Endowments and Market Access;

the Size of Towns in Historical Perspective:

Saxony, 1550-1834

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Abstract

The spatial concentration of inhabitants within towns shapes the population distribution, the factors explaining town size are therefore also important determinants on the spatial distribution of people. This paper uses a historical case study, Saxony in 1834, to analyze empirically the relative impact of endowments and agglomeration based on the application of a New Economic Geography model. The model and data allow the analysis of the complete population distribution, from large cities down to the smallest village. The results suggest that location characteristics explain the relative size of settlements, but only 9% of absolute town and 2% of absolute village population. Similarly, the direct effects of location characteristics shape the relative size of urban growth between 1550 and 1834, but conditional on transportation cost decreases the size of the effects is only between 1/4 and 1/9 of the second order effect through the impact on market access. Finally, the model implies a location characteristics index value for each settlement. Actual geographic characteristics, ranging from agricultural land quality to weather patterns, explain a significant of these values, and therefore settlement size.

Keywords: Population History, Town Size, New Economic Geography, Location Amenity, Agglomeration

1 Introduction

A central characteristic of towns[1] is their sizeable numbers of inhabitants concentrated densely in small spatial areas (DeVries, 1984). This implies that towns are important components of the spatial distribution of the whole population within a region or country. Determining the factors underlying the size of towns is therefore a central part of an explanation for where people, and thereby economic activity, are located. This paper uses a New Economic Geography model in an empirical case study set in Saxony in the early industrial revolution to determine the relative contributions of agglomeration and endowments for town size, and growth. This is followed by an analysis whether the derived contribution of endowments can be explained by actual geographic location characteristics.

The literature uses two main theoretical approaches to explain the spatial population distribution. One is the primacy of endowments, which sees geographic location characteristics as the central determinants for geographic population patterns. These endowments can take a number of different environmental or physical forms. Although this theoretical approach does not specify an exact mechanism, these characteristics might impact the productivity of local agriculture and industry or might affect people directly through health, welfare or what is colloquially referred to as location amenities like for example certain weather patterns.[2]

The other approach focuses on the role of agglomeration. The New Economic Geography is based on the existence of increasing returns in spatially connected economic activities. Changes in spatial transaction costs, for exam-

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[1]There are some definitional approaches that do not take population size into account (Ploeckl, 2011).

[2]See for example Gallup, Sachs, and Mellinger (1999), Gallup and Sachs (2000), Rappaport and Sachs (2003), and Beeson, DeJong, and Troesken (2001).

ple decreasing transportation costs or increases in trade barriers, stimulate or dampen agglomeration processes in this view. Employment-related migration links then the affected concentrations of economic activity with changes in the spatial population distributions.[3]

The two approaches do not necessarily exclude each other. On the contrary, they can even be seen as complementary as suggested by Gallup, Sachs, and Mellinger (1999). Davis and Weinstein (2002) similarly propose that a combination of both factors can explain the spatial distribution of population. Location fundamentals provide some form of starting point and increasing returns enforce and strengthen agglomeration. Such an approach also fits with the description of favorable geographic factors as *first-nature* advantages, while the reinforcing factors are labelled as s*econd-nature* advantages (Krugman, 1993). Ayuda, Collantes, and Pinilla (2010) practically demonstrate such an effect by analyzing the development of regional population in Spain over the last two hundred years.

The identification of the underlying causes for the spatial distribution, and growth, of population is not only of interest by itself, it also has practical consequences for the use of population characteristics to analyze economic development. One such case is the investigation of institutional changes, Redding and Sturm (2008) for example determine the impact of the German separation after World War II focusing on urban population growth. In a historical example Ploeckl (2010a) shows the impact of the Zollverein, the 1834 customs union between German states. Both studies demonstrate that such an analysis of institutional changes needs to control for the potentially confounding influence of location endowments. A clear identification of the effect of institutional changes is only possible if the changing impact of endowments has

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[3]See for example Krugman (1991), Fujita, Krugman, and Venables (1999), and Neary (2001) for an overview about the New Economic Geography literature.

been accounted for.

This paper applies the New Economic Geography framework developed by Redding and Sturm (2008) for their study of the Germany separation, which formally links local population to market access and a location endowment[4] thereby providing also a link to the influence of geography. The model was originally designed to deliver testable implications about the effect of institutional change on town growth. The effect on growth however is not the only implication from this framework. The model equilibrium provides additionally formal implications for the relationship between the size of a town, its local endowments and their impact on the town's market access. These linkages, which allow to identify the respective impact of market access and location endowments, are the basis for the empirical analysis of the influence of location characteristics.

The model and my data allow the analysis of the complete population distribution on an extremely detailed geographic level. The literature usually has to sacrifice either the completeness of the population or the precision of the locations. Some focus on the analysis of urbanization and take only major cities into account (Redding and Sturm, 2008). Another strand has looked at larger regional aggregates, like provinces or administrative units, rather than the small, cohesive economic units of towns and villages (Ayuda, Collantes, and Pinilla, 2010; Davis and Weinstein, 2002). Here I am able to overcome this problem and focus on the distribution of the total population over specific locations. This includes the historically rather large rural part of the population next to the usual urban inhabitants. Locations include all

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[4]Redding and Sturm follow Helpman, Pines, Sadka, and Zilcha (1998), since their model is an extension, and call this endowment component a location amenity. I therefore use terms endowment, amenity and location characteristic interchangeably, unless otherwise noted. The usual differing definitions of amenities and endowments are taken up in section 6.

settlements down to small, individual villages, which allows me to model not only the relationship between major towns but especially between towns and villages.

Based on implications derived from the model I focus on three particular effects. First I determine how much of the town population is due to the underlying endowments once the agglomeration effects are removed. Since the model allows the identification of the relative contribution of endowments, trade between towns and villages and inter-town trade, I calculate the counterfactual size for settlements when either inter-town trade or all trade is shut down. Second, I investigate what share of long-term town population growth is caused by a first-order increase in the amenity and how much is due the resulting second-order feedback through market access. After identifying the relative contributions of the amenity at two points in time, I calculate the counterfactual growth due to the direct effect of changes in the amenity as implied by the model and compare it to the growth not explained by changes in transportation costs to identify the size of the feedback effect. And third, can real geographic location characteristics explain the location amenity values derived by the model? Based on an actual population distribution the model implies a unique amenity value for each location, this set of derived values is then linked with the actual geographic characteristics of the town locations to see whether such characteristics have explanatory power for the amenity value and therefore town size.

The particular setting used in this paper is Saxony in 1834. It was an independent, historically important state located between Prussia and Bohemia[5]. The geographical are of the state in 1834 had been the core of Saxon territories for a number of centuries prior to the redrawing of its boundaries at the

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[5]Bohemia was the northern province of the Austrian Empire at the time.

congress in Vienna in 1815. Saxony started to industrialize in the beginning of the 19th century and was therefore one of the first major regions in central Europe to do so. As a consequence of its membership in the Zollverein, the 1834 customs union between a number of independent German states, the government started formal and regular population counts in 1834. The results are published with enough detail to determine the precise population distribution of towns and villages throughout the whole state. The results of earlier tax lists also allow the determination of town populations in 1550, opening up the investigation of long-term urban growth. The settlement of Saxon territories was complete by the middle of 16th century (Blaschke, 1967), which implies a stable set of towns between the 16th and the middle of the 19th century as basis for this part of the analysis. By the 19th century this stability also extended to the set of villages, therefore entry and exit of settlements are not confounding the analysis.

The empirical analysis focuses on town size in a historical context. The use of historical data helps to understand long-term development and consequently the contemporary situations. This is due to the persistence of the European settlement pattern, which is consistent since centuries despite strong variations in the relative sizes of individual settlements (DeVries, 1984; Duranton, 2007). One period of major increases in urbanization is the industrial revolution, which is a predominantly urban phenomenon. And although these changes may have influenced town size, the underlying causes of agglomeration effects and local endowments were already present around the time of the industrial revolution (Ploeckl, 2010a). This allows to draw inference about these effects not only for the historical situation that was the starting point for modern developments but about these effects in general. The use of a historical setting to test the above described effects does have a number of

distinct advantages over modern data. The historical development of locations allows a clearer definition of their population because of the existence of clear town boundaries, in some cases even physical boundaries like walls. This advantage of a clear delineation of towns also applies to villages which were clustered settlements. This makes the rather precise information about the spatial population distribution much more useful and robust. Furthermore the close connections between towns and their rural hinterlands show supply patterns of towns with food much clearer than today's relationships. This allows the estimation of the importance of the market access to food and agricultural goods in a clear and precise way. Additionally, the separation into trade with villages and other towns provides evidence for the relative importance of intra-regional and inter-regional trade.

The next section introduces the theoretical model and lays out the implications tested in this paper. This is followed by a more detailed description of the data and the historical context. Section 4 contains the results for the implication regarding counterfactual town size without trade. These show that shutting down trade between towns as well as towns and villages leads to significant reductions in the implied population size, while the relative location sizes are more stable. The urban population drops by 55% in the first counterfactual, and over 90% in the second. This corresponds well with the results in section 5, which concern the causes of relative long-term growth. Endowments were more relevant for relative size, while market access effects were causing the larger part of the total increase in urban population over the three centuries between 1550 and 1834. The ratio between direct endowment effect and the related market access feedback effect is between 1/4 and 1/9, depending on the assumed change in transportation costs. Section 6 links the contribution of endowments to actual geographic location characteristics. It demonstrates

that these do explain the values derived from the model for towns and as well as villages. This also holds for explaining long-term effects, most notably the relative importance of natural resources like coal.

2   Theoretical Background

The model developed by Redding and Sturm (2008) incorporates population as a mass of representative consumers, each of them living in a specific location. These consumers supply labor and are compensated with a location specific wage. Their labor also represents the sole factor of production. Locations produce horizontally differentiated manufacturing goods with the differentiation of these varieties based on the Dixit-Stiglitz form. The production process of each variety follows the standard increasing returns specification with a fixed cost and a constant marginal cost. Varieties are produced under monopolistic competition and are traded between locations. Transportation costs are modeled as standard iceberg trading costs.[6] 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 based on the relative real wage.

The formal equilibrium of the model is a system of seven equations with

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[6]Empirically I use the distance between two locations as a proxy for trade costs.

seven unknowns[7]. Redding and Sturm show 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}. 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 $CMA_c \equiv \Sigma_{n_i}(p_i T_{ic})^{1-\sigma}$.

One of the equilibrium equations models the real wage equalization between locations. A reformulation of this equation reveals the explicit link between local population size and the idea of agglomeration economies, represented as market access, as well as the importance of location fundamentals, modeled 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 the firm market access of location c, CMA_c the customer 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[8], which implies a positive correlation between urban size and both market access measures as well as local characteristics.

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

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[7]These 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.

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

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.

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 exogenously given, non-tradeable location factors. 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 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 for the model using given population numbers, as well as transportation costs, will therefore result in an implied amenity value for each location. Similar, given amenity values and transportation costs a numerical solution for population numbers can be derived. The following empirical tests 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, who demonstrate with a simulation exercise the empirical appropriateness of this choice.

2.1 Empirical Implications

In particular I test three main implications of the model. The first is the relative importance of market access and location amenity for town size. This is quantified by calculating a counterfactual town size for the case of a complete shutdown of trade between locations. The second looks at the impact of long term growth between 1550 and 1834 by establishing the size of the increase in the amenity and the increase in market access caused by that increase of the amenity. And third, the calculated index value of the amenity for each settlement can be linked with real geographic endowments; therefore I test whether actual location characteristics explain the implied amenity value.

The model has the population in location c consume a combination of a basket of tradeables goods and the location amenity H_c. The basket of trade-

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ables goods contains varieties produced in the location itself as well as those produced in all other town locations. Similar the varieties produced in location c are sold there as well as in all other town locations. Access to larger markets has two positive effects on the real wage in a location, first it raises nominal income through more sales to other locations and it lowers the price index for tradeables through more varieties from other locations. This implies that changes in market access change the real wage and as a consequence of full labor mobility also change the local population L_c. Increasing the trade costs such that trade essentially shuts down allows then the determination of the population size a location can sustain through the local amenity and its home market only. A comparison between the actual size and the resulting counterfactual size allows the determination of the relative importance of market access. Trade can be shut down in two stages. Historically towns had distinct trade relationships with their hinterland as well as with other towns. The counterfactual will first shut down trade between towns, effectively turning towns and hinterlands into unconnected islands. In a second step trade of towns with their hinterland villages is shut down to see what population size the location itself can sustain without any economic connections. This reveals the relative importance of the location itself, of trade with towns' rural hinterlands and of trade with other towns.

The next step focusses on the relationship between the two factors for long-term growth. Although equation 1 seems to indicate independence between the two, an increase in the population through a higher amenity triggers a second-order increase in population through a feedback effect on market access. This effect is however asymmetric, an increase in market access, in particular through a reduction in transportation costs, has no additionally feedback effect through the amenity. This leads to the question, how important is the market

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access feedback in comparison to the underlying amenity increase. Formally, an increase in H_c, the amenity at location c, has as a first-order impact on the local population, L_c, but as a consequence it also increases the population of all locations L_i. This second order effect is due to increases in the market access, FMA_i and CMA_i, for all locations i through the population growth in c. The additional population in locations L_i increases FMA_c and CMA_c leading to the second-order increase in L_c. I quantify the relative size of these two effects using the long-term growth of towns between 1550 and 1834. The analysis uses two scenarios, first transport costs are held constant over the time period, which implies that the resulting absolute values are an upper bound, and second a drop of two thirds, where the population increase through lower transportation costs is explicitly taken into account. The increase in amenity is calculated by taking the ratio of the respective amenity values, which are derived separately for the situation in 1550 and in 1834. The second order effect is then revealed by the size of the population increase which is not explained by the calculated effect of the amenity increase and the increase in population based on the change in transportation costs.

Explanations for the actual level of the amenity are the focus of the third point. The model utilizes a single value, H_c, to characterize the local non-traded amenity endowment. The use of of the population distribution in 1834 allows to numerical solve for the equilibrium of the model, including the implied amenity values. The numerical calculation of these values allows linking them to real location characteristics. The model does not have any particular implications regarding the nature of this amenity except its geographically fixed nature, it cannot be traded between locations. Helpman, Pines, Sadka, and Zilcha (1998) justifies this modeling choice with the case of housing, an example which is taken up by Redding and Sturm (2008). I expand this to

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a whole set of endowments, in particular geographic ones ranging from local agricultural land quality to elevation and weather, which will be detailed in the next section. Using this set of fixed, non-tradeable characteristics the tests will investigate the implication that local endowments have a significant influence on the size of a settlement.

3   Data

The described analysis requires three particular types of data, namely population numbers, distance measurement between the locations and finally the set of geographic location characteristics.

Population data for 1834 are based on census counts by the Saxon government, which were introduced because of Saxony's entry into the Zollverein, the German customs union of 1834 (Ploeckl, 2010b; Henderson, 1984). The data, which lists the number of inhabitants for 140 towns and 3441 villages, is taken from Waechter (1901) and Lommatzsch (1905), their locations are depicted in maps 1 and 2. The Saxon government reformed the structure of the municipal administration in 1832 which simplified the status of settlements into either towns or villages. This implies that every location was classified as either town or village and had the corresponding institutional differences. The classification was based on the historical status of settlements, so the set of towns of 1832 was for the most part very close to the set of settlements people called towns in 1550 (Ploeckl, 2010a). A central institutional difference between towns and villages, which already existed prior to the reform, was the existence of an excise tax on goods traded in towns and the related restrictions on occupations and trade in rural locations (Reuschel, 1930). Those restrictions provide the basis for the distinction between trade between towns

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and the trade of towns with their hinterlands. The set of towns for 1550 was in its extent very close to that of 1834, which leads me to restrict the 1550 set to those locations which are towns in 1834 for reasons of simplification. The population data for 1550 are based on tax rolls and are taken from Blaschke (2003). The data for 1550 only covers towns itself, it does not contain information about the rural population. Table 1 provides summary statistics for the populations of towns in 1834 and 1550 as well as for villages in 1834. Additionally I utilize information on towns within regions in neighbour states that bordered Saxony. There are 339 such towns in Bavaria, Bohemia, Prussia and the Thuringian principalities. These data are taken from Ploeckl (2010a).

The second required part contains transportation costs between locations. Following the standard approach in the Trade and Economic Geography literature the distance between two locations is used as a proxy for the trade costs between the two. Ploeckl (2010a) constructs for the case of Saxony an improved distance measure which includes geography and infrastructure into the measurement. The analysis is conducted using this particular distance measure.

The final component covers location characteristics of settlement sites, in particular it contains a number of geographic endowments of these locations. The included characteristics for all sites are the suitability of the site for farming as well as pasture purposes, the vicinity to flowing surface water, average rainfall and temperature, elevation above sea level and ruggedness as well as the distance to coal mines. A second part contains information about towns, in particular the presence of military importance and whether the town in 1550 was the site of mining, a center of trade or had a Jewish community.[9]

The suitability for farming and pasture is measured by an index value

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[9]The appendix describes the sources and specifications in more details.

between 0 and 100. The number is based on extensive geographical surveys conducted by the Saxon government in the middle of the 20th century. The respective index value combines a number of input factors like soil type, water and climatic conditions. The data is reported as average value for late 20th century political parishes. This implies that there are about 1600 observations, one of them covers the local condition for approximately two villages. Elevation is measured as meter above sea level at the particular location. The elevation values are also the basis for the measure of ruggedness, which is calculated as the standard deviation of elevation levels in a two kilometer radius around the settlement location. The presence of flowing water is measured with a dummy. It indicates whether the location is within a kilometer of any water that could potentially serve as a source of energy and easy access to water taking into account the complete Saxon river system. Technically the measurement is based on modern geographic data, but the differences between historic and current water flows are minimal, especially since there was no real canal building activity in Saxony. The geographic surveys underlying the farming and pasture suitability also include explicit climatic conditions. In particular I use two of these, namely rain fall and temperature. Rain fall is measured in average yearly amount of rain while temperature is again turned into a index value between 0 and 100 based on agricultural criteria. The distance to coal mines is measured in kilometer to the nearest mine active during the first half of the 19th century. The distance measure is that used above for the distance measurement between towns.

The second set of location characteristics only concerns towns. One of the variables indicates whether the location had strategic importance. This is measured through a dummy indicating the presence of military bases in the direct vicinity in the early 19th century. The next three are town char-

acteristics in 1550 so they are predominantly relevant for the analysis of the long-term growth of the amenity. The first indicates whether the town had historically substantial mining activity in the vicinity. The major resource found in Saxony was silver, the state was renowned for its technical mining capabilities during the centuries before the industrial revolution (Kiesewetter, 2007). Saxony also was a center for international trade, the second variable indicates whether the town was a historical trading city. The third concerns the social composition of the town population and indicates the presence of Jewish community. Summary statistics for all of these locations characteristics are given in Table 2.

4   Counterfactual Size

The model allows the identification of the contribution trade made to the size of Saxon towns. The responsible mechanism is agglomeration economies. Trade opened markets which allowed towns to utilize economies of scale, the increased production required additional labor inputs, leading to an increase in town population. Shutting down trade allows the determination of a counterfactual population, a comparison of that with the actual population reveals trade's contribution to the size of Saxon towns in 1834.

The first step is to solve the model equilibrium with 1834 population numbers and distance values. The set of locations includes all towns and villages in Saxony as well as foreign towns in the vicinity of Saxony. This implies a total of 3920 locations, 140 Saxon towns, 339 foreign ones and 3441 Saxon villages.

The distinction between towns and villages influences the relevant transport costs between the different locations. The costs for trade between towns

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are modeled as in the standard New Economic Geography framework with the Iceberg form based on distance. This inter-town trade is complemented by trade between towns and their surrounding villages. For each town these are all villages, such that that particular town is the closest urban location. Trade within this set of locations centers around the urban-rural relationship, which makes distance less of a concern. The relevant distance value is therefore set such that population in the other locations around the same town represent 2/3 of the population in the location itself.[10]

These data allow the calculation of the implied amenity values for each of the locations. An analysis of the actual derived values follows in a later section. The values can now be used to determine the counterfactual population for different trade relationships. The first step is to shut down[11] long-distance, inter-town trade, while urban-rural trade is still active. The second step is to shut-down trade completely, each location is then only producing for itself and only itself.

The results show that shutting down trade between towns leads to a total urban population of 235954, a reduction of 55% from the actual urban population in 1834. This shows that trade significantly influenced the size of towns by allowing economies of scale in the production process. While the impact on total population is quite significant, the impact on the variation in town size is negligible. The correlation between original size and the counterfactual size is 0.99. Additionally the effect of shutting down trade between towns affects villages through the effect on the size of connected towns. Total counterfactual rural population sees a reduction of 8% as a consequence, though it still does not affect the size distribution.

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[10]This value also coincides with some estimates of the urban-rural wage gap (Hatton and Williamson, 1993).

[11]This is achieved by setting distance value large enough that trade costs become essentially prohibitive.

Preventing trade between locations leads to a considerable further reduction in population. Town locations now only sustain 47297 inhabitants, which represents about 9% of the actual population. Correlation between this counterfactual and the actual urban population is 0.95. Rural population collapses even more dramatic, it's down to 19691, which represents only 2% of the current rural population. In this case the shut-down of trade also affects the distribution of village size, the correlation drops to 0.57.

5   Long Term Growth

An increase in a location's amenity has a direct growth effect on the town's population as well as an indirect one through a market access feedback effect. These effects are additionally dependent on the change in transportation costs during the same time frame. Transportation costs have stylized two main components, one is the actual monetary cost while the second is the time it takes for the transport to get from origin to destination. Jackman in his history of transportation in England notes in this respect two distinct developments of domestic, land-based transportation costs during the three centuries before the railroad. First monetary costs remained extremely stable over the time in question, while the second observation states that the speed of transportation[12] trebled (Jackman, 1962). These two developments in costs, no change and a drop by two-thirds, are consequently the two boundaries I use to control for changes in transportation costs.

Total urban population grew between 1550 and 1834 by 214%, from 166879 to 523563 inhabitants. In the first scenario, no change in transportation costs, solving for the implied amenity values in both years shows that the total

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[12]Bogart (2005) shows that this was predominantly driven by improvements in road quality and related infrastructure through the turnpike system. Saxony improved its road system in the early 19th century, though not to the same extent as England (Thimme, 1931).

combined urban amenity grew by much less, namely only by 47.5%. The growth pattern of a town's amenity, the mean of individual growth rates is 66.8%, however was not unrelated to its level, the correlation between the growth rate and amenity size is −0.42, between growth rate and 1550 town size −0.26. This negative correlation between size and amenity growth also explains that the implied total population growth caused by the increase in amenity values is only 42.0%. This shows that the direct growth effect of changes in the amenity is outweighed by the indirect effect through changes in market access by a ratio of approximately 4 to 1. The correlation between the growth of a town's amenity and its population growth however is 0.98. This indicates that the change in the amenity is the predominant factor for the relative size of the population increase while market access works as a multiplication effect that simply magnifies the underlying relative differences in the amenity values.

In the second scenario a counterfactual population for 1834 is calculated that only takes the direct effect of the transportation cost decrease into account. This is done in two steps, first the amenity values implied by the actual population in 1550 and the triple transportation costs are calculated. In the second step the resulting amenity values and the transportation costs for 1834 are combined to derive the implied counterfactual population in 1834. The results show that the total population in this case would have been 348479 inhabitants, which implies that the drop in transportation costs had an increase of 108.8% as its direct effect, which leaves an increase of 105.2% due to the increase in the amenity and its market access feedback effect. The derived amenity values also imply that the direct growth effect of the amenity is only 9.2%, which leaves 96% growth due to the amenity feedback. The correlation between a town's amenity and population growth is 0.95.

Taking the two scenarios as boundaries for the development of land-based transportation costs before the advent of the railroad the results suggest that population growth of towns was on the one hand shaped by the changes in the underlying amenity level but on the other hand driven in its magnitude by the increases in market access, caused either by amenity growth or transportation cost decreases.

6   Amenity

As demonstrated above, the main driver for the relative population size of towns is the local amenity. These values are assumed to represent a non-traded exogenously given characteristic for each town, summarizing actual local amenities. The derived index values allow therefore a link between the theoretical representation of local endowments and real characteristics. Formal tests can therefore show which location endowments are relevant for the size, and growth, of the amenity index and therefore town size.

The term amenity is usually associated with certain location conditions which directly enter the utility function of the consumer as mirrored in the model. This however excludes a whole range of factors that might influence town size, for example coal deposits. These factors are location characteristics, endowments, that influence the productivity, and therefore the income side, of workers rather than their consumption. A refinement of the model however does allow including them into the empirical estimation.

The first step of this refinement groups a town's individual workers into households, formally $L_c = \sum_N \phi_c * N_c$, where N_c is the number of households and ϕ_c is household size in town c. The next step introduces town-specific labor productivity into the production process, so $L_c = A_c * J_c$. The factor

A_c is the town-specific productivity with $A_c \geq 1$ and J_c is the number of actual workers in the town, which therefore provide L_c units of labor. This formulation implies that there is therefore a number of persons, J_c, who split the total town income while the rest, $L_c - J_c$, has no income at all. I link the two introduced components by assuming that every household consists of exactly one person that supplies labor, so $N_c = J_c$, and a number of dependents, $\phi_c - 1 = A_c - 1$. The model now assumes that the working member of each household receives a wage such that every member of the household can consume the same consumption bundle as everybody else in town. Since the household size is determined by labor productivity it implies an essentially malthusian idea, any increase in productivity leads to a higher population rather than an increase in consumption. This modeling choice is appropriate for settings until the advent of modern economic growth during the industrial revolution, therefore fits well with the utilized empirical example.

How does that allow the inclusion of productivity influencing endowments into the amenity? Assume that a town has a positive shock with regard to one of these endowments, for example the opening up of newly found coal deposits. The individual productivity increases which allows a higher household size and therefore implies a higher total town as well as national population. As argued above, given all amenity values H_c as well as transport costs d_{ij} the model has a unique equilibrium with a total population L. If the new coal deposit increases L it implies that at least one H_c or d_{ij} has to change to ensure the new equilibrium. Since the productivity shock is town specific rather than affecting transportation I assume that exactly one amenity value changes, namely that of the town with the new coal deposit. This leads to the conclusion that the introduced household structure and individual productivity explains a mechanism that links productivity influencing endowments with the

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index value of the amenity for each town. In more intuitive terms, the shock allows household size to increase, the amenity increase is then the mechanism that attracts the necessary people to increase the number of people in each household.[13]

Empirically the link between the actual endowments and the implied values is investigated with a simple regression framework. I estimate

$$\ln(H_c) = \alpha + \sum_j \gamma_j E_{cj} + \varepsilon_c$$

with each E_j being one element of the set of location characteristics which is described above. These are predominantly geographic characteristics that are exogenously given and therefore are not influenced by the local population.[14] Additionally I also look the factors behind long-term growth, which is formally tested by replacing the dependent variables with the town amenity growth between 1550 and 1834. The tests are organized into three groups.

The first focusses on explaining the derived amenity values for towns. The tests are separately estimated for the two resulting sets of amenity values in 1834 and the values for 1550. The set of endowments is the set of geographic endowments as well as the additional set of town characteristics in 1550.

The second focuses on the growth in amenity values between in 1550 and 1834. Here the growth rate of H, rather than its level, is used as the dependent variable. The specification remains identical otherwise. The specification is estimated with different sets of actual endowments used as independent

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[13]A change in the amenity obviously causes a market access feedback, as shown in the preceding section. The increase in population is therefore the direct effect of the amenity increase combined with the resulting feedback.

[14]Modern technology does allow the reshaping of geographic characteristics, however given the historical setting, the only major historical technology which might influence the used set of characteristics is the creation of canals. However due to local circumstances, especially the nature of the river network, this was not the case in Saxony at the time.

variables.

The third group uses the resulting amenity values from the first section, which includes the hinterland component. The tests then derive the influence of geography on towns, villages and all settlements together.

Table 3 reports the results for the three tests of the first group, which show the impact of actual location characteristics on the implied amenity levels of towns. The first two columns show the results for the year 1834 using the town amenity values calculated with wither the full set of locations or the set of legal towns only. The resulting numbers of the two test match very well with only minor differences in the magnitudes of the coefficients. The results show that by the early 19th century the very local geographic characteristics did not strongly influence the amenity value while more general characteristic did to a much larger degree. The only two characteristics that had a statistically significant influence were the distance to coal mines and the proximity to water. While the distance to coal shows the expected coefficient, the closer to the mines the larger the amenity value becomes, has proximity to water a counterintuitive impact. The amenity of towns located on a river is smaller than their counterparts without direct water access. The difference in size, towns on the water are 21% respective 14% smaller, is considerable. A possible explanation could lay in settlement patterns, locations might be more likely to develop into towns when they are close to water, the result might be smaller but more towns. Interestingly the effect is not related to the use of rivers for shipping, since the amenity levels of towns on the Elbe, the only navigable river, are not statistically significantly different from their counterparts not on this river. The group of characteristics which capture other aspects of township show their influence in the results. Military, Trade and Religion all have a statistically significant effect that increases town size. Mining also has

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statistically significant effect, however the direction is counterintuitively negative. The absence of an influence in 1550 offers an explanation. These towns, mostly known as *Bergstaedte*, mountain towns, were developed around particular mining activity[15]. Although the towns developed other economic activity, mining related occupations were central income sources for these places. The decline in the relevance of these mining activities, either through exhaustion or decreases in demand, implies that by the early 19th century the negative location characteristics of old mining locations outweigh the remaining positive factors of former resource deposits.

The analysis of the growth in the implied amenity values between 1550 and 1834 are shown in Table 4. The results are based on amenity growth derived with no change in transportation costs; repeating the same regression with the values derived with a decrease in transportation costs results in the same pattern of significance and direction, though with lower magnitudes in line with the lower total amenity growth. Two of the basic geographic characteristics, rainfall and the distance to hard coal mines, have a statistically significant effect on the growth of the amenity. Their direction corresponds with the results of the previous sections. Rain loses its significant positive effect on amenity levels which it had in 1550 while the distance to coal mines begin to have an effect, which implies that proximity to the miles has a positive effect on amenity levels. Adding the additional town characteristics also confirms the previous results. The amenity of mining towns was growing slower than their counterparts. This result together with the result for distance to coal mines shows the structural change in the economy, where traditional resources like silver begin to lose their importance while coal become more relevant for the economy. Trade, in particular shipping trade on the Elbe, also has a

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[15]Mining focused predominantly on silver. Coal did not play any significant role.

positive effect on growth, but the effect is not strong enough that the amenity levels of Elbe towns are statistically significantly affected. A final result is the inclusion of the amenity level in 1550, which appears to have a statistically significant negative effect. This looks like a convergence effect of smaller towns to larger towns, though more research on the statistical properties of the size distribution is needed to draw further conclusions.

The final set of results in Table 5 compares the influence of location characteristics on towns and villages in 1834. While only distance to coal mines and pasture have a statistically significant effect for towns do all of the characteristics affect the amenity levels of towns. This demonstrates the relevance of geographic factors for rural regions which are dominated by agricultural while urban settlements are much less dependent on local agriculture and therefore local geographical conditions.

7   Conclusion

Towns are quite persistent; once settlement patterns are determined towns might change their places within the urban hierarchy but the set of towns tends to stay fairly stable. This longevity allows to set the analysis in a historical setting to draw inference about the factors underlying the distribution of population. Here I do so with the situation in the state of Saxony at the onset of the Industrial Revolution and its urban growth all through the early modern period. As demonstrated the analysis not only shows the factors shaping long-term growth, but is able to utilize other advantages in the analysis. Examples are the separation of local and regional trade as well as the clear demarcation of settlement boundaries. These characteristics indicate that other historical conditions might be advantageous for the analysis of urban and rural

developments.

The regional science literature has a different version of the endowments argument, namely a focus on living amenities. It explains migration patterns, and thereby the spatial distribution of population, through the importance of specific location amenities. The main contrast to New Economic Geography models is the shift from employment as the motive underlying migration to living environments and consumption. Partridge (2010) summarizes and contrasts the amenity and New Economic Geography approaches. The model utilized in this paper begins to bridge this divide through the inclusion of a non-tradeable, exogeneously given amenity in the consumption baskets and thereby utility function of the consumers. This implies that the real wage, the location selection criterium of the consumers, is affected by the location specific amenity as well as the income derived from work. The above discussed model refinement about the use of geographic amenities shows some formal avenues and possibilities to develop models that formally incorporate local specific characteristics that affect not only labor productivity but also consumer utility.

Geography and agglomeration are not necessarily contradictory explanations for the size of towns and villages and thereby the spatial population distribution. This paper demonstrates that the two can be combined in a formal way to determine the importance of particular factors for population patterns. It shows the relative importance of both factors for location size, endowments shape the relative size and market access the magnitude, as well as some implications for long-term growth. The link between theoretical and actual location characteristics, made possible through the formal model, shows the relevance of geographic characteristics for the spatial population distribution, including change in impact over time. Finally the results show that the

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impact of endowments and market access is differing between urban areas and the rural countryside.

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Tables

Table 1: Summary Statistics for Settlement Population

Variables	Mean	St.Dev	Min	Max
Towns 1834	3740	7425.4	449	73610
Towns 1550	1192	1487.6	112	8481
Villages	312.5	392.3	6	5107

Table 2: Summary Statistics for Town Endowment Characteristics

Variables	Mean	St.Dev	Min	Max
Elevation	338.76	181.11	107.00	917.00
Ruggedness	29.12	16.34	3.73	94.26
Farm quality	43.30	14.62	17.00	91.00
Pasture quality	41.37	9.85	16.00	65.00
Temperature	71.76	10.69	40.00	90.00
Rain	781.20	114.93	551.00	999.00
Brown Coal	73.86	51.77	0.00	218.50
Stone Coal	79.44	42.42	0.17	210.30
River	0.61	0.49	0.00	1.00
Elbe River	0.04	0.20	0.00	1.00
Mining	0.24	0.43	0.00	1.00
Military	0.20	0.40	0.00	1.00
Trade	0.18	0.38	0.00	1.00
Jews	0.16	0.37	0.00	1.00

Further information about the individual variables, in particular their sources as well as units, is given in the appendix

Table 3: Town only Amenity

Data set	1834 All	1834 Towns only	1550 Towns only
(Intercept)	4.892***	4.416***	1.579
	(1.696)	(1.357)	(1.541)
Elevation	-0.001	0	-0.001
	(0.001)	(0.001)	(0.001)
Ruggedness	0	-0.002	-0.006*
	(0.004)	(0.003)	(0.003)
Rain	0	0.001	0.002***
	(0.001)	(0.001)	(0.001)
Temperature	-0.025	-0.022	-0.012
	(0.017)	(0.013)	(0.015)
Farm	0.009	0.005	0.012**
	(0.006)	(0.005)	(0.006)
Pasture	-0.016*	-0.005	-0.008
	(0.01)	(0.008)	(0.009)
HardCoal	-0.005***	-0.002***	0
	(0.001)	(0.001)	(0.001)
SoftCoal	0.001	0	0.003*
	(0.002)	(0.002)	(0.002)
Water	-0.24***	-0.148**	-0.17**
	(0.089)	(0.071)	(0.081)
Elbe	0.095	0.148	-0.222
	(0.205)	(0.164)	(0.186)
Mining	-0.214*	-0.221**	0.025
	(0.115)	(0.092)	(0.104)
Military	0.489***	0.411***	0.512***
	(0.121)	(0.097)	(0.11)
Trade	0.445***	0.399***	0.542***
	(0.116)	(0.093)	(0.106)
Jews	0.24**	0.235**	0.356***
	(0.12)	(0.096)	(0.109)
N	140	140	140
R^2	0.527	0.525	0.58

*** $p \leq 0.01$,** $p \leq 0.05$,* $p \leq 0.1$

Table 4: Amenity Growth Regression for 1550-1834

	Geography	Full	Full+Amenity
(Intercept)	8.055***	7.553***	7.874***
	(2.854)	(2.794)	(2.606)
Elevation	0	0.001	0
	(0.002)	(0.002)	(0.001)
Ruggedness	0.008	0.006	0.003
	(0.006)	(0.006)	(0.006)
Rain	-0.004***	-0.004***	-0.003**
	(0.001)	(0.001)	(0.001)
Temperature	-0.036	-0.028	-0.037
	(0.028)	(0.028)	(0.026)
Farm	-0.016	-0.016	-0.01
	(0.01)	(0.01)	(0.01)
Pasture	0.009	0.004	0.001
	(0.016)	(0.016)	(0.015)
HardCoal	-0.005***	-0.004***	-0.004***
	(0.002)	(0.001)	(0.001)
SoftCoal	-0.004	-0.005	-0.004
	(0.003)	(0.003)	(0.003)
Water	0.05	0.092	-0.033
	(0.149)	(0.146)	(0.139)
Elbe	0.461	0.642*	0.672**
	(0.346)	(0.338)	(0.315)
Mining	.	-0.342*	-0.328*
		(0.189)	(0.176)
Military	.	-0.163	0.256
		(0.199)	(0.208)
Trade	.	-0.286	0.082
		(0.192)	(0.197)
Jews	.	-0.229	0.061
		(0.198)	(0.195)
Amenity1550[SaxT, 1]	.	.	-0.048***
			(0.011)
N	140	140	140
R^2	0.148	0.238	0.343

*** $p \leq 0.01$,** $p \leq 0.05$,* $p \leq 0.1$

Table 5: All Location Amenity

	Towns	Villages	All Locations
(Intercept)	6.04***	0.808***	1.153***
	(2.145)	(0.162)	(0.164)
Elevation	-0.001	-0.001***	0
	(0.001)	(0)	(0)
Ruggedness	-0.003	-0.006***	-0.003**
	(0.005)	(0.002)	(0.002)
Rain	-0.001	0.002***	0.002***
	(0.001)	(0)	(0)
Temperature	-0.024	-0.018***	-0.011***
	(0.021)	(0.003)	(0.003)
Farm	0.009	-0.007***	-0.011***
	(0.008)	(0.002)	(0.002)
Pasture	-0.025**	-0.006*	-0.011***
	(0.012)	(0.004)	(0.004)
Water	-0.168	0.102***	0.154***
	(0.111)	(0.037)	(0.037)
HardCoal	-0.004***	0***	0***
	(0.001)	(0)	(0)
SoftCoal	-0.001	0*	0***
	(0.002)	(0)	(0)
N	140	3441	3581
R^2	0.178	0.147	0.202

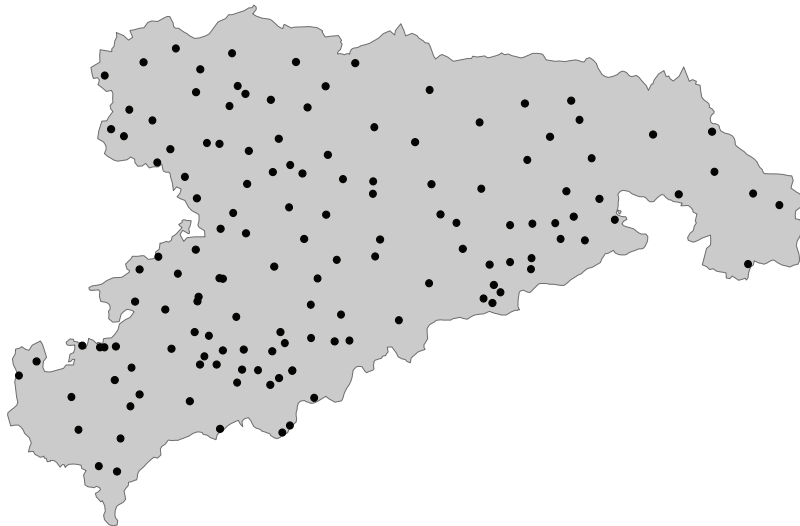*** $p \leq 0.01$,** $p \leq 0.05$,* $p \leq 0.1$

Maps

Map 1: Settlements in Saxony 1834
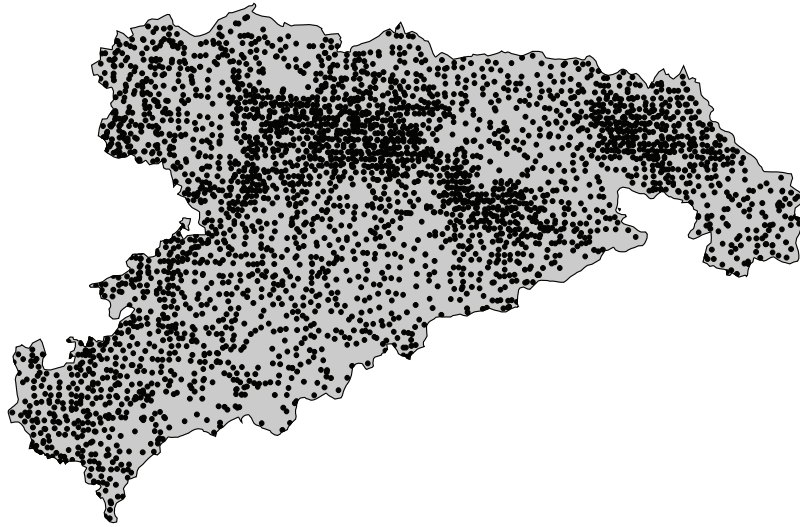
The map depicts all settlements within Saxony in its borders of 1834. Locations are taken from Blaschke and Baudisch (2006).

Map 2: Legal Towns

The map depicts all towns within Saxony in its borders of 1834. Locations are taken from Blaschke and Baudisch (2006).

Appendix

Geographic Characteristics

The data used in this analysis is taken from Ploeckl (2010a), which is also the source for the following description of the geographic factors.

Farmland quality This variable indicates the quality of the soil with respect to farming purposes, based on public geological surveys during the middle of the 20th century. The surveys are based on thousands of measurements, and report average values for about 1600 parishes covering all of Saxony. The classification scheme uses a scale of 0-100, which is the same specification used for the empirical analysis.Saechsisches
Source: Ministerium fuer Umwelt und Landwirtschaft:GEMDAT-LABO
Database, Akademie der Landwirtschaft der DDR, Muencheberg-Eberswalde

Pasture quality This variable indicates the quality of the soil with respect to pasture purposes. The data are based on the same surveys as the farmland quality and the variable is specified in the same way.
Source: Ministerium fuer Umwelt und Landwirtschaft:GEMDAT-LABO
Database, Akademie der Landwirtschaft der DDR, Muencheberg-Eberswalde

Elevation This variable indicates the elevation over sea level measured in meters; the data are from current digital elevation models.
Source:U.S.Geological Survey ,National Elevation Data

Ruggedness This variable indicates the flatness of the area immediately surrounding the town. The elevation profile of an area influences agricultural suitability as well as ease of transportation. I specify this as the standard deviation of all elevation values within a two kilometer radius

of the town's location.

Source:U.S.Geological Survey ,National Elevation Data

Temperature This variable indicates the suitability of a location's annual temperature with respect to agricultural purposes. The data are based on the same surveys as the farmland quality and the variable is specified in the same way.

Source: Ministerium fuer Umwelt und Landwirtschaft:GEMDAT-LABO Database, Akademie der Landwirtschaft der DDR, Muencheberg-Eberswalde

Rain This variable indicates the average rainfall at the location. The data are based on the same surveys as the farmland quality.

Source: Ministerium fuer Umwelt und Landwirtschaft:GEMDAT-LABO Database, Akademie der Landwirtschaft der DDR, Muencheberg-Eberswalde

Rivers This variable indicates whether there is a flowing water body within a kilometer of the town location, which is specified as a simple dummy variable.

Source: Saechsisches Ministerium fuer Umwelt und Landwirtschaft: -Gewässerdurchgängigkeitsprogramm (Oberflächengewässer)

Elbe One of the major means of transportation in the early 19th century was shipping, especially so on rivers. In Saxony, only the Elbe offered this possibility, as no other river was navigable. Rivers also have other effects such as as a source of energy, but this variable captures the effect of shipping, since most Saxon towns were located at rivers. The variable indicates whether the town is located on this particular river.

Source: Saechsisches Ministerium fuer Umwelt und Landwirtschaft: -Gewässerdurchgängigkeitsprogramm (Oberflächengewässer)

Roads The data for roads are based on information from a number of historical maps. Maps drawn in 1834 show the network of major trade routes spanning Saxony and its neighbors; road classifications are quite consistent between them. Major roads either saw service by *Eilwagen*, regular priority people transportation, or were chauseed. Small roads are all other marked important road connections. The exact routes within Saxony are based on a detailed 1852 Saxony road map.

Institutional Factors

These town characteristics are based on the description about the history of Saxony's urban system in Blaschke (2003), which lists the presence of a Jewish Community and the status as a trading and mining town. Ploeckl (2010a) provides the information about military presence.

Mining The presence of particular natural resources, most notably silver, led to the development of settlements and towns around those mining sites. The variable indicates whether the origin of towns is based on the historical presence of mining activities.

Trading A number of towns originated as settlements dominated by merchants and traders. The variable indicates whether a particular settlement has such origins.

Jews Jewish communities remained fairly distinct from the general population, nevertheless they provide an indication for religious and social diversity. The variable indicates with a dummy whether such a community existed in a particular town.

Military Waechter (1901) provides not only the total population of towns for 1834, but also the number of soldiers stationed in particular towns. This

variable indicates with a dummy whether a town had a military presence. The long territorial persistence of the central Saxon lands implies that the relative strategic importance of particular locations should be similarly persistent.