimated a long-run price-gap reducing effect from trains of about 0.2, while the institutions effect may be around one third of that, at 0.06. (2) Also over a shorter period of twenty-five years, we estimated that transportation improvements have larger effects than institutional change, but the difference is relatively smaller. (3) Currency agreements have a substantial long-run effect on the size of the market, while customs liberalizations have a relatively stronger short-run effect.

Our results point to the importance of comparing causal effects from technology and institutions on economic performance in a single framework. We showed how this can be done in a particular case. But is it possible that institutional change actually drives technological change, and thus the comparison of the two is therefore a moot issue? Along these lines, in our context one claim is that train connections were built where the Zollverein had eliminated customs borders. While we agree that institutions may in general affect the rate of technological change, we do not believe that institutional change was important in driving technological change in our setting.[46]

Should we believe that technological change today is of equal importance today as it was in the 19th century? After all, it has been argued that the 19th century has seen the "transportation revolution"–is anything of comparable significance happening right now? Quite possibly so. The 20th century saw the arrival of container shipping and the expan-

[46] There is no evidence that customs liberalization or currency agreements caused the establishment of train connections. The positive correlation of TR_{ijt} with CU_{ijt} and LT_{ijt} (about 0.06) is due to the general time trend.

sion of large-scale air freight shipping. More recently, the reduction of transport costs for intermediate products, including technological knowledge through advances in information and communications technologies, has played a major role in the globalization and vertical disintegration of production.[47]

Finally, our analysis suggests that it is crucial for research seeking to explain differences in economic performance to include a good measure of technological change; in many cases, it is not difficult to measure, and it may yield dramatic new insights on the economics of development.

[47] See Hummels (2007) for an overview.

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6 Appendix

6.1 Robustness Analysis

In this section, we first discuss a number of additional results that shed light on the robustness of the results, see Table A1 and A2. These two tables follow the same pattern, except that the Table A1 results are for the entire 19th century, while Table A2 presents results for a 25-year window around the changes (train connection, currency agreement, and customs liberalization).

In the upper left part, we repeat for convenience the baseline results from Tables 4, 5, and 6 in the text, in abbreviated form (not all tests and statistics are listed). Please refer to these tables and the discussion in the text for additional details. The following Tables A1 and A2 include the following alternative specifications. First, we present limited-information maximum likelihood (LIML) estimates, which have in some settings better properties than two-stage least squares estimators. We employ LIML estimation in the form of the continuously updating GMM estimator proposed by Hansen, Heaton, and Yaron (1996).

Second, we show results for market-pair instead of state-pair fixed effects. Recall that the analysis is at the level of the market-pair, so using deterministic market-pair fixed amounts to the standard within estimator panel specification. This has the advantage that time-invariant heterogeneity (including bilateral distance) at the market-pair level is controlled for. It may, however, exacerbate measurement error problems and eliminate too much identifying variation.

In the lower part of Tables A1 and A2, on the left side the first set of results is for

unweighted regressions (recall that in the baseline we perform weighted regressions, where the number of bilateral observations for a given market-pair serves as the weight).

The set of results in the middle of the lower row of Tables A1 and A2 restricts the sample to the years from 1820 to 1880. It is during these 60 years that most of the train connections were established, customs liberalized, and currency agreements formed. Moreover, this period also excludes the early 1800s, where prices and trade may be particularly strongly affected by wars (coalition and Napoleonic Wars until 1815).

Finally, the set of results in the lower right of Tables A1 and A2 presents results from trimmed price gap samples. Specifically, there we drop the market-pairs that exhibit the 5% highest and 5% lowest average price differences over the sample period. This enables us to see whether our results are strongly driven by a small number of unusual but influential observations.[48]

For the full sample of the entire 19th century, the trains effect tends to be around -0.2. Over the sixty years from 1820 to 1880, the trains effect varies a bit more, from -0.12 to -0.21 (Table A1, lower row, center). The long-run impact of currency agreements is estimated around -0.06, with only one specification which leads to no significant effect (Market-Pair Fixed Effects, Table A1), while there is no robust long-run effect from customs liberalizations. Over the twenty-five year period, the trains effect is mostly around -0.1

[48] In Table A1, the number of observations for Table A1 Baseline, Limited-Information ML, Market-Pair Fixed Effects, and No Weights specifications is equal to 10,434. The Years 1820-80 results are based on 7,643 observations, and the Trimmed Price Gap Sample results are based on 9,394 observations. In Table A2, the numbers of observations in the Baseline are 6,477, 6,949, and 6,990 for columns 1, 2, and 3, respectively. The same figures apply for LIML, Market-Pair Fixed Effects, and No Weights. For the Years 1820 to 1880 set in Table 2, the number of observations are 6,471, 6,942, and 6,957 for columns 1, 2, and 3, respectively. In the lower right corner of Table A2, the number of observations are, from left to right, 6,046, 6,507, and 6,987.

to -0.12, with a minimum (maximum) estimate of -0.07 (-0.18). The currency effect is somewhat less robustly estimated, but tends to be around -0.04. The impact from customs liberalizations is typically estimated around -0.09 (see Table A2).

Second, we also examine the robustness of the results in terms of our emphasis of the customs liberalizations associated with Zollverein treaties. In Table A3, results for two alternative treatments of customs liberalizations are presented. The Zollverein had no external duties on wheat for some time after the year 1853 (Tracy 1989, 87), Henderson (1959, 226). However, with the arrival of grain from the United States about two decades later (see O'Rourke 1997), pressure for import protection mounted and in 1879, the German Reichstag reverted to import tariffs for wheat (Tracy 1989, 89). For the Pervasive Liberalization specification, we assume that the other European countries' policies were identical to that of the Zollverein, respectively the German Reich; we assume that during the years 1853 to 1879, no customs duties were paid between any two markets in the sample. For the second specification, Only ZV Liberalization, we make the alternative assumption that there were no external customs duties for the Zollverein markets, that customs greater than zero remained in place between the non-Zollverein markets.[49] Table A3 shows that the results of either treatment are quite similar to our baseline (reproduced from Tables 5 and 6 for convenience). This suggests that accounting fully for temporary liberalizations in grain trade will not change our main conclusions.

Third, we examine the sensitivity of our results with respect to features specific to par-

[49] Even though many European countries had relatively low duties on grain in the period of 1850-80, and in particular between 1866-79, they were typically not equal to zero; see figures in Bairoch (1989) and the data compiled by Jacks (2005).

ticular countries. For example, Austria-Hungary around the year 1820 still had internal customs duties (Bairoch 1989,6). This would be in contrast to our assumption that there are no customs borders between any two markets of a given state or country with contiguous areas ($CU_{ijt} = 1$, all t). The following analysis is also useful to examine whether our analysis holds even if we restrict the analysis to the German states. Tables A4 and A5 show the result, with the former presenting results for the entire 19th century, and the latter for the twenty-five year period after a change in CU, LT, or TR. The tables report only coefficient estimates, standard errors, and the number of observations; more details are available from the authors upon request.

In the upper left corner, we reproduce the Baseline results from Tables 4, 5, and 6, column 2, respectively. The following six blocks of results are for restricted samples; the first, "No France", for example, drops all market-pair observations that involve a market in France. The sixth set of results is labeled "Only Germany", which means that these results are obtained from an analysis of markets in the 15 German states only (note the lower number of observations). Finally, the "No [X-country] Average" figures are the average estimates computed from the six previous sets of results (analogous to jackknife estimates). It is useful to compare these averages to the Baseline results. Generally, the results are highly consistent. Relative to the Baseline, the long-run average train effects are slightly higher (around -0.24 instead of -0.22). The long-run currency effect is somewhat lower than in the Baseline (-0.03 versus -0.07), while the opposite is true for the customs coefficients. Also in the short-run, the trains effect is on average similar to the Baseline results (Table A5). The short-run currency effect is somewhat higher than the Baseline (-0.064 versus -0.038), while

the short-run customs estimate is a bit lower (-0.082 versus -0.093), so that it is unsurprising that the Institutions ($INST$) effect is very similar to the Baseline result. A focus on the German states would not lead to very different conclusions, except perhaps a somewhat larger relative impact from trains.

Overall, the long-run impact from trains is quite consistently several times larger than the institutions effect. For the shorter period of twenty-five years after the change, the difference in the relative magnitudes is smaller but trains are still estimated to have a substantially larger impact onthe expansion of markets than institutions.

Table 1: Summary Statistics

Overall sample period: 1800 - 1899

No	City	State/Country	Number of price obs.	Mean price	Year of Earliest Obs.	Year of Zollverein Accession	Year of Earliest Rail Connection	Year of Earliest Legal Tender Status
1	Prague	Austria-Hungary	8	19.47	1836		1845	
2	Salzburg	Austria-Hungary	4	29.02	1849		1860	
3	Venice	Austria-Hungary	7	15.57	1836		1856	
4	Vienna	Austria-Hungary	86	20.57	1820		1845	
5	Baden	Baden	28	16.29	1818	1836	1846	1837
6	Augsburg	Bavaria	41	16.92	1815	1834	1840	1837
7	Bamberg	Bavaria	41	16.32	1815	1834	1844	1837
8	Bayreuth	Bavaria	41	16.82	1815	1834	1853	1837
9	Erding	Bavaria	41	16.33	1815	1834	1859	1837
10	Kempten	Bavaria	41	18.81	1815	1834	1852	1837
11	Landshut	Bavaria	41	15.58	1815	1834	1854	1837
12	Lindau	Bavaria	41	19.14	1815	1834	1852	1837
13	Memmingen	Bavaria	41	18.00	1815	1834	1858	1837
14	Munich	Bavaria	100	18.69	1800	1834	1840	1837
15	Noerdlingen	Bavaria	41	16.14	1815	1834	1849	1837
16	Nurnberg	Bavaria	45	16.42	1811	1834	1844	1837
17	Regensburg	Bavaria	41	15.09	1815	1834	1859	1837
18	Straubing	Bavaria	41	14.65	1815	1834	1858	1837
19	Wuerzburg	Bavaria	41	16.41	1815	1834	1854	1837
20	Zweibruecken	Bavaria	38	16.57	1818	1834	1857	1837
21	Brugge	Belgium	100	20.62	1800		1838	
22	Brussels	Belgium	91	22.45	1800		1838	
23	Braunschweig	Brunswick	50	16.50	1800	1841	1844	1857
24	Bar-le-Duc	France	30	18.08	1825		1851	
25	Chalons sur Marne	France	30	18.55	1825		1851	
26	Luneville	France	30	19.03	1825		1851	
27	Mulhouse	France	76	22.41	1800		1841	
28	Strassburg	France	76	21.63	1800		1841	
29	Toulouse	France	100	21.40	1800		1859	
30	Bremen	Free City	11	20.53	1837	1888	1847	1871
31	Frankfurt/Main	Free City	14	22.57	1816	1836	1840	1837
32	Hamburg	Free City	100	19.68	1800	1888	1846	1871
33	Luebeck	Free City	9	17.58	1837	1867	1851	1871

Table 1, cont'd

No	City	State/Country	Number of price obs.	Mean price	Year of Earliest Obs.	Year of Zollverein Accession	Year of Earliest Rail Connection	Year of Earliest Legal Tender Status
34	Goettingen	Hannover	68	17.12	1800	1854	1854	1857
35	Hannover	Hannover	50	17.81	1801	1854	1844	1857
36	Kassel	Hesse-Cassel	27	14.22	1822	1831	1849	1857
37	Bingen	Hesse-Darmstadt	1	20.34	1840	1828	1858	1837
38	Giessen	Hesse-Darmstadt	1	19.12	1840	1828	1850	1837
39	Mainz	Hesse-Darmstadt	3	23.68	1840	1828	1853	1837
40	Worms	Hesse-Darmstadt	1	20.68	1840	1828	1853	1837
41	Wiesbaden	Hesse-Nassau	1	18.13	1840	1836	1840	1837
42	Grabow	Mecklenburg	71	18.45	1800	1867	1846	1871
43	Boizenburg	Mecklenburg	71	18.30	1800	1867	1846	1871
44	Parchim	Mecklenburg	71	17.43	1800	1867	1880	1871
45	Rostock	Mecklenburg	71	17.57	1800	1867	1850	1871
46	Schwerin	Mecklenburg	71	17.67	1800	1867	1847	1871
47	Wismar	Mecklenburg	57	16.65	1800	1867	1848	1871
48	Nijmegen	Netherlands	93	21.46	1800		1856	
49	Utrecht	Netherlands	15	30.66	1800		1856	
50	Aachen	Prussia	61	18.88	1800	1834	1841	1857
51	Berlin	Prussia	61	18.14	1800	1834	1841	1857
52	Cologne	Prussia	100	18.25	1800	1834	1841	1857
53	Hamm	Prussia	20	20.86	1800	1834	1847	1857
54	Herdecke	Prussia	20	23.23	1800	1834	1848	1857
55	Minden	Prussia	13	21.49	1800	1834	1847	1857
56	Muenster	Prussia	64	18.91	1800	1834	1848	1857
57	Saarlouis	Prussia	20	17.70	1800	1834	1858	1857
58	Soest	Prussia	20	17.71	1800	1834	1850	1857
59	Wetzlar	Prussia	20	19.27	1800	1834	1862	1857
60	Xanten	Prussia	20	18.48	1800	1834	1880	1857
61	Dresden	Saxony	21	16.78	1832	1834	1839	1857
62	Leipzig	Saxony	68	20.15	1832	1834	1839	1857
63	Zwickau	Saxony	21	18.44	1832	1834	1845	1857
64	Basel	Switzerland	10	24.75	1845		1844	
65	Lucerne	Switzerland	9	23.94	1845		1856	
66	Rorschach	Switzerland	14	20.79	1824		1856	
67	Stuttgart	Wurttemberg	5	23.68	1850	1834	1850	1837
68	Ulm	Wurttemberg	6	22.81	1850	1834	1850	1837

Prices in Bavarian Gulden, per Bavarian Scheffel (about 223 liter)

Table 2: Sample Summary Statistics

Variable	Mean	Std. Dev.	Variable Description
Price Gap	0.18	0.15	Absolute value of the log difference of wheat price in market i and market j (pdif)
Train Connection	0.14	0.35	0/1 variable; 1 if train connection exists between markets i and j in year t, 0 otherwise (TR)
Currency Agreement	0.18	0.38	0/1 variable; 1 if currencies of i and j are legal tender in both markets in year t, 0 otherwise (LT)
Customs Liberalization	0.22	0.42	Dichotomous variable; 1 if customs are liberalized between markets i and j in year t, 0 otherwise (CU)
City Population in 1800	0.38	0.39	Average of the population of city i and city j in the year 1800; in 100,000 people
Market Potential	13.81	1.44	Log distance-weighted state population in year t; see eq. (3)
Gulden in 1754	0.11	0.31	Minimum of whether market i and market j had Gulden as its currency in the year 1754
Currency Population	7.87	8.19	Log population of German states that gave each other legal tender status in year t
Distance to the Coast	1.69	1.66	Minimum of market i and market j's distance to the nearest coast, in 100 kilometers
Zollverein Population	11.18	8.12	Log population of German states that belonged to the Zollverein in year t
Length of Observation	11.58	4.59	Number of observations per market-pair

Number of observations: 10,434
Statistics weighted by number of observations of market-pair

Table 3: Determinants of Market Expansion

	(1) Trains	(2) Customs	(3) Currencies
Panel A: Second-Stage Results			
Train Connection	-0.347#		
	(0.119)		
Customs Liberalization		-0.978#	
		(0.340)	
Currency Agreement			-0.815*
			(0.329)
Panel B: First-Stage Results			
Market Potential	0.007*		
	(0.003)		
City Population in 1800	0.059+		
	(0.033)		
Zollverein population		0.011#	
		(0.004)	
Distance to Coast		0.006	
		(0.004)	
Currency Agreement Population			0.012#
			(0.004)
Gulden in 1754			1.0004#
			(0.004)
F-statistic	7.41	5.99	29,007
[p-value]	[<.001]	[0.003]	[<.001]
Shea Partial R-squared (percent)	0.8	0.7	2.7
Panel C: Ordinary Least Squares			
Train Connection	-0.015		
	(0.010)		
Customs Liberalization		0.003	
		(0.010)	
Currency Agreement			-0.005
			(0.013)
Hausman Exogeneity Test p-value	0.005	0.003	0.007
Hansen OverID Test p-value	0.67	0.37	0.24

Dependent variable: absolute value of percentage bilateral price difference; robust standard errors clustered at the state-pair level in parentheses. All regressions include year- and state-pair fixed effects. #/*/+ Estimate is significant at the 1%/5%/10% level
Number of observations: 10,434

Table 4: Trains versus Currency Agreements

	(1) Years 1800-99	(2) Years 1800-99	(3) 25-Year Window
	Panel A: Second-Stage Results		
Train Connection	-0.208#	-0.213#	-0.139#
	(0.041)	(0.022)	(0.024)
Currency Agreem't	-0.040	-0.071#	-0.038*
	(0.137)	(0.020)	(0.018)
No. of Excluded Instruments	4	27	25
	Panel B1: First-Stage Train Connection		
City Popul'n in 1800	0.059+		
	(0.033)		
Market Potential	0.007*		
	(0.003)		
F-statistic	1742.8	1.00E+05	45630.3
[p-value]	[<0.001]	[<0.001]	[<0.001]
Shea Partial R-squared (percent)	1.8	7.6	9.4
	Panel B2: First-Stage Currency Agreement		
Currency Ag't Pop'n	0.012#		
	(0.004)		
Gulden in 1754	1.015#		
	(0.020)		
F-statistic	15345	1.70E+07	18423.4
[p-value]	[<0.001]	[<0.001]	[<0.001]
Shea Partial R-squared (percent)	0.4	2.9	4.0
Hansen OverID Test p-value	0.61	0.34	0.34
Number of obs	10,434	10,434	6,477

Dependent variable: absolute value of percentage bilateral price difference; robust standard errors clustered at the state-pair level in parentheses.
All regressions include year- and state-pair fixed effects. Columns 1-3 first stages include the following instruments: Market Potential
Currency agreement population, Gulden in 1754 and City Population in 1800; Gulden and City Population are interacted by state in columns 2-3
Not all coefficients are shown; the full set of results is available from the authors upon request. #/*/** significant at the 1%/5%/10% level

Table 5: Trains versus Customs Liberalization

	(1) Years 1800-99	(2) Years 1800-99	(3) 25-Year Window
	Panel A: Second-Stage Results		
Train Connection	-0.244#	-0.222#	-0.124#
	(0.075)	(0.013)	(0.010)
Customs Liberalization	0.140	-0.015	-0.093#
	(0.339)	(0.013)	(0.011)
No. of Excluded Instruments	4	74	74
	Panel B1: First-Stage Train Connection		
City Popul'n in 1800	0.060+		
	(0.034)		
Market Potential	0.006+		
	(0.003)		
F-statistic	1744.2	570.8	2210.2
[p-value]	[<0.001]	[<0.001]	[<0.001]
Shea Partial R-squared (percent)	3.0	15.2	12.4
	Panel B2: First-Stage Customs Liberalization		
Zollverein Population	0.012#		
	(0.004)		
Distance to Coast	0.006		
	(0.004)		
F-statistic	3.060	1.08E+04	11617.8
[p-value]	[0.017]	[<0.001]	[<0.001]
Shea Partial R-squared (percent)	0.2	10.1	10.4
Hansen test p-value	0.67	0.37	0.14
Number of obs	10,434	10,434	6,949

Dependent variable: absolute value of percentage bilateral price difference; robust standard errors clustered at the state-pair level in parentheses.
All regressions include year- and state-pair fixed effects. The first stages in columns 1-3 include the following instruments:
Market potential, currency agreement population, City Population in 1800, and Distance to Coast, all interacted by state in columns 2-3
Not all coefficients are shown; the full set of results is available from the authors upon request. #/*/** significant at the 1%/5%/10% level

Table 6: Trains versus Institutions

	(1) Years 1800-99	(2) Years 1800-99	(3) 25-Year Window
	Panel A: Second-Stage Results		
Train Connection	-0.165#	-0.217#	-0.090#
	(0.034)	(0.013)	(0.015)
Institutions	-0.120*	-0.008*	-0.059#
	(0.055)	(0.004)	(0.004)
No. of Excluded Instruments	4	58	57
	Panel B1: First-Stage Train Connection		
Market Potential	0.015#		
	(0.004)		
F-statistic	1660.1	2.90E+08	27395.3
[p-value]	[<0.001]	[<0.001]	[<0.001]
Shea Partial R-squared (percent)	1.2	13.1	10.8
	Panel B2: First-Stage Institutions		
Zollverein Population	0.024#		
	(0.008)		
Gulden in 1754	1.985#		
	(0.034)		
Distance to Coast	0.009*		
	(0.005)		
F-statistic	9442.2	7.2	908.0
[p-value]	[<0.001]	[<0.001]	[<0.001]
Shea Partial R-squared (percent)	0.2	10.5	12.3
Hansen test p-value	0.52	0.30	0.18
Number of obs	10,434	10,434	6,990

Dependent variable: absolute value of percentage bilateral price difference; robust standard errors clustered at the state-pair level in parentheses. All regressions include year- and state-pair fixed effects. Column 1-3 include the following instruments: Market potential, currency agreement population, City Population in 1800, and Distance to Coast; all interacted by state in columns 2-3 The full set of results is available from the authors upon request. #/*/** significant at the 1%/5%/10% level

Figure 1

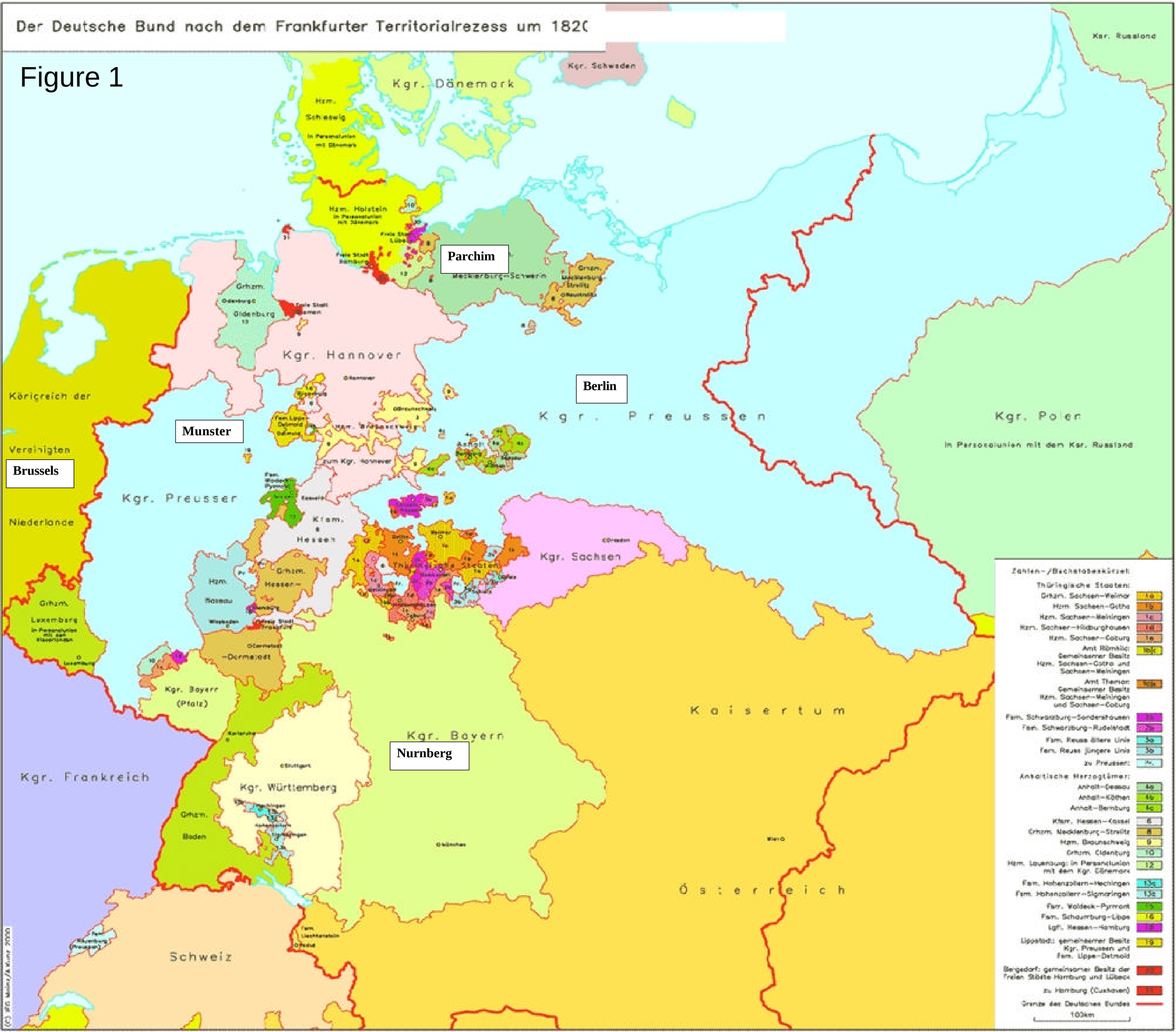
Der Deutsche Bund nach dem Frankfurter Territorialrezess um 1820
Kgr. Dänemark
Kgr. Schweden
Kgr. Russland
Parchim
Berlin
Munster
Brussels
Nurnberg
Kgr. Hannover
Kgr. Preussen
Kgr. Polen
Königreich der Vereinigten Niederlande
Kgr. Preusser
Kgr. Sachsen
Kgr. Bayern
Kgr. Württemberg
Kgr. Frankreich
Kaisertum Österreich
Schweiz
Kgr. Bayern (Pfalz)
Grhzm. Luxemburg
Zahlen-/Buchstabenkürzel
Thüringische Staaten:
Grhzm. Sachsen-Weimar
Hzm. Sachsen-Gotha
Hzm. Sachsen-Meiningen
Hzm. Sachsen-Hildburghausen
Hzm. Sachsen-Coburg
Anhaltische Herzogtümer:
Anhalt-Dessau
Anhalt-Köthen
Anhalt-Bernburg
Kfm. Hessen-Kassel
Grhzm. Mecklenburg-Strelitz
Hzm. Braunschweig
Grhzm. Oldenburg
Grenze des Deutschen Bundes
100km

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Figure 2

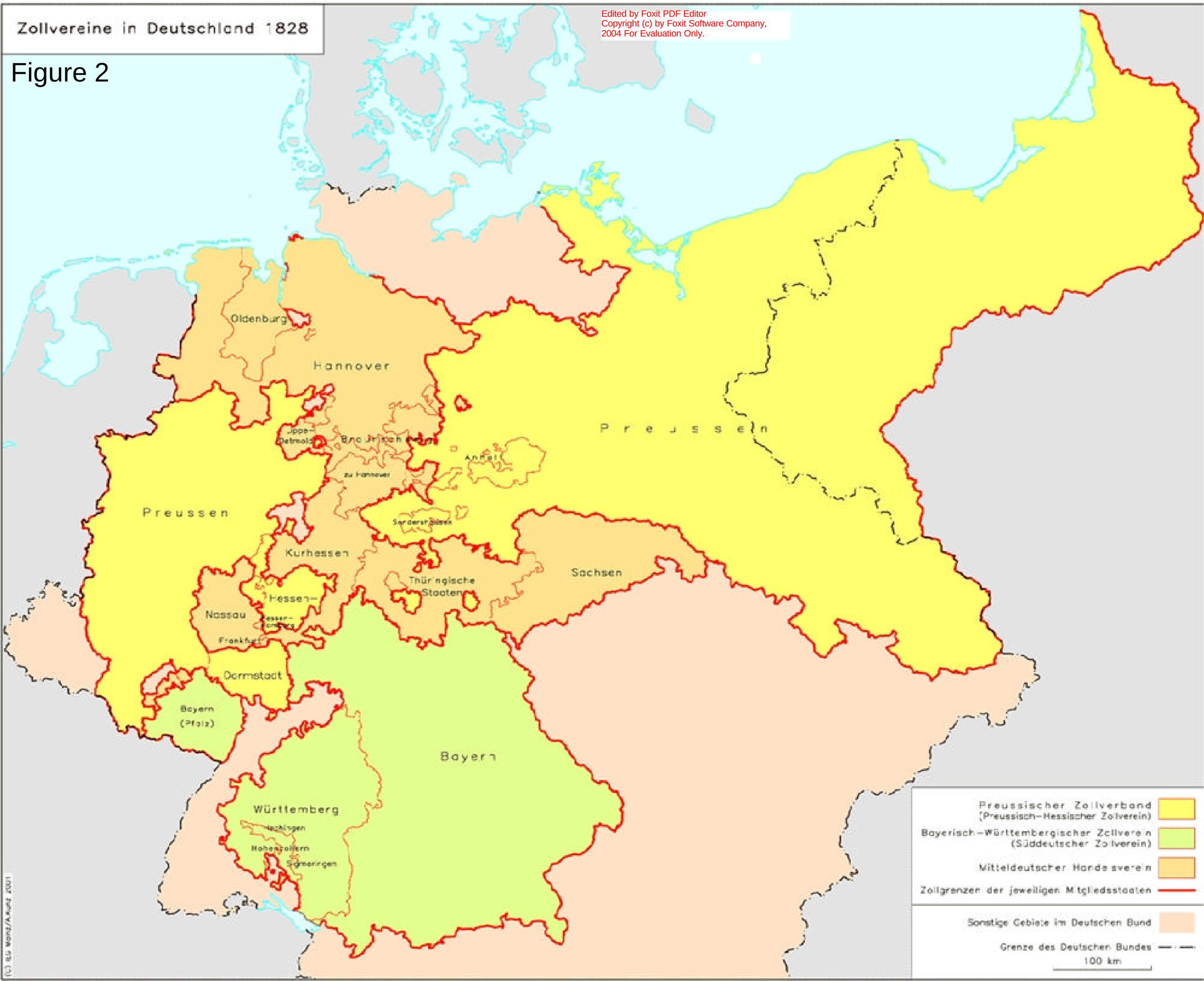

Figure 3: Four Markets and the Zollverein Liberalization of 1834

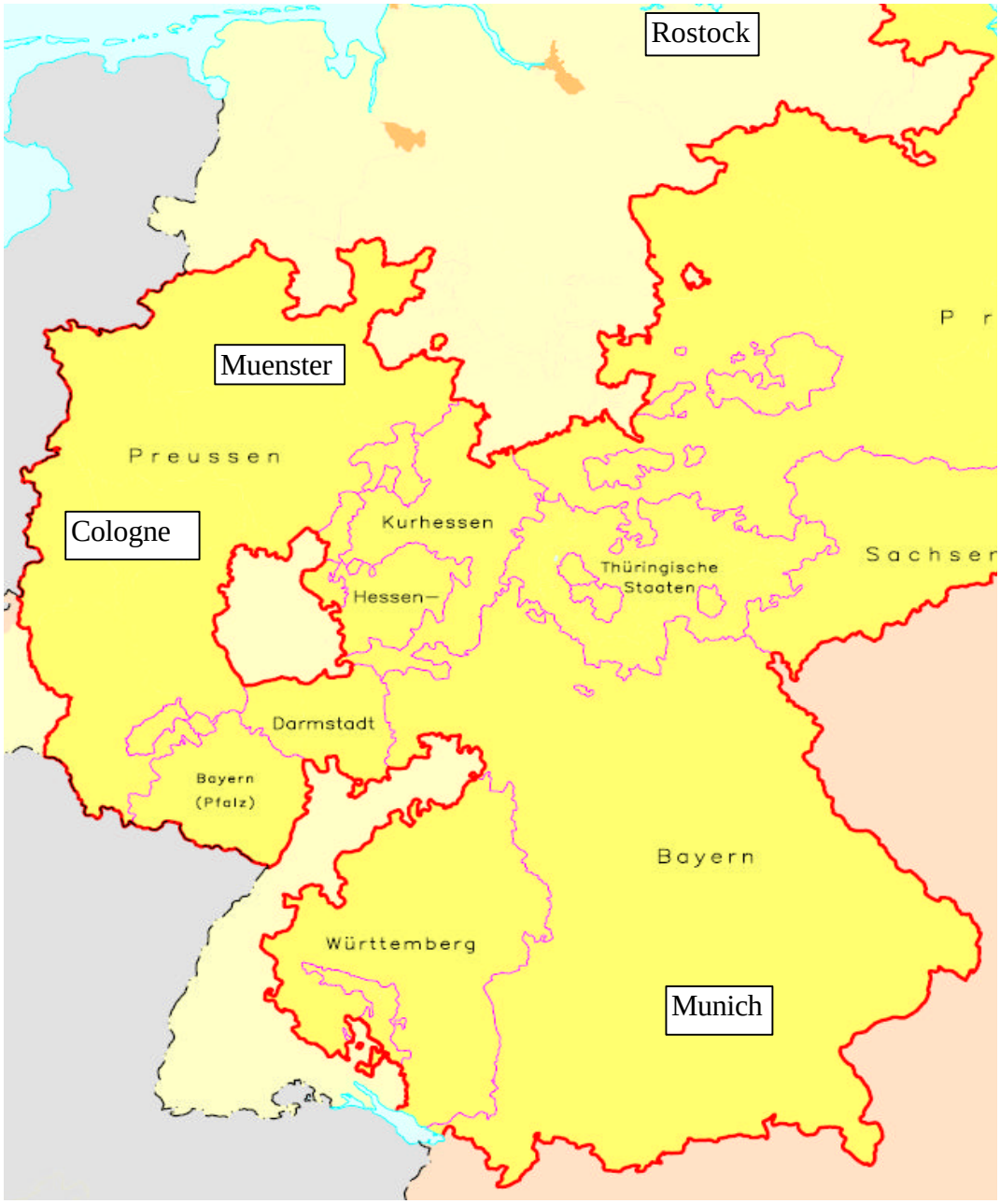

Figure 4: Train connections in the year 1850

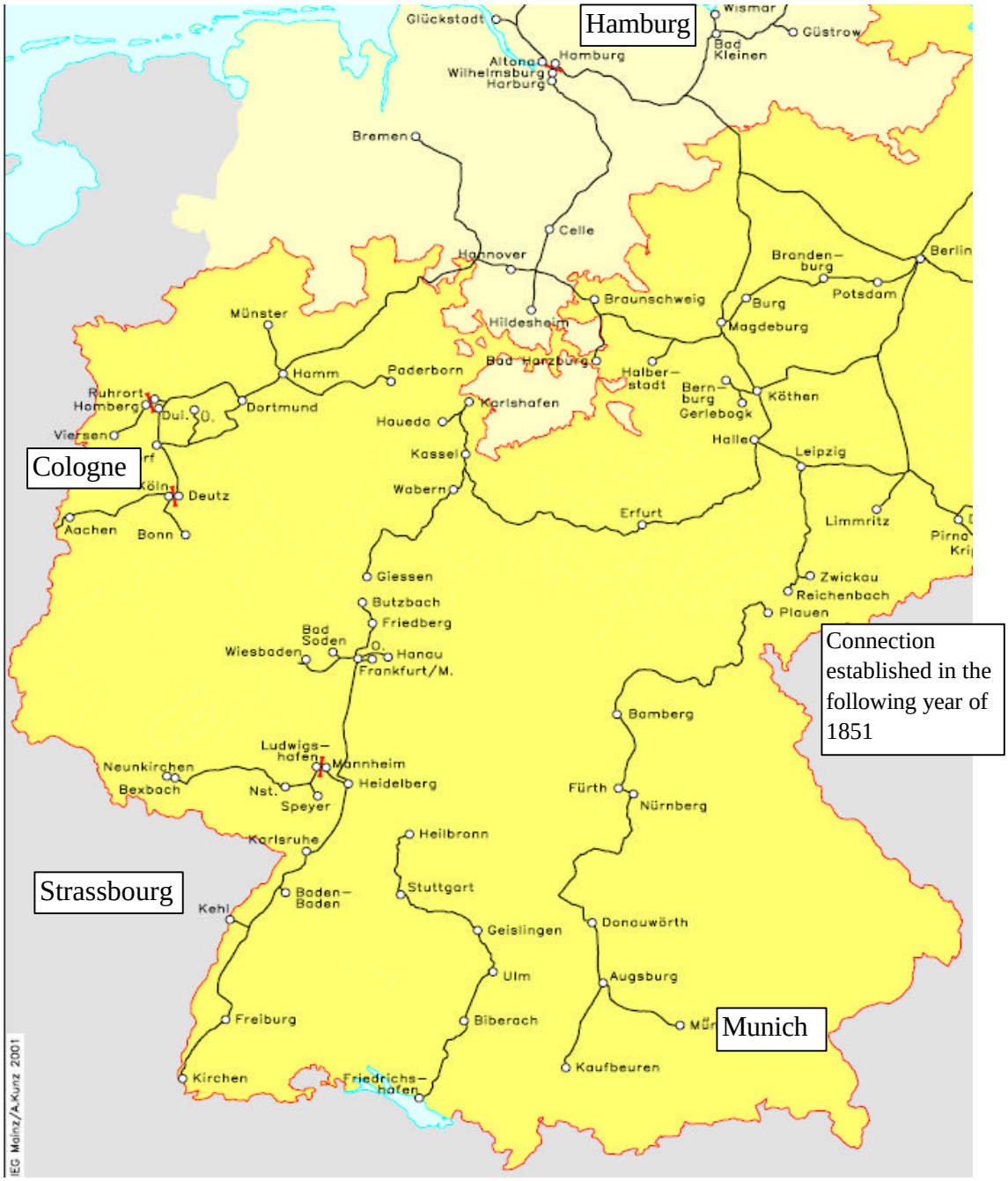

Figure 5: Cities in states further away from the seaboard join the Zollverein earlier

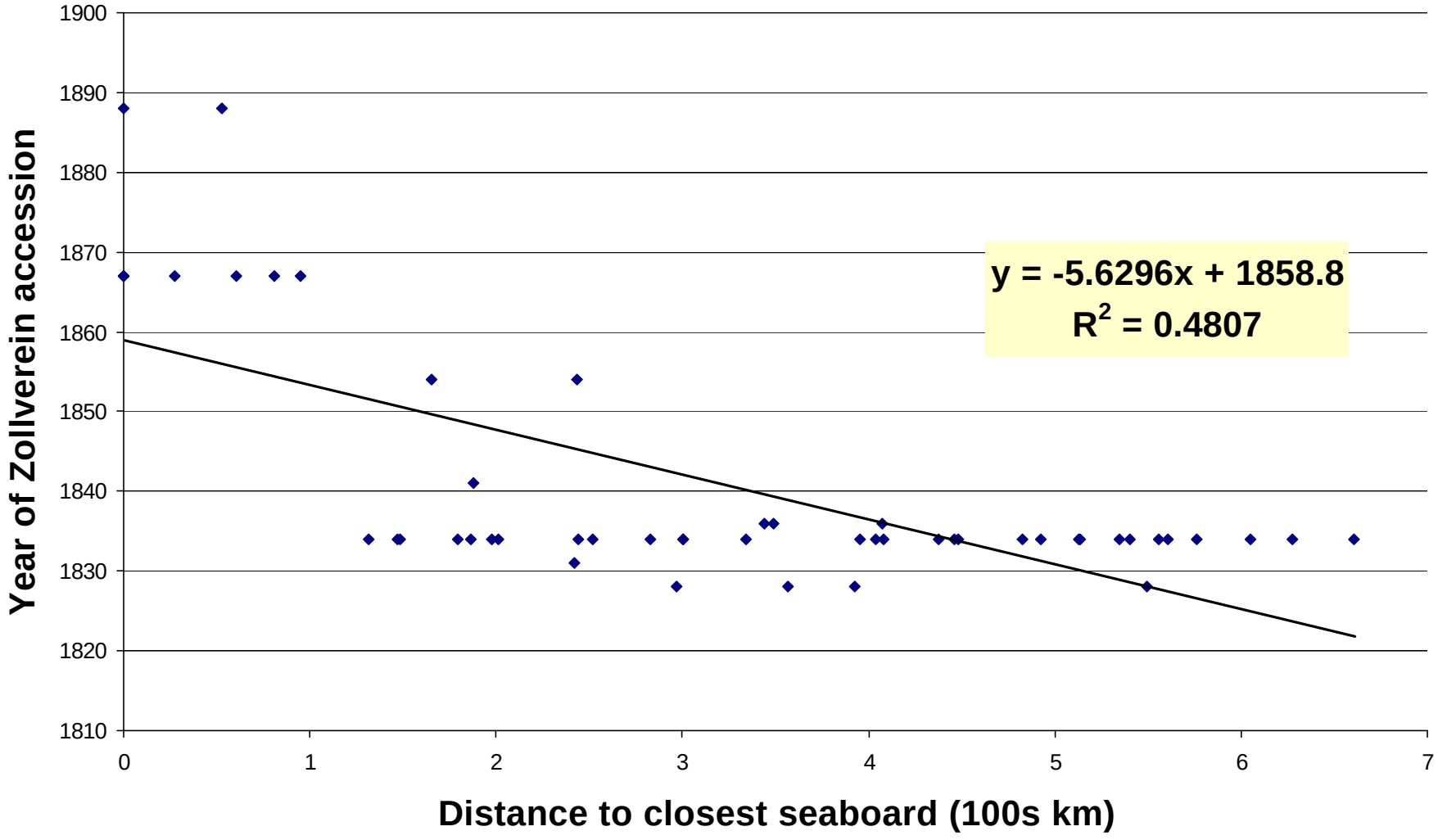

Figure 6: Larger Cities Have Railways Earlier

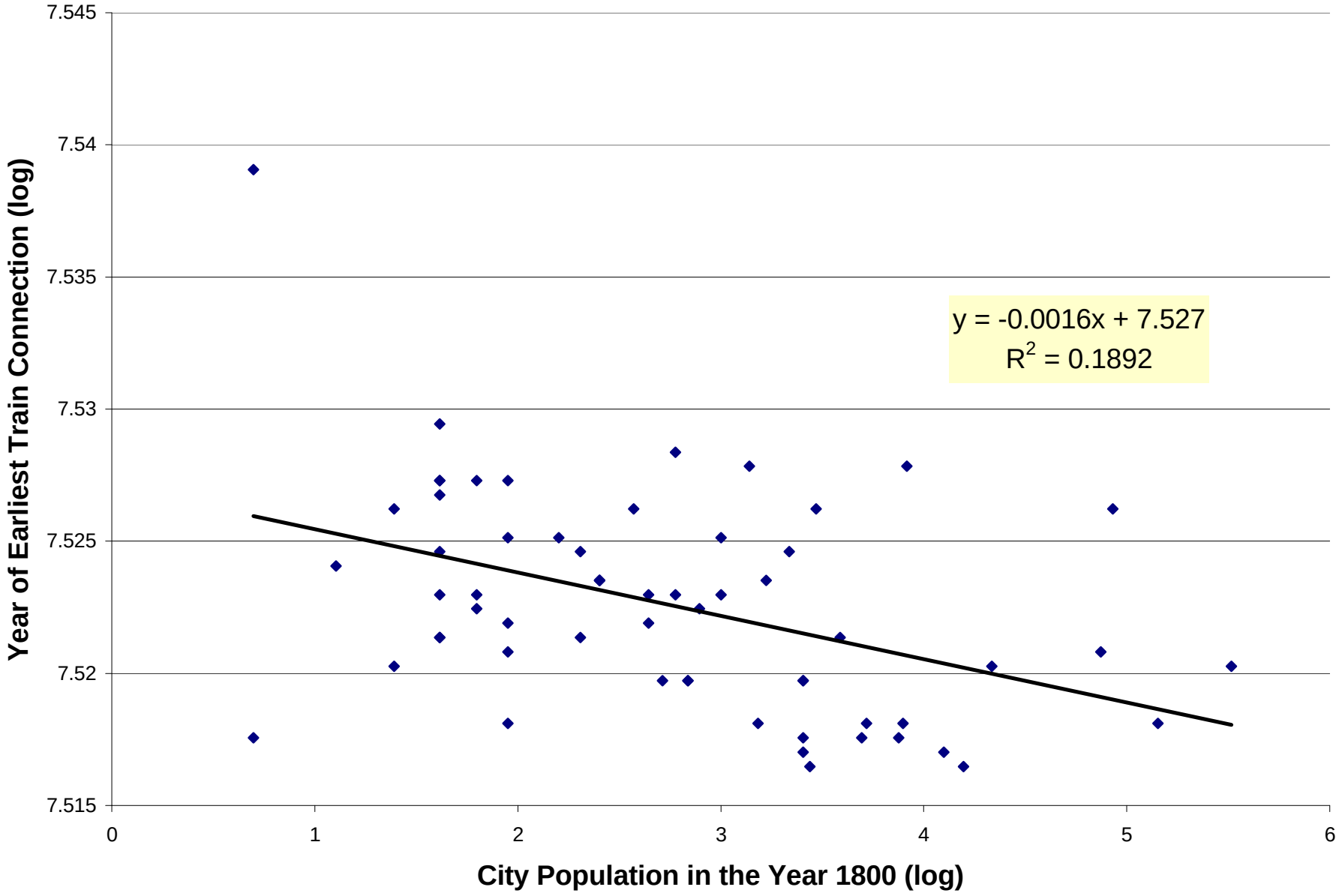

Table A1: Robustness

	Baseline			Limited-Information ML			Market-Pair Fixed Effects		
Train Connection	-0.213#	-0.222#	-0.217#	-0.197#	-0.214#	-0.209#	-0.184#	-0.181#	-0.182#
	(0.022)	(0.013)	(0.013)	(0.020)	(0.013)	(0.013)	(0.020)	(0.018)	(0.018)
Currency Agreement	-0.071#			-0.094#			-0.001		
	(0.020)			(0.020)			(0.026)		
Customs Liberal'n		-0.015			-0.082#			-0.007	
		(0.013)			(0.014)			(0.018)	
Institutions			-0.008*			-0.003			-0.003
			(0.004)			(0.003)			(0.012)
No. of excluded IVs	27	74	58	27	74	59	38	38	38
1st-stage Trains R-sq(%)	7.6	15.2	13.1	7.4	15.2	13.1	15.0	15.1	14.8
1st-stage Institutions R-sq (%)	2.9	10.1	10.5	2.7	10.1	10.5	19.1	15.2	19.8

	No Weights			Years 1820 to 1880			Trimmed Price Gap Sample		
Train Connection	-0.231#	-0.231#	-0.209#	-0.119#	-0.205#	-0.173#	-0.186#	-0.217#	-0.214#
	(0.025)	(0.014)	(0.013)	(0.013)	(0.011)	(0.015)	(0.019)	(0.012)	(0.014)
Currency Agreement	-0.041#			-0.060#			-0.072#		
	(0.020)			(0.019)			(0.009)		
Customs Liberal'n		-0.034*			0.103#			0.005	
		(0.015)			(0.020)			(0.010)	
Institutions			-0.022#			0.016			0.005
			(0.005)			(0.017)			(0.003)
No. of excluded IVs	25	74	57	25	74	58	24	71	57
1st-stage Trains R-sq(%)	9.6	12.6	11.5	5.3	17.5	11.1	9.0	16.5	14.6
1st-stage Institutions R-sq (%)	11.4	11.3	13.4	2.9	6.7	6.3	3.4	10.5	12.5

Robust standard errors clustered on state-pair in parentheses; #/*/+ indicates significant at a 1%/5%/10% level; all 1st-stage F-statistic p-value <0.001 (not shown)

Table A2: Robustness - 25-Year Window

	Baseline			Limited-Information ML			Market-Pair Fixed Effects		
Train Connection	-0.139#	-0.124#	-0.090#	-0.097#	-0.070#	-0.070#	-0.182#	-0.134#	-0.146#
	(0.024)	(0.010)	(0.015)	(0.025)	(0.012)	(0.013)	(0.023)	(0.024)	(0.021)
Currency Agreement	-0.038#			-0.019*			-0.057*		
	(0.018)			(0.009)			(0.024)		
Customs Liberal'n		-0.093#			0.018*			-0.028+	
		(0.011)			(0.009)			(0.014)	
Institutions			-0.059#			-0.028#			-0.011
			(0.004)			(0.005)			(0.010)
No. of excluded IVs	25	74	57	25	74	57	38	38	38
1st-stage Trains R-sq(%)	9.4	12.4	10.8	9.4	12.4	10.8	12.6	10.2	11.3
1st-stage Institutions R-sq (%)	4.0	10.4	12.3	4.3	10.4	12.9	18.6	16.0	21.2

	No Weights			Years 1820 to 1880			Trimmed Price Gap Sample		
Train Connection	-0.164#	-0.134#	-0.122#	-0.124#	-0.126#	-0.104#	-0.127#	-0.125#	-0.095#
	(0.022)	(0.014)	(0.013)	(0.018)	(0.010)	(0.015)	(0.023)	(0.010)	(0.013)
Currency Agreement	-0.011			-0.055#			-0.045#		
	(0.007)			(0.012)			(0.005)		
Customs Liberal'n		-0.091#			-0.090#			-0.084#	
		(0.013)			(0.011)			(0.013)	
Institutions			-0.051#			-0.059#			-0.064#
			(0.008)			(0.004)			(0.003)
No. of excluded IVs	25	74	59	25	74	58	24	73	58
1st-stage Trains R-sq(%)	9.7	11.8	10.5	8.8	12.3	10.6	10.0	13.2	12.9
1st-stage Institutions R-sq (%)	16.9	10.4	16.9	3.1	10.6	12.0	4.1	9.8	10.8

Robust standard errors clustered on state-pair in parentheses; #/*/+ indicates significant at a 1%/5%/10% level; all 1st-stage F-statistic p-value <0.001 (not shown)

Table A3: Broad Customs Liberalizations and Third-Country Effects

	Baseline		Pervasiva Liberalization		Only ZV Liberalization	
	(1)	(2)	(3)	(4)	(5)	(6)
Train Connection	-0.222#	-0.217#	-0.226#	-0.212#	-0.226#	-0.216#
	(0.013)	(0.013)	(0.012)	(0.013)	(0.013)	(0.013)
Customs Liberalization	-0.015		-0.015		-0.007	
	(0.013)		(0.013)		(0.013)	
Institutions		-0.008*		-0.014#		-0.005
		(0.004)		(0.004)		(0.003)
No. of Excluded Instruments	74	58	74	58	74	59
First-stage Trains						
F-statistic	570.8	2.90E+08	570.8	15499.2	570.8	1.10E+08
[p-value]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]
Shea Partial R-squared (percent)	15.2	13.1	15.4	12.6	15.4	13.2
First-State Institutions						
F-statistic	1.08E+04	7.2	8581.4	1.80E+09	5342	51496
[p-value]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]
Shea Partial R-squared (percent)	10.1	10.5	5.2	6.8	6.3	7.8
Hansen OverID Test p-value	0.37	0.30	0.34	0.35	0.35	0.32

Dependent variable: absolute value of percentage bilateral price difference; robust standard errors clustered at the state-pair level in parentheses.
All regressions include year- and state-pair fixed effects. Instrumental variables as in Tables 5 (column 2) and 6 (column 2); number of obs: 10,434
Not all coefficients are shown; the full set of results is available from the authors upon request. #/*/** significant at the 1%/5%/10% level
Pervasive Liberalization: No customs duties between any markets between the years 1853-1879
Only ZV Liberalization: Assumes Zollverein eliminated external tariff between 1853-79 while tariffs between non-Zollverein markets remained greater than zero.

Table A4: Period 1800 - 1899

	Trains	Currency	Customs	Inst.	Nobs
Baseline	-0.213#	-0.071#			10,434
	(0.022)	(0.020)			
	-0.222#		-0.015		10,434
	(0.013)		(0.013)		
	-0.217#			-0.008*	10,434
	(0.013)			(0.004)	
No France	-0.226#	-0.032#			8,110
	(0.026)	(0.011)			
	-0.218#		-0.059#		8,110
	(0.012)		(0.012)		
	-0.214#			-0.044#	8,110
	(0.011)			(0.004)	
No Belgium	-0.259#	-0.062#			9,329
	(0.019)	(0.009)			
	-0.253#		-0.010		9,329
	(0.013)		(0.011)		
	-0.253#			-0.007*	9,329
	(0.012)			(0.003)	
No Netherlands	-0.227#	-0.053#			9,807
	(0.021)	(0.013)			
	-0.235#		-0.022		9,807
	(0.013)		(0.014)		
	-0.228#			-0.019#	9,807
	(0.013)			(0.004)	

	Trains	Currency	Customs	Inst.	Nobs
No Switzerland	-0.223#	-0.057#			10,111
	(0.020)	(0.007)			
	-0.222#		-0.015		10,111
	(0.013)		(0.013)		
	-0.213#			-0.008	10,111
	(0.013)			(0.006)	
No Austria-H	-0.193#	-0.048			9,802
	(0.067)	(0.204)			
	-0.221#		0.001		9,802
	(0.013)		(0.012)		
	-0.225#			0.030	9,802
	(0.035)			(0.026)	
Only Germany	-0.343#	0.017			5,896
	(0.018)	(0.027)			
	-0.269#		-0.046#		5,896
	(0.015)		(0.013)		
	-0.274#			-0.027#	5,896
	(0.015)			(0.007)	
No [X-Country] Average	-0.245	-0.034			
	-0.236		-0.018		
	-0.235			-0.016	

Robust standard errors clustered on state-pair in parentheses; #/*/+ indicates significant at a 1%/5%/10% level

Table A5: 25-Year Window

	Trains	Currency	Customs	Inst.	Nobs
Baseline	-0.139#	-0.038*			6,477
	(0.024)	(0.018)			
	-0.124#		-0.093#		6,949
	(0.010)		(0.011)		
	-0.090#			-0.059#	6,990
	(0.015)			(0.004)	
No France	-0.118#	-0.078#			5,422
	(0.025)	(0.009)			
	-0.111#		-0.110#		5,894
	(0.007)		(0.010)		
	-0.096#			-0.064#	5,935
	(0.013)			(0.010)	
No Belgium	-0.118#	-0.081#			5,939
	(0.022)	(0.009)			
	-0.139#		-0.078#		6,411
	(0.011)		(0.010)		
	-0.114#			-0.057#	6,452
	(0.010)			(0.005)	
No Netherlands	-0.128#	-0.054#			6,247
	(0.025)	(0.009)			
	-0.127#		-0.090#		6,719
	(0.011)		(0.011)		
	-0.097#			-0.051#	6,760
	(0.015)			(0.005)	

	Trains	Currency	Customs	Inst.	Nobs
No Switzerland	-0.135#	-0.054#			6,207
	(0.020)	(0.009)			
	-0.124#		-0.094#		6,679
	(0.011)		(0.010)		
	-0.092#			-0.067#	6,720
	(0.012)			(0.004)	
No Austria-H	-0.118#	-0.068#			6,077
	(0.025)	(0.014)			
	-0.142#		-0.049#		6,549
	(0.011)		(0.011)		
	-0.105#			-0.049#	6,590
	(0.010)			(0.003)	
Only Germany	-0.119#	-0.046#			4,240
	(0.013)	(0.008)			
	-0.109#		-0.072#		4,712
	(0.007)		(0.008)		
	-0.107#			-0.037#	4,753
	(0.009)			(0.005)	
No [X-Country] Average	-0.123	-0.064			
	-0.125		-0.082		
	-0.102			-0.054	

Robust standard errors clustered on state-pair in parentheses; #/*/+ indicates significant at a 1%/5%/10% level