Tariffs, Trains, and Trade:
The Role of Institutions versus Technology in the Expansion of Markets[1]

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Abstract

Were institutional or technological factors more important for commodity market integration in 19th century Europe? This period witnessed major institutional changes in the form of currency agreements and the *Zollverein* customs liberalizations as well as transport cost reductions in the form of the building of railways. A priori, it is not evident which of these factors were most important, although much research on currency and trade agreements suggests these institutions had significant impacts on market integration in both historical and contemporary settings. This paper studies changes in market integration 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. In our direct comparison of the leading factors that contribute to market integration, we find that the emergence of integrated commodity markets in 19th century Europe is in a major part due to the transportation revolution in form of the railways. The evidence for the effect of customs liberalizations is mixed, and in a direct comparison, much smaller than the impact of railroads. Finally, we do not find evidence for effects from currency agreements on market integration. These results suggest that as significant as institutional factors were for the expansion of markets, technology factors may have been even more important. Implications for economic development are discussed.

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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 history of the origins and the spread of the market economy (Braudel 1992, 225). While it is uncontroversial to claim that trade liberalization, monetary arrangements, and new technologies that reduce transportation costs all could potentially benefit commercial exchange, to date little is known about the relative importance of these factors. How and when did markets expand? What is it that allows markets to perform well? How important are institutional and technological factors in producing more integrated trade relations? This paper sheds new light on this issue by studying the functioning of commodity markets in Europe throughout the 19th century. Our primary goal is to compare the importance of institutional versus technological factors affecting market integration.

The setting of 19th century Europe presents a unique opportunity, we argue, to address this issue. During this period, we observe institutional changes (tariff and monetary agreements) as well as transport cost reductions (the building of railways). A key institution that emerged during the 19th century was the German *Zollverein*, the classic example of a customs union (Viner 1950, 97). 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. Also, the first major monetary arrangements between several currencies were created in the first half of the 19th century. The institutional framework provided by these laws governing commodity and foreign exchange transactions was a clear break from centuries of relatively chaotic conditions.

Over the same years, the key transport technology of the 19th century, the steam train was beginning to be built and its network of rail tracks rapidly expanded. 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 steam train.

A priori, it is not evident which of these factors were most important. There is ample research on currency and trade agreements that suggests these institutions had significant impacts on market integration in both contemporary settings (Rose 2000, Frankel and Rose 2002, Rose 2004, Subramaniam and Wei 2006, Baier and Bergstrand 2007) and historical experiences (Eichengreen and Irwin 1995, Flandreau and Maurel 2001, Lopez-Cordova and Meissner 2003, Estevadeordal, Frantz, and Taylor 2003, Jacks 2006). Baier and Bergstrand (2007) in particular find that membership in a free trade agreement raises the volume of trade by about 100% in the post-World War II era. And in estimating the effect of currency agreements on trade, Lopez-Cordova and Meissner (2003) as well as Estevadeordal, Frantz, and Taylor (2003) show that if both trade partners were on the gold standard, this raises trade by 40% to 60% during the period of 1870 to 1939.

Moreover, there can be no doubt that technological innovations such as the building of railroad within and across European countries were very important to improvements in trade. Empirical research on European railroads exists, but these studies examine railroads in isolation from the impact of currency and trade agreements.[4] Since we compare the arguably most important institutions and technologies for trade in the

[4] The German case has been examined by Fremdling (1977). See also O'Brien (1983) for studies on other countries. The impact of railways has also been the focus of classic work by Fogel (1964) and Fishlow (1965) who study the importance of railroads for industrialization in the U.S. using social savings calculations.

19th century, the analysis also sheds new light on the question whether trade leads to growth (Frankel and Romer 1999, Acemoglu, Johnson, and Robinson 2005, Shiue and Keller 2007), as well as on the importance of institutions for economic performance more generally (Acemoglu, Johnson, Robinson 2001; Rodrik, Subramaniam, Trebbi 2002).

At the same time, there is no consensus yet on qualitative or quantitative findings.[5] This is partly due to the fact that often, only a small fraction of any sample has ever been part of a trade or currency agreement. Moreover, the trade and currency arrangement effects are often identified largely from cross-sectional variation, as for example in a comparison of economies on the gold standard versus those that are not. In these situations, it is difficult to find an appropriate control group. Consequently, estimation results may vary strongly or identification may fail altogether.

The key features of our analysis present clear advantages in these respects. In particular, almost all economies in our sample experience 'treatments' over the course of the 19th century. Currency or trade arrangements did not exist between any of the states in the early 1800s, whereas by the closing years of the 19th century they existed between all German states. Similarly, railroads did not exist before the 1830s, whereas by the end of the 19th century trains had arrived almost everywhere in our sample. Thus, we observe changes in all major dimensions for a constant set of economies, as opposed to, for example, being only able to observe a trade agreement for one set of economies and a currency agreement for a different set of economies.

Market integration is studied in terms of the spatial dispersion of grain prices in 68 markets in Europe for the entire 19th century. These markets are located in five different countries and fifteen different sovereign German states, including Prussia. The

[5] For example, Rose (2004) finds no effect of trade agreements on post-World War II trade.

area corresponds approximately to the location of today's Austria, Belgium, Czech Republic, France, Germany, Italy, the Netherlands, and Switzerland. In this sample, the average bilateral price gap fell over the 19th century from 27 percent to 11 percent, or by 16 percentage points. How much of this is the result of institutional, and how much of technological change? This is what we would like to explain.

We show in the paper 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 some evidence that the *Zollverein* liberalizations triggered improvements in market integration as well.[6] However, the results are less robust than those for the railroad effect. In a direct comparison between customs and railroad effects, only trains but not customs liberalization had a significant impact on market integration. We do not find evidence that currency agreements had a significant effect on market integration. Overall, these results suggest that technology factors were more important than institutional (e.g. monetary) factors in creating integrated commodity markets. A number of implications of this are discussed in section 6.

In this paper, the customs union, currency agreement, and trains effects are estimated from time-series variation: there are systematic differences in the timing of when European economies became members of the *Zollverein*, agreed on currency arrangements, and became part of the expanding railway network.[8] Rather than tackling

[6] Shiue (2005) has also compared border effect estimates from the 1834 and 1836 *Zollverein* liberalizations to the contemporaneous estimates by Engel and Rogers (1996).

[8] Another paper that uses time-series variation for identification is Estevadeordal, Frantz, and Taylor (2003). Our specific contribution relative to this work lies primarily in estimating the effect of transportation improvements using actual data on bilateral transportation technology, as opposed to data on geographic distance.

a global sample of the late 19th century, we adopt a more constrained sample in terms of the number of countries or market integration determinants considered. We do so to be better able to estimate the causal effects of customs unions, currency agreements, and trains. While we do not link railroads directly to growth, our analysis is in some ways also more comprehensive in that it allows us to quantitatively compare the effects of railroads with that of the institutional framework of customs union and currency agreements. Another distinctive feature of this paper is that it examines changes in both intra-national and international market integration. In addition, it covers the early 1800s on which generally less is known than on the past-1870 period, except that the process of industrialization was taking root in these economies at this time.

In the following section, we introduce our approach of studying market integration and trade. Section 3 provides the historical background for this study. The data is described in section 4, while our empirical results are in section 5. The following section 6 concludes.

2. Modeling Market Integration

Market integration is analyzed by analyzing the gap in prices for a relatively homogeneous good, wheat, across geographic space. Let p_{it} be the price in market i at time t, i = 1,…,I, and t = 1,…,T. The absolute percentage price gap between two markets i and j, $pdif_{ijt}$ is defined as

(1) $$pdif_{ijt} = \left|\ln(p_{it}) - \ln(p_{jt})\right|.$$

Our approach of studying market integration by tracing out systematic differences from the Law of One Price has been employed in various forms by a large number of authors (Engel and Rogers 1996, Parsley and Wei 1996, O'Rourke and Williamson 1999, Shiue 2005). In the simplest case, $pdif_{ijt}$ in equation (1) gives the price difference that cannot be eliminated through the process of arbitrage. Thus, $pdif_{ijt}$ is a measure of the trade barriers of all types that exist between i and j at time t. In the presence of supply and demand shocks affecting autarky prices in i and j, this will be true subject to a stochastic error, e_{ijt}.

We study the effect of trade and currency agreements as well as transportation technology by augmenting (1) with variables that measure these changes:

(2) $$pdif_{ijt} = bX' + g_1 CU_{ijt} + g_2 LT_{ijt} + g_3 TR_{ijt} + e_{ijt},$$

where CU_{ijt} and LT_{ijt} are dichotomous variables indicating whether at time t a customs union or a currency agreement between i and j existed (*LT* is mnemonic for legal-tender, see below). The variable TR_{ijt} is a measure of railway activity between i and j in year t, and *X* is a vector of other measures that might influence price gaps that we discuss below.

The leading alternative framework to studying these issues is the gravity model, which has been employed in a number of papers (e.g., Estevadeordal, Frantz, Taylor 2003, Rose 2004). There are good reasons for choosing the gravity framework. One is that the gravity equation can be derived from several specific trade models (Anderson 1979, Helpman and Krugman 1985), and estimated parameters can have a direct interpretation in terms of the models (Evenett and Keller 2002, Anderson and van Wincoop 2004). The Law of One Price framework of equation (1), in contrast, focuses on the equilibrium relationship between prices in two markets. It is very general,

applying to any trade model where the force of price arbitrage is present. We use it here because arguably price gaps measure the strength of market integration better than the volume of trade. In addition, comprehensive trade statistics do not exist for the early 19th century.

The next section provides the historical background for our analysis.

3. The *Zollverein*, Currency Agreements, and Trains in 19th Century Europe

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. The main economic impact of the *Zollverein* treaties was the abolishment of tariff barriers among member states, and the implementation of a single tariff on consumption goods for non-members. Prior to these treaties, Germany's political structure was divided into the thirty-nine states of the German Confederation (*Deutscher Bund*), wherein Austria was the most powerful of the

German states, followed by Prussia. See Figure 1.[10] The confederation consisted of sovereign states in which joint action depended upon unanimity. Individual states tended to be protectionist and the tariffs that were imposed were complicated. There is no reliable information on enforcement, but it was likely that it was costly for the many small states to each monitor their own borders.[11]

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 would be the case for 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.

The process of customs union enlargement in 19th century Central Europe materialized over a large part of the century (the years 1828 to 1888). There were a number of reasons why states would have wanted to join the *Zollverein.* First, fiscal reasons may also have played a role for *Zollverein* accession: for many of the relatively small states, it was prohibitively costly to establish and enforce tariff borders (Dumke 1976, Chapter 1). Joining the Prussian-led customs union in exchange for a fraction of the joint tariff revenue may have been preferable in these cases. At the same time, state size cannot be the full explanation for the timing of when states joined since there were several highly indebted and small states that joined the Zollverein relatively late.

Second, tariff-free access to the large market of Prussia, which included the leading industrial areas of the time was one major reason for joining the *Zollverein*. This

[10] For more details on the history of the *Zollverein*, see Henderson (1939) and Hahn (1984).
[11] Dumke (1976) presents estimates on border control costs, p. 44.

benefit, however, would have been shared relatively equally among most states. Third, idiosyncratic cases can be identified. For example, Hanover joined relatively late partly 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. Personal animosity between feudal lords played a role as well, and so did general fear of increasing one's ties with the relatively authoritarian Prussia (see Hahn 1984).

In this paper, we hypothesize that it was market access, not protectionism or the reasons just mentioned, that was the driving motivation explaining *Zollverein* accession. The general trade patterns within Germany before the *Zollverein* era was primarily grain and raw material from the South to the Northern seaboard, and manufactured products from the Northern seaboard to South. At least in the short term the *Zollverein* changed neither the direction nor the composition of the North-South trade. As Dumke (1977) has shown, in terms of external trade, the *Zollverein* was, since 1834, a net exporter of manufactured products and an importer of raw materials, semi-finished products, and consumption goods (including tobacco, sugar, and wine). This was also Prussia's trade pattern before the *Zollverein* foundation (Dumke 1976, Chapter 3). This implies that states located further South in Europe had higher incentives to join the *Zollverein* earlier. This is because not joining implied having to pay hefty tolls before reaching the Baltic or North Sea coast. This trade was important as states sought to trade with the emerging industrial powers, in particular England.[12]

Protectionism was also a consideration in the 19th century, especially in light of the movement towards infant-industry protection that was backed by Friedrich List and other writers, but it was unlikely to be the singular force in determining the timing of

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

Zollverein entry.[13] Moreover, the initial reluctance of many German states to join the *Zollverein* cannot be directly attributed to a desire to be more protectionist than Prussia's external tariff would allow since Prussia's tariff levels before the *Zollverein* creation were actually higher on average than those of other states (Dumke 1976, 366-369).

The overall sequence with which states joined appears consistent with the market access argument. Hesse-Darmstadt was the first territorially separate state to join the Prussian Customs Union in the year 1828. It received a share of the joint tariff revenue in exchange for adopting the Prussian tariff structure.[14] In the same year, as a defensive agreement not to join the Prussian Customs 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).[15] The latter was not a customs union, but a defensive 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.[16] In the year 1834, the Thuringian states and the Kingdom of Saxony, the Southern German Customs Union, and 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.

[13] Certain small-scale producers feared that by agreeing to an internal free trade within Zollverein borders, they would be driven out of business by producers from Silesia and the Rhine-Ruhr area that were more productive.
[14] Throughout, Prussia reserved the right to negotiate with foreign countries such as France, Belgium, and England for itself.
[15] The states were Hanover, Saxony, Hesse-Cassel, Nassau, Brunswick, Oldenburg, Frankfurt, Bremen, the Saxon duchies, and a couple of smaller ones. Henderson (1939, 67).
[16] 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.

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 relying on international trade, joined only in 1888.

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 all the areas of Bavaria were joined without custom borders. The entry of Frankfurt meant that trade 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 states became members of the *Zollverein* only after Germany became politically unified in 1871, namely the Free Cities of Bremen and Hamburg in 1888. Austria-Hungary did not become member of the *Zollverein*.[17]

Since the *Zollverein* was a customs union, joining it was not identical to a move towards multilateral free trade, but the basic character of the *Zollverein* was likely to have been trade-liberalizing. Although trade diversion was a possible outcome, most of trade of the German states at the time was with other German states. Similarly, although the external tariff of the *Zollverein* was, as noted above, higher than the pre-*Zollverein* external tariff in a number of states, relatively high *Zollverein* tariffs were mostly on

[17] Among the main reasons are that Austria-Hungary favored too high an external tariff compared to the *Zollverein*, it was internally relatively diverse, and Prussia opposed the inclusion of Austria-Hungary for these and other reasons.

consumption goods (*Kolonialwaren* [colonial imports] such as tobacco, sugar). The trade diversion effect arising from these imports were most likely quite limited.[18]

We now turn to a brief discussion of currency agreements in the sample areas. In the first decades of the 19th century, Germany was replete with coins issued by the many different states. The diversity was immense, in sharp contrast to the unified monetary conditions in Great Britain and France, for example (Holtfrerich 1989, 1993).

The differences in the monetary developments between the South and the Middle/Northern German states were rooted in the different ways of how the states financed wars following the French revolution (see Rittmann 1975, 467-469). In 1754, the *Gulden* was first adopted in the Southern states, as it was the case in the Austro-Hungarian empire. In the Northern states the currency was typically called *Thaler*. Irrespective of similarities in 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*.[19] 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. The dividing line between full-value specie money and debased coins was therefore fluid.

[18] Also see Dumke (1976), Chapter 3.
[19] The exception is Bremen which was from 1863 to 1871 on the gold standard, due to its strong overseas connections.

In the Southern states, transactions costs were particularly high in the early 19th century because coins from different states had different silver contents even though they had the same face value. Therefore, the Southern Gulden states had relatively more to gain from currency agreements (Holtfrerich 1993, 521). Consistent with this, the Southern states formed currency agreements before other German states did. In the *Munich Coin Treaty* of 1837, Southern states agreed that the silver content of the *Gulden* should be the same, no matter which state minted it (nine-tenth of face value).[20] 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 fell short of the 1837 *Munich* agreement among the set of Southern states. First of all, 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*. Moreover, the *Dresden Coin Convention* agreement did not specify that the *Zollverein* members were obliged to accept the coins of other signatory states as legal tender.

The fact that the *Dresden Coin Convention* did not give full legal tender status to all currencies throughout the *Zollverein* created an important barrier to commercial

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

exchange for the Northern *Zollverein* states.[21] 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, this coin never played the role for which it was introduced.[22] Instead, the Prussian one-*Thaler* piece was increasingly used for commercial transactions after 1838. Indicative of the fact that a generally accepted medium of exchange was needed is the fact that the Prussian one-*Thaler* coin even gained *de facto* acceptance to some extent in the *Gulden* states of Southern Germany. The missing medium-of-exchange function was only provided 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).[23] 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

[21] This affected trade between 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.
[22] The goal in 1838 was that by the year 1842, the common coin (*Vereinsthaler*) would account for 1.2% of the total coin circulation in Germany. In fact, *Vereinsthaler* circulation fell well short of this; Holtfrerich (1993).
[23] The main purpose of the *Vienna Coin Treaty* was to extend these currency arrangements to include Austria; however, it failed to do so; see Willis (1896) for an analysis.

German states. Also, Germany moved from the silver to the gold standard after the year 1871, in line with the international trend at the time.[24]

The following section discusses the introduction of railways in Europe.[25] Economic growth from the 19th century on coincided there with a series of major innovations. These innovations included paved roads, improvements in waterways, innovations in materials such as iron and steel, and later on also 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, the 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 timing of railway construction was affected by the support from the political leaders, as well as by geographic factors such as the availability of alternative means of transportation (rivers, coastal traffic). One factor that played an important role was the size of the markets that the railway connected. Of course, exceptions and idiosyncratic factors may be noted in each case. The first German railway was opened in December 1835. With only 4 miles of tracks, it was a short suburban line located in Bavaria,

[24] 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).

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

between Nürnberg 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 were over 2,000 miles of rail in Germany (Henderson 1939, 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 non-German countries that our analysis covers, 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 may also be 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.[26] In the late 19th century, for example, sending one ton of grain from Posen (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.[27] At the same time, transportation of grain on railways was of utmost importance when it connected the drainage areas of the main rivers. Grain transportation on railways was also of major significance whenever sea or river transport was not an option. Seuffert (1857) documents for example that the great majority of all grain exported from Bavaria to Switzerland in the early 1850s was transported on railways (Chapters 5, 6). The attractiveness of transporting grain on railways was not only affected by geographic features across Germany. Also the freight rates per ton-kilometer mattered, and while there is no detailed information on this, we know that rates differed both across states as

[26] On the comparison between land transport and rail transport of grain, see Fremdling and Hohorst (1979, 64).
[27] Even from Breslau (Silesia, a Prussian province), grain was shipped to Mannheim (Baden) via the Baltic Sea harbor of Stettin, Rotterdam, and then upstream on the Rhine river (Köttgen 1890, 64).

well as over time (Hohorst and Fremdling 1979, 64-65).[28] We therefore expect that the significance of railways for grain trade between different markets in the sample varies.

The following section describes the data.

4. Data

This study employs the prices for wheat across markets in Europe to analyze market integration. We have compiled information on market prices in sixty-eight locations; Table 1 provides an overview. There are 16 markets in non-German countries in the sample, or about 24% of the sample. They are located in Austria-Hungary, Belgium, France, the Netherlands, and Switzerland. The remaining 52 price series are for markets located in fifteen different sovereign German states.[29] The prices are averages for an entire year. Since we are interested in low-frequency changes of price gaps over an entire century, this is appropriate. All prices are quoted in terms of Bavarian *Gulden* per one Bavarian *Scheffel* (about 223 liters). To arrive at this 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 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,

[28] See also Kopsidis (2002, 1999, 1996) for a careful analysis of the impact of railways for agricultural development in 19th century Westphalia.

[29] The German territories 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 Hanover, (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.

1996). Further details on the sources and the construction of these series are given in the appendix [to be written].[30]

The overall sample period is 1800 to 1899, but data availability varies greatly across the series. For example, all 100 annual price observations exist for the Free City of Hamburg 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 we should place more weight on markets where prices are observed for a long time. The tables report the number of observations for each market as well as the year of the earliest price observation.

The *Zollverein* was the most important element in the move towards trade liberalization in 19th century continental Europe. For each market, we have recorded the year in which it joined the *Zollverein*; this year is listed in Table 1.[31] 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 that existed between markets before they joined the customs union. Instead of exploiting the size of the tariff change, we rely on the timing of the move towards zero trade barriers.

[30] The population of cities, information we employ in the instrumental variable section below, comes from Bairoch et al. (1988) and de Vries (1984).

[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 short-lived—the Bavaria/ Württemberg one lasted for five years before it dissolved in the Zollverein--, and other agreements fell well short of being customs unions to begin with (for example, the Middle German Commercial Union involving Saxony, Thuringia and other territories from 1828 until 1834 did not reduce tariffs to zero between these countries). Clearly, the *Zollverein* was the major development.

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 Nürnberg and Munich. For each market pair in our sample, we have thus established using maps whether a direct trade route would involve passing any customs 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, CU_{ijt} is equal to 0 for all years.[32]

The major event in the area of currency agreements was that currencies were giving full legal tender status in other states. As discussed above, this occurred between the Southern German 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, the variable LT_{ijt} for the pair of Munich (Bavaria) and Stuttgart (Württemberg) up to the year 1837 is equal to 0 and 1 afterwards, for example. In contrast, the variable LT_{ijt}

[32] The *Zollverein* had at times trade agreements with other countries, including the Netherlands (in 1839, which was cancelled soon after, and another in 1851), as well as Belgium (in 1844). Because these tended to be far less comprehensive than the internal *Zollverein* treaties, our analysis abstracts from them. This is appropriate because we also do not factor in various tariff increases that foreign countries adopted as a response to the *Zollverein* creation, such as the Netherlands in 1834 (Hahn 1984, 111). Also these activities tended to be much more limited and temporary than the *Zollverein* agreements. Moreover, a number of European countries tried to give trade preferences to individual German states, typically with the goal of keeping them out of the Prussian-led *Zollverein*. Typically, these attempts failed, however. For example, in 1829, some French politicians tried to keep Baden, Württemberg, and Bavaria outside of the Prussian customs union by offering French trade preferences. This plan failed due to protectionist opposition in some French ministries and trade associations. Treaties between France and both Nassau and Mecklenburg were actually finalized; however, they were never ratified by the French parliament (Hahn 1984, 73). Thus, the *Zollverein* treaties between the German states were of greater importance than other trade treaties involving *Zollverein* members. This is true irrespective of the fact that the general climate towards free trade in Europe varied over the 19th century (relatively pro-trade in the 1860s and 1870s, and more protectionist in the last two decades of the 19th century, for example).

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.[33] Table 1 gives the year in which the currency used in a particular city had for the first time full legal tender status in another state.[34]

Turning to our information on trains, the last column in Table 1 gives the year in which a particular city 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 give this year for Dresden and Leipzig. Our trains measure is a dichotomous variable, TR_{ijt}, which for the Dresden-Leipzig pair is 0 until the year 1839, and 1 thereafter.

Since it clearly matters for competition between different modes of transport how circuitous a particular route between two markets is, we have set TR_{ijt} equal to one for a given market pair ij and time t only when a direct and non-circuitous train connection came into existence.[35] This has been determined by analyzing maps that give the precise geographic location of the historical train tracks.[36] As an example, Figure 3 which shows the railway lines in the German states in the year 1850. As of this time, the Bavarian

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

[34] We have also considered the effects of the fixing of exchange rates among the different German currencies. Incorporating this into our analysis would not change the main findings.

[35] The leading example illustrating this issue is the French railways system, which is centered on Paris. To reach Bordeaux from Toulouse during the early railway days in France, one had to go through Paris. Given the increase in distance, it is likely that the rail connection Toulouse-Bordeaux, over Paris, was not that important for arbitrage between the two Southern cities.

[36] The most important source for these maps is IEG (2007).

capital of Munich, located in the lower right of the figure, did not have a train connection to Central and Northern Germany. Only in the next year, 1851, the filling in of the gap between the Saxon towns of Reichenbach and Plauen established train service between Munich and Northern markets such as Berlin and Hamburg.

Figure 3 also illustrates how the railroad system was built in the German states. In the early stages, typically the major cities in a given state were connected. The figure clearly shows the separate Bavarian and Wurttemberg networks (on the lower right, and further west of it around Stuttgart). At a later stage, the states' different lines would be connected, as is the case already for the Baden network (lower left) which links up to the railways around Frankfurt. The *TR* variable also incorporates other relevant elements of Europe's topography, such as the existence of bridges across rivers. For example, the railway line between Cologne and Aachen (center left in Figure 3) 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 near Cologne by the year 1847 via the *Köln-Mindener* line. But only the town of Deutz, located opposite of Cologne on the east side of the Rhine river, could be reached—the railway bridge across the Rhine was completed only in the year 1859, and until then, Cologne itself, Aachen, as well as the Belgian markets could effectively not be supplied by rail with the relatively cheap Eastern European grain. In Figure 3, the non-existence of a railway bridge between Cologne and Deutz in the year 1850 is marked with an orthogonal line.

While we do not have market-specific information, broadly speaking the unit transactions costs for grain trade resulting from customs duties, different currencies, and transport costs between the sample markets are comparable. In terms of location of markets, our sample covers bilateral distances between markets ranging from about nine to 1,560 kilometers, with a median of 437 kilometers. Over the course of the 19th century, grain trade by railways became important in areas where ship transport was not feasible, particularly the case in the East-West dimension away from the coast.[37] In our sample, the East-West dimension is spanned by the cities of Brugge and Vienna, and the sample includes cities in Bavaria, Hesse, and the western parts of Prussia where grain transport by rail was often the least-cost means of transportation.

There is also a fair amount of similarity in terms of market-pairs with respect to customs borders, currency agreements, and train lines. For example, the mode of the distribution of market pairs with customs borders in our sample is at a distance of about 500 kilometers, the same as for the distribution of market pairs for which no train connection existed during the sample observations.

We now turn to the empirical analysis.

5. Empirical Results

We start by discussing the sources of data variation that are used in the estimations. Figure 4 shows Central Europe in 1834, the year in which the *Zollverein* was founded; the bold line gives the customs borders of the *Zollverein*. Four cities in our sample are noted. They are, from North to South, Rostock, Muenster, Cologne, and

[37] 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).

Munich. Muenster is located in the state of Prussia, and Munich is the capital of Bavaria. Identification for the customs liberalization effect comes in part from comparing price gaps between Muenster and Munich before and after 1834. Before 1834, Bavaria and Prussia were separated by a customs border, while after 1834 both states were part of the internal border-free *Zollverein*.

Additional information comes from market pairs such as Muenster-Cologne and Muenster-Rostock. In the former case, both Muenster and Cologne are located in Prussia and thus this pair was never subject to a customs border during the sample period. In the latter case, Rostock is located in Mecklenburg and thus entered the *Zollverein* only later, in 1867. Figure 5 shows the price gaps between these markets between 1815 and 1860. There is a considerable amount of variability from year to year, although price gaps are downward trending at least for some market pairs. The figure also notes the *Zollverein* liberalization in the year 1834. The price gap between the affected cities Muenster and Munich comes down from 1830 to 1835 from about 0.30 to 0.13. At the same time, the price gap between the unaffected pair Muenster-Cologne comes down as well. This is consistent with factors other than the customs liberalization playing an important role as well.

Identification of the railway effect is based primarily on the timing of train adoption. Since in the early sample years steam trains did not exist anywhere in Europe, while towards the end of the sample railways were operating between most markets, we do not observe, for example, situations analogous to customs liberalization, or a currency agreement throughout the sample period.[38] Figure 3 from above shows the German

[38] Due to data availability, the price data does not always allow us to study the period before or after the building of railways.

railway network in the year 1850, as well as the location of four cities, Hamburg, Cologne, Strassbourg, and Munich. The connection between Munich and Hamburg was established in 1851, the link between Munich and Cologne was completed in 1859, and railway travel from Munich to Strassbourg in the Alsace was possible starting in the year 1861.

Figure 6 shows the price gaps for these pairs over time. Between 1850 and 1855, the Munich-Hamburg price differential falls from 0.19 to 0.08, but this need not be due to the new train connection since price gaps from Munich to Cologne as well as Strassbourg fall as well. Moreover, the price gap between Munich and Strassbourg even rises upon establishment of the train connection in 1861, although this is no proof against a train effect since the price gap rose even more between 1860 and 1865 for the Munich-Cologne pair. This discussion shows that it will be important to eliminate both common trends and idiosyncratic shocks in our analysis. We now turn to results using matching estimators.

Treatment effects for customs liberalization, currency agreements, and train connections are calculated employing matching estimators. These estimators are extensively used in the policy evaluation literature where the independent variable of interest is dichotomous, as CU, LT, and TR are here. Under certain conditions, including exogeneity of treatment, this technique provides consistent estimates. In contrast to OLS regressions, these matching estimators do not require parametric assumptions while at the same time they pick up potentially important non-linear effects. Table 2 shows the results.

In the table, columns (1) and (2) show results from propensity score matching, and (3) and (4) nearest-neighbor matching.[39] Each cell is for a different analysis, with the entry giving the average treatment effect for the particular 0/1 variable given in the row; robust standard errors are in parentheses. The columns differ in the set of matching variables used to compute the effect of CU, LT, and TR on the price gap. The results are consistent with price-gap reducing effects for both institutions and technology. In terms of magnitudes, on average across columns (1) to (4) both customs liberalizations and currency agreements are associated with a reduction in price gaps by about five percent. In contrast, train connections are associated on average with roughly a ten percent lower price gap. This suggests that the technological innovation may possibly have a larger effect on price gaps than that coming from institutional agreements on tariffs and currencies. The matching results rely on exogenous arrival of customs and currency agreements as well as train connections. Given the historical record, this assumption may be violated, and we therefore consider these results as preliminary.

This is also true for the OLS regressions reported in Table 3.[40] The main lessons from this table are the following. First, shocks common to all markets have a major effect on the results; the inclusion of time fixed effects reduces, for example, the absolute size of the trains coefficient substantially (see (5)). Second, price differences vary importantly at the bilateral level; consequently, in specifications (6) to (10), market-pair or state-pair fixed effects are included. For the linear specifications (6) and (7), the point estimates on CU and LT are positive and the point estimate for TR is negative, while any possible

[39] The main difference between propensity score and nearest-neighbor matching estimators is that the former forms treatment and control groups on the basis of the propensity score, while nearest-neighbor matching occurs directly on the matching variables.

[40] All regressions are weighted by the number of observations for a given market-pair, unless otherwise noted.

impact is minor since the coefficients are close to zero. Adding time- and distance interactions, there is some evidence that train connections may have stronger effects if introduced relatively early and for relatively long distances (see (8) and (9)). On average, however, the computed marginal effects at the bottom of (8) and (9) indicate that neither customs and currency agreements nor train connections have a significant price-gap reducing effect according to these OLS regressions. We now turn to instrumental-variable estimation.

For the customs liberalization variable CU, we consider the distance of a market to the seaboard. 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 quite clearly related to the distance to the seaboard. 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 seaboard, which gave relatively low-transport access to distant markets. Figure 7 shows the positive correlation of *Zollverein* accession with distance to the seaboard for the 68 wheat markets. With an R^2 of 0.48, this is a strong relationship. This translates into a correlation of 0.39 in our sample of market-pairs.

The timing of railway construction was affected by idiosyncratic factors such as the support from the political leaders as well as geographic factors such as the availability of alternative means of transportation (rivers, coastal traffic). One factor that played an important role was the size of the markets that the railway connected. In Figure 8, we show the positive correlation between city population in the year 1800 and the earliest date at which a city had a railway connection for our 68 wheat markets. In our sample,

the correlation of train connection with average city-pair size is 0.25. One concern is that city size might have a direct effect on the price gap, because then city size would not be a valid instrument. However, the correlation between the price gap and average city size in the data is with -0.02 very close to zero, so this is not a major concern.

To create a good instrument for the formation of currency agreements is more challenging, in part because there is less time series variation. Currency agreements were adopted among the German states in 1837 (the Southern states), in 1857 (all *Zollverein* states), and in 1871 (all German states). In the Southern states, transactions costs were particularly high because coins from different states had different silver contents even though they had the same face value, one Gulden, adopted in the year 1754. 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). The Southern Gulden states thus had relatively more to gain from currency agreements (Holtfrerich 1993, 521). Consistent with this, these states forming currency agreements before other German states did. We therefore compute an indicator variable that is equal to one if both markets i and j belong to the Gulden of 1754 area, and zero if at least one of the markets is not part of the Gulden area. The sample correlation of legal tender status (LT) with this Gulden 1754 variable is equal to 0.61.[41]

The three instrumental variables have variation only across market-pairs, not over time. As a consequence, our IV specifications cannot include market-pair fixed effects.

[41] The correlation between the price gap and distance to seaboard is 0.01, and between price gap and Gulden in 1754, the correlation is -0.09; these correlations are relatively small, and we do have any evidence that the instruments have a significant direct effect on the price gap.

Instead, we will employ state-pair fixed effects. The OLS results in Table 3, columns (6) to (9) suggest that this will not affect our results qualitatively.

Table 4 shows two stage least squares results for each of the three variables separately. The second stage of the two stage least squares regression is shown in Panel A, while Panel B shows the first stage, and Panel C shows the corresponding OLS regression. According to column (1), customs liberalizations lead to a major reduction in price gaps. The first stage regression shows a positive coefficient for the distance to the coast, which is consistent with the Southern German states joining the *Zollverein* relatively early, as shown in Figure 7. The distance variable appears to be also a strong instrument, with a F-statistic p-value smaller than 0.001. The endogeneity test in Panel C is based on a comparison of the IV results and the corresponding OLS regressions. The null hypothesis of exogeneity of CU is rejected at a high level of significance.

Turning to the introduction of trains, Panel A in column (2) shows with a coefficient of -0.341 that they also have a substantial impact on reducing price gaps across markets. The first-stage regression is strong and captures the fact that cities that were relatively large in 1800 were on average relatively early connected by trains (recall Figure 8). The corresponding OLS regression produces the much-smaller coefficient of -0.016 (Panel C). This is strong evidence that train adoption was endogenous.

For currency agreements, we estimate a coefficient of 0.006, insignificantly different from zero. This is not due to a weak instrument problem, as the first stage regression in Panel B indicates. However, Panel C shows that the IV results are close to the OLS results. Indeed, since we cannot reject the null of exogeneity of currency agreements in this context (p-value 0.747), OLS is the preferred estimator since it has

lower variance. The evidence on currency agreements is therefore discussed in Table 3 above. In addition, specification (10) in Table 3 shows the OLS results for the currency agreement variable by itself with year- and distance interactions. The average marginal effect is estimated at -0.026, with a standard error of 0.026. Thus, we do not find significant price-gap reducing effects from currency agreements.

We can gauge the relative size of the customs and trains effects when both variables are included simultaneously; Table 5 shows the results. In column (1), the customs coefficient is similar in size to the trains coefficient (-0.371 versus -0.399, respectively). In contrast, the customs effect is substantially less precisely estimated. In column (2), we report standard errors that are not only heteroskedasticity-consistent but also clustered for each state-pair. One reason for this is that when customs borders were liberalized between two states, this often affected bilateral arbitrage relationships between any two markets in these two states in the same way. Similarly, the train networks were often developed state by state initially, and only later they would become connected across states (recall Figure 3). Clustering is a way to deal with this dependence. It comes at the cost of a greatly reduced number of effective (independent) observations. Although this may result in a loss of useful information, it helps to keep the inferences conservative.

As expected, the clustered standard errors are considerably larger than the non-clustered ones. The customs variable is not significant anymore at standard levels, with a standard error of 0.645, while the trains variable is roughly significant at a 10% level (p-value of 10.7%).[42] In line with the higher standard errors, the F-statistics are now lower

[42] If one eliminates the insignificant customs variable, the trains coefficient is estimated at -0.341, as in Table 4, with a clustered standard error of 0.122 (p-value of 0.005).

than before. Specifically, the first-stage F-statistic for trains falls from about 285 to about 5, while that for customs liberalizations falls from about 30 to about 1, not significant anymore at standard levels (p-value of 0.38).

One reason of why the customs effect is not estimated more precisely may be that over the 19th century the numerous other influences on price gaps overshadow the effect from customs liberalization. In the following, we attempt to sharpen identification by considering a number of smaller samples. First, in column (3) of Table 5, we restrict the sample to the years between 1820 and 1880. This period covers most of the customs liberalizations and train line construction, and moreover, it excludes the early years of the 19th century where wheat prices were relatively strongly affected by wars. The first stage regressions yield the expected results: a positive correlation both between distance to coast and customs liberalizations and between city size and train building. The customs coefficient is estimated at 0.121, not significantly different from zero, while the trains coefficient is equal to -0.233 and marginally significant (p-value of 0.10).

An alternative to restricting the sample to particular decades is to consider only specific years before and after the 'change' for a particular market-pair. This is done for the results shown in columns (4) and (5); in (4), the window around customs and trains treatment includes up to three price observations before and after, while for (5), there are up to two observations before and after. The results for these two specifications are broadly similar. There is no significant effect from customs liberalization on price gaps, whereas the trains effect is around -0.30 and significant at standard levels.

Overall, this analysis has shown that unlike for trains, there is no robust evidence for a price-gap reducing effect through customs liberalization. To see whether this

finding continues to hold when we allow for non-linear effects on price gaps, we consider instrumental variable specifications with interaction effects. In Table 6, we show results for two types of interaction effects: each variable interacted with time and distance, as in the OLS Table 3, and an interaction between customs liberalization and trains.

In terms of empirical fit, the interaction specifications are slightly preferred to the corresponding linear term-only regressions. Specifications (1) and (2) show results on the distance- and time interactions. The former tend to be significant while the latter are not; in particular, train connections had a stronger effect for long-distance trade than for short-distance trade. Interaction results for the train and customs variables are shown in columns (3) and (4). The coefficient on the interaction is positive. Its magnitude suggests that if a train connection was established between two cities where customs borders had already fallen away, the price gap reduction brought about by trains is about one fourth smaller than when customs borders still exist (0.077 over 0.317). Overall, as the marginal effects at the bottom indicate, the results remain largely unchanged: building train connections had a substantial effect on reducing price gaps, in the order of 30 to 45 percent, whereas there is no evidence for a significant customs effect.[43]

We now turn to a discussion of these estimates. Our results indicate that one considerably underestimates the effect of trains on market integration if one disregards the fact that the adoption of railways was an endogenous decision. The OLS point estimate for trains of -0.074 in (9), Table 3, is less than one fourth of the trains IV point estimates we obtain in Tables 4 to 6. Where does this difference come from? For markets where train connections were established relatively late, the incremental effect on price

[43] Additional interaction effects, including between currency agreements and trains as well as between currency agreements and customs liberalization, have been considered as well. We do not report them here as these estimates have a negligible impact on our findings.

gaps was muted since several partially parallel rail lines existed already. This is consistent with the finding that later railways tended to have a lower effect on closing price gaps, although not always significantly so (Tables 2 and 6). An interpretation of the lower OLS than IV estimates is that many of the late train-adopting market pairs would have experienced relatively large reductions in price gaps if the date of train adoption would not be systematically related to market size. The IV estimates un-do the relation between timing of adoption and market size, and the relatively large effect of trains on shrinking price gaps becomes apparent.

While it is thus plausible that the IV estimates are larger than the OLS coefficients (in absolute values), it is also important to ask how the estimated trains effect compares to the overall decline in price gaps over the 19th century. As noted above, the average price gap fell from the first to the last decade of the 19th century from 0.27 to 0.11, or by 16 percentage points. Given that we estimate the trains coefficient at about - 0.34 (Table 4, second column), this would mean that the introduction of railways more than accounts for the entire decline in the price gap over the 19th century, which is impossible.

At the same time, the IV estimation results depend on which observations drive identification. This may be observations for which price differences are relatively small, or it may be observations where price differences are relatively large. [44] In this case, the IV estimates appear to capture primarily the impact of trains on large price gaps. Specifically, the 90th percentile of price differences in 1800-10 was 0.55, while in the last decade of the 19th century, it was 0.21. This 34 percentage points decline and the IV estimates are similar in magnitude.

[44] See Card (2001) for another example.

6. Conclusion

In this paper, we have examined institutional and technological barriers to market integration and trade in 19th century Europe. Building on some unique features of this historical setting, we have quantitatively compared the effects of the *Zollverein* liberalizations, currency agreements, and the building of the railway network.

The evidence suggests that transport technology has a major effect on improving market integration, and the effect of trains would be underestimated without taking account of the endogenous choice of railway adoption. Our estimates suggest that trains had a particularly large effect on integration for markets between which substantial price gaps remained at the beginning of the 19th century. This includes in particular arbitrage relationships between geographically distant markets.

There is some evidence that the *Zollverein* liberalizations triggered improvements in market integration as well. However, the results are less robust than for the railroad effect. In a direct comparison between customs and railroad effects, only trains but not customs liberalization had a significant impact on market integration. Moreover, we do not find evidence that currency agreements had a significant effect on market integration.

Our results suggest that the trade in Germany during the 19th century progressed despite its relative monetary and customs border chaos compared to other European economies, including England and France.[45] Moreover, since railroad construction in France proceeded at a distinctly slower pace than in Germany, the relatively strong trains effect we identify in this paper may help to explain why Germany's industrialization outpaced France's, at least from 1860's on. The fact that Europe as a whole was

[45] Externally, English Corn Laws, repealed only in 1846, imposed tariffs on imported bread grains.

composed of relatively many borders and currencies may not in itself have been a severe disadvantage for trade within Europe markets.

Beyond continental Europe, we may ask how much unified customs and monetary markets contributed to trade in countries like China. Our results suggest that China did not benefit much from these relative to the more segmented Western Europe. Trade in a large market improves the division of labor and specialization, thereby reaping static and perhaps also dynamic welfare gains. However, the limits imposed by institutional factors such as customs borders and different currencies are minor, according to our results, relative to those dictated by technology in the form of transport costs.

Even though we have seen that transportation improvements had a far greater impact on price gaps than customs liberalizations, both were blamed in the backlash against free trade in Europe in the late 19th century. By then, European industrialists as well as farmers had seen increased international competition, which was in part attributed to the trade treaties of the 1860s and 1870s. The return to protectionism finally arrived when Otto von Bismarck began a retraction of the (external) *Zollverein* trade treaties in 1879. His actions were instigated to a significant degree by falling transport costs on bulky low-value goods from the expansion of railroads in the Americas and Eastern Europe, and falling ocean freight rates.

By and large, the literature to date has emphasized the importance of institutional barriers, such as tariffs and the absence of currency agreements. Our results suggest that as important as these seem to be, they should not lead us to ignore the fact that advances in transportation technology had a major effect, and perhaps it was the major impact on

the expansion of markets in the era of industrialization and the first wave of globalization.

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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: Matching Estimator Results

	Propensity Score[#]		Nearest Neighbor[&]	
	(I)	(II)	(III)	(IV)
Customs Liberalization	-0.043	-0.051	-0.054	-0.041
	(0.006)	(0.006)	(0.006)	(0.008)
Currency Agreement	-0.021	-0.077	-0.044	-0.056
	(0.012)	(0.013)	(0.005)	(0.011)
Train Connection	-0.12	-0.119	-0.073	-0.076
	(0.026)	(0.029)	(0.015)	(0.014)
Matching Variables	Log bilateral distance, year	Log bilateral distance, year, other two treatment variables	Log bilateral distance, year	Log bilateral distance, year, other two treatment variables

[#] Propensity score estimated with a probit regression (not shown); bootstrapped standard errors in parentheses

[&] Matching to the nearest three neighbors, using the inverse variance as weighting matrix; heteroskedasticity-consistent standard errors in parentheses

Number of observations: 10,434

Size of treatment group for customs liberalization 2,534 (24%), for train connection 942 (9%), and for currency agreement 1,888 (18%)

Table 3: Ordinary Least Squares Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Customs Liberalization	-0.082			-0.034	-0.015	0.008	0.004	-0.031	-0.017	
	(0.001)			(0.001)	(0.002)	(0.002)	(0.002)	(0.010)	(0.007)	
Train Connection		-0.103		-0.105	-0.021	-0.002	-0.015	-0.083	-0.142	
		(0.001)		(0.001)	(0.002)	(0.001)	(0.001)	(0.011)	(0.011)	
Currency Agreement			-0.086	0.003	-0.006	0.003	0.006	0.051	-0.065	-0.090
			(0.001)	(0.002)	(0.002)	(0.004)	(0.003)	(0.011)	(0.008)	(0.004)
Distance				0.049	0.054					
				(0.001)	(0.001)					
Customs Liberalization x Year								0.001	0.0004	
								(0.0001)	(0.0001)	
Train Connection x Year								0.002	0.003	
								(0.0002)	(0.0003)	
Currency Agreement x Year								-0.0004	0.0001	0.001
								(0.0001)	(0.0001)	(0.0001)
Customs Liberalization x Distance								-0.01	0.01	
								(0.005)	(0.004)	
Train Connection x Distance								-0.022	-0.025	
								(0.001)	(0.001)	
Currency Agreement x Distance								-0.033	0.023	0.029
								(0.007)	(0.004)	(0.001)
Year Fixed Effects					yes	yes	yes	yes	yes	yes
Market pair Fixed Effects						yes		yes		
State-pair Fixed Effects							yes		yes	yes
Average Marginal Effects										
Customs Liberalization								-0.014	0.01	
								(0.024)	(0.011)	
Train Connection								-0.044	-0.074	
								(0.04)	(0.057)	
Currency Agreement								-0.01	-0.032	-0.026
								(0.026)	(0.017)	(0.026)
Root Mean Squared Error	0.142	0.142	0.142	0.135	0.128	0.109	0.119	0.108	0.118	0.119
R-squared	0.055	0.060	0.051	0.149	0.235	0.456	0.340	0.460	0.346	0.343

Dependent variable: absolute log price difference between markets
Number of observations: 10,434
Heteroskedasticity-consistent standard errors in parentheses

Table 4: Instrumental Variable Estimation of Customs, Currency and Train Effects

	Panel A: Two Stage Least Squares Regression		
Customs Liberalization	-0.285 (0.118)		
Train Connection		-0.341 (0.028)	
Currency Agreement			0.006 (0.031)
Root Mean Squared Error	0.130	0.133	0.119
	Panel B: First-Stage Regression		
Distance from Coast	0.006 (0.001)		
Population in 1800		0.088 (0.004)	
Gulden in 1754			1.001 (0.001)
F-statistic [p-value]	61.24 [<.001]	569.44 [<.001]	62010 [<.001]
	Panel C: Ordinary Least Squares Regression		
Customs Liberalization	0.003 (0.002)		
Train Connection		-0.016 (0.001)	
Currency Agreement			-0.005 (0.002)
Endogeneity test [p-value]	6.74 [<.01]	169.04 [<.001]	0.104 [0.747]

Dependent variable: Log absolute price difference between market i and j
All regressions include fixed effects for each year and for each state-pair
Number of observations: 10,434
Heteroskedasticity-consistent standard errors in parentheses

Table 5: Customs and Trains Effects Compared

	(1) Full Sample	(2) Full Sample	(3) Years 1820 to 1880	(4) Window of 15 Years Before and After Change	(5) Window of 10 Years Before and After Change
	Panel A: Two Stage Least Squares				
Customs Liberalization	-0.371	-0.371	0.121	0.116	0.187
	(0.143)	(0.645)	(0.580)	(0.203)	(0.543)
Train Connection	-0.399	-0.399	-0.233	-0.283	-0.374
	(0.041)	(0.247)	(0.142)	(0.123)	(0.183)
Root Mean Squared Error	0.155	0.155	0.123	0.117	0.138
	Panel B: First-stage for Customs Liberalization				
Distance from Coast	0.005	0.005	0.007	0.015	0.012
	(0.001)	(0.004)	(0.004)	(0.006)	(0.008)
Population in 1800	-0.011	-0.011	0.023	0.027	0.034
	(0.005)	(0.051)	(0.023)	(0.021)	(0.016)
F-statistic	30.60	0.97	2.24	4.32	3.84
[p-value]	[<.001]	[0.381]	[0.109]	[0.014]	[0.022]
	Panel C: First-stage for Train Connection				
Distance from Coast	0.002	0.002	0.005	0.006	0.008
	(0.001)	(0.007)	(0.009)	(0.016)	(0.020)
Population in 1800	0.089	0.089	0.121	0.155	0.176
	(0.004)	(0.029)	(0.045)	(0.070)	(0.084)
F-statistic	285.36	4.89	3.65	2.46	2.22
[p-value]	[<.001]	[0.008]	[0.027]	[0.087]	[0.111]
Number of observations	10,434	10,434	7,643	4,709	3,365

Dependent variable: Log absolute price difference between market i and market j
All regressions include fixed effects for each year and for each state-pair
Heteroskedasticity-consistent standard errors in parentheses; in columns (2) to (5) standard errors are clustered by by state-pair

Table 6: Instrumental Variable Regressions with Non-linear Effects

	Two Stage Least Squares			
	(1) Full Sample	(2) Window of 15 Years Before and After Change	(3) Full Sample	(4) Window of 15 Years Before and After Change
Customs Liberalization	-0.019	0.201	-0.366	0.172
	(0.909)	(0.247)	(0.572)	(0.258)
Customs Liberalization x Year	0.0005	0.002		
	(0.0004)	(0.001)		
Customs Liberalization x Distance	0.039	0.033		
	(0.015)	(0.015)		
Train Connection	-0.378	-0.308	-0.432	-0.317
	(0.247)	(0.119)	(0.195)	(0.104)
Train Connection x Year	0.002	0.0004		
	(0.003)	(0.002)		
Train Connection x Distance	-0.038	-0.020		
	(0.012)	(0.011)		
Customs Liberalization x Train Connection			0.086	0.077
			(0.024)	(0.024)
Root Mean Squared Error	0.118	0.092	0.12	0.095
Marginal Effects				
Customs Liberalization	0.054	0.149	0.012	0.006
	(0.031)	(0.047)	(0.025)	(0.027)
Train Connection	-0.431	-0.335	-0.413	-0.319
	(0.028)	(0.014)	(0.032)	(0.046)
Number of Observations	10,434	4,709	10,434	4,709

Dependent variable: log price difference between market i and market j
All regressions include fixed effects for each year and for each state-pair
Heteroskedasticity-consistent standard errors clustered on state-pair in parentheses
Threshold significance level for the computation of the marginal effects is 15%

Table 7: The Effect of Establishing Train Connections on Price Gaps

	(1) Period 1800-99	(2) Short-run Effect	(3) Period 1800-99 Market Potential Instrument	(4) Short-run Effect Market Potential Instrument	(5) Instrument Validity	(6) Period 1800-99 Time-varying Market Potential Instrument	(7) Period 1800-99 Central 90% Price Gaps	(8) Period 1800-99 Additional Controls
Panel A: Two Stage Least Squares								
Train Connection	-0.341	-0.140	-0.394	-0.102	-0.362	-0.382	-0.276	-0.397
	(0.122)	(0.048)	(0.146)	(0.043)	(0.122)	(0.144)	(0.142)	(0.106)
Customs Liberalization								0.009
								(0.014)
Currency Agreements								0.010
								(0.022)
Bilateral distance								0.015
								(0.009)
Panel B: First-stage for Train Connection								
Population in 1800	0.088	0.260			0.057		0.083	0.101
	(0.028)	(0.116)			(0.033)		(0.029)	(0.020)
Market Potential			0.015	0.050	0.007			
			(0.004)	(0.018)	(0.003)			
Time-varying Market Potential						0.015		
						(0.004)		
F-stat	9.61	5.02	12.57	7.96	7.67	12.43	8.03	25.14
[p-value]	[0.002]	[0.026]	[<.001]	[0.005]	[<.001]	[<.001]	[0.005]	[<.001]
Partial R-sq (%)	0.75	2.39	0.7	2.72	0.81	0.68	0.71	0.97
OverID Hansen J statistic					0.28			
[p-value]					[0.60]			
# of obs	10,434	2,267	10,434	2,267	10,434	10,434	9,394	10,434

Dependent variable: Log price difference between market i and market j; heteroskedasticity-consistent standard errors clustering on state-pairs in parentheses
State-pair and year- fixed effects included

Figure 1

Der Deutsche Bund nach dem Frankfurter Territorialrezess um 1820

Kgr. Dänemark
Kgr. Schweden
Ksr. Russland
Hzm. Schleswig
in Personalunion mit Dänemark
Hzm. Holstein
in Personalunion mit Dänemark
Freie Stadt Lübeck
Freie Stadt Hamburg
Grhzm. Mecklenburg-Schwerin
Schwerin
Grhzm. Mecklenburg-Strelitz
Neustrelitz
Grhzm. Oldenburg
Oldenburg
Freie Stadt Bremen
Kgr. Hannover
Hannover
Braunschweig
Hzm. Braunschweig
Fsm. Lippe-Detmold
Detmold
zum Kgr. Hannover
Fsm. Waldeck-Pyrmont
Arolsen
Kassel
Kfsm. Hessen
Anhalt
Dessau
Berlin
Kgr. Preussen
Kgr. Polen
in Personalunion mit dem Ksr. Russland
Königreich der Vereinigten Niederlande
Grhzm. Luxemburg
in Personalunion mit den Niederlanden
Luxemburg
Hzm. Nassau
Wiesbaden
Grhzm. Hessen-Darmstadt
Darmstadt
Freie Stadt Frankfurt
Kgr. Bayern (Pfalz)
Kgr. Sachsen
Dresden
Thüringische Staaten
Weimar
Gotha
Rudolstadt
Sondershausen
Hildburghausen
Coburg
Meiningen
Sachsen-Altenburg
Zeitz
Kgr. Bayern
München
Kaisertum Österreich
Wien
Kgr. Württemberg
Stuttgart
Grhzm. Baden
Karlsruhe
Hechingen
Sigmaringen
Hohenzollern
Kgr. Frankreich
Fsm. Liechtenstein
Vaduz
Schweiz
Fsm. Neuenburg (Preussen)

Zahlen-/Buchstabenkürzel:

Thüringische Staaten:
Grhzm. Sachsen-Weimar 1a
Hzm. Sachsen-Gotha 1b
Hzm. Sachsen-Meiningen 1c
Hzm. Sachsen-Hildburghausen 1d
Hzm. Sachsen-Coburg 1e
Amt Römhild: Gemeinsamer Besitz Hzm. Sachsen-Gotha und Sachsen-Meiningen 1b|c
Amt Themar: Gemeinsamer Besitz Hzm. Sachsen-Meiningen und Sachsen-Coburg 1c|e
Fsm. Schwarzburg-Sondershausen 2a
Fsm. Schwarzburg-Rudolstadt 2b
Fsm. Reuss ältere Linie 3a
Fsm. Reuss jüngere Linie 3b
zu Preussen: Pr.

Anhaltische Herzogtümer:
Anhalt-Dessau 4a
Anhalt-Köthen 4b
Anhalt-Bernburg 4c
Kfsm. Hessen-Kassel 8
Grhzm. Mecklenburg-Strelitz 8
Hzm. Braunschweig 9
Grhzm. Oldenburg 10
Hzm. Lauenburg: in Personalunion mit dem Kgr. Dänemark 12
Fsm. Hohenzollern-Hechingen 13a
Fsm. Hohenzollern-Sigmaringen 13b
Fsm. Waldeck-Pyrmont 15
Fsm. Schaumburg-Lippe 16
Lgft. Hessen-Homburg 18
Lippstadt: gemeinsamer Besitz Kgr. Preussen und Fsm. Lippe-Detmold 19
Bergedorf: gemeinsamer Besitz der Freien Städte Hamburg und Lübeck 20
zu Hamburg (Cuxhaven) 31
Grenze des Deutschen Bundes
100km

Zollvereine in Deutschland 1828

Figure 2

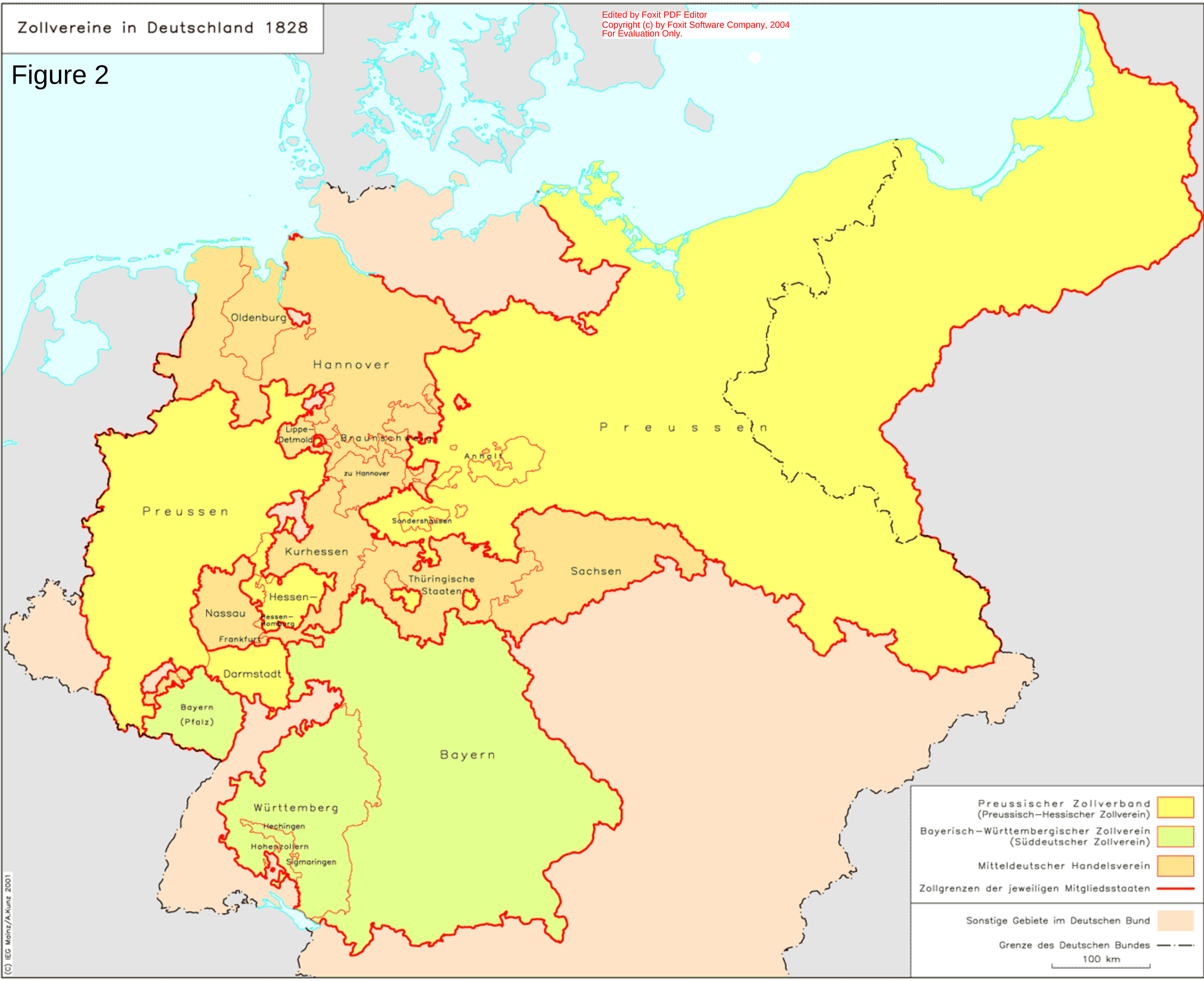

Figure 3: Train connections in the year 1850

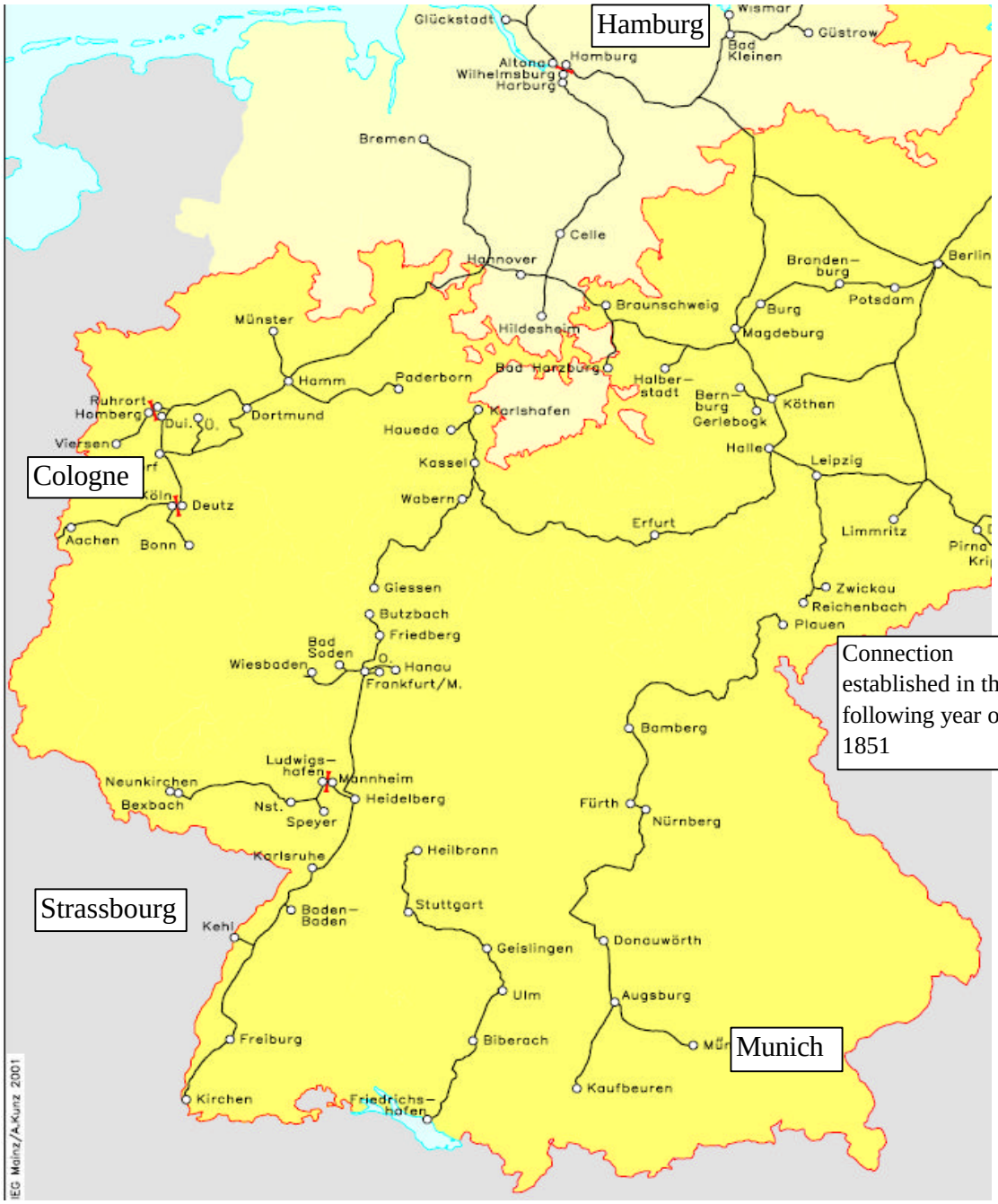

Figure 4: Four Markets and the Zollverein Liberalization of 1834

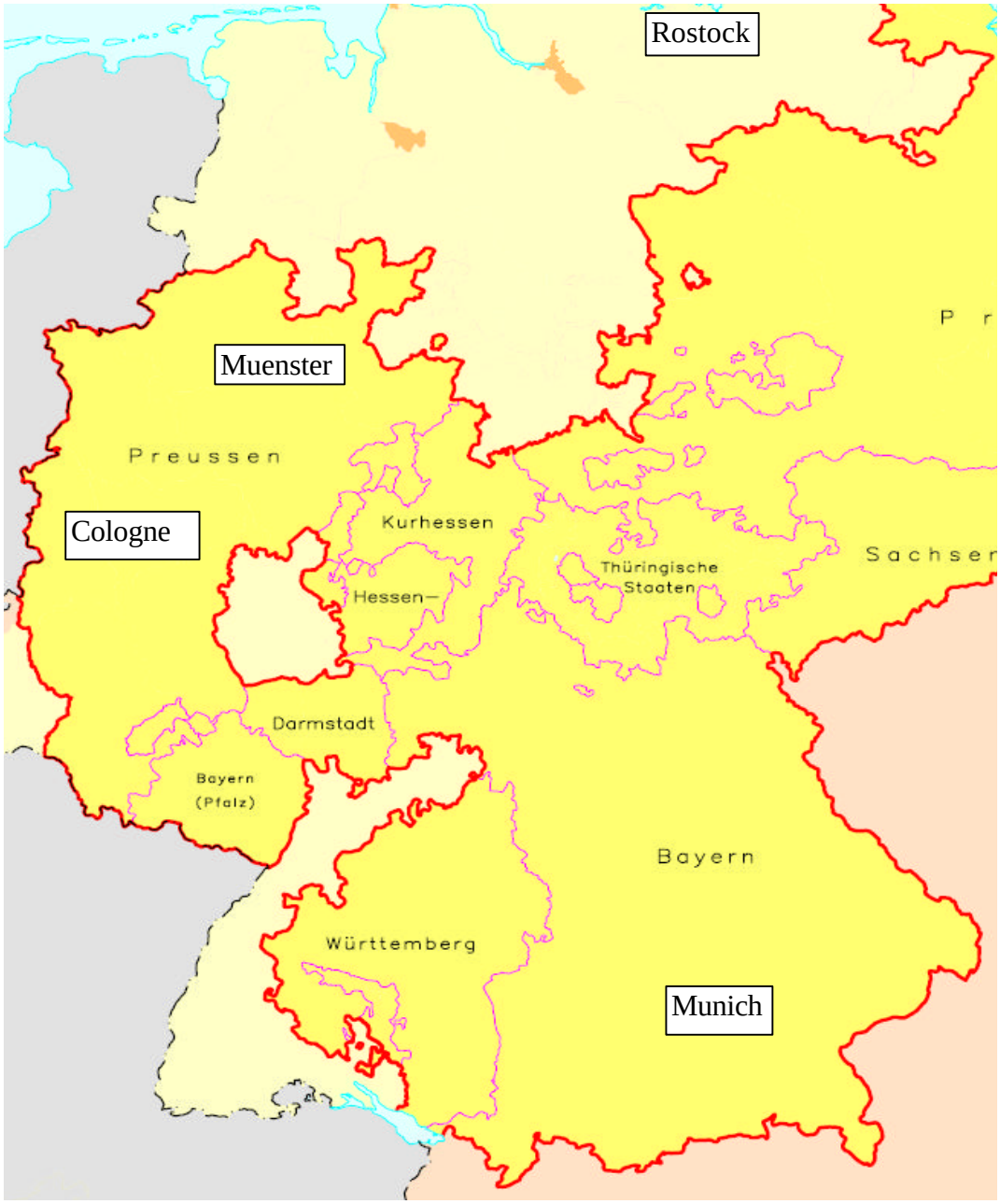

Figure 5: Do Customs Liberalizations Reduce Price Gaps?

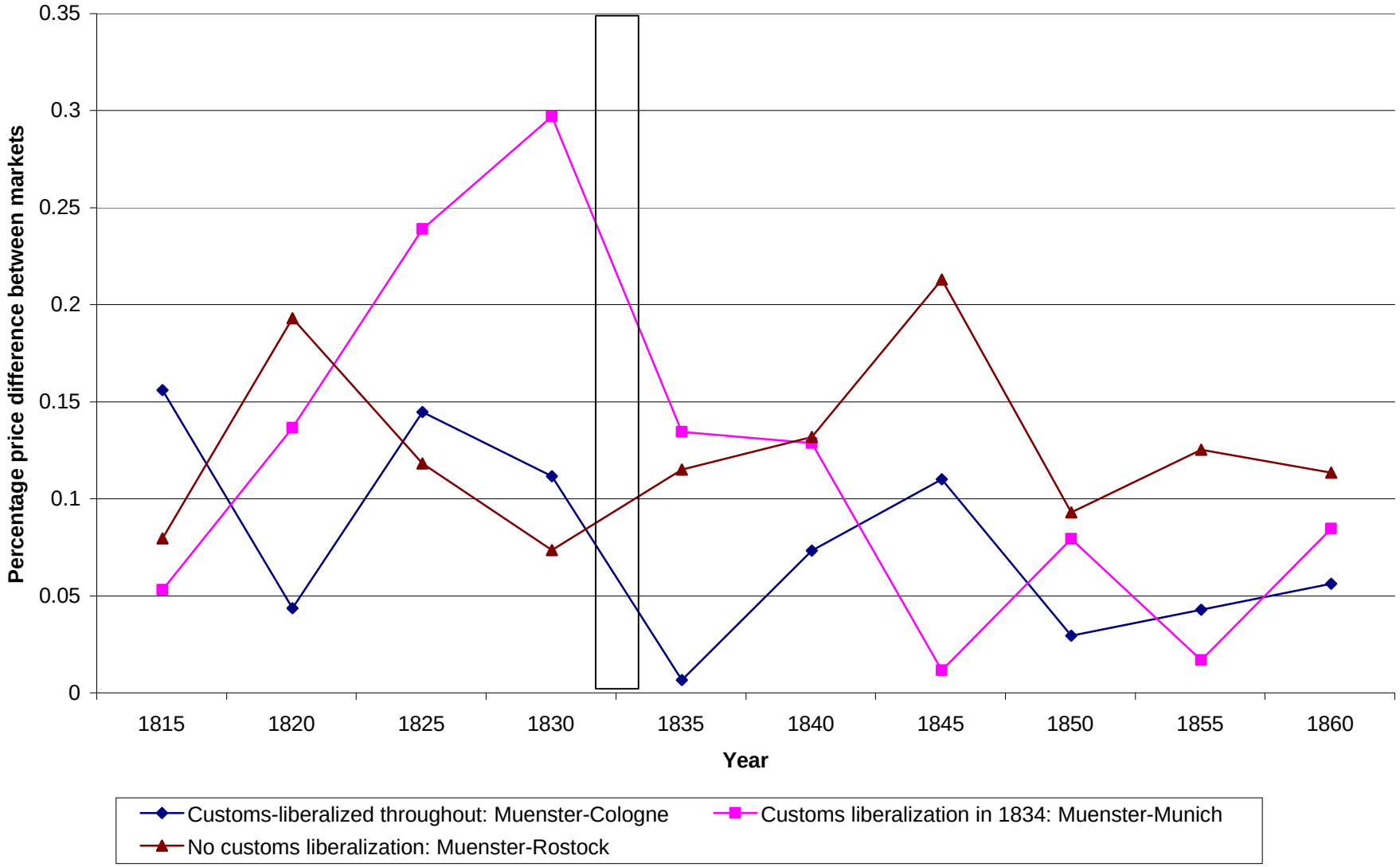

Figure 6: Do Train Connections Reduce Price Gaps? The Railroad Effect over Time

Figure 7: Cities in states further away from the seaboard join the Zollverein earlier

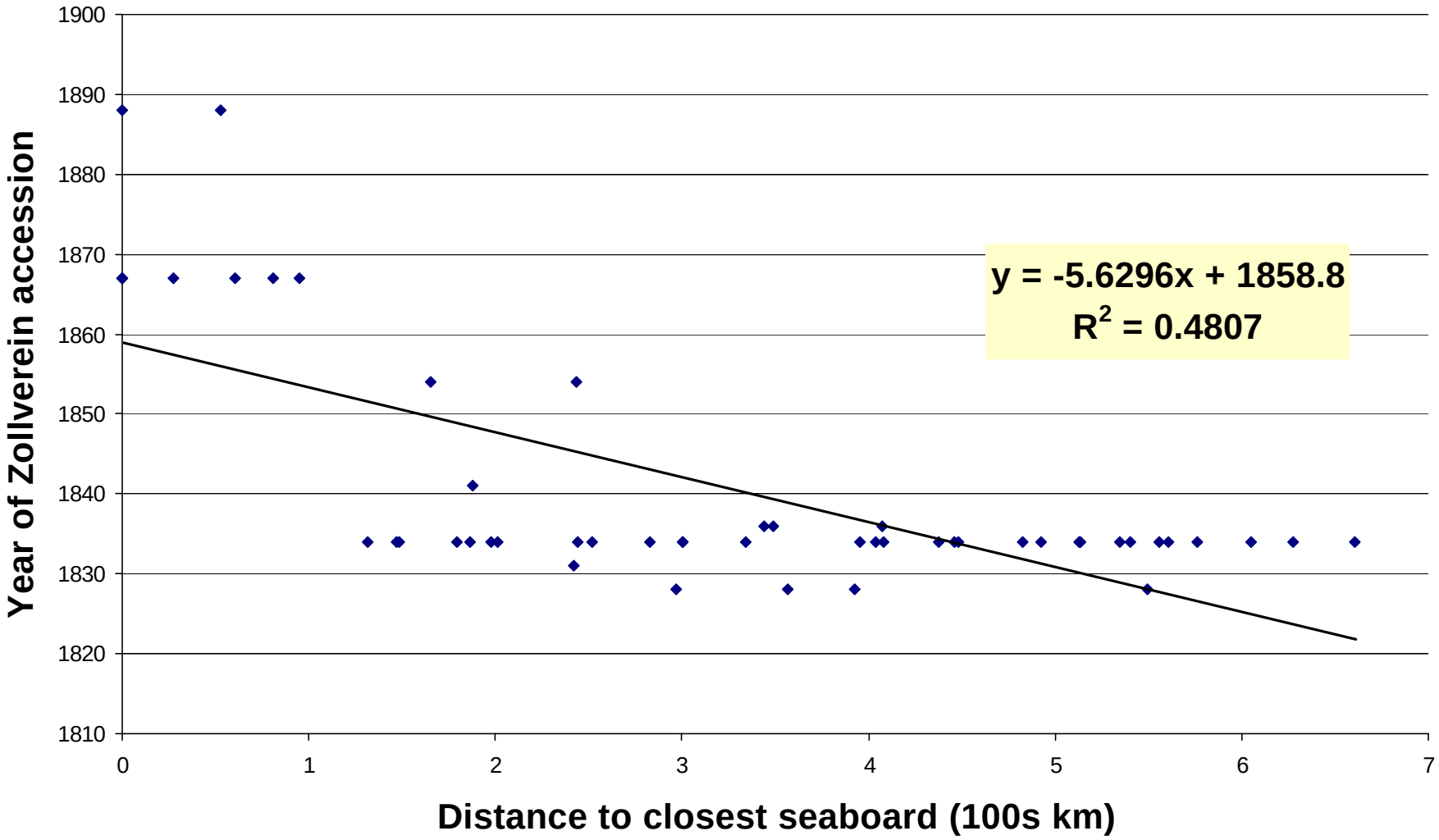

Figure 8: Larger Cities Have Railways Earlier