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Abstract

Information exchange is a necessary prerequisite for economic exchange over space. This relationship implies that information exchange data corresponds to the location of economic activity and therefore also of population. Building on this relationship we use postal data to analyse the spatial structure of the population distribution in the German Empire of 1871. In particular we utilize local volume data of a number of postal information transmission services and a New Economic Geography model to create two index measures, Information Intensity and Amenity. These variables respectively influence the two mechanisms behind the urban population distribution, namely agglomeration forces and location endowments. By testing the influence of actual location characteristics on these indices we identify which location factors mattered for the population distribution and show that a number of characteristics worked through both mechanisms. The model is then used to determine counterfactual population distributions, which demonstrate the relative importance of particular factors, most notably the railroad whose removal shows a 34% lower urban population. A data set of large locations for the years 1877 to 1895 shows that market access increases drove the magnitude of the increase in urban population, while endowment changes shaped their relative pattern.

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[1] All errors are of course my own

1. Introduction

The spatial distribution of economic activity is far from uniform; its density ranges from essentially empty spaces, for example in deserts and high mountains, to extreme spikes in economic centres like New York, London or Singapore. This uneven distribution is mirrored in the population distribution, in particular in the existence of the high clustering areas of towns and cities. Identifying and understanding the forces that have shaped and are still shaping this distribution is an important step in addressing a number of economic and policy issues. These range from cost and benefits of infrastructure, the distribution of public services to urban and regional development policies. Here we provide such an investigation by identifying the forces underlying the spatial population structure of the German Empire in the late 19th century.

The central forces shaping these distributions then as now are endowments and agglomeration forces or what Krugman labelled First and Second nature geography (Krugman, 1991, 1993). The forces are not exclusionary, but as Gallup et al. (1999) and Davis and Weinstein (2002) argue should be considered in combination. It still presents a considerable challenge to disentangle the two and identify the role of certain agglomeration and dispersion forces, which depend on the relative geographic position of economic actors, from the impact of location fundamentals, which depend on their absolute position. Some studies apply a reduced form approach and specify a priori what factors are endowments and the form of market access (Ayuda

et al., 2010). Another approach is to utilize a theoretical model combining agglomeration forces and location endowments in a theoretical model to determine location size, which is used in conjunction with a natural experiment for changes in market access (Redding and Sturm, 2008) or by calibrating it with location specific endowment data (Ploeckl, 2012b). Here we go one step further and combine the approach of explaining the population distribution through a model incorporating market access and location endowments with an analysis of the influence of actual location characteristics. More precisely we test through which of the two mechanisms these characteristics influenced the population distribution.

The empirical analysis investigates Imperial Germany shortly after its inception in 1871 when it covered the territories of today's Germany as well as territories that are today in neighbour states like Poland. The new state was rapidly industrializing in a number of regions, while other parts were still substantially dominated by agriculture (Pierenkemper and Tilly, 2004). The urban system, a set of 2789 locations in this paper, reflected this diversity not only with some regions showing a substantially higher population density than others but also in a strong spatial correlation between density and industrialization. The relative strong importance of coal and the railroad for German industrialization also point towards the importance of location endowments and economic exchange based on market access for the location of industrialization and associated population structures (Fremdling, 1977; Pierenkemper and Tilly, 2004).

A central problem in analysing the role of market access is the required specification of the spatial interaction process. Following Tobler's first law of Geography that 'Everything is related to everything else, but near things are more related than distant things' (Tobler, 1970) and the empirical validation through the gravity equation the literature usually takes distance as a proxy for the transaction costs, the economic distance, between locations. This, however, neglects to ask: How exactly places are related and how are these connections made? Any economic exchange over space has a necessary condition, namely the exchange of information over space. Trade will not happen if information like prices is not exchanged. This absence from the literature implies that an important factor to explain spatial relationships has not been utilized yet.

This paper remedies this problem through the use of postal data. These data, ranging in this historical setting from mail to telegrams to parcels and money orders, are able to cover most of the formal exchange of information between, but also within, locations. This allows the determination of the extent of communication and information exchange in each location. Incorporating such data about information transmission leads to a better measurement of spatial relationships and therefore of the forces that underlay the size of locations and the shape the spatial population distribution.

The first step of the analysis uses postal data to calculate Information Intensity, a location-specific value indicating the local density of information exchange. More precisely the estimation uses data from a range of business

focused postal services like telegrams and money orders to estimate business mail volumes for each location, which are then set in relationship to the empirical, population based market potential of the location. The resulting measure, which indicates the relative size of information exchange a particular location is involved in, is labelled Information Intensity and is consequently used to modify the transaction cost matrix underlying any determination of the relative importance of market access for the urban system.

The second step utilizes the New Economic Geography model of Redding and Sturm (2008), which combines market access and endowments as determinants of location population size and therefore the spatial population distribution. Given a population distribution and a transaction cost matrix the model allows backing out a value for the endowment in each location. This implied value, called Amenity, is an index value that represents the weighted combination of various endowments.

The third step uses the results of the first two steps to determine the explanatory power of actual location characteristics on location size and the population distribution. The New Economic Geography model used in step two describes how market access and endowments are combined to determine location size. Information Intensity and Amenity are parameters through which actual location characteristics influence market access and endowments, and thereby population size. The model and the incorporation of Information Intensity into the market access measure allow therefore not only demonstrating the general influence of particular location characteristics

but also through which of the two general mechanisms each of them works.

The described analysis utilizes a cross-section of data to analyse the characteristics of location size and the population distribution at one point in time. The distribution however is not static but changes over time. The utilized approach and model allows not only a repeated analysis of cross-sections but also of changes over time. More precisely the model allows decomposing the observed population growth into the effect of changes in market access, endowments and a market access feedback to changes in the endowment. Again the calculation and incorporation of Information Intensity and Amenity values allows determining the influence of actual location characteristics on the two mechanisms underlying changes in population.

The analysis of the impact of various geographic, cultural and institutional factors shows that a number of important factors like railroads and hard coal[2] actually worked through both channels, affecting the urban population distribution through market access and endowments. In some cases this dual impact shows a specialization, for example coal has a positive effect through the endowments channel counteracted by a negative impact through market access. Besides the railroad and hard coal, central factors in Germany's industrialization, also the historical legacy of the Hanse and Imperial township, the university system, the prevalence of non-German native language and harbours mattered. A counterfactual analysis quantifies the

[2]Following German customs we classify coal into two categories, *Steinkohle* is labelled as hard coal and *Braunkohle* is labelled as brown coal.

impact of the factors and shows that the implied urban population in a counterfactual without a railroad system is 34% lower. Focusing on the growth of a smaller set of larger locations, the improvements in transportation costs between 1877 and 1895 did sustain most of the actual urban population increase. Endowments are consequently associated with only a small impact, though they still influenced the relative growth of towns more strongly.

A central institution that reflects this decrease in spatial transaction costs within the urban system was the Imperial Postal and Telegraph service. Despite the strongly federal nature of the Empire a centralized postal service was established which was the result of elevating the Prussian service to an imperial service and having it absorb the services of most of the other member states (Sautter, 1952, 1951). The unification of the mail service also led to an equalization of service in terms of postage and associated regulations. This uniform service provision implies that that the conditions for using these postal services were identical all over the empire. The postal agency also improved its statistics section and collected a substantial amount of information about various postal activities from local to national level. A newly collected, extensive data set containing such statistics, especially for the local level, provides the main data source for the analysis, especially for the modelling of the market access channel. This postal data, which also contains information on population, location and cultural characteristics of the included locations, is combined with a range of further geographic, institutional and cultural location characteristics.

The next section introduces the historical and economic background of the German Empire as well as the *Reichspost*, the Imperial mail service. This is followed a section discussing the theoretical framework behind Information Intensity and the model underlying population size in more detail. The empirical analysis starts after a description of the data by estimating business mail volume and the Information Intensity measure, which is then used to determine the Amenity index values for each location. Geographic, institutional and cultural location characteristics are then used to investigate their influence on the two mechanisms. This influence is quantified by deriving counterfactual population distributions, which is followed by the analysis of population growth for the period 1877 to 1896 and its decomposition into relative effects of endowments and market access. The final section concludes.

2. The German Empire

In the aftermath of the Napoleonic Wars the congress of Vienna redrew the borders in central Europe resulting in about 40 sovereign German states. These ranged from free cities like Frankfurt, small and mid-sized states to the large European powers of Austria and Prussia. Although a supra-national institution, the German Federation, the *Deutsche Bund*, was instituted by the congress as well it only had very limited internal powers and functioned mostly as a military and internal security pact (Angelow, 2003; Mueller, 2006). Though almost all states embarked on an institutional modernization process, the actual institutional changes differed substantially between states

except for minor constraints by the German Federation.

The political pressure to unify Germany intensified until the full break-out of military conflict in 1866. After Prussia achieved a swift military victory it became the hegemonic power in Germany. Additionally it created the Norddeutsche Bund, a formal union of German states north of the Main under Prussian leadership. After the combined German troops beat the French in 1871 the political structure of Germany was once more reorganized and the German empire was created as a federal structure of German states[3] under the emperorship of the Prussian king (Nipperdey, 1992; Wehler, 1995).

The existence of a number of sovereign, nation-state like German states before the formation of the strongly federal empire imply that this new state had still substantial internal differences and related borders influencing the economic structure. The empire began to unify a number of important issues, for example instituting a single currency, a new measurement system, developing a new civil code and creating a number of centralized political institutions. Despite forming the Bundesrat, Reichstag and the Reichskanzler, the council of member state representatives, the parliament and the chancellor, most practical executive issues however remained under the control of the individual states' political structures.[4] This political structure persisted for over four decades and came to an end with Germany's defeat in the First

[3]See Map 1 for political boundaries.

[4]The close connection between the imperial offices and their Prussian counterparts, for example most chancellors were at the same time also prime minister of Prussia, implied that the imperial executive had in practice however more power than it appeared on paper.

World War (Nipperdey, 1992; Wehler, 1995).

Wolf (2009) analyses market integration within Germany during the Empire and finds that the fragmented administrative structures, next to cultural heterogeneity and geographical barriers, did significantly impede integration during the time of the Empire before World War I. The poor integration is also reflected in the substantial regional disparities in a number of other economic characteristics. In terms of GDP due to institutional fragmentation and data problems no regional numbers have really been constructed yet, though preliminary results for the western part in 1895 confirm the history of industrialization in Germany as a strongly regional phenomenon (Wolf, 2012). Regional industrialization differences however also reflect the location of population. Regional population density shows a pattern that correlates to some degree with the industrialization pattern. Map 2 shows the density in 1876 in administrative regions. The pattern shows clear population centres in the Ruhr area in the west, Saxony in the centre and the along the Rhine in the southwest of the empire. More generally especially the north and east was considerably more sparsely settled, though a number of concentrated population centres, in particular the capital Berlin and the harbour cities of Hamburg and Bremen, were situated within the area. Map 3 shows the pattern for the year 1913, which exhibits substantial similarity with the pattern at the start of the Empire. Nevertheless shifts are visible and relative regional differences changed during this period.

Although there had already been attempts to economic unification before

the empire, most notably the Zollverein (the 1834 customs union between a large number of German states) this fragmentation was still visible in the Empire as Wolf (2009) shows. Additionally the borders were not static during the 19th century. Prussia annexed a number of states in 1866, which implies that after the formation of the Empire these borders were no official state borders, but their historic origins might still have had an effect for quite some time afterwards. The effect of such administrative borders however was and is not only limited to trade between regions, it can also influence regional population growth and the location of population (Redding and Sturm, 2008; Ploeckl, 2010a).

The fragmentation was also seen in the individual states' approach to the railroad, which was as Fremdling (1977) demonstrates a central factor in Germany's industrialization. Some like Bavaria already took control early and operated a public monopoly from the start, while others initially granted concessions to private companies and then nationalized later on. The later process hadn't been fully completed everywhere at the institution of the empire. The new imperial government was however not able to combine the state systems into a common imperial system and only created an administrative agency that dealt with legal and practical questions as well as the coordination between the different systems. Railroads affected the growth of towns,[5] which implies that the regional fragmentation, and related differences

[5]Hornung (2012) shows this for the case of Prussia in the 19th century and Ploeckl (2010a) touches on the issue for the German state of Saxony at the same time.

in expansion and resulting density, should shape impact on the population distribution in a regionally uneven way.

One of the main inputs for German industrialization and industrialization in general was coal. A number of German regions, in particular the Ruhr area, Saxony and Silesia had substantial deposits of coal, though the precise quality and nature differed between the regions. The availability of coal was one of the main location factors for the development of heavy industries and associated sectoral changes (Pierenkemper and Tilly, 2004). The increase in coal production and the associated industries required a substantial labour force, which implies an effect on regional population growth. The effect of coal on location population however started before this time, as Ploeckl (2012b) demonstrates for the case of Saxony in the time frame leading up to the Industrial revolution.

Strong regional differences are also visible in a number of other characteristics. These range from cultural factors to natural resources and other geographic characteristics. Two main factors of cultural heterogeneity in the Empire were religious differences as well as different native languages. As centre of the protestant reformation in the 16th century and the subsequent religious wars Germany exhibited persistent, substantial regional differences in denominational adherence after the settlement in the Peace of Westphalia in 1648. As Becker and Woessmann (2009) have shown, different denominations had a substantial effect on human capital acquisition, however Cantoni (2011) argues that the effect was not visible in relative, long term growth

rates of German cities.

Cultural heterogeneity was not just limited to religious differences. Another form of heterogeneity concerned the native language of the population with the existence of substantial minorities with non-German native languages, most prominently Polish but also Danish and other ethnic minorities. Linguistic differences are one of the main obstacles shown in the gravity literature,[6] additionally the presence of ethnic minorities underlying these linguistic differences might influence regional economic development and population.

These cultural differences were however relative large-scale phenomena since the presence of religious denominations and non-German languages were predominantly regional characteristics, often characterizing most locations within the same area. A different cultural characteristic is the historical legacy of towns; most notably for the German Empire are the legacy of the Hanse, the medieval trading association, and the Imperial township status under the old German Empire, a town characteristic that usually had its roots in medieval times and was with the end of the Empire in 1806 essentially meaningless. The lasting impact of these historical legacies, which were usually linked to a particular time span of self governance, is often associated with the concept of social capital and might have through this mechanism have an effect on town population (Helliwell and Putnam, 1995; Guiso et al.,

[6]For an example from 19th century Germany see Shiue (2005).

2008).

Geographic differences were however not just restricted to coal deposits, German regions differ in a number of surface characteristics. Elevation ranges from sea-level to mountain regions, there are other climatic differences, and there are a number of rivers crossing the landscape. Historically the two most important navigable rivers, the Rhine and the Elbe, were geographic factors that directed trade flows predominantly in a South-North direction (Wolf, 2009). The historical importance of the river network is also visible in the establishment of special international bodies by the congress of Vienna to administer shipping on the Rhine and the Elbe, while staying silent on land-based transportation (Ploeckl, 2010b) .

Railroads were an important factor to overcome this underlying impact of geography. However the physical transport of goods isn't the only input necessary for economic activity to be conducted over space. Another important requirement is the exchange of information. In the 19th century this happened predominantly through the mail and later on additionally through the telegraph. In the Empire both were in the purview of the *Reichspost*, the Imperial Postal service.

Although emperor Rudolf II of the old German Empire had granted an exclusive privilege to the Tassis family to operate a mail service throughout the old empire, some of the more powerful princes had over time instituted postal services in their own states. After the fall of the old empire during the Napoleonic wars and the congress of Vienna about a dozen different postal

systems[7] existed within German states. The growing economic integration in the wake of the Zollverein pushed the different systems to better coordinate cross-system mail. In 1850 a number of states created the Postal and Telegraph union, instituting a unified German postal area, making it substantially simpler to send letters to recipients in another postal area (von Stephan, 1859). This cooperation coincided with the emergence of other structural changes, in particular pre-paid postage, distance-independent pricing and the idea of universal access, which began to spread across the systems.

In contrast to the railroad the postal system became substantially more centralized in the new Empire. The Prussian service integrated a number of systems after Prussia's victory in 1867 and then again after the creation of the empire in 1871 and crucially was administratively shifted from Prussia's purview to the new Imperial administration. Two independent services remained in Bavaria and Wuerttemberg, but as the size of the respectively covered population (36 million, 4 million and 2 million inhabitants) indicates the Postal Service had become a unified service for most of the new Empire (Hesse, 2002; Sautter, 1951).

The imperial mail service was headquartered in Berlin, the political seat of the new imperial government. A structural reform in 1876 merged the previously distinct post and telegraph administrations into the new *Reichspost- und Telegraphenverwaltung*. This new agency was headed by the General-

[7]See map 4 for the regional extent of these systems.

postmeister,[8] who reported to the chancellor of the empire. The post was filled by Heinrich von Stephan, an official who already had played a central role in the formation of the Imperial mail and the creation of the international Universal Postal Union. The service was organized in 41 postal districts called Oberpostdirektionen[9]. These districts lined up roughly with internal political boundaries, and therefore also the different predecessor postal systems, though the match was far from perfect and substantial differences existed. This structure existed until the demise of the Empire in the wake of Germany's defeat in the First World War (Hesse, 2002; Sautter, 1951).

Although the Taxis family had carried the operational, contingent risk of the mail services it operated until 1866 the postal service was not conceptualized as a business venture (Behringer, 1990). One formal example for that is the Zollverein treaty, which regulated for which goods member states could assert public monopolies and did not list the postal service as such an area (Parry, 1969). Historically the provision of mail services was therefore considered more of a public good like security and defence.

The postal service began to spread all over German areas after its inception at the turn of the 16th century, the figure in the appendix shows the quantitative expansion of the postal system displaying the cumulative number of post office locations. The number of places served by at least one

[8]After 1880 the agency was headed by a *Staatssekretaer*, who still reported to the chancellor

[9]Map 5 shows these districts

of the different systems grows exponentially and reaches close to 3000 by the time the Reichspost is established. This number of places continued to grow and by 1910 the number of offices[10] had reached over 34000 (Hesse, 2002).

The appendix explores the mechanisms behind the spatial expansion of these services until the early years of the empire. The central determinant seems to be population size, the larger a place the earlier it received a post office. The statistical significant positive impact of Hanse and especially Imperial town legacy implies that a number of other factors, including economic and political ones, had an influence as well. The results indicate that the mail service had been widely diffused with a central focus on population coverage and thereby becoming the central mechanism underlying the formalized exchange of information within the Empire. This makes the use of postal statistics a credible data source for analysing the underpinnings of the complete urban system.

3. Theoretical framework

With the mail services spreading to more and more locations they began to affect more and more spatial relationships between locations and by the time of German Empire provided coverage to the complete urban system. This allows the utilization of postal data in the analysis of the factors influencing the population distribution in a large number of locations. The first

[10] A number of locations had multiple branches therefore the number of locations served is substantially lower than this number.

step is to calculate a measure, labelled Information Intensity, which modifies the transaction costs between locations based on observed information exchange volumes. This measure represents the mechanism how particular location factors can influence the market access and therefore the size of locations. The measure is then used in a New Economic Geography model in the second step, which results in an amenity value for each location. This value represents the way how actual location characteristics can affect the location size through the endowment mechanism.

Redding (2010) in his discussion of the empirics of New Economic Geography models argues that the transaction cost matrix between locations is usually not the focus of attention. The use of postal data, which are a direct representation of information (and therefore economic) relationships between locations, addresses this issue. The derived Information Intensity modifies the transaction costs between locations to give a better representation about the underlying cost structure for spatial exchange and trade and allows making this cost structure dependent on location characteristics.

3.1. Information Intensity

The quantity of mail has been used in the economics and economic history literature in a number of ways relating to the level of economic activity. Crafts (1983) uses it to estimate regional GDP numbers, similarly Kenny (2005) shows the correlation between mail volume and a country's GDP.

Additionally the literature on mail demand[11] also relates volumes to GDP but focuses on questions of pricing and market structures. The correlation between mail volume and GDP mentioned above is usually shown on a countrywide basis. As Hines and Velk (2010) argue with US Official Register data for the 19th century the underlying logic of mail fluctuating with economic activityalso holds for smaller regional units.[12] Here we go down to the local level and utilize this relationship to determine the relative local level of economic exchange.

The similarity between economic exchange and information exchange holds not only for location specific volumes but also for flows between locations. Most evidence focusses on the telephone as medium of exchange (Wong, 2004, 2008), but preliminary evidence shows that the gravity model explains other postal flows as well (Anson and Helble, 2012). Additionally this gravity pattern for information exchange holds not only for international flows but also for intra-national flows between towns (Lampe and Ploeckl, 2014).

Studies using mail volumes, or other postal data, usually take the total volume without distinguishing whether the communication is of a private or business nature. This raises concerns for the use of postal data, in particular the volume of private mail in a location may not be correlated with the

[11] See Harding (2005) for an overview about demand models.

[12] An interpretation of the postal service as a General Purpose Technology provides a more general justification for this relationship.

volume of business mail, introducing a distortion. Different literacy levels, customs, and local culture can all influence the propensity to write personal mail independently of the level of commercial activity.

One issue for correcting this is that in historical settings there was for a large share of the volume no outwardly distinguishing characteristic, which made an estimation of the relative shares difficult (Bunbury, 1935). One contemporary, system-wide estimate for Germany during the interwar period is an approximately 5:1 split between business and private mail (Michalski, 1937). Such an estimate however does not take local differences into account but applies the same number to all locations. Instead of attempting to directly split the total mail volume of a location the approach applied here is to derive a predicted measure of business mail as a weighted index of other, business-related postal services with the index measured in number of mail items.[13] Additionally this use of multiple input volumes mitigates potential distortions if a particular sector utilizes the mail more or less intensively than it should in line with the underlying economic activity. Formally per capita business mail is determined as $BM_i = \sum \beta_B BS_{Bi}$, where BS_{Bi} is the per capita volume of a particular business-related postal service BS_B in location i. β_B is the marginal effect between a unit of the service BS_B and the number of total mail items as estimated on a system-wide basis.

[13]The calculation does not guarantee that the predicted business mail volume is smaller than actual recorded total mail volume. Ploeckl (2012a) discusses the use of the residual between the recorded total volume and the predicted business volume as a measure for applied literacy.

After deriving predicted business mail the next step is to incorporate it into the market access mechanism underlying location population. Predicted business mail is taken as a measure of the amount of economic exchange and consequently trade within and more importantly between spatially distinct locations a particular location is involved in. This implies that it is directly related to the market potential of a location, where the formulation of this potential is based on a gravity approach, adding up all the implied flows involving the location. Empirical estimations of the gravity equation in trade usually include flow specific factors that increase or decrease these specific flows. One focus in this literature is on the determining the impact of these factors on flows; the large literature on borders effects is a prime example of this approach (Engel and Rogers, 1996; Shiue, 2005). A more general approach in this direction are Jacks et al. (2010, 2011), which use the flow size predicted by a gravity model and actual flows to infer general trade costs between two countries.

Here we take up this idea of factors shifting flows but modify it for the given context. Due to the homogeneity of the environment, the nature of the data and the large number of locations we move the factors shifting trade costs from being flow-specific to being location-specific. This shift implies that the predicted business mail volumes as well as the market size and distances between locations are used for the derivation of a location specific, trade cost modifier. This specific factor is taken as the Information Intensity measure.

The underlying idea for the measure argues that each location has a specific ability to exchange information which in turn determines subsequently trade and transaction costs. This implies that the derived business mail volume and the size of market potential implied by an underlying gravity approach to the expected amount of transactions can therefore be used to derive the trade ability measures.

In particular the baseline assumption is that business mail volume equals market potential, formally:

$$BM_i = \sum_j b_i * \frac{Pop_j}{d_{ij}^{\alpha}}$$

where BM_i is the per capita volume of business mail in town i, Pop_i is the population of town i and d_{ij} is the distance between locations i and j, while α is a coefficient implying the elasticity of exchange to distance.[14] The included factor b_i is the location specific factor, which formally is the Information Intensity measure.

The section looking at dynamics later on adds the multiplicative factor $\frac{\sum_j BM_{jt1} * Pop_{jt1} / \sum_j BM_{jt0} * Pop_{jt0}}{NNP_{t1} \sum_j Pop_{jt1} / \sum_j Pop_{jt0}}$, where NNP is the net national product of Germany,[15] indexed to 1 for the starting year of the data.[16] This factor rescales the decrease in trade costs seen in the increase in average items

[14] The empirical part uses $\alpha = 1.75$, which follows the results obtained by Combes et al. (2005).

[15] The utilized numbers are from Burhop and Wolff (2005)

[16] In the case of the cross-sectional analysis this is therefore not influencing the result.

per head by the increase in the Net National Product, essentially keeping the number of mail items per unit of NNP constant. This corrects for the increase in information exchange that is related to income increases rather than population changes.

The measure can be interpreted as a fixed cost that is added multiplicatively to the standard distance, similar to modifying factors for gravity equations, and can therefore be translated in terms of distance added. Practically this measure is used in such a way that every element of the transaction cost matrix is multiplied by the Information Intensity value[17] of the location that produces the traded variety, so $T_{ij} = b_i \frac{1}{d_{ij}^{\alpha}}$.

3.2. Population Distribution

While the derived Information Intensity represents the way location characteristics can influence the size of a location through the market access mechanism this leaves the endowment mechanism. The model, Redding and Sturm's multi-location version of Helpman's model about the size of regions, provides a way to derive a location amenity index value, that represents the link between location characteristics and town size through the endowment mechanism (Redding and Sturm, 2008; Helpman et al., 1998). The following description of this approach is closely based on Ploeckl (2012b) use of the model with a similar purpose.

The model by Redding and Sturm (2008) incorporates population as a

[17]The value is rescaled such that the average b_i value equals one.

mass of representative consumers that live in particular locations where they supply labour and receive a location specific wage. With this labour as sole factor of production locations produce horizontally differentiated manufacturing goods with the differentiation of these varieties based on the Dixit-Stiglitz form. This production process follows the standard increasing returns specification with a fixed cost and a constant marginal cost for each variety. These are produced under monopolistic competition and are traded between locations. Transportation costs are included as the standard iceberg trading costs. Additionally each location is endowed with a stock of a non-tradable amenity, the level of which is exogenously determined. The amenity is supplied perfectly inelastic for consumption by consumers at the location; the total expenditure on the amenity is redistributed to the consumers. The utility function of each consumer has the Cobb-Douglas form, with an index of manufacturing varieties and the amenity as the two consumption inputs. The demand from all locations for goods from a particular location is summarized as firm market access, while the total supply of varieties in a particular location is formally defined as consumer market access. Consumers are able to migrate freely between locations and are assumed to do so based on the relative real wage.

The appendix describes the model and the equilibrium in more technical detail. In equilibrium the real wage is equalized between locations. This equalization conditions can be reformulated to explicitly show the link between local population size and the idea of agglomeration economies, repre-

sented as market access, as well as the importance of endowments, modelled as the local amenity. Formally the link is shown in the central equation:

$$\ln L_c = \ln \chi + \frac{\mu}{\sigma(1-\mu)} \ln FMA_c + \frac{\mu}{(1-\mu)(\sigma-1)} \ln CMA_c + \ln H_c \quad (1)$$

where L_c is the population of town c, χ a collection of model parameters, FMA_c and CMA_c are firm and consumer market access of location c, and H_c is the local amenity. μ and σ are model parameter, namely the consumption share of non-tradeables and the elasticity of substitution. The resulting scalars in the equation are positive,[18] which implies a positive correlation between urban size and both market access measures as well as the amenity value.

The two market access measures model different aspects of market access. FMA_c, firm market access, represents the size of the markets local producers in c sell to. Increasing returns in the production process imply that a larger firm market access allows for cheaper production, higher profits, higher nominal and real wages and consequently a higher population. But the theoretical framework also takes the consumer side into account. CMA_c represents the size of the market for consumers with regard to the range of varieties offered in location c. Given consumers love of variety a larger range of market suppliers reduces the price level, increases the real wage and attracts therefore a higher population.

[18] This is implied by a condition for a unique equilibrium.

The second factor explaining location size is H_c, the level of the amenity for location c. The framework uses a single value to model an exogenously given, non-tradeable location factor. The amenity is included in the consumption basket of the consumers rather than in the production process. This inclusion in the consumption basket is combined with the assumption that consumers spend a fixed share of their income on the amenity, so a higher population for a given amenity level leads to a higher price due to the higher demand. This higher price leads to a reduction of the real wage and a dispersion effect for the population.

Location size is determined by real wage equalization, in the equilibrium it is therefore influenced by two agglomeration factors as well as two dispersion forces. The two mechanisms that attract people are the two above mentioned market access effects. A larger firm market access attracts more people due to a higher nominal wage and therefore a higher real wage. A larger consumer market access attracts more people due to a lower price level and therefore a higher real wage. A larger domestic market also implies more producers and therefore a competition effect that dilutes profits and therefore real wages. This acts as a dispersion force together with the described congestion effect for the amenity.

The empirical analysis of Redding and Sturm (2008) treats the exogenously given amenity essentially as permanent and unchanging over time. Ploeckl (2012b) argues that a wider interpretation of the amenity factor should relax this particular assumption. This implies that not only changes

to market access but also changes to the amenity can drive changes in the population distribution. Furthermore the central argument is that endowments have now a variable part. They can adjust in such a way that with a relative short regularity the system is in equilibrium given the population distribution and the transport costs. This implies that certain, mostly non-physical factors for the location choice, for example nostalgia, that would shift the population 'off-equilibrium' can then be incorporated in the variable component of endowments.

Real wage equality is another assumption that can be relaxed with a wider interpretation of the amenity term. The structure of the model is such that a systematic, underlying real wage differential can be masked by a different amenity level such that the model mechanism of real wage equalization, which drives mobility between locations, is taking this into account and does retain the systematic differentials.

As further explained in the appendix given a population distribution and a trade cost matrix the model allows to numerically calculate the implied amenity value for each location, which is the parameter through which location characteristics can influence the endowment mechanism. Ploeckl (2012b) demonstrates that this allows the model to be used for counterfactual scenarios. In particular it is possible to derive the counterfactual population distribution for scenarios that quantify the impact of the changes to trade costs or amenity values. Furthermore this also allows decomposing any population changes over time into relative contributions of a direct effect of

changes to trade costs as well as a direct effect of amenity changes and an indirect market access impact of such amenity changes.

4. Data

The described framework contains two indices, Information Intensity and the Amenity. The practical calculation of these values requires mail volume and related information service usage volumes, population and the distance matrix.

The second component of the empirical analysis is to utilize these indices to investigate which location characteristics are influencing them and thereby the spatial distribution of population and economic activity within the industrializing German Empire. This is achieved by incorporating them as dependent variables into econometric specifications with an extensive set of location characteristics as independent variables. The relative importance of a number of location characteristics for the total population can then be quantified with the aforementioned calculation of a counterfactual population distribution. Furthermore the location characteristics are also used in the same way for analysing changes in the indices over time.

Postal service publications are the main sources for the first set of data. In particular there are two sources, first the Post-Lexikon (des Kaiserlichen General-Postamts, 1878) reporting the data for the complete set of location with postal offices for the year 1876 and second the annual statistical reports of the Postal service which list a smaller set of data for the set of locations

with a first class post office for a number of years afterwards.

The postal data set for 1876 contains the total incoming and outgoing volume of mail, which is a combination of letters and other, similar items like post cards. Furthermore the total number of incoming and outgoing packets without value declaration as well as packets with value declaration is included as is the number and combined value of money orders, the number of collection on delivery items and the number of order letters, a postal service to collect bills of exchange payments. The reported population data in the Post-Lexikon and the annual reports are based on the official censuses conducted by the Imperial statistical office in a five year rhythm. The numbers for the intermediate years between official census years are linearly interpolated from the two surrounding censuses. Additionally the information in the Post-Lexikon is used to identify locations and create geographic references, which allow the calculation of the great-circle distance matrix between them.

The second part of the analysis, the explanation of the derived index values with actual location characteristics, requires an additional set of data.[19] These data can be grouped in three categories, namely geographic, institutional and cultural. The geographic data include elevation, measured in meters above sea level, and a range of climate measures, in particular a number of temperature and rain values. Furthermore the proximity of a major river is included with a dummy. Similarly proximity to the North sea coast

[19]The sources for these data are described in the appendix.

as well as the Baltic sea one is included. Finally the major areas with coal deposits, split into hard and brown coal, are identified and included with a dummy if a location is within the specific general area. A related set of data concerns infrastructure, namely the presence and opening year of a railroad as well as the proximity to a canal. Institutional variables are a number of contemporary and historical institutional characteristics of the location. The first group is a set of variables indicating proximity to a border, in particular the external border of the German empire, the borders of Bavaria and Wuerttemberg, the Prussian state border (for locations not in Prussia) and the border of other German states (for locations in Prussia). More contemporary institutions are the presence of a university as well as the presence of a deep sea port. Historical variables include a town's membership in the Hanse, the medieval association of trading towns, and a past as a free Imperial town at any time during the old empire until the inception of the new German empire in 1871. These last two can also be categorized with the included cultural variables, which are the share of Catholics in the location's population and the share of those who are native speakers of a foreign language. Summary statistics are given in Table 1.

The extent of the population distribution analysed is given by the inclusion of the location into the postal network. The data set for the cross-section in 1876 contains currently information for 2789 observations, which also excludes locations with a population size below 1000 inhabitants. This threshold is introduced due to issues that in rural areas post offices effectively

served a group of rather than just one village, therefore showing substantially higher per capita values than reasonable. At the moment the data set also misses two post districts[20] for which there are problems identifying their location and the southern states of Baden and Alsace-Lorraine due to geographic reasons.[21] The panel data set contains 442 observations of locations which continuously had a first class post office between 1877 and 1908. Due to missing data issues a number of regressions only utilize 363 of them.

5. Estimation

5.1. Information Intensity and Amenity

As detailed above, the first empirical step is the prediction of the business mail volume. As discussed above the index is based on the results from a regression of total per capital mail volume on other, business-related postal numbers. In particular we include the following indicators, the number of telegrams received, the number of collect on delivery items, the number of order letters, the number of packets with value declaration and the value of the incoming money orders. All of the values are actually the incoming rather than outgoing numbers for the respective services. Every information exchange has a sender and receiver similar to seller and buyer in an economic exchange. This allows using incoming rather outgoing values and avoids in

[20] These are Koenigsberg and Gumbinnen.

[21] This is due to the gap created by the Bavarian Palatinate, which implies that the data covers the territory of the *Norddeutsche Bund* plus the southern province of Hesse as seen in Map 5.

this way outliers driven by the presence of certain sectors, that used particular services, like packets, to distribute their products as discussed by Hull (1892) and would therefore distort the results.

The formal specification is

$$TM_i = \alpha + \beta_t Tel_i + \beta_c CoD_i + \beta_o OL_i + \beta_v VP_i + \beta_m VMO_i + \epsilon_i$$

where TM_i is the total mail volume, Tel is the number of telegrams, CoD the number of collect on delivery items, OL the number of order letters, VP the number of packets with value declaration, VMO the value of money orders and *epsilon* is the residual. All the values are in per capita terms.

The results are shown in Table 2. They show a clear positive correlation between all business items and total mail, and the magnitudes of coefficients imply that each of such an item is associated with a substantial larger number of mail items, fitting with mail's status as the cheapest way to transmit information.

Additionally if the intercept is taken as the average volume of private letters per head for each location it allows an estimation of the relative volume of business and private mail for the complete system. The resulting numbers imply a 4:1 split, which fits fairly well with the estimate of 17% derived by Michalski (1937) for the interwar time period.

Next this predicted business mail volume is set in relation to the market potential of each location. Under the assumptions that market potential

translates in commercial transactions and that each transaction causes the same amount of mail the standard market potential measure is taken as the predicted amount of transactions. The Information Intensity is then introduced as an adjustment factor for market potential such that the implied transaction volumes equal the predicted business mail values of each location. As introduced above this adjustment factor is a location specific multiplicative factor b_i that can be calculated based on market potential $\sum_j \frac{Pop_j}{d_{ij}^2}$ and predicted business mail volume BM_i.

This is followed by determining values for the endowment index in each location. As described above the use of a given population distribution and a trade cost matrix allows the calculation of implied endowment values for all locations. Practically this implies searching over possible amenity value sets minimizing the differences in real wages between locations implied by solving the model for particular amenity values. This methodology follows the example of Ploeckl (2012b), which describes it in more detail.

Figures 1 and 2 provide an overview about the spatial distribution of these values by showing the average values by post district. Although both exhibit some similar spatial patterns, there is also a substantial difference in this regard. This indicates that some particular location characteristics were likely shaping both values, which is the focus of the next section.

5.1.1. Empirical Determinants

The two index values for Information Intensity and the Amenity are directly associated with the two mechanisms underlying the spatial population distribution, namely agglomeration forces and location endowments, which are shaped by the characteristics of the actual locations. To identify the impact of these characteristics we estimate the following regression:

$$log(Index_i) = \alpha + \sum \beta_g Geo_i + \sum \gamma_{in} Ins_i + \sum \lambda_{cu} Cul_i + \psi D_i + \epsilon_i$$

where $Index$ is the either the Information Intensity or the amenity level, Geo, Ins, and Cul are the respective included geographic, institutional and cultural characteristics, D_i are dummies for the respective Post districts, in case of the Information Intensity, or for respective states and Prussian provinces and ϵ is an error term.

Table 3 reports the results for both regression with Information Intensity respective the Amenity as dependent variable. The first noticeable result concerns the mechanisms through which location characteristics influenced the population distribution. Although there are a number of factors that only work through one mechanism, a substantial number of them work through both mechanisms. In particular the railroad, hard coal and institutional characteristics influenced the location of population, and therefore economic activity, through both the market access and endowment channel. There is however no clear correlation pattern between particular groups of location

characteristics and the mechanism they worked through.

In terms of geography elevation did not affect population size, while a number of climatic factors did through the endowment mechanism, but had no impact on the market access mechanism. The presence of natural resources in form of hard coal deposits had not only the expected positive impact as an endowment characteristic, it is also connected with a negative impact on market access, lowering the intensity of the spatial relationships with other locations.

The dual impact on both mechanisms is also clearly visible in the other central component of Germany's industrialization, namely the railroad. The exact pattern of the effect will be discussed in the counterfactual section later on. While another main form of transportation infrastructure, rivers, had a positive impact through market access, they did not work as a location endowment. Canals had no significant impact at all, which likely reflects their minor importance in Germany's transportation system. This is in contrast to deep sea harbours, which improved market access and had a positive effect through the endowment mechanism.

There is no clear pattern with regard to borders and shore lines. The positive impact of proximity to a foreign border can be explained through the importance of places in neighbouring regions that are not in the data set. The positive effect implies that the borders were not completely sealed but neighbours did have some positive effect on border locations.

The final category, institutional and cultural factors, indicates that these

characteristics had a substantial impact. Historical legacy, the Hanse as well Imperial township, were linked to positive effects through both mechanisms, a similar effect is observed for the university system. While the presence of Catholics in the town population led to negative effect on population through both mechanisms the presence of non-German native language speakers only had a negative impact through the endowment mechanism

5.1.2. Counterfactuals

The previous section identifies which characteristics influence the Information Intensity and the amenity value, but the coefficients do not directly reflect their impact on location population. They do however allow the calculation of counterfactual spatial distributions for Information Intensity and Amenity values, which can then be used with the model to derive a counterfactual population distribution, highlighting the difference in population implied by changes to underlying location factors. This approach not only delivers counterfactual distributions, it also allows quantifying the impact of derived estimation coefficients in terms of total population of the included town system.[22]

The calculation of counterfactuals however does not allow for alternate developments; it closely resembles a destruction effect and provides therefore an upper bound for the impact of particular factors. Although this analysis

[22]The model does not take into account the entry or exit of locations nor does it make any particular claim about the mechanism, demographic change or migration, through which population change occurred.

has a different metric than the usual social savings approach pioneered by Fogel (1964) it nevertheless has the substantial advantage that this approach can quantify the impact out of spatial[23] rather than temporal information.

The central equation of the model furthermore implies that the first-order effect of changes to the Amenity is simply the ratio of the original and counterfactual Amenity index values, so a ten percent increase in a location's Amenity value translates into a ten percent higher population. This implies that the total difference in population can be separated into a direct endowment effect and a market access effect. The latter combines the direct effect of transportation cost changes and the impact of market access changes due to the changes in the Amenity values.

The counterfactual population is the result of solving the model with changed Information intensity and Amenity values. The magnitude of the changes to these values are based on the results of the above regressions, so for example with an Amenity regression coefficient of 0.2 adding a harbour to a particular location the Amenity value of this particular locations is increased with a factor $e^{0.2}$, so somewhat over 22%. The focus of the following counterfactual calculations is the total effect of particular characteristics, so these will be changed for all locations.

Removing the railroad system shows a counterfactual total population of the included urban locations that is 34.02% lower, where the direct amenity

[23]This obviously requires a certain amount of spatial variation in the particular location factor.

effect alone is 13.81% while the removal of the direct trade cost effect results in a population decrease of 2.43%, leaving the remaining difference of 17.78% as the market access feedback due to changes in the Amenity.

A reason for the market access impact pattern, an initial positive shock that dissipates over time, and the relative small direct effect of trade cost decreases is the diffusion of positive trade effects beyond towns with stations only. The general expansion of the system also started to benefit locations that were close to railroad stations but not directly linked. This implies that railroad trade costs decreases shifted to become general trade cost decreases, and are no longer separately captured. The direct Amenity impact through the endowment channel also has a particular pattern in its impact. The coefficients on the station dummy variables indicate next to the initial positive shock to trade costs a negative, statistical insignificant, shock to the amenity. This negative impact on the amenity reflects that through the trade cost shock the town should be significantly larger, but population growth has not yet caught up completely. Over time the resulting additional population growth let this effect on the amenity disappear and consequently the railroad turned into an endowment effect. This implies that the impact of the railroad worked initially through an impact through market access before it shifted to become a more endowment focused effect.

The spatial pattern of the impact is shown in Figures 3 and 4. The first depicts the average population density implied by the counterfactual calculation, which still shows quite similar spatial pattern to the actual distribution.

The direct comparison is provided in Figure 4, which plots the ratio between counterfactual and actual population density. The results show that the impact is larger in more densely population area, implying that the effect of the railroad helped strengthening existing differences rather substantial redistribution population.

The magnitude of the effect is substantial especially when compared with the total difference of hard coal which barely registers at 0.6%, a negative impact related to market access appears to have been strong enough to balance the positive effect through the endowment mechanism. A stark contrast to this is the effect of historical town legacies. While the existence of non-German native languages reduces population by 1.1%, the difference in the counterfactual population related to the Hanse with 14.1% and the Imperial township with 8.0% is rather substantial and indicating the impact of path-dependent, historical forces that shape the population distribution long after their original importance.

6. Dynamics

The interpretation of the counterfactual results for the railroad already indicates that the population distribution evolves over time and the effect of factors was and still is not constant. This raises the question whether changes in the population distribution were driven by these factors, again asking through which of the mechanisms they worked through.

Using a balanced data set with postal numbers for 442 locations with

a first class post office the correlation between total mail volume and the business-related services is repeatedly estimated for each year from 1877 to 1908. Figure 5 plots the results and shows that in the late 1890's the relative stable relationships begin to substantially fluctuate and change predominantly due to technological and price changes (Hesse, 2002). One important example in this regard is the emergence of the telephone as a medium of exchange. For the following analysis we use therefore the two stable decades from 1877 to 1895.

As outlined above for the counterfactual calculations any population change can be due to three underlying causes, namely a direct change in transport costs, the amenity level as well as the feedback effect a change in the amenity has through impact on market access. Calculating the Information Intensity and consequently Amenity values for the two points in time allows calculating the population change due to changes in the Amenity values by simply comparing the two results and the changes in population due to trade cost changes by calculating a counterfactual population with the 1896 Information Intensity values and the 1877 Amenity values.

The period 1877 to 1895 saw the total urban population of these locations with a first class post office increase by 52.4%, with a location mean of 36.8% and a median of 29.1%. Decomposing this increase shows that the total Amenity based change was 8.3%, with a mean of 2.5% and a median of 4.1%, while the direct effect of changes in trade costs was 19.8% with a mean of 20.1% and a median of 20.1%. This implies that the change of the Amenity

had a feedback effect leading to an increase by 24.3% with a mean of 6.2% and a median of 12.7%. These numbers show that the population change during the first two decades of the German Empire was driven predominantly by improvements in market access and therefore agglomeration forces, increasing the relative importance of this factor.

This pattern of a direct trade cost based population increase combined with by the market access feedback of the Amenity change also shapes the pattern of the population change. Linking total increase with each of the mechanism based increases shows that changes through the endowment mechanism can explain close to 95% of the variation. This implies that that the pattern of population change was strongly drawn by changes to endowment mechanism while the magnitude of the total increase was driven by trade cost decreases.

Furthermore Table 4 shows the results of regressing the change in the Information Intensity and Amenity indices on the set of location factors utilized above.[24] The results confirm the relevance of the railroad and coal for the evolution population distribution. The negative impact on trade cost growth for towns with stations in 1875 points towards the impact of a further expansion of the system and the diffusion of the effect beyond these towns. The pattern of other changes shows a decrease of the trade cost impact of cultural and institutional factor, an effect that is mirrored by the lower trade

[24]Due to missing data only 367 locations are included here.

cost advantage of towns with harbours.

The results indicate that towns with a railroad station in 1875 had a lower increase in Information intensity than towns without a station. Since this assumes that the railroad system remained in its extent of 1876 this result has two potential explanation. First the trade advantage of the railroad was diffusing towards locations without direct access to the system, and second the extension of the system to new locations might have led to stronger increase in Information intensity in previously unconnected locations . Data on the connection of towns by 1886, the halfway point of the previous time period, allows to calculate the population effect of the expansion of the system in the decade between 1876 and 1886. In particular the system expanded during this decade from 303 to 338 of the included towns[25]. Conducting a counterfactual estimation for 1886, including a dummy for the opening of a station during the preceding decade, allows determining what share of the population growth of the included urban locations is due to the railroad expansion. The results show that an increase of 0.12% is due to new railroad stations, which is negligible compared to an urban population increase of 21.70%. This implies that the effect of the railroad on trade costs was not driven by the extensive margin of a new systems, but by a wider diffusion of the effect on locations that had no direct link.

[25]Again this refers to the 367 locations used for the regression above.

7. Conclusion

The spatial distribution of people is strongly related to the equivalent distribution of economic activity. The later requires the exchange of information, which gave rise to the establishment of institutions to facilitate this. The central service used to coordinate and facilitate economic transactions over space at the time of the industrial revolution and the onset of modern economic growth was the postal service. The spread of this service, especially in the 19th century driven by the idea of universal access, not only provided a channel for economic transactions reaching most of the population, it also substantially touched personal lives and people‘s methods of communication. This reach, the homogeneity and the combination of commercial and private motives allow postal data to be an excellent source to analyse the influence of spatial relationships on the shape of the population landscape.

This distribution is shaped by two mechanisms, market access and endowment effects. This paper demonstrates that incorporating postal data into the analysis to model the market access channel allows the analysis not only to combine the two channels as the underlying mechanisms behind the population distribution, it also allows to incorporate the role of particular location characteristics. More precisely it illuminates the possibility that such location factors had an influence not only as endowments but also affected the population through influencing market access.

Enabled through the inclusion of postal data in the market access channel the analysis of the impact of various location factors shows that a number of

important factors like railroads and hard coal indeed worked through both channels and showed in some cases a specialization, impacting the population positively through one channel and negatively through the other. The population distribution was influenced not only by the railroad and hard coal, central factors in Germany's industrialization, but also by the historical legacy of the Hanse and Imperial township, the university system, the prevalence of non-German native language and other factors. The counterfactual analysis quantifies the impact of a counterfactual removal of the railroad system as close to 30% in terms of total location population. Focusing on the growth of a smaller set of larger locations, the improvements in transportation costs between 1877 and 1895 did support most of urban population while endowments are shown to have remained extremely influential in shaping the relative growth between towns.

Postal data cannot only be used to analyse the spatial distribution of population and economic activity. The short analysis of the spread of the postal system points towards the diffusion of technology, the development of market structures like monopolies and the impact of the government interaction with the economy through the provision of important public services. Additionally the nature of mail as written communication points towards the use of postal data for investigations into local literacy levels. Economic activity did not and still does not happen without communication and the exchange of information, incorporating the postal system and information exchange more general in the analysis helps us to better understand where,

when and why people and therefore economic activity locates.

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Tables

Table 1: Summary Statistics of Location Characteristics

	Mean	SD	Min	Max
Population	4799	21967	1001	966900
Longitude	11.38	3.51	6.00	19.83
Latitude	51.69	1.23	49.16	55.25
Elevation	159	145.25	0	872
Brown Coal	0.02		0	1
Hard Coal	0.06		0	1
Railroad	0.47		0	1
log Railroad age	1.24	1.44	0	3.69
River	0.14		0	1
Canal	0.01		0	1
Harbour	0.03		0	1
Baltic Sea	0.02		0	1
North Sea	0.01		0	1
Foreign Border	0.13		0	1
BaWu Border	0.19		0	1
Prussia Border	0.12		0	1
Other Border	0.13		0	1
Rain	661.1	114.00	473	1228
Rain SD	22.01	7.90	10	49
Temp Mean	86.13	8.73	47	103
Temp SD	6482	583.46	5482	8223
University	0.01		0	1
Imperial Town	0.01		0	1
Hanse Town	0.05		0	1
Catholics	0.28	0.41	0	1
Language	0.04	0.20	0	1
Observations	2789			

Table 2: Relationship between Mail and other postal service items

	Estimate	S E.	
(Intercept)	6.120	0.25	***
Telegrams	11.160	0.61	***
CoD	25.793	0.74	***
Order Letters	24.355	1.64	***
Value Packets	2.687	0.62	***
Money Orders	0.083	0.00	***
R-squared	0.75		
Observations	2789		

Table 3: Explanatory Factors for Information Intensity and Amenity Indices in 1876

	Information	**Intensity**		**Amenity**		
	Estimate	S.E.		Estimate	S.E.	
Intercept	-21.98	4.71	***	1.00	1.23	
Longitude	0.04	0.05		0.00	0.01	
Latitude	0.36	0.08	***	0.02	0.02	
Elevation	0.00	0.00		-0.00	0.00	
Brown Coal	-0.00	0.12		-0.11	0.04	**
Hard Coal	-0.32	0.09	***	0.08	0.03	**
Railroad Station	0.45	0.08	***	-0.03	0.03	
log Railroad age	-0.12	0.03	***	0.08	0.01	***
River	0.11	0.06	**	0.01	0.02	
Canal	-0.03	0.19		0.02	0.05	
Harbour	0.44	0.13	***	0.20	0.04	***
Baltic Sea	-0.33	0.15	**	-0.05	0.05	
North Sea	-0.22	0.23		-0.07	0.07	
Foreign Border	0.10	0.07		0.08	0.02	***
BaWu Border	0.21	0.08	**	0.03	0.02	
Prussia Border	0.03	0.07		-0.02	0.02	
Other Border	0.19	0.06	***	0.02	0.02	
Rain	0.00	0.00		0.00	0.00	***
Rain SD	0.01	0.01		0.01	0.00	**
Temp Mean	0.01	0.01		0.00	0.00	*
Temp SD	0.00	0.00		0.00	0.00	
University	0.73	0.24	***	0.75	0.08	***
Imperial Town	0.63	0.12	***	0.57	0.06	***
Hanse Town	0.59	0.06	***	0.32	0.03	***
Catholics	-0.12	0.06	*	-0.05	0.02	**
Language	-0.02	0.12		-0.13	0.03	***
Post districts	Y					
Provinces				Y		
R-squared	0.33			0.32		
Observations	2789			2789		

$^{*}p < 0.10,^{**}\, p < 0.05,^{***}\, p < 0.01$

OLS regression with robust standard errors. The regional dummies for the Information Intensity regression are based on Post districts, while those for the Amenity regression are based on states and Prussian provinces.

Table 4: Explanatory factors for changes in Information Intensity and Amenity 1877-1895

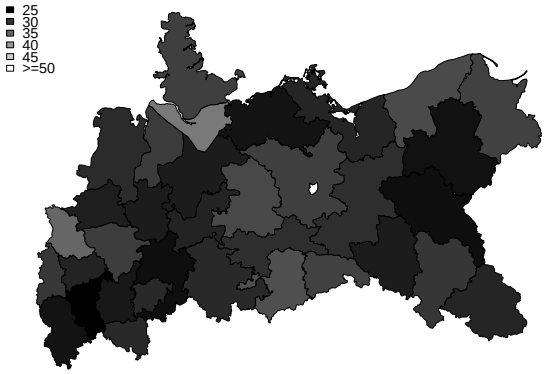
	Information Intensity			**Amenity**		
	Estimate	S.E.		Estimate	S.E.	
Intercept	2.69	2.40		1.39	0.75	*
Longitude	0.01	0.01		0.00	0.00	
Latitude	0.01	0.04		-0.01	0.01	
Elevation	0.00	0.00		0.00	0.00	
Brown coal	0.05	0.06		0.02	0.02	
Hard coal	-0.08	0.05	*	0.05	0.02	**
Railroad 1875	-0.12	0.04	***	0.03	0.01	**
River	-0.02	0.03		-0.01	0.01	
Canal	0.06	0.10		-0.02	0.01	
Harbor	-0.17	0.06	**	0.01	0.02	
Baltic Sea	0.10	0.10		-0.02	0.02	
North Sea	0.04	0.10		0.05	0.03	*
Foreign Border	-0.04	0.04		-0.03	0.01	*
BaWu Border	0.03	0.04		-0.02	0.02	
Prussia Border	-0.00	0.04		-0.02	0.01	*
Other Border	-0.01	0.04		-0.00	0.01	
Rain	-0.00	0.00	*	0.00	0.00	
Rain SD	-0.01	0.00	**	-0.00	0.00	
Temp Mean	-0.01	0.01		0.00	0.00	
Temp SD	-0.00	0.00		-0.00	0.00	
University	-0.12	0.04	***	0.04	0.01	***
Imperial Town	-0.01	0.05		0.02	0.01	
Hanse Town	-0.08	0.03	**	0.00	0.01	
Catholics	-0.10	0.05	**	0.01	0.02	
Language	0.08	0.10		0.01	0.03	
R-squared	0.23			0.09		
Observations	367			367		

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

OLS regression with robust standard errors. Dependent variables are the relative size of Information Intensity and Amenity in 1895 and 1877.

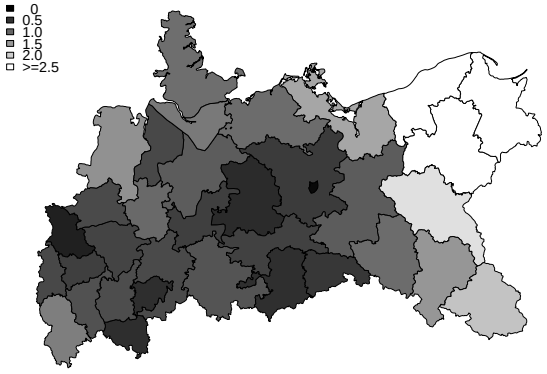
Figures

Figure 1: Average Amenity Values



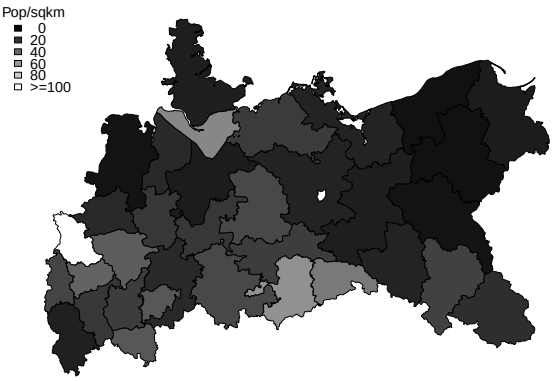
The graph plots the average Amenity values by Post district.

Figure 2: Average Information Intensity



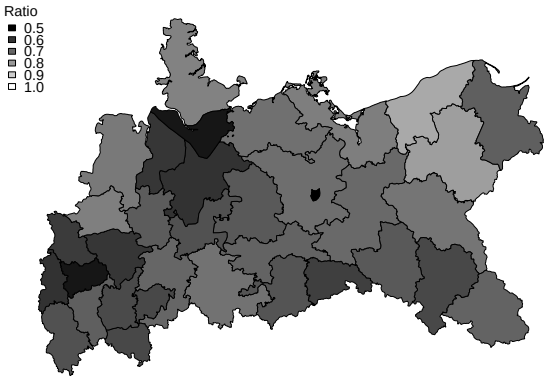
The graph plots the average Information Intensity by Post district.

Figure 3: Railroad Counterfactual Population Density



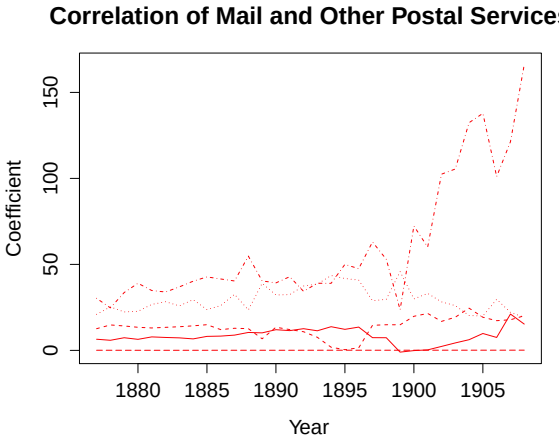
The graph plots the railroad counterfactual population density.

Figure 4: Railroad Counterfactual Relative Density



The graph plots the ratio between the railroad counterfactual population density and the actual 1876 population density.

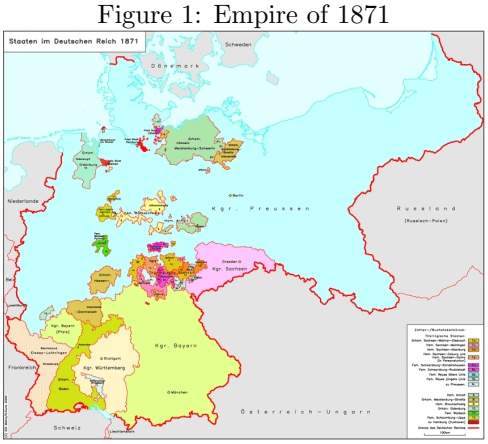
Figure 5: Business Mail Weights



The graph plots the coefficients for the Mail volume regressions over time.

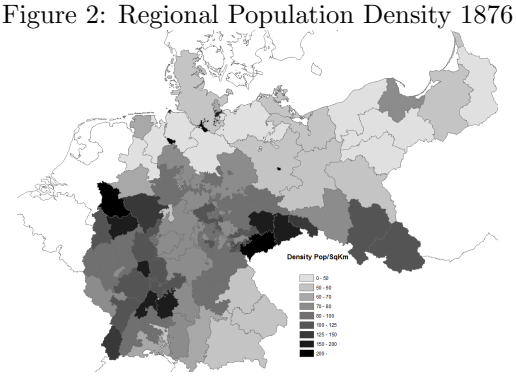
Maps

Figure 1: Empire of 1871



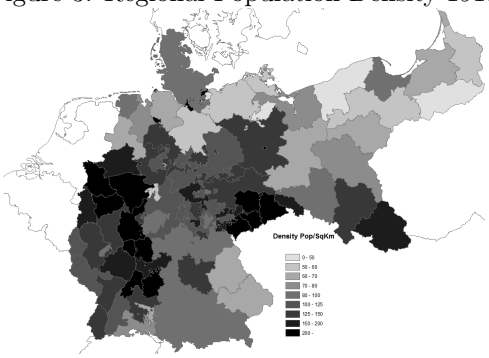
The map shows the internal and external borders of the German Empire of 1871.
Source: IEG Maps

Figure 2: Regional Population Density 1876



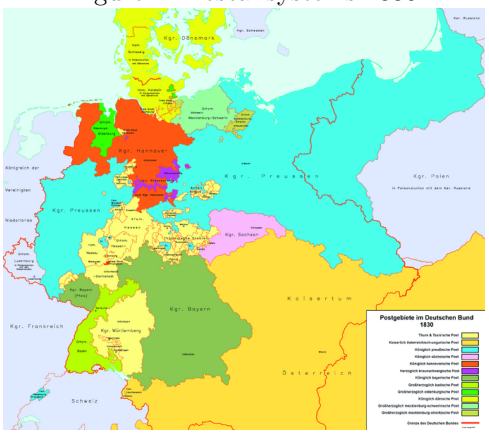
The map shows population density of *Regierungsbezirk*-level in 1876.
Source: IEG Maps

Figure 3: Regional Population Density 1913



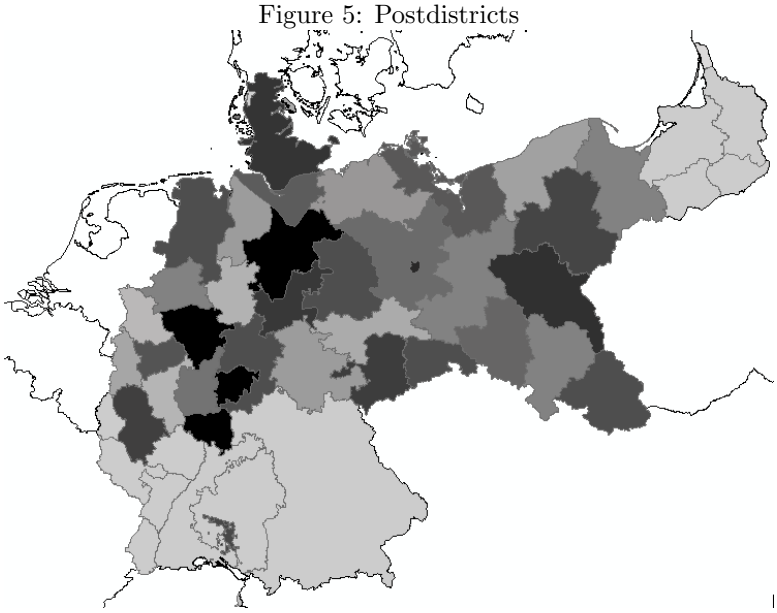
The map shows population density of *Regierungsbezirk*-level in 1813.
Source: IEG Maps

Figure 4: Postal systems 1830



The map shows the different postal systems of the German states around 1830.
Source: Frank Gnegel

Figure 5: Postdistricts



The map shows the included Post districts and the remaining parts of the Empire (lightest grey)

Appendix

Data Sources

- Postal Data
  The postal data comes from three sources. All traffic data for 1876 comes from the Postlexikon (des Kaiserlichen General-Postamts, 1878). Similarly the corresponding data for the panel starting in 1877 comes from the *Statistische Jahresbericht*, the annual statistical report of the postal service. The third part of the data is the opening year of the first post office in a particular location. This data comes from Hass (2002),, a station directory that lists the relevant years derived from a variety of sources including official publications.

- Population
  The population data for each location is also reported in the Postlexikon and the annual reports of the postal services. The underlying source for these numbers is the census held by the Imperial statistical office every five years.

- Religion
  The religious affiliation of the location population is also reported in the Postlexikon. There is no clear reporting structure for various forms of Protestantism, so no differentiation along Lutheran, Reformed or similar Protestant classifications is undertaken.

- Language
  Similar to religion the Postlexikon also reports the native language of the location population.

- Location coordinates
  The utilized distance matrix is based on singular location coordinates for each place. Coordinates are taken from the "Geographische Namen (GN250)" data set of the *Bundesamt fuer Kartographie und Geodaesie*, the official German cartographic agency, the "Genealogische Ortsverzeichnis" database of the *Verein fuer Computergenealogie*, a genealogical association, as well as through manual selection through Google Earth and Bing Maps.

- Climate and Elevation
  The data comes from the WorldClim data base (Hijmans et al., 2005).

- Railroad
  The information about railroad location and track openings is taken from a data set provided by the HGIS Germany project (Kunz and Zipf, 2006).

- Canals and Rivers
  The locations of canals and the river network are also taken from the data set provided by the HGIS project.

- Borders
  All borders are taken from the data set provided by the HGIS project.

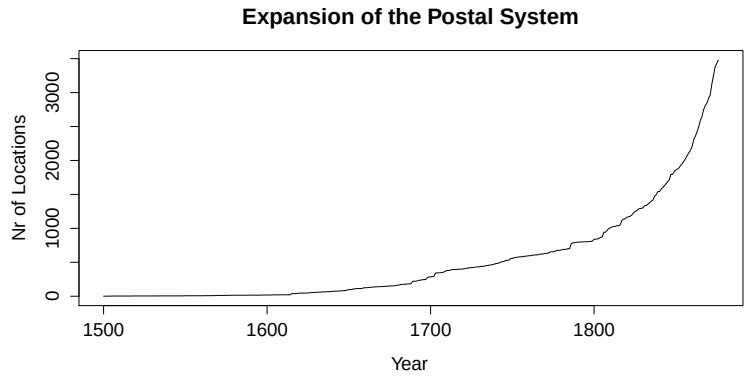
- Universities
  Location, opening year and classification in regular and technical universities are based on Ruegg (2010).

- Harbours
  The existence of a deep sea harbor in a location is based on statistical information provided by Amt (1878)

- Hanse Town
  The membership of a location in the Hanse trade system is based on Hammel-Kiesow (2008) and Dollinger (2012)

- Imperial Town
  The historical status of a town as an Imperial town is based on Jacob (2010)

Establishment date



The graph plots the expansion of the number of locations served by the postal systems.

As described above the establishment of the postal system started at the turn of the 16th century. Initially connecting a single route the system began to be expanded wider and wider. The data set contains information about the year in which each town saw the establishment of its first post office. This allows to estimate the factors driving the expansion of the system. The spatial extent of the coverage is the area served by the Imperial mail system, essentially the borders of the German Empire of 1871 minus Bavaria and Wuerttemberg. This includes the original imperial mail system run by the Tassis family as well as the systems established by individual German states, most notably the Prussian mail service instituted in 1649.

Formally we estimate a survival analysis with the years since the opening of the first office in the sample in 1500 as dependent variable and a series of independent variables. In particular these are many of the geographic ones, longitude and latitude, elevation, proximity to a river, lake, the North or Baltic sea, as well as mean and standard deviation of rain and temperature. Furthermore we include a town's history as an imperial or a Hanse town, a designation which most of the affected towns had received prior to the establishment of the postal system. While all of these are clearly exogenous, we additionally include a town's modern population as a proxy for its historic population. This variable would be endogenous if the current size is differentially influenced, i.e. if towns that received a post office earlier had

a systematically larger size effect through said post office. Since these two assumptions, first a substantial influence on population and second that said influence actually was growing over time, are rather strong we do not believe this to be a substantial issue affecting the results.

We estimate empirically the factors influencing the hazard rate, which describes the likelihood that a town gets a post office at a particular point in time. Formally the rate is

$$h(t) = pt^{p-1}[exp(x(t)'\beta]$$

where t is time starting in the year 1500, x is the set of location characteristics, p a parameter of the underlying distribution and β a vector of parameters for the influence of covariates on the hazard rate. We use a Weibull distribution as the underlying distributional form.

The following table shows the results of this regression. As is clearly visible larger towns did receive post offices earlier. This points to two possible explanations for this result, first is a political motive, larger towns were more likely to be politically important, so they got connected earlier, and second an economic motive, larger towns are likely to see a stronger demand for postal services, therefore provide higher revenues for the service provider. These two motives can be complementary, richer towns might be more important politically, and they can vary over time, political importance might have been a stronger motive early on while in the later stage economic motives prevailed. Additionally the motive of universal service provision, the intent of expanding the service to as many people possible, might be reflected in this result. The explanatory factors of economic and political importance are also reflected by the strong significance of the Hanse and Imperial town variables. Since these two variables capture these effects beyond what is done through simple differential population size, this points to substantial political and economic motives in the early expansion of the system.

Table 5: Survival analysis of Establishment of Post Offices

	Hazard Ratio	Std. Err.	z	p-value
Population	1.000009	4.61e-07	18.52	0.000
Hanse	3.996606	.3690894	15.00	0.000
Imperial town	26.90537	5.474196	16.18	0.000
Catholics	.9754499	.0546501	-0.44	0.657
Language	1.396679	1.91271	0.24	0.807
Latitude	1.072085	.0689079	1.08	0.279
Longitude	.9989454	.0240362	-0.04	0.965
Lake	1.41225	.4304285	1.13	0.257
Rain	.9995618	.0003143	-1.39	0.163
Rain Sd	.9907408	.0066323	-1.39	0.165
Temp Mean	.9994406	.0075633	-0.07	0.941
Temp Sd	.9999717	.0000938	-0.30	0.763
Elevation	.9998136	.0005083	-0.37	0.714
Hard Coal	.9390683	.0782386	-0.75	0.451
Brown Coal	.8443089	.1104173	-1.29	0.196
Baltic Sea	.8702337	.1502863	-0.80	0.421
North Sea	.9185801	.113095	-0.69	0.490
River	1.090286	.0599229	1.57	0.116
Foreign border	.9994562	.0004029	-1.35	0.177
Ba & Wu border	.9995595	.0003237	-1.36	0.174
ln(p)	2.042781	.0150672	135.58	0.000
p	7.712028	.1161985		
1/p	.1296676	.0019537		

NEG Model

The formal equilibrium of the model by Redding and Sturm (2008) is a system of seven equations with seven unknowns, which are the real wage ω_c, the price of local varieties p_c, town population L_c, number of varieties n_c, tradeables price index P_c^M, amenity price P_c^M, and total expenditure E_c. It is shown that the model has under certain conditions a unique, though not analytically tractable, solution. The equilibrium relies on exogenously given values for the amenity, H_c, and transportation costs, d_{ij}. Additionally there are a number of parameters, F is the fixed cost for each variety, σ is the elasticity of substitution and μ is the consumption share of non-tradeables.

To simplify the exposition, two market access measures are defined in terms of model variables and parameters, formally
$FMA_c \equiv \Sigma_i (w_i L_i)(P_i^M)^{\sigma-1}(T_{ci})^{1-\sigma}$ and $CMA_c \equiv \Sigma_{n_i}(p_i T_{ic})^{1-\sigma}$.

The model equilibrium consists of the following seven equations

- Equation 1: $n_c = \frac{L_c}{F\sigma}$
- Equation 2: $p_c = (\frac{\sigma}{\sigma-1})w_c$
- Equation 3: $P_c^M = [\sum_i n_i (p_i T_{ic})^{\sigma-1}(T_{ic})^{1-\sigma}]^{1/(1-\sigma)}$
- Equation 4: $w_c = \xi[\sum_i (w_i L_i)(P_i^M)^{\sigma-1}(T_{ic})^{1\sigma}]$
- Equation 5: $E_c = \frac{w_c L_c}{\mu}$
- Equation 6: $P_c^H = \frac{(1-\mu)E_c}{H_c}$
- Equation 7: $\omega_c = \frac{w_c}{(P_c^M)^{\mu}(P_c^H)^{1-\mu}} = \omega$

The model equilibrium contains the town populations L_c as a variable, while the amenity values, H_c, are exogenous. The uniqueness of the equilibrium however implies that the reverse also holds. If the population of each town is known then L_c can be treated as exogenous and H_c becomes the outcome variable. A numerical solution derived with the applied numerical algorithm from Redding and Sturm (2008), which searches over possible values of H such that the real wage is equalized between locations, for the model using given population numbers, as well as transportation costs, will therefore result in the implied Amenity value for each location. Similar, given Amenity values and transportation costs a numerical solution for population numbers can be derived. The empirical tests using the Amenity values as

well as the counterfactuals and dynamic analyses are based on such implied values derived for different sets of Amenity, population and transportation cost numbers. The necessary uniqueness of the equilibrium depends on the values of μ and σ, the consumption share of non-tradeables and the elasticity of substitution. Redding and Sturm demonstrates that it is guaranteed for $\sigma(1-\mu) > 1$. Solving for the equilibrium numerically obviously requires the selection of actual parameter values. The empirical analysis in this paper uses $\sigma = 4$ and $\mu = 0.25$, which follows Redding and Sturm (2008), who demonstrate with a simulation exercise the empirical appropriateness of this choice.