Market Integration as a Mechanism of Growth*

Wolfgang Keller†
and
Carol H. Shiue‡

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Abstract

In what sense are institutions a deep determinant of growth? In this paper, we address this question by examining the relationship between city growth and institutional reform in 19th century Germany, when some cities experienced deep institutional reform as a result of French rule. Employing an instrumental-variables approach, we find there is a hierarchy of growth factors in which institutions affect market integration more than market integration affects institutions. It was institutional improvements that were crucial to market integration, rather than just declining transport costs, which increased city growth during this time period. The institutional reforms, however, were transmitted through the mechanism of market integration. This created a much larger impact on city growth compared to the institutional impact independent from the market integration mechanism. The approach we take can be applied to other causes of economic growth.

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†University of Colorado, Boulder, NBER, CEPR, and CESifo; kellerw@colorado.edu
‡University of Colorado, Boulder, NBER, CEPR, and CESifo; shiue@colorado.edu

1 Introduction

Institutions are widely viewed as one of the most important determinants of growth (Acemoglu, Johnson, and Robinson 2005; Helpman 2004).[1] Yet it has proven difficult to describe how institutions affect growth, which one might call the mechanism question. In this paper we argue that an important mechanism by which institutions affect growth is via increased market integration. Our context are cities in 19th century Germany, where radical institutional changes increased the potential for economic growth. Around the year 1800, reforms imposed from France swept away feudal institutions in Germany, replacing them with better institutions that were inspired by new ideas of freedom and equality (Ganser 1922, Kisch 1962). At the same time steam railways were introduced, with Germany's rail network growing 60-fold between 1840 and 1877 (Ashworth 1974, Hornung 2014). Prior to the 19th century market integration was low and transactions costs high, limiting the exchange of factors and goods, the division of labor, as well as investment.[2] We show, first, that city population increased particularly fast in German areas that also saw the biggest improvements in interregional market integration. Second, the impact of institutions on city size independent of market integration changes is relatively small, indicating that most of institutions' effect is through market integration.

Our analysis is part of the large literature on the impact of institutions on economic performance (Acemoglu, Johnson, and Robinson 2001, Rodrik, Subramaniam, and Trebbi 2004, and La Porta, Lopez-de-Silanes, and Shleifer 2008), and it is most closely related to Acemoglu, Cantoni, Johnson and Robinson (2011) who study the impact of institutional improvements in Germany brought about by French rule around 1800. We extend their analysis by examining institutions alongside market integration between cities, measured by price gaps for homogeneous goods, as a second cause of growth. To address the potential endogeneity of market integration changes we employ railway costs, reflecting terrain differences (Duflo and Pande 2007, Nunn and Puga 2012), as instrumental variables. We also evaluate numerous alternative explanations for city growth, including geography, the availability of coal, human capital, and religious differences. None of these alternatives explains our findings.

Even though the mechanism question has been central in research seeking to explain growth and income differences, we still know relatively little about how institutions, culture, or other factors induce a certain economic behavior. Human capital has recently been emphasized as the mechanism through which religion leads to income differences (Becker and

[1] Greif (2000) defines institutions as "a system of social factors--such as rules, beliefs, norms, and organisations-that guide, enable, and constrain the actions of individuals, thereby generating regularities of behaviour" (p. 257). See also North (1981).

[2] Greif (2000) refers to this as the "fundamental problem of exchange".

Woessmann 2009, Bai and Kung 2015). Physical capital investment and total factor productivity are often noted as mechanisms through which institutions operate, and furthermore, good institutions might also stimulate human capital accumulation (Acemoglu, Gallego, and Robinson 2014). By showing that market integration is an important mechanism through which institutions work we shift the focus to the key role played by interdependencies between economies, which can be contrasted to mechanisms like capital accumulation which can operate in each economy separately. Our finding has been anticipated in the literature by Helpman (2004) who argued that "since...market integration is important for growth, an analysis of non-market institutions and their relationship to market integration should lead to a better understanding of the growth process" (p. 119). Our contribution is to provide one of the first empirical corroborations of it.

2 Institutions and market integration in 19th century Germany

Over much of the 19th century, despite centuries of shared language and culture Germany consisted of numerous independent states. Politically, states had shifting alliances, at times fighting wars on opposing sides, and economically their institutions differed. Furthermore, there was substantial variation at the sub-state level, especially in larger states such as Prussia or Bavaria. This is one reason why we conduct this study at the city-level.

Our sample period is the central sixty years of the 19th century, from 1820 to 1880.[3] City size growth in Germany during this period was affected by two events. The first was the impact of new ideas of freedom and equality surrounding the French Revolution (1789) that led to institutional change in Germany. Second, the new technologies of the British Industrial Revolution, including the steam engine, led to improvements in transportation technology in Germany.

Economic institutions before 1789 By the end of the 18th century, many German areas had experienced several centuries of feudal, protectionist, and generally inefficient rule.[4] During this period cities were typically ruled by a small group of patrician families. One of the key instruments of their domination was guilds. Guilds were organizations of merchants and craftsmen that financially supported the cities in exchange for exclusive political and

[3]We exclude the first years of the 19th century because economic activity was strongly affected by wars. The period 1880 to 1900 is dropped because the foundation of the German Reich (1871) led to institutional convergence.

[4]See Ganser (1922), Kisch (1962), and Lindberg (2009).

economic influence. Non-residents could not become guild members, and they were generally not allowed to work, produce, or trade in a particular city.[5] In addition to restrictions on entry, tight regulation on production and materials usage was a key aspect of guild policy. For example, Aachen cloth merchants had to commit to produce exclusively in Aachen, not in the nearby towns of Eupen or Burtscheid (Ganser 1922, Ch. I.4).[6] The legal framework in which commercial activity took place favored the noble and wealthy, and the lack of strict enforcement strengthened their hand further.[7] This set of institutions led to poor economic outcomes and contributed to an overall decline; the city of Aachen, for example, had around 40,000 inhabitants in the 14th century while at the end of the 18th century city size had fallen to just over half that number (Ganser 1922, Ch. I.1, I. 3).

Change under French rule During the period of the French Revolutionary and Napoleonic Wars (1792 to 1815), French rule meant not only that Germany came under the influence of ideas of freedom and equality, but also led to the introduction of a purposive and uniform administration (Kisch 1962). The reforms included, first, the abolishment of guilds through the introduction of freedom of economic activity (*Gewerbefreiheit*). Second, a new civil code based on the *Code Napoleon* was introduced that gave equality before the law to everyone. More generally, economic activity in the areas under French rule came to be governed by new commercial law and courts in line with the needs of rapidly growing economies (Kisch 1962). One example of this are new labor courts (*Conseil de Prud'hommes*, or *Werkverstaendigenrat*), whose most common tasks included adjudicating contract disputes (Ganser 1922, Ch.III.4).

While generally these changes moved German institutions towards freedom and equality, in some ways their effects were partial and discrimination persisted. For example, Jews were not granted full *Gewerbefreiheit* because of exclusionary rules regarding usury (Ganser 1922, Ch.III.4 e). The reforms under French rule also led to distributional effects by favoring one group over another. For example, workers had to carry work books (*livret ouvrier*, or *Arbeiterbuechelchen*) that recorded the worker's past conduct, arguably enhancing the position of employers (Kisch 1962, 317). The reforms did not always have long-lasting effects. While Napoleon supported many reforms that were started before, he sided at times with the elites to garner their support. In addition, certain reforms were reversed in several German

[5] "No Nurembergers, Lombardians, English, Dutch, Flemish, Jews or any other foreigner had the right to live or trade in the city", describing the rules in the North German cities of Luebeck and Danzig (Lindberg 2009, 622). Religious barriers were common; in Aachen, for example, all non-catholics faced severe restrictions (Ganser 1922, Ch. I.4).

[6] Urban guilds also supported the emergence of guilds outside the city walls in an attempt to strengthen their grip on market regulation (Ehmer 2008).

[7] Ganser (1922, Ch. I.4) cites bankruptcy and product liability laws as examples.

cities after Napoleon's defeat (1815). Nevertheless the reforms in Germany under French rule were a clear break from past centuries.

Economic effects of institutional change In general, institutions granting greater freedom and equality affect the efficiency of commercial activity in several ways. First, the reduction of the risk of expropriation through equality before the law eliminates the commitment problem emphasized by North and Weingast (1989). Second, impartial and swiftly operating courts encourage economic activity; for example, courts addressing labor contract disputes such as *Conseil de Prud'hommes* reduce labor unrest and work stoppage time. Among the various elements in the French reform package the one most important to economic development were the guilds, to which we turn now.

Guilds restrict both entry and trade volumes, and they raise output prices while lowering input prices (Ogilvie 2014).[8] As a consequence, the abolishment of guilds through introducing *Gewerbefreiheit* had a pro-competitive effect. One central way in which guilds affected productivity was in their stance towards the reallocation of industry sales. Guilds fiercely opposed the reallocation of sales from low productivity to high productivity firms. For example, when the cloth producers of Burtscheid offered to cloth producers in Aachen to fill in for the unexpectedly high demand in Burtscheid, the Aachen guild rejected the proposal, arguing that this would only benefit the strong Aachen producers while driving the weaker Aachen producers into poverty, and that it would raise wages.[9] Once guilds were abolished, such market share reallocations could proceed.

The influence of guilds extended beyond policies affecting the static equilibrium to those that influence long-term growth. In particular, the inherent master-apprenticeship structure of guilds implied members were generally opposed to innovation. Masters would be the ones to choose production technologies, and since many years of training on a given technology was required to eventually become a master craftsman, this created strong incentives to resist technical change (Mokyr 2009). Further, guilds reduced the rate of innovation because their regulation prevented experimentation, in particular in the area of material usage and production processes (Ogilvie 2014). Guilds also affect the rate of technology diffusion. In premodern societies, the migration of individuals embodying innovative industrial and commercial practices is the most common form of technological diffusion (Ogilvie 2014). Once guilds were abolished, foreign craftsmen and engineers could locate in new markets, bringing their knowledge with them. Overall, the largely non-discriminatory institutions introduced in Germany during French rule that replaced the particularistic system dominated by guilds

[8] Guilds are seen in a more favorable light in Epstein (2008).

[9] According to the Aachen guild, it has to be prevented that the big fish would swallow the small ["..die grossen Fische die kleinen innschluckten"], Ganser (1922), Ch. I.4.

likely increased economic efficiency. Below we find empirical support for this interpretation.

We are interested in the impact of these reforms on spatial market integration, which will be measured by city-to-city price gaps. Two effects can be distinguished. First, there is the supplier effect. The deregulation implied by the abolishment of guilds in a particular city will allow a greater degree of reallocation of market shares among existing suppliers. This increase in the degree of competition will strengthen the position of stronger versus weaker firms, and to the extent that stronger firms have lower costs that they pass on to consumers the reforms will tend to lower prices. On this account the impact of institutional reform in a given city k does not have a clear implication for the absolute price gap between city k and other cities because it depends on the pattern of trade.[10] In contrast, the abolishment of guilds also removes entry barriers to non-resident suppliers. This increases the degree of competition because one of the non-residents could become the new low-cost supplier. If post reform city k imports from another city j, the local price in k will tend to fall towards the trade-cost inclusive price of j and the price gap between k and j will fall.

Second, there is the transactions cost effect of institutional change. Whenever the optimal organization of economic activity dictates the division of labor between independent parties, the question is how to ensure that ex-ante optimal contract commitments will be honored ex-post (see Greif 2000). Institutional quality can affect the cost of production and trade because incomplete contracts ex-post lead to under-investment in relationship-specific investments ex-ante (Nunn 2007). In this setting, a higher institutional quality in city k lowers the price of the good in k, and the effect on price gaps is analogous to the supplier effect.

When buyer and seller are located in different cities the difference between the price in k and in j captures the size of the transactions costs between cities. It is reasonable to assume that problems of exchange between cities are larger than within cities: commitment and enforcement costs tend to increase with geographic distance, and cities might have different legal systems. The importance of transactions costs for modern economies is well established. For example, Anderson and Marcouiller (2002) estimate that a 10% improvement in a country's institutions leads to a 5% higher volume of imports. Institutional quality likely affected trade between early modern German cities as well.[11]

Overall, the impact of higher institutional quality is to (weakly) lower city-to-city price gaps. The effect is strongest when institutions affect the transactions costs between cities, and when institutional improvements imply a switch to low-cost suppliers from other cities.

[10] If city k continues to import a good its price gap will fall, while if city k exports it the price gap will rise.

[11] One may be concerned that high price gaps could be a sign of strongly *different* institutions in the two cities: good institutions in one, and bad institutions in the other. Empirically, we do not find evidence that price gaps are increasing in the difference of institutional quality between cities.

Non-institutional determinants of market integration Across different economies and over time, the degree of market integration may be affected by a range of non-institutional factors, from transport costs over tariffs to transactions costs imposed by different monetary regimes (Jacks 2006, Shiue and Keller 2007). In the case of 19th century Germany, the *Zollverein* customs union, established in the year 1834, has played a significant role for market integration (Henderson 1939, Keller and Shiue 2014). The 19th century also saw the emergence of international organizations that liberalized waterway transport, such as the Central Commission for Navigation on the Rhine. It was founded as part of the Congress of Vienna (1815) and oversaw major agreements in the years 1831 and 1868. Our empirical analysis considers these factors.

The single most important technology affecting market integration in 19th century Germany was the introduction of steam railways.[12] Because of its prominence in the historical literature on Germany, our analysis focuses on railroad costs as the main non-institutional determinant of market integration. The first short railway track in Germany was opened in December 1835 between the Bavarian cities of Nuernberg and Fuerth, and the subsequent growth in the German rail network was at one of the most rapid rates witnessed in Europe.

The immediate impact of steam trains was that transport costs between two cities were substantially reduced (Fremdling 1995). Average freight rates on roads are estimated at around 40 *Pfennige* per tonkilometer during the 19th century. Railways cut overland rates by around 90% towards the end of the 19th century (Gutberlet 2013, Table 2). The introduction of railways led to a dramatic decline of transport costs for most low value-to-weight goods, one of which was wheat (O'Brien 1983).[13]

Because transport costs affect price differences across cities, city-to-city wheat price gaps tended to fall in Germany with the arrival of steam railways. This motivates our focus on railways as the key non-institutional driver of market integration, and to use railway costs as an instrumental variable. Nevertheless, we expect heterogeneity across cities because railways did not operate everywhere given that ship transport remained the low-cost mode of transportation throughout the 19th century.[14]

Market integration, trade, and growth We have noted that both institutional and non-institutional factors can affect market integration (measured by price gaps) or trade

[12] See the seminal contribution of Fogel (1964) for the United States, and Donaldson (2014) for a recent study of railways in colonial India. Nineteenth century railways in Germany are discussed for example in Fremdling (1975), Gutlerbet (2013), and Hornung (2014).

[13] While comprehensive freight statistics on wheat for our sample do not exist we know that virtually all wheat from Bavaria in the early 1850s was exported by railways (Seuffert 1857, Chapters 5, 6).

[14] For example, sending grain from the East Prussian town of Posen to Cologne by railway was at least three times as expensive as transporting it by ship in the late 19th century (Köttgen 1890, 64).

(measured by goods volume). In an influential paper Frankel and Romer (1999) have shown that one percent increase in the ratio of trade to GDP raises income per capita by at least half a percent. Furthermore, a recent study of colonial India using information on both prices and quantities has found that the introduction of railways increased agricultural incomes by around 16% (Donaldson 2014). In principle, this growth can be driven by a number of factors. Greater integration allows more specialization, which may increase capital accumulation. The introduction of railways in Germany generated indeed a higher level of capital investment that sped up structural change towards industrialization (Fremdling 1975). The larger effective market size resulting from more integrated markets may lead to scale economies, or stimulate innovation (Grossman and Helpman 1991). Market integration fosters competition which may increase innovation if the escape-competition effect outweighs the decline in innovation due to lower profits (Aghion, Bloom, Blundell, Griffith, and Howitt 2005). A higher level of market integration generally fosters the diffusion of knowledge between producers, scientists, and consumers, thereby increasing growth (Keller 2010 provides a survey). Evidence for 19th century Germany shows that gains in market integration raised knowledge diffusion and the rate of innovation: patenting in the late 19th century was systematically higher in German regions that were served early on by railways than other German regions where railways came later (Yin 2005).

3 Data and economic environment

This section describes the data employed in this study. Additional information on the sources and data construction are given in the Appendix.

Market integration Our approach of using price information in different geographic locations to examine spatial market integration follows a large literature in economic history (O'Rourke 1997, O'Rourke and Williamson 1999, Ozmucur and Pamuk 2005, Federico 2007, and Studer 2008).[15] As in most studies, we study market integration using annual data at the level of city pairs, for example, the price gap between Berlin and Cologne in 1850. Key to our empirical strategy is that city-to-city price gaps came down at differential speed during the 19th century. The sample consists of about 3,500 city-pair-by-year observations. We employ a novel data set that combines existing sources (from Persson 1999, Kopsidis 2002, Shiue and Keller 2007) with additional figures (based on Vierteljahrshefte 1935, Jahrbuch 1868), yielding an unusually detailed picture of the spatial structure of market integration in 19th century Germany.

[15] Analyses of modern economies include Engel and Rogers (1996) and Goldberg and Verboven (2005).

The analysis focuses largely on the price of wheat. This is, first, because wheat is the good that has been studied most before. Second, and related, wheat was important, both as a staple food in economies where a large share of the labor force worked in agriculture and as a major commodity in trade. Third, a comprehensive study of the integration of wheat markets is quite feasible. The price of wheat was recorded in relatively many cities, both small and large, not least because food riots following price spikes were a perennial concern for the authorities. The choice of wheat maximizes our sample size compared to other commodities, and we include all observations in the sample for which we can calculate city-to-city price gaps in a given year. Despite the authorities' interest in the price of wheat, it was mostly driven by market forces, and not, for example, by policies to stabilize food prices. Wheat is also a relatively homogeneous good so that its price across cities is comparable.

Market integration between cities k and j in year t is measured as the absolute value of the percentage price difference of wheat: $Pgap_{jkt} \equiv |ln\left((p_{jt}) - ln\left(p_{kt}\right)\right)|$. The measure is motivated by the so-called law of one price, a central equilibrium condition in the theory of arbitrage (Dybvig and Ross 1987, Froot, Kim, and Rogoff 1995). In a given year the bilateral transactions costs between cities k and j could not have been larger than the price gap, as this would be inconsistent with arbitrage. City-to-city price gaps are equal to transactions costs when there is trade.[16] In the current context, both institutional aspects of transactions costs, such as rules based commerce and contract enforcement, as well as non-institutional factors (especially transport costs) are plausibly reflected in price gaps. Summary statistics on the wheat price gaps are shown in Table 1B; the mean of the price gaps is 0.15, ranging from a minimum of 0 to a maximum of 0.82.

We make the following assumptions about the economic environment. First, there exist many wheat suppliers taking prices as given. While certain European areas had a comparative advantage in agriculture (in particular Eastern Prussia), there were sufficiently many small-scale suppliers near most sample cities that the assumption of perfectly competitive markets is reasonable. In the year 1847, for example, there were 1,666 licensed grain traders in Bavaria (Seuffert 1857, 6).[17] Pre-trade prices were mostly driven by random weather shocks. Changes in the direction of trade in different years were common. We eliminate these fluctuations by focusing on the absolute value of the price difference between cities. Note that the city-to-city price gaps are not independent from each other because a change in the price for city k affects price gaps between k and all other cities. Furthermore, a change in a single price

[16] Absent information on wheat trade between all cities we address the question whether transactions costs are equal to or smaller than the price gap by separating out cities located on waterways. Due to the relatively low cost of ship transport we expect that in waterway cities trade took place in virtually every period. Below we find that price gaps are informative even in the absence of data on traded quantities.

[17] The general conditions of 19th century wheat markets in Germany, as well as wheat trade, are discussed in Seuffert (1857).

will affect other price gaps through general equilibrium channels. We will shed light on the importance of dependence between observations as well as general equilibrium effects in the analysis below.

The second assumption we make is that there is no storage. The possibility of storage would generate an additional set of no-arbitrage conditions (see Shiue 2002, Steinwender 2014), and it would also affect price dynamics (Keller, Shiue, and Wang 2016). We abstract from storage because in addition to data constraints we do not believe that storage is of first-order importance in our context. Third, we assume that wheat price gaps are indicative of city-to-city transactions costs in general. This will be the case if institutional and non-institutional determinants affect wheat markets in similar ways as other markets. To shed some light on this we have compared wheat price gaps with those for butter and pork, two other widely traded homogeneous goods, for the cities Aachen, Berlin, Cologne, and Muenster. Computing all city-to-city price gaps among these cities, we find that wheat price gaps at Aachen and Berlin fell considerably more than at Cologne and Muenster during the 19th century. The same is true for the price gaps of butter and pork. This common component in changes of spatial price gaps supports the assumption that wheat price gap changes capture general changes in transactions costs between cities.

The city-level sample We employ a two-sample instrumental variables approach (Angrist and Krueger 1992) to map the city-to-city price gaps to city-level information (population size, institutions); see Appendix B for a description of the two-sample instrumental variables approach. [18] The sample covers the largest German cities (Berlin, Hamburg, and Muenchen), but also mid-sized cities such as Rostock as well as small towns such as Boizenburg (in the state of Mecklenburg) or Kempten (in Bavaria).

Our panel of quinquennial observations between 1820 and 1880 ($n = 312$ observations) is unbalanced. To see whether this may influence the results we have regressed the city's number of observations in the sample on the main city characteristics. The only consistent predictor of the number of observations turns out to be institutions: cities with better institutions are observed more frequently in the data (see Table A). To reduce concerns that sample composition affects the results, we report many results for the sample of cities that are frequently observed in the data. For these 28 cities, we have about three quarters of all possible observations (n=268 city-year observations, out of 28×13=364 possible). All 40 cities are listed in Table 1A, with the baseline sample of 28 cities noted.

Figure 1 shows the location of the sample cities. It is evident that although the sample

[18] The two-sample approach implies that for any city k, its price gap is the average of all price gaps involving city k.

includes most of Germany's regions the coverage varies. This reflects the fact that the available wheat price information varies across regions. The focus and depth of data collection across German areas differed before 1871, and given that institutional diversity is at the heart of the analysis we examine the role of the non-uniform coverage for our results in a number of ways. The main concern with non-uniform coverage is that it introduces a systematic bias. Below we conduct a range of checks using various samples and sample weights, finding that our results are robust. Consistent with that, the sample distribution is quite similar to a normal distribution, see Figure 2. This figure also shows that in comparison to the frequently employed Bairoch, Batou, and Chevre (1988) data our sample has a smaller overrepresentation of cities with around five thousand inhabitants.[19]

To reduce problems of serial correlation we employ data every five years instead of annual data. Our statistical inferences allow for an arbitrary variance-covariance matrix capturing potential serial correlation in the residual error term through clustering at the city level (Wooldridge 2002, Chapter 7). Spatial correlation of city events by region might mean that assuming independence unduly inflates the sample size. To address these concerns we present results based on clustering at a regional level, as well as based on Conley's (1999) spatial dependence-adjusted standard errors.

City population City population in the sample is between 2,800 and around 1.1 million people (see Table 1B). The data is based on German Historical GIS, Kunz (2014a). City size growth can be due to internal forces or through net in-migration, two forces that cannot be distinguished using our data. As migration movements often lead to redistricting we can gauge the importance of migration by using an alternative population series that incorporates redistricting (Keyser 1939).

Institutions Our analysis of institutional change builds on the work by Acemoglu, Cantoni, Johnson, and Robinson (2011; ACJR for short). For every city and year in the sample, we code variables that can take on the value of 0 or 1 for (1) the abolition of guilds, (2) the possibility to redeem feudal lands, and (3) a guarantee of equality before the law. The institutions in a particular city k and year t, $Inst_{kt}$, are defined as the average of these indicator variables. We refer to this also as the institutional quality of a city.

Thus-defined this can be plausibly seen as a broad institutions measure because the indicator (1) concerns crafts production, (2) affects agriculture, and (3) is relatively general. Furthermore, each of these indicators is a proxy for rules affecting activities in multiple

[19]The sample restriction in Bairoch, Chevre, and Batou (1988) is that a city had more than five thousand inhabitants at some point during their sample period; the density for Bairoch, Chevre, and Batou in Figure 2 is based on all German cities they cover in the years 1800 and 1850.

sectors. For example, the regulation of crafts that abolished the requirement of guild membership (*Gewerbefreiheit*) often coincided with equivalent concessions permitting the setting up of manufacturing activities. Similarly, the year in which equality before the law was guaranteed through a written civil code was correlated with the creation of a written commercial code.

One might still favor some over other indicators. For example, the measure of market integration is based on wheat prices, which may be closer to an indicator such as the redeemability of feudal lands than to the existence of craft guilds. To address such concerns we employ all four definitions of institutional quality that can be formed with two or more indicators. Our main definition is based on the (I) abolition of guilds and equality before the law; we also employ (II) redeemability of feudal lands together with equality before the law, (III) abolition of guilds with redeemability of feudal lands, and the broadest definition using (IV) all three indicators. As will be shown our results are similar in all four cases. This supports our hypothesis that the indicators can be taken as indicative of the overall "package" of institutional reform.

The institutional variables have means between 0.2 and 0.5, and there is substantial variation over time (see Table 1B). For example, for Institutions definition IV there is institutional change for close to three quarters of the cities. When the unit of analysis is the city pair, the institutions variable is defined as the average of the institutional qualities of the two cities in that pair. To gauge the influence of this for our results we also show results that separate the institutional qualities of cities j and k in the analysis.

Railroad costs and French rule as instrumental variables We employ railway costs between any two cities k and j as one of our instrumental variables. Given the role of steam railways in reducing transport costs we hypothesize that railway costs predict market integration. Railway costs were a key determinant of the likelihood that a particular line of track would be built and thus whether the arbitrage-enhancing effect of railways would materialize. Railway building in Germany was a highly decentralized decision where local governments and business groups mattered. Our measure of railway costs is derived from Nicolls (1878) who presents information on how much freight capacity had to be given up when operating on steeper versus flatter terrain. In particular, for a locomotive with 1,200 tons pulling capacity on flat land the towing capacity goes down to 1,150 tons when the gradient is 5 feet to the mile, down to 939 tons if the gradient is 10 feet to the mile, and so on (see Appendix A.1 for details). Using this information to fit a smooth cost function, we apply the ArcGIS least-cost distance module in a 90 by 90 meter grid to compute the costs of the least-cost railway routes for all city pairs in the sample. Because these railway costs necessarily increase with the distance between two cities we divide by distance to arrive at the average gradient cost of terrain between k and j in terms of foregone railway freight capacity.

The second instrumental variable is the length of French rule in years during the period 1792 to 1815, as in ACJR. The longer was French rule in a certain city, the greater was its institutional change. It is an attractive feature that French rule was not chosen in Germany, rather, it was externally imposed. ACJR demonstrate that the primary French motives were not economic but defensive (to form a buffer zone versus Austria and Prussia) and ideological in nature (to export the ideas of the French revolution). The setting was arguably close to a natural experiment, and we find no evidence that would rule out employing the length of French rule as an instrumental variable. We focus on French rule through France itself or through a French-controlled satellite state, excluding purely military occupations, in the area in which a particular city is located. The length of French rule ranges from 0 to 19 years, with higher values mostly in Germany's west and northwest (see Table 1B).

Alternative explanations Although the list of potential alternative influences is long, based on previous studies we have collected information on what are arguably the most plausible factors affecting city size in our setting. In particular, coal features prominently as a factor behind industrialization in 19th century Germany, and it might also explain city size growth (Fernihough and O'Rourke 2014). Therefore we employ information on coal production in Germany. We also control for religion, shedding new light on Weber's (1930) hypothesis that Protestantism is conducive for economic development. To assess the importance of cultural and other influences from France, distinct from France's influence in shaping German institutions, we include the distance of each city to Paris. We have, in addition, information on each city's latitude and longitude to control for its geography and basic climatic differences, as well as data on each city's access to water transport and specifically to wheat imports from the United States, which increased in importance during the 19th century.

Of particular interest is the influence of human capital accumulation. We obtain from *Deutsches Staedtebuch* (Keyser 1939) information on the date at which the first *Gymnasium* was introduced in each city.[20] Holding constant other city characteristics, a relatively early date should be indicative of greater emphasis on human capital accumulation. Furthermore, we have some information on the number of students in schools of higher learning (*Hoehere Schulen*, which includes *Gymnasium*). We also employ distance from the town of Wittenberg to assess the human capital channel because the Protestant reformation origi-

[20] A *Gymnasium* is a type of secondary school which had to be completed to be able to attend university.

nating in Wittenberg gave an incentive to acquire literary skills to be able to read the Bible (Becker and Woessmann 2009). For the medieval period, Cantoni and Yuchtmann (2014) have demonstrated the importance of university graduates for institutional quality and commercialization. At the turn of the 19th century German universities experienced changes, including closures in some cities (for example, the University of Cologne was closed between 1798 and 1919). To be able to distinguish the impact of French rule from university restructuring we employ an indicator for whether the nearest university to each sample city was subject to restructuring around the year 1800. [21]

Table 1C gives information on the variation in the sample by length of French rule and railway costs. In the upper part of the table, we distinguish cities that experienced no French rule ($n = 240$) from those that were subject to French rule at any length ($n = 72$). French rule was more likely in coal-producing areas, which might raise the possibility that the French targeted areas that would later grow faster. At the same time, city size in the year 1800 was relatively low among cities under French rule, and they also tended to have less access to waterways than cities not under French rule. The distance to Paris for cities under French rule tended to be smaller than for cities not under French rule. One explanation for this is the relative ease of military campaigns when they are close to one's capital.

In the lower part of Table 1C we show city characteristics separately for high versus low railway costs (split at the median). The size of city population in the year 1800 was relatively low in high railway cost cities. To the extent that railway costs are relatively high in mountainous areas, this may result in a disadvantage due to lower levels of trade during pre-railway times. Railway costs tend to be higher for cities with low latitude, which is related to the fact that Germany's south has more mountains compared to the generally flat north. The table also indicates that low railway cost cities tend to have better waterway access than high railway cost cities, presumably in part because of access to coastal shipping in the north. Overall, while there are differences across cities depending on treatment status, the differences do not systematically point in one direction.

4 Empirical analysis

4.1 Overview

To study the role of institutions and market integration for city growth, we adopt an instrumental variables approach with two instrumental variables: the length of French rule and

[21] All variables are described in the Appendix. Note that in some cases the most disaggregated information available is above the city level, and the coverage for a particular variable in the sample varies.

railway costs. Note that the market integration and railway cost measures are at the city-pair level while the length of French rule and institutional quality are observed at the city-level. We combine city-pair and city variables using a two-sample instrumental variables approach (Angrist and Krueger 1992). In our context this involves constructing city-level averages from city-pair observations; see Appendix B. We begin with the reduced-form relationship between city population and the proposed instrumental variables.[22] We also examine the robustness of the reduced-form relationships to provide evidence on the exclusion restrictions. The analysis of the first-stages shows an asymmetry- factors that improve institutional quality affect market integration more strongly than factors that enhance market integration influence institutional quality. We then turn to the second stage, showing that market integration is an important mechanism through which institutions work.

4.2 The impact of institutions and market integration on city size

4.2.1 Reduced-form estimation

The reduced form relationship is given by

$$lpop_{kt} = \beta_k + \beta_t + \sum_s \beta_{s1} I_{st} FrenchRule_k + \sum_s \beta_{s2} I_{st} \overline{RailCost}_k + Q'\beta + u_{kt}, \tag{1}$$

where $lpop_{kt}$ is log city population in city k and year t. $FrenchRule_k$ is defined as log years of French rule, plus 1 at city k, and $\overline{RailCost}_k$ is the average of the log railway cost per unit of distance of city k to other cities.[23] The term I_{st} is an indicator variable for time-windows of roughly twenty years length (1820-35, 1840-1860, and 1865-1880), of which two are included in equation (1). The coefficients are relative to the excluded time window, for which the coefficient is equal to zero by construction. Time windows ensure that the instrumental variables can have a time-varying effect. We expect the effect from railway costs on market integration to materialize more in 1840-60 because during 1820-35 steam railways were not yet introduced in Germany, so the time windows yield a falsification test. Second, employing time windows allows to include city fixed effects β_k which address several time invariant factors that might affect size, such as city location. While three twenty-year time windows is our preferred specification, we obtain similar results with alternative time window definitions or by exploiting only the cross-sectional variation in French rule and railway costs (which requires dropping the β_k). Equation (1) includes fixed effects for every sample year (β_t) to

[22] Angrist and Pischke (2009) emphasize the usefulness of reduced-form estimates as they are related to the causal effects of interest.

[23] It is the average distance of city k across all cities j as part of the two-sample instrumental variables approach.

control for common shocks, as well as the average log distance between city k and other cities (the vector Q) interacted with decade fixed effects to address factors that may have changed differentially for shorter versus longer distances.

OLS results are presented in Table 2 on the left side. If French rule caused institutional improvements that led to higher city size, it should enter equation (1) with positive coefficients. Furthermore, if high railway costs slowed down railway building and that reduced city growth, we expect negative coefficients on railway costs (the railway coefficient for the excluded period 1820-35 is zero). The results shown in column 1 conform to that pattern. City size is increasing in the length of French rule during the years 1820 and 1860 (relative to 1865-1880), consistent with the hypothesis that French rule led to institutional improvements which raised city size between 1820-60. The median regression results on the right side of Table 2 broadly confirm our OLS results. Overall the reduced-form results support our instrumental variables strategy.

4.2.2 Evidence on the exclusion restrictions

This instrumental variables approach requires that railway costs and French rule are as good as randomly assigned and not highly correlated with other determinants of city size (Angrist and Pischke 2009, Ch. 4). Externally imposed French rule and the exogenous nature of terrain are good candidates for random assignment. Whether railway costs and French rule impact city size only through market integration and institutions cannot be formally tested, as usual, because it involves the unobservable error. We can, however, provide evidence on the likelihood that the exclusion restrictions hold by adding potential determinants of city size to the reduced-form equation (1). If the coefficients on French rule and railway costs were to drastically change it would be reason to believe that the instrumental variables pick up more than the impact of market integration and institutions. Results are shown in Table 3.

Each of the columns 1 to 11 gives results from flexibly adding one possible determinant of city size with decade fixed effects in equation (1). The first is an indicator for coal production in the year 1850.[24] The location of coal deposits figures prominently in accounts of 19th century industrialization (Fernihough and O'Rourke 2014). There is some evidence that city size and coal production are correlated (a p-value of about 6% in the test of inclusion). The coal coefficients are generally positive (not shown), consistent with the hypothesis that coal production leads to city size growth.[25] At the same time, French rule and railway costs

[24]Because by the year 1850 there was coal production in virtually all areas with significant coal deposits, this should be thought of as an indicator of coal endowments. The years 1860 to 1880 are the omitted group.

[25]The full set of results is available upon request.

coefficients do not change much. Next we consider city size in the year 1800 (column 2). It has been argued that the apparently beneficial effect of French rule in Germany might have been due to Germany's relatively high level of development (Kisch 1962), and city size in 1800 is correlated with that. City size strengthens somewhat the French rule coefficients and weakens the railway cost coefficients, but overall the instrumental variables results are similar to before.

Geography is another potential influence of city size. Climate and disease environment within Germany are not very different but latitude may pick up terrain differences (more hilly in the south), for example. We see that although latitude and city size are correlated–Northern cities in the sample tended to grow faster than Southern cities–the French rule and railway cost coefficients are of the same sign and only somewhat larger than before (column 3). We do not find that the east-west dimension is significantly correlated with city size (column 4). Turning from geography to religion we examine the influence of Protestantism along Weber's (1930) hypothesis for the results. Protestantism is positively correlated with city population size though its main impact on the instrumental variables seems to be to increase (not weaken) the influence of French rule (column 5).

The role of human capital for the results is examined in several ways. First, early opening of a Gymnasium is taken as an indicator for emphasis on human capital accumulation at the tertiary level; we find no evidence that this is correlated with city size conditional on other covariates (column 6). Second, we consider the distance of a city to Wittenberg, Luther's workplace, based on Becker and Woessmann's (2009) finding that the spread of Protestantism might proxy for human capital effects in terms of literacy to be able to read the bible. Here, distance to Wittenberg is not a significant predictor of city size (column 7).[26] Third, around the turn of the 19th century some universities in Germany were restructured or closed in the process of secularization. To the extent that this had an influence on regional graduation rates it may be correlated with institutional quality in our analysis. However, it turns out that university restructuring plays no major role for the reduced-form results (column 8). While the findings of columns 6 to 8 do not suggest that our results are driven by human capital, given the prominence of human capital in the literature we will return to it below.

Next we consider the distance of each city in the sample to Paris. Cities closer to Paris would have been easier to occupy, and including the distance from Paris helps to distinguish French influence overall from the institutional consequences of French rule. Furthermore, if France had targeted nearby German areas with high growth potential the inclusion of distance to Paris may lead to a much smaller French rule effect. It turns out that there is

[26] In contrast to us Becker and Woessmann (2009) study a cross section of Prussian counties in the year 1871, which might explain the different finding.

little evidence that distance to Paris matters for the reduced-form results (column 9).

Given our emphasis on railway costs it is important to see the influence of transportation by ship. To hold constant ease of water transport we include an indicator for location on a navigable river, canal, or the coast. In addition, there is reason to believe that prices gaps are a relatively good measure of market integration for waterway cities because price gaps are equal to trade costs whenever there is trade, and that should be likely in virtually every year for waterway cities because water transport was the low-cost mode of transport. Another important influence might be overseas trade. If Hamburg and Bremen were to import wheat from Philadelphia at roughly the same price, the Hamburg-Bremen price gap would be close to zero despite possible substantial trade costs between Hamburg and Bremen. We define an indicator variable based on proximity to the northern coast and low U.S. wheat prices to gauge the importance of Atlantic wheat trade for the results. Neither controlling for waterway location nor for wheat imports from the U.S. leads to very different reduced form coefficients (columns 10 and 11). Finally, we have added all significant determinants of city size simultaneously to the reduced form equation, see column 12. We see some changes in the size of the instrumental variables coefficients, however judged by the tests for inclusion in the bottom of Table 3, accounting for other city size determinants if anything increases the reduced-form impact of railway costs and French rule on city size. To sum up, the railway costs effect is in line with the hypothesis that market integration was lower in the absence of railways. Furthermore, a city size that is increasing with the length of French rule is consistent with French rule creating more efficiency-oriented institutions that benefit city size. These results are supportive of our instrumental variables strategy.

4.2.3 First stages

The first-stage regression for market integration relates the absolute value of the price gap between cities j and k to railway costs and length of French rule:

$$pgap_{jkt} = \sum_{s} \delta_{s1} I_{st} RailCost_{jk} + \sum_{s} \delta_{s2} I_{st} FrenchRule_{jk} + \delta_{jk} + \delta_t + \overline{Q}'\delta + u_{jkt}. \qquad (2)$$

$RailCost_{jk}$ is defined as log railway cost between cities j and k per unit of distance between j and k. $FrenchRule_{jk}$ is defined as log of the average years of French rule in cities j and k plus one. This definition implicitly assumes that the institutional quality in either city has an equal weight in affecting city-to-city transactions costs. We show below that results are similar when the length of French rule in each city is entered as a separate variable (Table C). The term $\overline{Q}'\delta$ is defined as log distance between j and k interacted with decade fixed effects. The first stage results for market integration are shown in Table 4, Panel A, columns 1 and 2. In the baseline sample there are $n = 2,166$ city-pair by year observations. Railway costs enters the market integration first stage with positive coefficients (column 1): high railway costs lead to higher price gaps and lower levels of market integration during the years 1840 to 1880 relative to 1820-35–the excluded period–when steam railways were not available yet. Thus, railway costs have the expected sign and the pattern indicates that the results pass the placebo test. We also see that long French rule leads to relatively low price gaps during the years 1820 to 1860. [27] This supports the hypothesis that French rule led to institutions that reduced transactions costs between cities. Broadly similar results are found for the larger sample with all cities (column 2).

The first-stage equation for institutions is given by

$$Inst_{kt} = \sum_s \gamma_{s1} I_{st} FrenchRule_k + \sum_s \gamma_{s2} I_{st} \overline{RailCost}_k + \gamma_k + \gamma_t + Q'\gamma + \epsilon_{kt}. \tag{3}$$

Institutional quality is defined as the average of the abolition of guilds and equality before the law indicators. We see that institutional quality is increasing in the length of French rule (columns 3 and 4). In contrast, railway costs do not affect institutional quality. French rule, the exogenous driver of institutional quality, affects market integration, while railway costs, as a determinant of market integration, do not affect institutions. This asymmetry suggests a hierarchy of growth factors: institutions affect market integration but market integration does not affect institutions.

Our approach estimates the impact of market integration and institutions for specifically those cities in which the instrumental variables induce changes in market integration and institutions. We have confirmed by estimating first-stage regressions for various subsamples that the relationships between instrumental variables on the one hand and market integration and institutions on the other hand hold rather broadly, and are not driven by a particular set of observations (see Table B).

4.2.4 Second stage results

The second stage relates log city population to market integration (measured by price gaps) and institutions,

$$lpop_{kt} = \alpha_k + \alpha_t + \alpha_1 pgap_{kt} + \alpha_2 Inst_{kt} + Q'\beta + \varepsilon_{kt}. \tag{4}$$

[27] The reduction in institutional differences due to the foundation of the German Reich (1871) may explain the weakening of the French rule effect towards the end of the sample period.

The institutions variable $Inst_{kt}$ is instrumented according to equation 3, and the price gap variable $pgap_{kt}$ is the city-k average of the city-to-city price gap predictions from equation 2. The parameters of interest α_1 and α_2 measure the effect of market integration and institutions on city population. Results are shown in Table 4.

The baseline results are given in column 3 of Panel B, drawing on the first stages in columns 1 and 3, Panel A, respectively. Market integration enters with a coefficient of about -4.7: a lower price gap, or better market integration, leads to higher city population.[28] The institutions coefficient is not significant at standard levels, with a point estimate of about 0.3. Note that the Kleibergen-Paap test shows no evidence of a weak first stage. Including all sample cities confirms the result that market integration raises city size, while institutions have no significant effect (column 4). The indicators underlying $Inst_{kt}$ are meant to be only indicative of a certain institutional quality-they do not represent an exhaustive list of these institutions. To be sure that our indicators indeed capture broad aspects of institutional quality we provide results for three alternative definitions.

The first is based on the indicators abolition of guilds and redeemability of feudal lands, the second employs equality before the law and redeemability of feudal lands, and the third, as the broadest measure, employs all three indicators (equality before the law, abolition of guilds, and redeemability of feudal lands). The results are shown in columns 5, 6, and 7 of Table 4.[29] Across the three alternative specifications the market integration coefficient is estimated between -5.1 and -5.2, while the institutions coefficient is between 0.03 and 0.20. As in the baseline results we do not estimate a significant institutions effect in the alternative specifications. Overall, we obtain broadly the same picture as in the baseline with all definitions of institutions.[30]

OLS results are shown in Table 4 at the bottom. Market integration and institutions tend to have coefficients close to zero, which is consistent with classical measurement error in these variables. Some of the institutions coefficients are negative and significant, suggesting that OLS results are affected by omitted variables bias.

Robustness This section examines the robustness of our finding that the impact of institutions on city size is predominantly through improvements in market integration. We begin with the definition of French rule, defined so far as the log average length of French rule in cities k and j plus 1. Because the average may mask some variation we include French

[28]Following Bjorklund and Jantti (1997) the inferences in our two-sample instrumental variables estimation are based on bootstrapped standard errors.

[29]The first stage for market integration remains the same as before and is given in Panel A, column 1.

[30]One difference is that there is some evidence that railway costs are correlated with institutional quality, although this is weaker than the role of French rule (column 7).

rule length in city k and French rule length in city j as separate variables. The second-stage institutions estimate increases from 0.30 to 0.38, although it remains imprecisely estimated (Table C, column 1). Third, price gaps for city-pairs located on waterways are likely relatively informative on transactions costs because of the higher likelihood of trade. With only non-waterway cities we obtain a market integration coefficient of about -3.5 (Table C, column 2). The finding that relatively informative data pushes the estimate away from zero parallels other recent findings (Steinwender 2014). The institutions coefficient remains not significantly different from zero.

Another concern is that our approach misses spillovers and general equilibrium changes. One alternative that is broadly consistent with German railway development is is a hub-and-spoke transport system. [31] It is reasonable to assume that the pairwise approach is more appropriate between any two hubs than between any two spokes, and that the hubs included the state capitals. Consistent with this, the market integration effect is estimated to be lower when state capitals are excluded (column 3). While this evidence is consistent with general equilibrium effects, it appears that the pairwise approach yields significant results even in the presence of more general effects. The institutions point estimate in the hub-and-spoke specification is close to zero.

Recall that our measures of the length of French rule and railway costs do not vary over time. It is worth asking whether the specification with time windows is important for the results. To see this we drop the time windows as well as the city (and city-pair) fixed effects to estimate the relationship between city population growth and changes in market integration as well as institutional quality.[32] Population growth is positively affected by market integration improvements (lower price gaps), with a coefficient of about -9.8; at the same time the institutions coefficient remains insignificant (column 4).

To check if our sample is representative of Germany, we have, first, verified that the results are not driven by certain states that are strongly represented in the sample, in particular Mecklenburg and Bavaria (not reported). Prussia, on the other hand, is arguably underrepresented in the sample. However, increasing the number of Prussian cities leads to similar results.[33] Giving more weight to larger cities yields coefficients on market integration and institutions of about -4.8 and 0.5, respectively, however the institutions estimate continues to be insignificant (column 5, Table C). This implies that the results are not driven by the

[31] Initially the main cities in each state received railway access, before connections between cities in different states were built (Fremdling et al. 1995).

[32] French rule and railway costs are not separately identified from city (and city-pair) fixed effects.

[33] Adding the Prussian cities of Breslau, Danzig, Koenigsberg, Magdeburg, Posen, and Stettin increases the sample size by 22% and leads to similar results for market integration. We do not include these cities in the main sample because most of them are located in East Prussia, which was not only a major grain-exporter but also much less under the influence of French ideas than the other areas.

small cities in the sample.[34] We also investigate whether the findings are driven by the relatively small states; for example, Prussia had about 30 times the number of inhabitants of Mecklenburg (year 1816). If we apply the 1816 state population figures as regression weights the market integration effect is estimated at -6.8 while the institutions coefficient is larger but still insignificant (column 6).[35] Taken together, the composition of the sample does not appear to be central to our findings.

Another concern is that our results reflect the influence of other factors, in particular that of human capital. There is a sizable negative correlation between price gaps and secondary students per capita, raising the possibility that gains in market integration mimic increases in human capital. Lamentably, time-varying human capital data is limited (mostly for Prussia and Bavaria). In any case, as emphasized by Acemoglu, Gallego, and Robinson (2014), human capital accumulation might well be endogenous. Therefore, we test for the influence of human capital by adding (the exogenous) distance to Wittenberg as an additional variable to the instrumental variables estimation. Further checks employ our measures of the early foundation of a *Gymnasium* as well as the restructuring of German universities around the year 1800. Results are shown in columns 7, 8, and 9 of Table C. In all three cases, including the proxy for human capital does not change the finding that market integration is an important channel through which institutions have an effect on city size, with little evidence for an independent institutions effect.

Given that institutions do not have a significant effect on city size independent of market integration, we drop $Inst_{kt}$ from the regression. When market integration is the sole endogenous variable in the regression its coefficient is around -5, not too different from the estimate of -4.7 when the institutions variable is included (see Table D, column 4). Table D shows additional results for other assumptions on the regression error. In particular, because a shock to the wheat price in city k affects price gaps between city k and all other cities one may want to cluster in the market integration first stage at the city- instead of the city-pair level. Comparing columns 1 and 2 in Table 4 indicates that this does not much affect the strength of the first-stage regression. We have also considered clustering at the state- instead of the city-pair level, not only because some of the institutional changes occurred at the state level but also because market integration changes may exhibit a state-to- state pattern (e.g., if a new railway connection between Bavaria and Saxony connected all Bavarian with all Saxon cities). Even though dropping all city-level variation may be too conservative and weakens the instrumental variables, coefficients continue to be significant at standard levels (column 3). Finally, we have employed the non-parametric adjustments for spatial dependence pro-

[34] We have also dropped cities with population below 5,000, finding similar results.

[35] Similar results are obtained when each observation's regression weight is set equal to the share of the state of which the city is part of in the 1816 German population.

posed by Conley (1999), finding that this does not affect our inferences (see Table D, column 6).[36]

Quantitative analysis This section compares three models in terms of explaining the observed city growth in the sample (see Table 5). The results reported in columns 1 and 2 are based on models where market integration is a mechanism through which institutions exert an effect on city size. Included as the sole explanatory variable, market integration enters with a coefficient of about -5, as shown column 1 (from Table C, column 3; referred to as Model 1). This specification would be preferred if one places much weight on the fact that the institutions coefficient is relatively imprecisely estimated and not statistically significant at standard levels. In the present quantitative analysis we do not want to limit ourselves to precisely estimated coefficients, and column 2 presents results for the specification with both $pgap_{kt}$ and $Inst_{kt}$ variables (from Table 4, column 3, referred to as Model 2). Finally, we show the impact of institutions on city size without the market integration (or any other) mechanism in column 3. Institutional quality is instrumented with length of French rule using a standard two-stage least squares approach (this is referred to as Model 3). The institutions coefficient is estimated positively at 0.508 (p-value of 0.14).

The main quantitative results are shown in Panel C. In the data city growth over the sample period is on average 43%. The predicted city growth of Model 3 on average is 8.2%, implying that this model captures 19% of the observed growth at the mean. In contrast, Models 1 and 2 predict average city growth of 29% and 32%, respectively, and account for around 70% of the observed average city growth. None of the models can explain the very high population growth levels (144% at the 95th percentile), although the market integration Models 1 and 2 do better in that respect than Model 3. The range of predicted growth increases when market integration is included as a mechanism, which is also shown in Table 5.

In addition to predicting the mean and the observed range of population growth that is in the data, a successful explanation of growth must account for the observed patterns of city growth: which cities grew rapidly and which did not? In part II of Panel C we compare predicted versus actual city growth patterns. The market integration model of column 1 can explain 68% of the variation in the observed city growth, in contrast to only about 15% in Model 3 where market integration is absent. This indicates that modeling the mechanism through which institutions affect city growth matters. Furthermore, allowing for

[36]We have also explored the importance of the 1848 revolution, wars, the foundation of the Zollverein, as well as the coding of French rule in the Hanse cities for our results, finding them to be robust. The role of migration can be gauged by employing an alternative series of city population, and we find that it does not change the main results.

an independent institutions impact in addition to their effect via market integration raises the R^2 to only 70%, see column 2. To sum up, our analysis shows that including market integration as a mechanism greatly enhances our ability to explain how institutions affect city growth.

5 Concluding discussion

We find that while both institutions and market integration affect city size, they do so asymmetrically. Market integration is more strongly affected by institutional change than the reverse. The finding points to a hierarchy of growth factors where institutions exert their impact on growth largely through market integration gains. We also find that explaining institutions' effect on growth via the market integration mechanism is considerably more successful than just focusing on the impact independent of market integration.

Despite the fact that our study covers a comparatively short period of time, our focus on growth mechanisms resonates strongly with the literature showing that events several centuries ago may exert a persistent influence on economic outcomes today. We conclude by contrasting our approach of incorporating the mechanism into a causal analysis of why institutional improvement causes growth to two related literatures. First, as contributions such as Nunn (2008) and Dell (2010) show, the mechanism question has loomed large in this literature right from its inception. Our approach is complementary to analyzing mechanisms in much of the persistence literature in that we seek to integrate the historical intervention and the growth mechanism into a causal analysis.

Second, our results suggest it is useful to separate out the explanation—institutions—and the mechanisms through which institutions operate. This is not an entirely new perspective. Acemoglu and Johnson (2005) and others have suggested that progress can be made through unbundling institutions to examine particular institutional types—whether that be property rights institutions, trade institutions, or contracting institutions—and their differential impacts may be useful to gain insights on important mechanisms. This paper proposed the empirical strategies which may make this difficult task more feasible.

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A Data sources and construction

This section describes the outcome, treatment, and instrumental variables employed in this paper. This is followed by a list of sources and construction of all other variables.

A.1 Main variables

City population We employ two measures of city population size. The first is based on data in the German Historical GIS Kompendium (Kunz 2014a), which gives the population at the *Regierungsbezirk* (county) level for all sample areas. For example, in the case of the Prussian cities of Cologne and Aachen, our estimates are based on the official population figures for the *Regierungsbezirke* of Cologne and Aachen that were collected every three years (in 1822, 1825, etc.). This gives an accurate estimate of city population changes because in each county our sample city is the major influence of population changes. These population trends are combined with information on population levels for the benchmark years of 1800 and 1850, which come from Bairoch, Batou, and Chevre (1988), de Vries (1984), and Mitchell (2008) for the larger cities, and from the local population histories for the smaller cities. The city population data for non-benchmark years for some of the smallest towns in the sample are our own estimates. An alternative source of population data is the *Deutsches Staedtebuch* data (Keyser 1939). Its primary advantage is that it provides information on the population of the smaller cities, as opposed to the areas in which the cities are located. A disadvantage is that it gives population figures less frequently so more data interpolation is necessary. Another difference is that the *Staedtebuch* figures generally include any increase in city size due to redistricting. The two city population series are similar, with a correlation above 0.99.

Price gaps The annual price of wheat in each city is computed from government records of the market price of wheat. They were typically recorded every month, and in some cases every week. The information on cities in Mecklenburg are taken from Shiue and Keller (2007), while Seuffert (1857) covers cities in Baden, Bavaria, Brunswick, Hesse-Darmstadt, Hesse-Cassel, Hesse-Nassau, Saxony, and Wurttemberg. Our main wheat prices for Prussian cities were provided by Michael Kopsidis, see Kopsidis (2002). We have further expanded the coverage of the wheat price data using Fremdling and Hohorst (1979), Gerhard and Kaufhold (1990), and Vierteljahrshefte (1935). General characteristics of the German wheat prices during this period, including spatial and temporal aggregation, are discussed in Shiue and Keller (2007). The number of wheat prices available to us varies by city. Wheat price gaps are calculated for all city pairs for which there is wheat price information for both cities. Table A shows that the number of available observations does generally not vary systematically with city characteristics. Since neither quantity nor monetary units were standardized in 19th century Germany conversion rates are required for our analysis of absolute price differences, and all prices are converted into Bavarian *Gulden* per Bavarian *Schaeffel*. The conversion factors are taken from the original sources reported in Shiue and Keller (2007) and from Seuffert (1857, p.351).

The market prices for wheat, butter, and pork in the cities of Aachen, Berlin, Cologne, and Muenster for the years 1820 to 1865 come from Jahrbuch (1868).

Railway costs Our measure is based on changes in the capacity of a 19th century steam locomotive to haul freight as a function of the gradient of the terrain. Nicolls (1878) describes railways in the United States of America, which we take as a proxy for railway costs in Germany. Specifically, Nicolls provides the following information (p. 82):

Gradient	5	10	20	30	40	50	60	70	80	90
Hauling	1,150	939	686	536	437	367	315	275	242	216

Gradient	100	110	120	130	140	150	160	170	180
Hauling	194	175	159	146	134	123	113	105	98

Gradient is measured in feet to the mile. Hauling is hauling capacity in tons. Five feet to the mile is a gradient of about 0.095%, while 180 feet to the mile is a gradient of about 3.4%. The data is for a locomotive weighing 27 tons, going at a speed of 8 to 12 miles per hour uphill. We do not know of comparable data for going downhill, and it is assumed that the freight capacity of a locomotive varied for downhill trips (due to strains on the brakes, etc.) in the same way as it did for uphill trips. To convert this information into a cost measure, we assume that on flat terrain the locomotive can haul 1,200 tons. Then, the cost in terms of foregone freight hauling capacity of a gradient of five feet to the mile is 50 tons (1,200-1,150), the cost of a gradient of ten feet to the mile is 261 tons, and so on. We fit a logarithmic function through this data to be able to work with any terrain gradient; this yields an R^2 of 0.98.

With this cost function in hand we use a 90 meter x 90 meter GIS map of the relevant area in central Europe and the ArcGIS least-cost distance solver to compute the least-cost routes, as well as the associated costs of those routes, from each city to all other cities in the sample. Lakes are blocked out in this calculation, but not rivers. Because these railway costs are necessarily increasing in the distance between cities k and j, we divide by distance to arrive at $RaiCost_{jk}$, the gradient cost of terrain between k and j in terms of foregone railway freight capacity per unit of direct distance. Geographic distance is computed using the Haversine formula. Summary statistics for this railway cost measure is given in Table

1B.

Institutional change and French rule The data on institutional change is closely related to Acemoglu, Cantoni, Johnson, and Robinson (ACJR; 2011), and to the extent that our analysis covers areas that are not included in ACJR'a sample we use their sources, in particular Dipper (1980). Departing from ACJR we define city-level institutions as the institutions that prevailed in the geographic area of the city. Furthermore, we employ three indicators of institutions: (1) abolition of guilds, (2) equality before the law, and (3) the redeemability of feudal lands. ACJR employ a fourth indicator, the *de jure* abolition of serfdom, which plays no big role in our setting. The main definition of institutions is the average of (1) and (2); three alternative definitions of institutional quality are (A) the average of (1) and (3), (B) the average of (2) and (3), and (C) the average of (1), (2), and (3). These institutional quality variables change over time to the extent that abolition of guilds, equality before the law, and redeemability of feudal lands changes over time. In contrast, ACJR define institutions as the mean number of years that the institutios were in place by a given year t. As a consequence, we capture primarily the contemporaneous effect while ACJR focus on the cumulative effect. Our data on the length of French rule follows ACJR. The criterion is effective French rule, excluding purely military occupation. A special case in this respect are the former Hanse cities: Hamburg, Bremen, and Luebeck. In the main results, we code these cities as not French-ruled, even though they actually were French departements from 1811 to 1814. We do so because French rule in the Hanse cities was different from French rule elsewhere because in the Hanse cities it was primarily designed to enforce the continental blockade versus England, which we expect had negative consequences on market integration. French rule in the Hanse cities was also more tenuous than in other areas; during part of the year 1812, for example, Hamburg was ruled by the Russians. The main results do not depend on our treatment of the Hanse cities.

A.2 Other variables

- City population in year 1800: Measured in thousands, defined in logs. Source: Bairoch, Batou, and Chevre (1988), de Vries (1984), and Mitchell (2008) for the larger cities; local population histories, wikipedia, and Keyser (1939) for smaller cities. Varies at the city level.
- State population in year 1816: Source: von Viebahn (1858). Varies at the state level.
- State population in years 1820 to 1880: Population of the state a city is located in. Source: HGIS, Kunz (2014a). Varies at the state-year level.

- Latitude and Longitude: Source: www.wikipedia.com -> city. Measured in decimals. Varies at the city level.
- Distance to Paris Source: Authors' calculations from latitude and longitude of cities together with latitude and longitude of Paris: 48.85, and 2.35, respectively. http://de.wikipedia.org/wiki/Paris. Varies at the city level.
- Distance to Wittenberg: City of Wittenberg, in Saxony. Latitude: 51.8744, longitude: 12.606.
  Source: http://zip-code.en.mapawi.com/germany/10/landkreis-wittenberg/2/400/lutherstadt-wittenberg/6886/14623/. Varies at the city level.
- University restructuring: Based on the universities' histories, the following universities are affected: Cologne (closed in 1798); Erfurt (closed in 1816); Trier (closed in 1798); Mainz (reduced importance since 1790s); Frankfurt/Oder (closed in 1811); Wittenberg (closed in 1813); Dillingen (closed in 1803); Helmstedt (closed in 1810); Paderborn (closed in 1819); Rinteln (closed in 1810); Altdorf (closed in 1809); Bamberg (reduced importance since 1803); Duisburg (closed in 1818); Fulda (closed in 1805); Bonn (closed in 1798), and Stuttgart (closed in 1794). In the main analysis we have abstracted from the fact that some of these were later re-opened, at times during the 19th century; the main results do not depend on this. The university restructuring indicator is equal to one if a city does not have one of these universities as the geographically closest within 50 kilometers, and zero otherwise. Source: The history of the universities, as well as their latitude and longitude. Varies at the city level.
- Protestantism: Defined as the average share of Protestants in the city's population between years 1820 and 1880. Source: Keyser (1939) for time-varying information on the share of Protestants in a ciy; we employ the mean for 1820 to 1880 given that time variation is limited. Varies at the city level.
- Early Gymnasium: Variable is equal to one if city established its first Gymnasium before the median city in the sample, which was the year 1581, and zero otherwise. Source: Keyser (1939), city histories and school histories on the internet. Varies at the city level.
- Overseas trade: Variable is defined as equal to one if the city is in the first quartile of distance to the nearest (North or Baltic Sea) coast and the U.S. price of wheat is below the detrended sample median, and zero otherwise. Source for distance to the nearest

coast: Keller and Shiue (2014). Source for U.S. price of wheat: Average of price in New York City, Cincinnati, and Philadelphia, from Jacks (2006). Varies at the city level.

- Waterway: Variable is defined to equal to one if the city is on a navigable river, canal, or on the coast in 1850, and zero otherwise. We have employed different thresholds for navigability (ship size in terms of tons), without changing the main results. Source: Kunz (2014b), http://www.ieg-maps.uni-mainz.de/mapsp/mapw850d.htm. Varies at the city level.

- Coal production: Variable is equal to one if there is coal production in the region the city is located in the year 1850, and zero otherwise. Source: Gutberlet (2013), Figure 2. Varies at the city level.

In results not reported we have employed the following data:

- *Zollverein*: Variable based on the distance of a city-pair to its nearest coast, relative to other cities that are not yet members of the Zollverein customs union. Source: Keller and Shiue (2014). Modified as the average for each city relative to its sample partner cities to conform to our city-level analysis. Varies at the city-year level.

- 1848 Revolution: Variable is equal to one if a city was in a region that experienced major 1848 revolutionary activity for the sample year 1850, and zero otherwise. Major revolutionary activity took place around the cities of Karlsruhe, Berlin, Dresden, Frankfurt, and Zweibruecken. Source: Hahn (2001). Varies at the city-year level.

- Wars: Variable is equal to one if a city was in an area that experienced a major war. Hamburg and Luebeck were affected by the First (1848-51) and Second (1864) Schleswig War. The Austro-Prussian War of 1866 and the Franco-Prussian War (1870-71) affected virtually all cities and is captured by year fixed effects.
Source: http://en.wikipedia.org/wiki/List_of_wars_1800%E2%80%9399 -> war. Varies at the city-year level.

B Two-sample instrumental variables estimation

The purpose of the two-sample instrumental variables approach (Angrist and Krueger 1992) in the present case is to combine city-pair variation (j and k) in price gaps and railway costs with city-k variation on population size and other variables. This is achieved by estimating the city-pair market integration first-stage equation, and then taking the average of the predicted values for a given city k over all j.

In the market integration first-stage regression bilateral price gaps are related to the instrumental variables and covariates as given in equation (2):

$$pgap_{jkt} = \sum_s \delta_{s1} I_{st} RailCost_{jk} + \sum_s \delta_{s2} I_{st} FrenchRule_{jk} + \delta_{jk} + \delta_t + \overline{Q}'\delta + u_{jkt}.$$

Using OLS we obtain the predicted values, denoted by $\widehat{pgap}_{jkt}$. The average of $\widehat{pgap}_{jkt}$ for city k across j is given by

$$\widehat{pgap}_{kt} = \frac{1}{N_{kt}} \sum_{j \neq k}^{N_{kt}} \widehat{pgap}_{jkt}, \tag{5}$$

for all k, t. The expression in equation (5) enters the second-stage regression. The first-stage equation for institutions is at the city level, given by equation (3) in the text:

$$Inst_{kt} = \sum_s \gamma_{s1} I_{st} FrenchRule_k + \sum_s \gamma_{s2} I_{st} \overline{RailCost}_k + \gamma_k + \gamma_t + Q'\gamma + \epsilon_{kt},$$

where $RailCost_k$ is the average railcost per unit of distance for city k to all the other cities j. The bilateral distance between cities, which is included in the term Q, is treated analogously to $RailCost_k$. Let $\widehat{Inst}_{kt}$ denote the predicted value of the institutions first stage. The second-stage regression is given by

$$lpop_{kt} = \alpha_1 \widehat{pgap}_{kt} + \alpha_2 \widehat{Inst}_{kt} + \alpha_k + \alpha_t + Q'\alpha + \epsilon_{kt}. \tag{6}$$

Following Bjorklund and Jantti (1997) our inferences are based on bootstrapped standard errors. In some of the results reported above we exclude the institutions variable $\widehat{Inst}_{kt}$ from equation (6).

Table 1A: Sample cities

City	State	Baseline Sample
Aachen	Prussia	Y
Augsburg	Bavaria	Y
Karlsruhe	Baden	
Bamberg	Bavaria	Y
Bayreuth	Bavaria	Y
Berlin	Prussia	Y
Boizenburg	Mecklenburg	Y
Braunschweig	Brunswick	
Bremen	Free City	
Dresden	Saxony	
Erding	Bavaria	Y
Frankfurt	Free City	
Goettingen	Hannover	Y
Grabow	Mecklenburg	Y
Hamburg	Free City	Y
Hannover	Hannover	
Kassel	Hesse-Cassel	
Kempten	Bavaria	Y
Cologne	Prussia	Y
Landshut	Bavaria	Y
Leipzig	Saxony	Y
Lindau	Bavaria	Y
Luebeck	Free City	
Mainz	Hesse-Darmstadt	
Memmingen	Bavaria	Y
Munich	Bavaria	Y
Muenster	Prussia	Y
Noerdlingen	Bavaria	Y
Nurnberg	Bavaria	Y
Parchim	Mecklenburg	Y
Regensburg	Bavaria	Y
Rostock	Mecklenburg	Y
Schwerin	Mecklenburg	Y
Straubing	Bavaria	Y
Stuttgart	Wuerttemberg	
Ulm	Wuerttemberg	
Wismar	Mecklenburg	Y
Wuerzburg	Bavaria	Y
Zweibruecken	Bavaria	Y
Zwickau	Saxony	

Table 1B: Descriptive statistics

City-Pair Variables	Mean	Std. Dev.	Max	Min	# Obs
Railway Cost	843,102	278,495	3,659,949	173,033	3570
Bilateral Distance (km)	379.9	152.5	746.8	31.8	3570
Price Gap	0.153	0.117	0.821	0	3570

Notes: Railway Cost is the average cost of terrain, on a per kilometer basis, in terms of foregone tons of railway freight. Bilateral Distance is the direct distance between a city-pair. Price Gap is the absolute value of the percentage price difference of wheat between a city-pair.

City Variables	Mean	Std. Dev.	Max	Min	# Obs
Population (thousands)	58.092	123.49	1122.3	2.8	312
Institutions: Main definition	0.202	0.337	1	0	312
Institutions definition II	0.405	0.313	1	0	312
Institutions definition III	0.486	0.366	1	0	312
Institutions definition IV	0.364	0.308	1	0	312
Years of French Rule	2.471	5.664	19	0	312
Latitude	50.89	2.10	54.07	47.53	312
Longitude	10.60	1.76	13.72	6.09	312
Distance to Paris (miles)	415.9	90.0	552.7	212.4	312
Protestant Share	0.642	0.385	0.993	0.004	312
University restructuring	0.840	0.367	1	0	312
Distance to Wittenberg (miles)	324.1	145.8	59.2	665.3	312
Year of First Gymnasium	1632.01	144.085	1964	1450	312
Waterway	0.426	0.495	1	0	312
Coal production	0.231	0.422	1	0	312

Notes: Institutions is defined as the mean of 0/1 indicators that were present in the city in a particular year: (1) craft guilds were abolished, (2) equality before the law was guaranteed, and (3) it was possible to redeem feudal lands. Institutions Main definition is (1) and (2), Institutions definition B is (1) and (3), and Institutions definition C is (1), (2), and (3). Years of French Rule is the number of years the city was under French rule from 1792 to 1815. Distance to Paris is the direct distance from the city to Paris. Protestant Share is the average share of protestants in the city between 1820 and 1880. University restructuring is equal to 1 if a city was not closest to and within 50 kilometers of a university that was closed around the year 1800. Distance to Wittenberg is the distance of the city to Wittenberg, where Martin Luther started the German reformation. Gymnasium is a school that prepares for study at universities. Waterway is an indicator variable equal to one if the city is on the coast or navigable river/canal in 1850 according to Kunz (2014b). Coal production is an indicator variable equal to one if the city was located in a region that had coal production in 1850.

Table 1C: Summary statistics by treatment status

	Coal (1)	Population in 1800 (2)	Latitude (3)	Longitude (4)	Protestant (5)	Early Gym-nasium (6)	Distance to Wittenberg (7)	Distance to Paris (8)	Waterway (9)	No university restruct'g (10)	Overseas Trade (11)
No French rule	0.100	28.892	50.802	11.303	0.661	0.508	286.047	447.198	0.483	0.892	0.171
n = 240	(0.300)	(44.996)	(2.332)	(1.102)	(0.383)	(0.501)	(118.379)	(67.363)	(0.501)	(0.311)	(0.377)
French rule	0.667	21.889	51.183	8.267	0.579	0.569	451.140	311.389	0.236	0.667	n/a
n = 72	(0.474)	(12.689)	(0.936)	(1.509)	(0.385)	(0.498)	(157.227)	(76.174)	(0.427)	(0.474)	
Difference	-0.566*	7.003	-0.381	3.036*	0.082	-0.061	-165.092*	135.808*	0.247*	0.225*	
Low railway costs	0.077	40.558	52.175	10.871	0.707	0.628	282.978	454.032	0.519	0.833	0.263
n = 156	(0.267)	(52.293)	(1.878)	(1.973)	(0.399)	(0.484)	(162.752)	(98.399)	(0.501)	(0.373)	(0.441)
High railway costs	0.385	13.994	49.605	10.334	0.577	0.417	365.314	377.682	0.333	0.846	n/a
n = 156	(0.488)	(11.113)	(1.411)	(1.473)	(0.360)	(0.494)	(113.009)	(60.245)	(0.473)	(0.362)	
Difference	-0.308*	26.564*	2.571*	0.536*	0.130*	0.212*	-82.336*	76.350*	0.186*	-0.013	
Total	0.231	27.276	50.890	10.603	0.642	0.522	324.146	415.857	0.426	0.840	0.131
	(0.422)	(40.018)	(2.100)	(1.759)	(0.385)	(0.500)	(145.832)	(89.981)	(0.495)	(0.367)	(0.338)

Notes: Reported are means, with standard deviation in parentheses. * means difference of means is significant at 5% level. (1) in region with positive levels of coal production; (2) population in year 1800 (in 000s); (3) latitude; (4) longitude); (5) average share Protestant 1820 to 1880; (6) first Gymnasium founded before year 1587; (7) distance to Wittenberg (miles); (8) distance to Paris (miles); (9) located on navigable river, canal, or coast; (10) unaffected by university restructuring; (11) indicator for location in first quartile of distance to nearest coast by low price of wheat in U.S.

Table 2: Reduced form results

	Least Squares		Median Regression	
	Baseline sample	Full sample	Baseline sample	Full sample
	(1)	(2)	(3)	(4)
[1840-1860] x	-0.270**	-0.285**	-0.150**	-0.155*
Railway costs	(0.065)	(0.066)	(0.049)	(0.063)
[1865-1880] x	-0.359	-0.369	-0.331**	-0.339**
Railway costs	(0.293)	(0.298)	(0.104)	(0.121)
[1820-1835] x	0.068	0.072	0.081**	0.085**
French rule	(0.049)	(0.047)	(0.025)	(0.025)
[1840-1860] x	0.069*	0.070*	0.086**	0.090**
French rule	(0.034)	(0.034)	(0.022)	(0.024)
[1820s] x	0.150	0.276	0.042	0.210
Distance	(0.312)	(0.304)	(0.257)	(0.347)
[1830s] x	0.364	0.404	0.211	0.253
Distance	(0.283)	(0.271)	(0.248)	(0.335)
[1840s] x	0.388	0.372	0.288	0.286
Distance	(0.246)	(0.247)	(0.235)	(0.304)
[1850s] x	0.462*	0.428*	0.400+	0.408
Distance	(0.195)	(0.200)	(0.228)	(0.277)
City fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
Tests of inclusion: p-values				
Railway costs	[<0.001]	[<0.001]	[0.001]	[0.015]
French rule	[0.004]	[0.014]	[<0.001]	[<0.001]
Distance	[0.005]	[0.044]	[<0.001]	[0.006]
Observations	268	312	268	312

Notes: Dependent variable is log city population. Railway costs is the average log lost freight capacity per unit of direct distance to other cities; French rule is log years of French rule plus 1, and Distance is the average log bilateral geographic distance to other cities. Variables in hard brackets are time indicator variables. The omitted category for railway costs is 1820-35, for French rule 1865-80, and for Distance 1860-80. The p-values of the tests of inclusion are given in brackets. Robust standard errors in parentheses, in columns 1 and 2 clustered by city. **/*/+ significant at the 1%/5%/10% level.

Table 3: Evidence on the exclusion restrictions

	Reduced Form	X = Coal (1)	Population in 1800 (2)	Latitude (3)	Longitude (4)	Protestant (5)	Early Gym'ium (6)	Distance Wittenberg (7)	University restruct'g (8)	Distance Paris (9)	Waterway (10)	Internat'l Trade (11)	All Determinants (12)
[1840-1860] x	-0.150**	-0.152*	-0.168*	-0.276**	-0.152**	-0.201**	-0.236**	-0.157**	-0.152+	-0.163**	-0.168**	-0.160*	-0.199**
Railway costs	(0.049)	(0.065)	(0.074)	(0.091)	(0.035)	(0.053)	(0.068)	(0.047)	(0.081)	(0.054)	(0.048)	(0.079)	(0.047)
[1865-1880] x	-0.331**	-0.293**	-0.218	-0.235	-0.302**	-0.107	-0.419**	-0.320**	-0.344**	-0.325**	-0.384**	-0.344*	0.054
Railway costs	(0.104)	(0.087)	(0.245)	(0.282)	(0.081)	(0.146)	(0.124)	(0.105)	(0.109)	(0.111)	(0.120)	(0.143)	(0.054)
[1820-1835] x	0.081**	0.087**	0.101**	0.110**	0.065**	0.206**	0.096**	0.086**	0.136**	0.083**	0.106**	0.083**	0.112**
French rule	(0.025)	(0.015)	(0.026)	(0.026)	(0.022)	(0.033)	(0.017)	(0.029)	(0.015)	(0.024)	(0.035)	(0.020)	(0.016)
[1840-1860] x	0.086**	0.108**	0.106**	0.118**	0.080**	0.213**	0.106**	0.089**	0.143**	0.088**	0.116**	0.094**	0.133**
French rule	(0.022)	(0.017)	(0.026)	(0.029)	(0.015)	(0.032)	(0.016)	(0.027)	(0.012)	(0.022)	(0.034)	(0.015)	(0.014)
City fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Distance	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Tests of inclusion: p-values													
X variable		[0.055]	[<.001]	[<.001]	[0.480]	[<.001]	[0.328]	[0.878]	[<.001]	[0.933]	[0.442]	[0.386]	
Railway costs	[0.001]	[0.001]	[0.020]	[0.010]	[<.001]	[0.001]	[0.001]	[<0.001]	[0.007]	[0.001]	[0.002]	[0.027]	[<.001]
French rule	[<.001]	[<.001]	[<.001]	[<.001]	[<.001]	[<.001]	[<.001]	[0.004]	[<.001]	[0.001]	[<.001]	[<.001]	[<.001]

Notes: Dependent variable is log city population. Estimation by median regression. Columns (1) to (11) introduce the variable at the top to the Reduced Form. (12) includes simultaneously all variables that are individually significant (Coal, Population in 1800, Latitude, Protestant, and University restructuring). Definitions are: (1) 0/1 indicator of positive coal production in 1850; (2) city population in 1800, in logs; (3) latitude; (4) longitude; (5) share of Protestants, average 1820-1880; (6) 0/1 indicator of first Gymnasium founded before year 1581; (7) distance to Wittenberg; (8) equal to 1 if city is not affected by university restructuring, 0 otherwise (9) distance to Paris; (10) 0/1 indicator of location on navigable river or coast; (11) 0/1 indicator of detrended price of US wheat over 1820-1880 in first quartile, and location of city in first quartile of minimum distance to coast. Each X variable is included with fixed effects for 1820s, 1830s, 1840s, and 1850s; excluded period is 1860 to 1880. Distance is average bilateral distance between city k and its partner cities in the sample, interacted with fixed effects for 1820s, 1830s, 1840s, and 1850s. Tests of inclusion have null hypothesis that all coefficients are zero. Number of observations: n = 268. P-values in brackets, robust standard errors in parentheses; **/*/+ is significance at 1%/5%/10% levels.

Table 4: Instrumental variables results

Panel A. First stages

					Alt. Institutions Definitions		
Dep. Variable	Market Integration		Institutions Main Def.		Guilds, Feud. Lands	Guilds, Equality Feud. Lands	Equality, Feud. Lands
Sample	Baseline	All Cities	Baseline	All Cities			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
[1820-1835] x	-0.020**	-0.026**	0.135**	0.135**	0.186**	0.147**	0.118**
French rule	(0.006)	(0.006)	(0.049)	(0.048)	(0.040)	(0.037)	(0.033)
[1840-1860] x	-0.022**	-0.020**	0.134**	0.135**	0.153**	0.125**	0.068**
French rule	(0.005)	(0.005)	(0.047)	(0.047)	(0.037)	(0.035)	(0.031)
[1840-1860] x	0.041**	0.030*	0.013	0.010	0.218	0.155	0.235
Railway costs	(0.014)	(0.012)	(0.016)	(0.015)	(0.147)	(0.104)	(0.169)
[1865-1880] x	0.041**	0.030**	0.024	0.025	0.170	0.265	0.602**
Railway costs	(0.012)	(0.012)	(0.291)	(0.291)	(0.272)	(0.223)	(0.211)
City-pair fixed effects	Y	Y	N	N	N	N	N
City fixed effects	N	N	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y	Y
Distance	Y	Y	Y	Y	Y	Y	Y
Tests of inclusion: p-values							
French rule	[<.001]	[<.001]	[0.007]	[0.009]	[<.001]	[<.001]	[0.004]
Railway costs	[<.001]	[<.001]	[0.632]	[0.734]	[0.114]	[0.145]	[0.022]
Observations	2,166	3,570	268	312	268	268	268
Number of clusters	252	642	28	40	28	28	28

Panel B. Second stage: market integration and institutions. Dep. Var.: log city population

Market Integration			-4.703*	-3.088**	-5.189**	-5.171**	-5.142*
			[0.015]	[0.010]	[0.005]	[0.010]	[0.015]
Institutions			0.325	0.364	0.189	0.196	0.026
			[0.200]	[0.195]	[0.300]	[0.380]	[0.500]
Kleibergen-Paap test of matrix rank of first stage							
			119.94	19.14	34.15	38.51	22.42
			[<.001]	[<.001]	[<.001]	[<.001]	[<.001]

Panel C. OLS results. Dep. Var.: log city population

Market Integration			0.096	0.009	0.087	0.091	0.092
			(0.061)	(0.059)	(0.186)	(0.062)	(0.065)
Institutions			-0.059	-0.049	-0.231*	-0.283+	-0.216**
			(0.267)	(0.269)	(0.102)	(0.164)	(0.069)

Notes: Dependent variable in Panel A noted at top of columns; in Panels B, C, and D, dependent variable is log city population. Estimation by least squares. Distance included with time effects for 1820s, 1830s, 1840s, and 1850s. Kleibergern-Paap tests the rank condition of identification, that the rank of the matrix of excluded instruments is of full rank (robust to clustering on city). Robust standard errors with clustering in parentheses, by city pair in columns (1) and (2), by city in in columns (3) to (6); robust clustered p-values in brackets, by city-pair in columns (1) and (2), and by city in columns (3) to (6). Bootstrapped standard errors in panels B and C. **/*/+ coefficient is significant at the 1%/5%/10% level.

Table 5: Quantitative analysis

	Institutions w/ Market Integration Mechanism		Institutions
	(1)	(2)	(3)
Panel A. Second-stage results			
Market Integration	-5.094*	-4.703*	
	[0.015]	[0.015]	
Institutions		0.325	0.508
		[0.200]	[0.141]
City fixed effects	Y	Y	Y
Year fixed effects	Y	Y	Y
Distance	Y	Y	Y
Panel B. First stage tests of inclusiond p-values			
I. Market Integration			
French rule	[<.001]	[<.001]	
Railway costs	[<.001]	[<.001]	
II. Institutions			
French rule		[0.007]	[<.001]
Railway costs		[0.632]	
Panel C. Model performance			
I. Predicted City Growth			
Mean	0.290	0.320	0.082
5th percentile	0.195	0.177	-0.004
95th percentile	0.568	0.564	0.242
Actual City Growth			
Mean	0.43	0.43	0.43
5th percentile	0.03	0.03	0.03
95th percentile	1.44	1.44	1.44
II. Explaining City Growth Patterns			
R-squared (%)	67.51	69.54	14.94
Observations	268	268	268
Number of clusters	28	28	28

Notes: Dependent variable is log city population. Two-sample instrumental variables estimation using least squares in columns (1), (2), and two-stage least squares estimation in column (3). Distance interacted with time effects for 1820s, 1830s, 1840s, and 1850s. Robust p-values clustered at the city level in brackets (bootstrapped in (1) and (2)); robust standard errors clustered at the city-level in parentheses. **/*/+ significance at the 1%/5%/10% level. Model performance criteria: Predicted Level of Growth reports the long difference of predicted market integration and institutions, respecitvely, times the respectively second-stage coefficients. Reported in column (2) is the sum of the predicted market integration and institutions fitted value (abstracting from the statistical insignificance of the institutions coefficient). Explaining City Growth Patterns gives the R-squared of the long-difference regression weighted using Cook's Distance for observed on predicted city growth.

Figure 1: Sample Cities

Figure 2: Population sample data in comparison

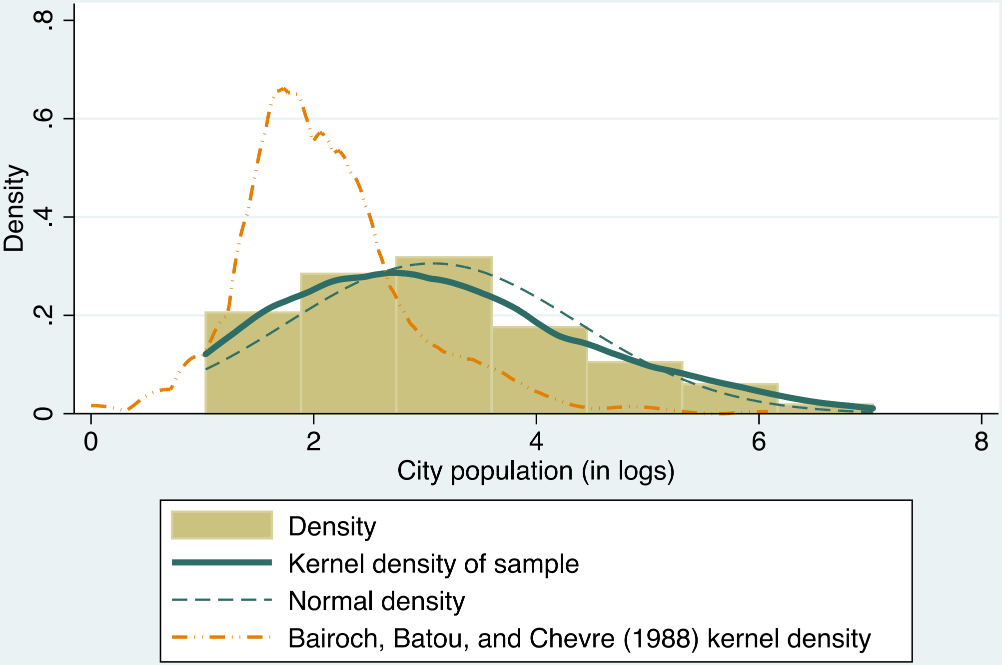

Table A: Number of observations and main city characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Price gap	-23.23													-14.61
	(14.31)													(12.71)
Length French rule		0.04												0.05
		(0.09)												(0.16)
City population			0.01**											0.01
			(0.00)											(0.02)
City population in 1800				0.02										-0.02
				(0.01)										(0.07)
Share Protestant					-0.65									-2.53
					(1.33)									(1.53)
Longitude						0.39								-2.68
						(0.36)								(3.75)
Latitude							0.40							-1.17
							(0.27)							(1.67)
Distance to Paris								0.01+						0.07
								(0.01)						(0.07)
Waterway									-1.52					-1.53
									(1.07)					(1.41)
Early Gymnasium										0.70				-0.18
										(1.06)				(0.93)
Institutions											2.65+			6.56*
											(1.47)			(2.72)
Coal												-0.80		-1.19
												(0.94)		(1.16)
Distance to Wittenberg													-0.47	-1.00
													(0.39)	(1.73)
R-squared	0.08	0.00	0.10	0.05	0.01	0.04	0.06	0.10	0.05	0.01	0.06	0.01	0.04	0.56

Notes: Dependent variable: number of observations by city. Regression on mean city characteristics and constant; definition of city characteristics, see Tables 1B and 1C. N = 40. Robust standard errors in parentheses. **/*/+ significant at 1%/5%/10% level.

Table B: First stage results for subsamples

	Dependent variable: price gap					Dependent variable: institutions				
	Base (1)	No Coal (2)	Waterway (3)	No Berlin & Hamburg (4)	Early Gymnasium (5)	Base (6)	No Coal (7)	Waterway (8)	No Berlin & Hamburg (9)	Early Gymnasium (10)
[1820-1835] x	-0.020**	-0.018**	-0.023**	-0.019**	-0.020**	0.135**	0.134**	0.059**	0.182**	0.139**
French rule	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.049)	(0.045)	(0.021)	(0.031)	(0.050)
[1840-1860] x	-0.022**	-0.023**	-0.022**	-0.027**	-0.017**	0.134**	0.134**	0.062**	0.178**	0.138**
French rule	(0.005)	(0.005)	(0.006)	(0.007)	(0.006)	(0.047)	(0.042)	(0.018)	(0.030)	(0.049)
[1840-1860] x	0.041**	0.040**	0.025*	0.045*	0.040*	0.013	0.036	0.009	0.003	0.010
Railway costs	(0.014)	(0.014)	(0.013)	(0.018)	(0.016)	(0.016)	(0.032)	(0.054)	(0.020)	(0.017)
[1865-1880] x	0.041**	0.040**	0.036**	0.036+	0.044**	0.024	0.011	-0.998**	0.264+	0.002
Railway costs	(0.012)	(0.012)	(0.012)	(0.020)	(0.014)	(0.291)	(0.302)	(0.359)	(0.157)	(0.279)
City-pair fixed eff.	Y	Y	Y	Y	Y	N	N	N	N	N
City fixed effects	N	N	N	N	N	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Distance	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Tests of inclusion: p-values										
French rule	[<.001]	[<.001]	[<.001]	[<.001]	[0.004]	[0.007]	[0.001]	[<.001]	[<.001]	[0.009]
Railway costs	[<.001]	[<.001]	[0.005]	[0.044]	[0.004]	[0.632]	[0.205]	[0.021]	[0.222]	[0.790]
Bilateral distance	[<.001]	[<.001]	[<.001]	[<.001]	[<.001]	[0.404]	[0.030]	[<.001]	[0.141]	[0.465]
N	2,166	2,060	1,465	1,669	1,518	268	216	112	242	222
Mean dep. Var.	0.149	0.149	0.148	0.154	0.148	0.209	0.137	0.205	0.196	0.248

Notes: Dependent variable given above. Estimation by least squares as in Table 4, Panel A. (2), (7): no coal production in 1850; (3), (8): located on navigable river, canal, or coast; (4), (9): excludes the two largest cities, Berlin and Hamburg; (5), (10): first Gymnasium founded before year 1581. Robust standard errors clustered by city-pair (when dependent variable is price gap) or by city (when dependent variable is institutions) in parentheses, p-values in brackets. **/*/+ significant at 1%/5%/10% level.

Table C: Robustness

	(1) French rule separately	(2) Non-water-way cities	(3) Hub-and-spoke	(4) Cross-sectional	(5) City pop'n weights	(6) State pop'n weights	(7) Distance to Wittenberg	(8) Early Gymnasium	(9) University Restruct'g
Market Integration	-3.684*	-3.493*	-2.900*	-9.781+	-4.836*	-6.768**	-5.922**	-4.349*	-4.509**
	[0.035]	[0.020]	[<.001]	[0.099]	[0.025]	[0.005]	[<.001]	[0.035]	[0.010]
Institutions	0.383	-0.468	0.045	-3.297	0.480	1.172	-0.129	0.353	0.398
	[0.195]	[0.545]	[0.385]	[0.823]	[0.175]	[0.250]	[0.660]	[0.190]	[0.125]
N	268	156	218	240	268	268	268	268	268
Clusters	28	17	24	28	28	28	28	28	28

Notes: Dependent variable: log city population. Second-stage results from two-sample instrumental variables estimation as in Table 4, Panel B. Included are city fixed effects, year fixed effects, and average bilateral distance interacted with decade fixed effects. (1) includes length of French rule in cities j and k separately in first stage; (2) excludes cities located on navigable rivers, canals, and coast; (3) excludes state capitals; (4) regresses city population growth on market integration change and institutional change using only cross-sectional instrumental variables and no city (city-pair) fixed effects (5) weights observations increasing in city population decile from 1 to 10; (6) weights observations with the state population to which city belongs in year 1816; (7) includes distance to Wittenberg interacted with decade fixed effects as additional X variables; (8) includes an indicator of Early Gymnasium interacted with decade fixed effects as additional X variable; (9) includes an indicator for University Restructuring interacted with decade fixed effects as additional X variable; see Table 3 for the variables added in (7) to (9). P-values in brackets based on robust standard errors clustered at city (and city-pair) level. **/* significant at 1%/5% level.

Table D: City-level clustering and spatial dependence

	First stage: Dep. Var. is price gap			Second stage: Dep. Var. is log city population		
	(1) City-Pair Clustering	(2) City Clustering	(3) State-Pair Clustering	(4) City Clustering	(5) State Clustering	(6) City Clustering and Spatial Dep.
Panel A. First stages						
[1820-1835] x	-0.020**	-0.020**	-0.020*			
French rule	(0.006)	(0.006)	(0.009)			
[1840-1860] x	-0.022**	-0.022**	-0.022*			
French rule	(0.005)	(0.005)	(0.010)			
[1840-1860] x	0.041**	0.041	0.041*			
Railway costs	(0.014)	(0.027)	(0.018)			
[1865-1880] x	0.041**	0.041**	0.041*			
Railway costs	(0.012)	(0.013)	(0.019)			
Tests of inclusion: p-values						
Railway costs	[<.001]	[0.005]	[0.045]			
French rule	[<.001]	[<.001]	[0.093]			
Panel B. Second stages						
Market Integration				-5.094*	-5.094*	-5.502**
				[0.015]	[0.015]	[<0.001]
City-pair fixed effects	Y	Y	Y	N	N	N
City fixed effects	N	N	N	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y
Distance	Y	Y	Y	Y	Y	Y
Observations	2,166	2,166	2,166	268	268	221
Number of Clusters	252	27	16	28	6	28

Notes: Dependent variable given at column header. Estimation method is least squares. Table gives alternative results for robust inference, with number of clusters shown at the bottom of table. P-values (bootstrapped in (4), (5), and (6)) in brackets, standard errors in parentheses. Distance is included with time effects for 1820s, 1830s, 1840s, and 1850s. **/*/+ significant at 1%/5%/10% level. Column (6) adjusts for spatial dependence using Conley's (1999) method for the balanced sample 1820 to 1855, with spatial dependence below 300 kilometers.