You Reap What You Know: Appropriability and the Origin of European States*

Thilo R. Huning† and Fabian Wahl‡

Abstract

Governments need to have at least a rudimentary knowledge about the income of their subjects. Since medieval states were predominantly agricultural, knowledge about the potential of their soil was crucial for their efforts to collect taxes. Lands with relatively homogeneous agricultural conditions were easier to assess and collect taxes from than lands with erratic soils and small-scale variation in local conditions. We therefore expect a relationship between soil heterogeneity as a measure of information costs and proxies of governmental success. To test this idea empirically, we propose a new measure of soil heterogeneity: caloric observability. We then show robust and significant correlations between this measure and proxies of government success on three levels, from European states 1300–1500, a new data set on the Holy Roman Empire 1150–1789, and municipality-level data on tax revenue per head in the 1545 Duchy of Württemberg.

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Keywords: *Fiscal capacity · soil heterogeneity · Holy Roman Empire · Duchy of Württtemberg*

Knowledge is power. A government that knows nothing about its means of income is powerless. It can (for some time) guess how much taxes, tariffs, levies, etc. it asks from its society, but it is always on the brink of living of its reserves, or losing out against rivals with better knowledge on their means of income. Governments of all times tried to expand their knowledge with various measures. They forced people to settle where

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they could easily monitor them (Scott 2009, 2017), invented bureaucracy, tried different organizational means (Johnson and Koyama 2014), persecuted those who resisted, some became representative (Stasavage 2020), and became our modern states (Karaman and Pamuk 2013).

Our study is motivated by the pioneering theoretical contribution of Mayshar, Moav, and Neeman (2017). The authors argue that early governments with better knowledge about their means of income established stronger and more centralized states because the process through which this income was generated was more transparent. They contrast ancient Egypt with ancient Babylon. Egypt, so they argue, gained its income from a highly transparent process, the annual Nile flooding. This flooding could be precisely measured with a simple tool that predicted the harvest well enough to have served the Egyptian government as a base for the tax assessment. Egypt in consequence became a strong and centralized state. In contrast, Babylon's agriculture depended on private irrigation, which was rather intransparent. To the Babylonian government, it was intractable how much water any farmer received, and the tax base depended on more guess work. In consequence, Babylon became a more decentralized state with strong rivaling elites, and a weaker state than Egypt.

We test their theory in medieval Europe. To do so, we develop a concept of soil heterogeneity in Section I and place it into a wider literature on appropriability. We argue that soil heterogeneity, everything else equal, makes taxation more complicated for many reasons, especially because it introduces information asymmetries that are costly to overcome. In Section II we provide a historical background that outlines are specific concept of how soil heterogeneity posed an unsolvable problem for tax collection in medieval Europe. In Section III, we introduce and explain our geographic measure of soil heterogeneity, *caloric observability*, which represents the ruggedness index of caloric suitability Galor and Özak (2014, 2015).

We introduce three different data sets on fiscal and administrative capacity of European states of increasingly smaller geographic regions. First, to show the general external validity of our argument, we focus on Europe and extend the established data set on European states by Nüssli (2008).

Second, we create a novel data set for this paper, which provides us with the most detailed geographic information on the states of the Holy Roman Empire. This historic area is ideal to test that soil heterogeneity helped governments *ceteris paribus*: It spans over several modern-day countries, providing plenty of variation in soil heterogeneity. It also consisted of hundreds of different states which differed along several dimensions; there were secular and ecclesiastical ones, territorial ones based on an agricultural economy, but also small city states engaging in trade and proto-industrial activities. Here we also draw on a large literature with a multitude of plausibly important control variables.

Third, our idea about the relationship between soil heterogeneity and fiscal capacity applies across states and within states. We therefore end with a case study of the municipalities in the early-modern Duchy of Württemberg. This has the additional advantage that a lot of potentially important confounding factors in relation to state capacity can be considered constant within such a territory.

In Section IV, we present partial correlations between different measures of fiscal and administrative capacity, and caloric observability. For the European data set, our outcome variable is the most abstract measure of government success, the geographic size of the state. For the Holy Roman Empire, we have data on the number of administrative buildings in cities. This acts as a proxy for administrative capacity and local presence of the state. The latter aspect is also connected to the degree of control the state could exert over a particular region. We also rely on the 1545 collection of the Imperial war tax ("Reichsmatrikel") as collected by Zeumer (1913), as a more direct measure and established measure of fiscal capacity (Cantoni 2012). For the Duchy of Württemberg in 1545 we collected actual wealth tax contributions on the municipality level, normalized per capita.

All these cross-sectional regressions show a robust and significant link between caloric observability and our outcomes. This supports our notion that European governments have faced the problem of relative soil heterogeneity. We conclude the paper in Section V.

I. APPROPRIABILITY, TRANSPARENCY, AND CALORIC OBSERVABILITY

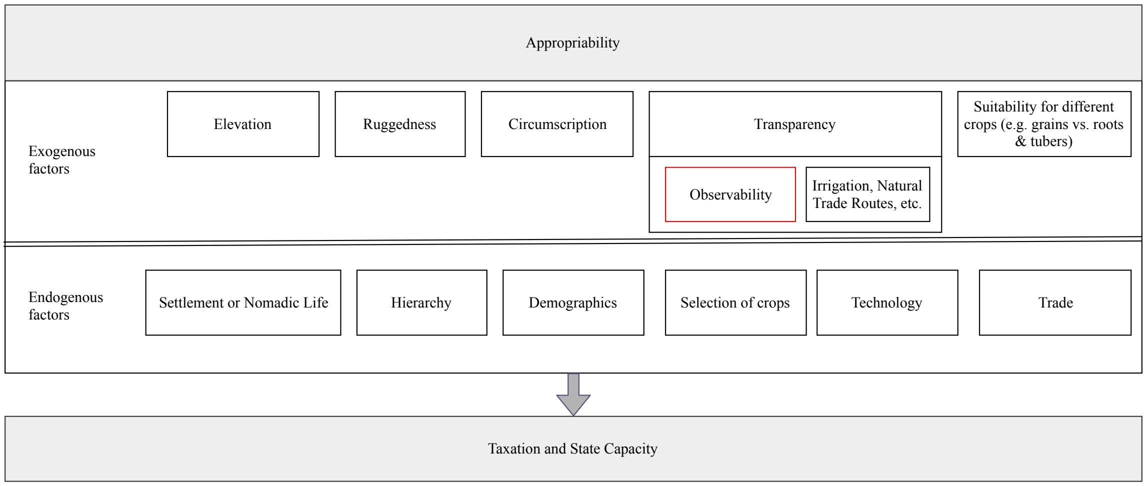


Figure 1: *Dimensions of appropriability and its influence on taxation and state capacity*

We contribute to a rapidly growing literature linking appropriability and fiscal capacity. Appropriability describes the degree to which a government can extract resources from its subjects. A low appropriability means that a government is restricted to extracting a small share of the revenues of its subject as taxes, tariffs, and other levies. The literature has explored many dimensions of appropriability, as can be seen from an overview diagram of this literature, Figure 1. The diagram shows that appropriability is an abstract concept. Parts of it can be explored empirically using exogenous variation (especially geography). Appropriability however also consists of a complex endogenous component, notably since it can be self-reinforcing. On the one hand, a government can find itself in geographic circumstances that ease the appropriation from its subjects, and can use these revenues to fund good institutions (for example a highly trained bureaucracy). Because of this, appropriability feeds into the related concept of state capacity.[1]

Some parts of appropriability have been studied empirically. Mayshar et al. (2019) provide an empirical study in which they show that a high soil suitability for roots and tubers relative to the suitability for grains determines appropriation. Grain-growing villagers who are raided right after the harvest could be left with nothing; their attackers can simply carry away the content of the granary. Those who grow roots and tubers harvest only what they plan to consume on the next days, so they are in parts assured against complete

1. Karaman and Pamuk (2013) measure state capacity by dividing states' tax revenues by their estimated GDP figures.

loss. The relative suitability of roots and tubers vs. grains cannot explain European divergences. There is hardly any variation. A historical overview of other exogenous factors is provided by Scott (2009) and Scott (2017)—the latter can be called a human history of appropriation. From these studies, we learn that elevation and ruggedness are also important control variables, for example because subjects might be able to hide themselves or valuables in caves, or escape tax collectors by ascending to altitudes that cannot be passed on horseback (compare Nunn and Puga 2012).

In this paper, we operationalize a part of what Mayshar, Moav, and Neeman (2017) coined as 'transparency'. According to their paper, the most crucial difference between ancient Egypt and Mesopotamia is exogenous: The Nile. Their verbal argument talks a lot of the consequences of its flood, and how the Nile irrigated with a higher level of transparency that Mesopotamia. In Western Europe, our case study, irrigation is not a crucial problem, so that our concept of caloric observability is distinct from these other factors. An important control variable coming from Mayshar, Moav, and Neeman (2017) however is that the city network, and hence also trade, might be shaped by the geographically induced possibility for trade. Since we will be looking at very small areas, we will also consider trade routes as an important control.

Figure 1 shows the complex changes a society can undergo due to variation in appropriability. Scott (2017), concerned with earliest states, explains how the distribution of humans today, the grains they grow, and the location of ethnic minorities today can be explained by appropriability. Mayshar, Moav, and Neeman (2017) argue that ancient states' city networks, degree of centralization, bureaucracy, political and social organization, are shaped by appropriability. To distinguish these endogenous factors of appropriability from other factors (unrelated to appropriability), we rely on two strategies. First, we provide an overview of historical literature to gain insights into which other factors this could be, and how we could potentially control for them, in the next section. Second, our three data sets allow us to move from a European data set (which pledges external validity but might be confounded by unobserved variation in factors that determine governments' fortunes which are unrelated to appropriability) to our small-scale municipality data set (where unobserved variation is expected to be lower). An empirical study which is close to ours is Ahmed and Stasavage (2020). Their study is also motivated by Mayshar, Moav, and Neeman (2017), relies on the standard deviation of soil quality as a measure of transparency, and provides evidence for a link to modern representation in a global anthropological data set.

II. Appropriability in the European Middle Ages

The European governments of the Middle Ages found themselves in vastly different geographic circumstances. These provided them with different means to appropriate, and they also tried different ways to increase the share of their subjects' revenues they could collect from them. In his landmark book, Jones (1981) explains how "core regions offered the largest tax base" (p. 105), pointing at geography as a determinant for governments' success. Some regions were more remote from the trade routes that re-emerged after around 1000 AD (Wickham 2016) than others, and had to rely more on their own agricultural base for income than others. However, given the size of this agricultural sector, as put by Wickham (2016, p. 14), "The wealth of lords, whether royal, ecclesiastical, or aristocratic [...] came from what they could extract from the peasantry [...] by force, or by the threat of force". As such, our study focuses on the agricultural sector and controls for other possible sources of government revenue.

The most widespread agricultural institution in Europe was the manorial system (North and Thomas 1973; Wickham 2016). Manors were "never universal, but they represented a state-of-the-art management of an estate for profit" (Wickham 2016, p. 126). The profit relies on a highly dynamic system of contributions, taxes, and labor services. The most important part of the tax base of territorial states came from agricultural goods of a grain based agriculture (also including livestock) and was paid in kind, primarily via the ubiquitous crops rye and oat (Mitterauer 2010; Henning 1994). If peasants failed to provide their in-kind taxes they had to provide corvée (a form of forced labor). Forced labor services were not well codified (Volckart 2002, p. 9), and allowed rulers to flexibly adjust the quantity of such services to circumstances. For example, a 1222 source from the Eiffel provides instructions on how to persuade peasants to take over new duties, selling them as old traditions (Epperlein 2003, p. 76).[2] This highlights that the medieval tax system in Europe was not a static customs-based order, but a highly dynamic negotiation process between those who were taxed, and those who wished to collect taxes. Appropriability is at the center of this problem, and the success of medieval lords to convince their peasants to comply with their wish of ever increasing revenues was dependent on subjects' environmental circumstances.

Medieval governments aimed to overcome the problem of tax collection with hierarchy. Based on a chain of bilateral relationships–between peasants and tax collectors, between

2. Large and extensive corvées were not unusual (see e.g., the discussion in Blickle 2006 on the particularly repressive feudal system in the Baltic Sea area).

tax collectors and lower gentry, between lower gentry and higher lords, and between lords and the king or emperor—were the backbone of the feudal society (Bloch 1961), "no institution of method could take the place of personal contact between human beings" (p. 62). In this chain, the peasants knew most about their soil's actual abilities in a given year. The lower lords who they interacted with already knew much less. It was also prohibitively expensive to increase this knowledge, given the basic state of understanding of agriculture at the time. In the early Middle Ages, as put by North and Thomas (1971) "the institution of serfdom gained efficiency and avoided the need for much enforcement and supervision, since in exchange for a fixed amount of labor services to the lord to perform the variety of activities involved in the self-sufficient manorial economy, the serf was granted the rest of the time to produce for himself" (p. 20). In order to circumvent the information costs, the lord appropriated only a small share of the peasants' labor potential, often only a couple of hours per week, but also did not have to—and in effect was not able to—institutionalize the collection of a larger share of the potential tax base. Lords gave up on solving the problem until the inflation of agricultural goods after the 13$^{\text{th}}$ century hit. This excluded lords from the benefits of surging land prices and serfs' rising wages, so that the costs of this resignation became more severe. To again quote North and Thomas (1971), "it was often less expensive for the lord to exercise his acknowledged right by returning the demesne to his own direct cultivation [...] despite the notorious shirking problems encountered with forced labor" (p. 60). This exemplifies how—across Europe—feudal lords were struggling to appropriate income from their peasants, who could engage in the most passive resistance—shirking (Bloch 1961, see also). Where they tried to overcome this with more bureaucracy, they also experienced a rise in rent-seeking. As such, the problem of appropriating from their peasants was shifted to trying to appropriate from their lower lords (North and Thomas 1973).

To summarize, imagine tax collection in the Duchy of Württemberg in the 16$^{\text{th}}$ century—a case that we study later. In this Duchy (a typical feudal state of that time), the tax base consisted predominantly of real estate, farm buildings, and agricultural land, wood, stored crops, natural interest from all kinds of agricultural goods, livestock, and wine barrels. Our hypothesis is that the Duke's administration was unable to appropriate as much from municipalities with a heterogeneous and complicated geography than from areas with a plane and more observable agricultural base. This could be either because the lower lords shirked the Duke, because the lower lords themselves were tricked by their farmers, or a combination of both.

III. Data

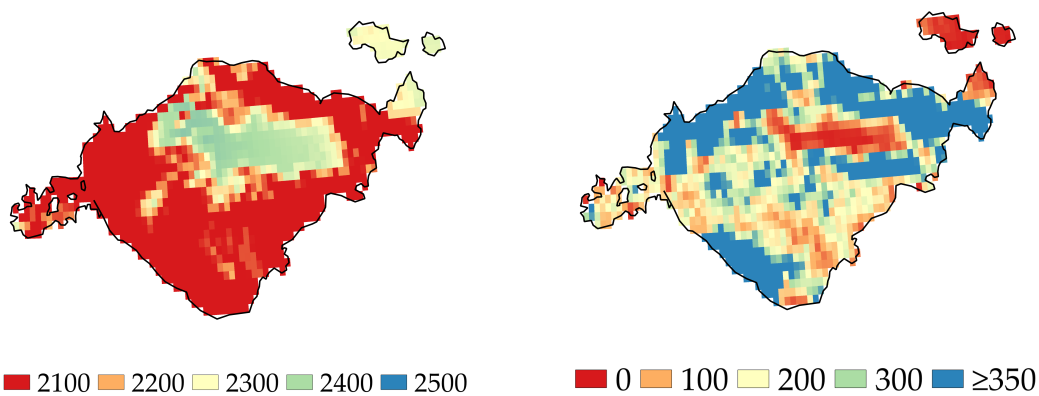
1. Main Explanatory Variable: Caloric Observability

Our measure of observability proxies the degree to which governments can infer the soil quality of a plot from the quality of the plots adjacent to it. This would allow officials to identify peasants (or subordinates in general) who lie about their actual (or potential) harvest, and their effort. If a government was able to find something close to an optimal tax rate of a single plot of land, an area with a high observability would mean that this government to scale up this increased understanding, and increase its taxation also for the surrounding fields. In an area of a large between-neighbor variation observability, knowledge gained from one plot cannot be transferred to others, which—if our theory is correct—limits the capacity of its government.

To construct our proxy for observability we employ GIS software tools. We first use raster data on soil suitability to calculate a new raster containing the variation in soil suitability between adjacent grid cells. In a last step aggregate the data from this second raster for any political unit of interest. As displayed in Figure 2 (with the example of 1378 Bohemia), we can transform any soil suitability raster to a raster with its between-neighbor variation using the same process that converts a digital elevation model (DEM) to a ruggedness raster. The generation of the between-neighbor variation raster itself is independent of political borders, it is simply a transformation of a suitability raster. The observability of a grid cell at the border is calculated using grid cells on the other side of the border. There are two advantages of this process. First, a theoretical one. Our measure of observability is designed to capture local irregularities in the soil quality, for example a break in the composition of the soil, geological consequences of the Ice Age, or local weather conditions. Second, an econometric advantage arising from the fact that this is the same process through which ruggedness data is created. This is important if ruggedness is one of the controls. Panel (a) of Figure 2 shows how the center of Bohemia has a higher soil quality, and Panel (b) shows that this varies little. As such, the government of Bohemia could expect a high agricultural productivity and in addition could also appropriate this product relatively well. In the Southern areas of Bohemia, the between-neighbor variation of the caloric suitability differs; if or hypothesis is true, in some regions (i.e. the Southwest) appropriation should have been easier than in the Northwest.

We rely on Galor and Özak (2014, 2015) as our suitability data. Since they provide caloric suitability (expressed in calories per hectare and year), we name the result caloric observability. This suitability data has important advantages. First, Galor and Özak (2014,

2015) provide data that is averaged for $10\,km \cdot 10\,km$ grid cells. This is large enough to believe that we are not measuring variation that affects the production capacity of agriculture itself. For example, if we had a measure of $1\,m \cdot 1\,m$ resolution, the resulting between-neighbor variation could also indicate that agriculture itself is less productive, already at small scale (because there would be a variation in a given field of rye, for example, and the farmers would have to plant a different fruit per small parcels of land to cater to the local conditions on each square meter). $10\,km$ is roughly the distance an observer at a slightly elevated position can see until the horizon.[3] As such, members of the lower gentry observing the work of their peasants around their castle can, if this between-neighbor variation is low, transfer the information also to plots behind the horizon. This is exactly what designed this measure for.



(a) *1378 Bohemia overlaid with pre-1500 caloric suitability, per hectare and year, taken from Galor and Özak (2014, 2015)*

(b) *1378 Bohemia overlaid with between-neighbor variation of calories pre-1500. This is generated in GIS by calculating the terrain ruggedness index of a caloric suitability layer*

Figure 2: *The calculation of between-neighbor variation of caloric suitability, the basis of our measure of caloric observability.*

To associate a single number to each state, we average this between-neighbor variation per state.[4] Then, since between-neighbor variation is a higher number for less observable areas (and it is inconvenient to interpret a higher number as a lower observability) we define caloric observability for a state s as a linear transformation of between-neighbor

3. See http://www.ringbell.co.uk/info/hdist.htm for a distance to the horizon calculator.

4. Since the observability of any raster field depends on the suitability of the eight raster fields surrounding it, caloric suitability of a state depends also on the suitability which lie directly adjacent, but outside of this state's borders. This captures the idea that governments cannot transfer ideas and innovations archived in a bordering states if the suitability variation is high.

variation BNV that relies on subtracting the maximum between-neighbor variation in the sample *States*, as follows.

$$Observability\ Index_s = -1(BNV_s - \max_{t \in States}(BNV_t)). \quad (1)$$

2. Dependent Variables

2.1. Data on States and State Size in Medieval Europe

The part of our empirical analysis that is focused on cross-sections of historical European states, is based on shapefiles of historical territories in Europe from Nüssli (2008). He provides shapefiles of territories for every 100 year period from year 1 to year 2000. For our analysis we use medieval state borders of the years 1200, 1300, 1400, and 1500. From these maps, we compute state size (in km^2) as proxy for fiscal capacity. On European level, we have to resort to state size as proxy for the fiscal capacity of a state as we lack any more direct measure for the Middle Ages. We argue that historically state size is a valid proxy for fiscal capacity and tax revenues. The economies of feudal states were based on agriculture, hence their tax systems relied primarily on in-kind taxes. In consequence, land was the tax-base and more land meant—ceteris paribus—a higher tax basis. It goes back to Aristotle that geographically small states can be governed with less effort than larger states (Olsson and Hansson 2011). We use this idea to argue that large states were only able to survive if they were efficiently governed and fiscally healthy.

We also derive dummy variables for state types according to the names of the territories (e.g., the Flanders is coded as county). We consider all historical states of which over 50% were located within the borders of modern countries completely covered by Nüssli's shapefiles.[5] We also restrict our sample to countries that have adopted the NUTS classification. The level of the analysis is what Nüssli calls "2$^{\text{nd}}$ order administrative divisions", a layer of his shapefile into which he has drawn the border of French counties, duchies, English counties, Spanish kingdoms etc. We remove what Nüssli calls "Small states of the Holy Roman Empire", a very large polygon in the shapefile containing hundreds of small states in the Holy Roman Empire for which he was not able to find reliable border information. We lose variation in state size and types (especially small and city states) and exclude large parts of today's Germany, Austria and Switzerland. This is a major shortcoming of the Nüssli maps, which we overcome with our new data set on the Holy

5. For example, only a small part of Sweden is included and Norway and Finland are entirely missing.

Roman Empire introduced below.

2.2. Fiscal and Administrative Capacity in the Holy Roman Empire

Data on the State of the Holy Roman Empire. A large part of our empirical analysis focuses on variation in tax revenues and state presence within the Holy Roman Empire. The basis of this data set are shapefiles containing information on the location and shape of the territories of the Holy Roman Empire for several points in time. To obtain this information, we digitize maps of the "reichsunmittelbare Territorien" (territories directly subordinate to the Emperor) of the Holy Roman Empire (without its Italian parts) by Wolff (1877).[6] Wolff drew these maps for years in which important events for the development of statehood in the Holy Roman Empire took place. These are the (i) collapse of the Staufer dynasty in 1250, (ii) the Western schism around the peak of political fragmentation in 1378, (iii) the Peace of Nancy in 1477, (iv) the Peaces of Augsburg (1556) and (v) Westphalia (1648), and (vi) the outbreak of the French Revolution in 1789.[7] Because our measures of tax returns and administrative presence are from the 15th and 16th centuries, we focus on the territories of the Holy Roman Empire in 1477 and 1556. The maps illustrate territories and their borders and include all types of states. These are city states (Imperial cities), large territorial states (kingdoms, duchies, principalities, margraviates, counties, etc.) and ecclesiastical states (bishoprics, archbishoprics, and monastic territories). We use this information to code state type dummies, which can act as important control variables.

To validate the maps and the included territories, we compare them to several other maps of historical states in the Holy Roman Empire (listed in the Appendix section A.1.1.).[8] Examples of coding decisions and other procedural issues are discussed in the Appendix section A.1.5. Overall, we identified 730 independent states. More detailed information on the type and frequency of the included territories is given in Appendix A.1.2.

Data on Administrative Capacity. Cantoni, Dittmar, and Yuchtman (2018) established administrative buildings as a measure of adminstrative capacity and local presence of

6. Figure A.1 in the Appendix shows the original map from Wolff 1877 for 1378.

7. A detailed historical overview of these critical points of Central European history is given in section A.1.3 of the Appendix.

8. To verify the existence of a territory included in the maps, we consulted the "Historisches Lexikon der deutschen Länder" (Historical Encyclopedia of German States) Köbler (1988), a comprehensive and reliable source that provides a historical overview of each German state from the Middle Ages until the late 20th century. To validate the city states drawn in the maps we also consulted the "Deutsches Städtebuch" (Handbook of German cities) by Keyser and Stoob (1939–1974), an encyclopedia containing information on the history of each German city.

the state. To get information about the number of administrative buildings present in a city, they rely on information on construction activities in cities from the "Deutsches Städtebuch" (Handbook of German cities) Keyser and Stoob (1939–1974).[9] Following this idea, we use their data set and create a variable reporting the number of administrative buildings in the cities of each state of the Holy Roman Empire as the sum of the constructed administrative buildings between 1400 and 1477 and between 1400 and 1556. Thus we have administrative buildings in a respective state for two points in time, 1477 and 1556. From these data, we also compute a variable containing the overall number of cities in a state which we will use as control variable for differences in the degree of urbanization among the states of the Holy Roman Empire.

Data on Fiscal Capacity. To have a measure for differences in fiscal capacity among the states of the Holy Roman Empire, we follow Cantoni (2012) and use states' contributions to the Imperial war tax ("Reichsmatrikel") in 1521 as collected by Zeumer (1913).[10] The "Reichsmatrikel" is one of the few source on empire-wide taxes available. These taxes were raised by the Emperor to finance the defense against the Ottoman invasion.

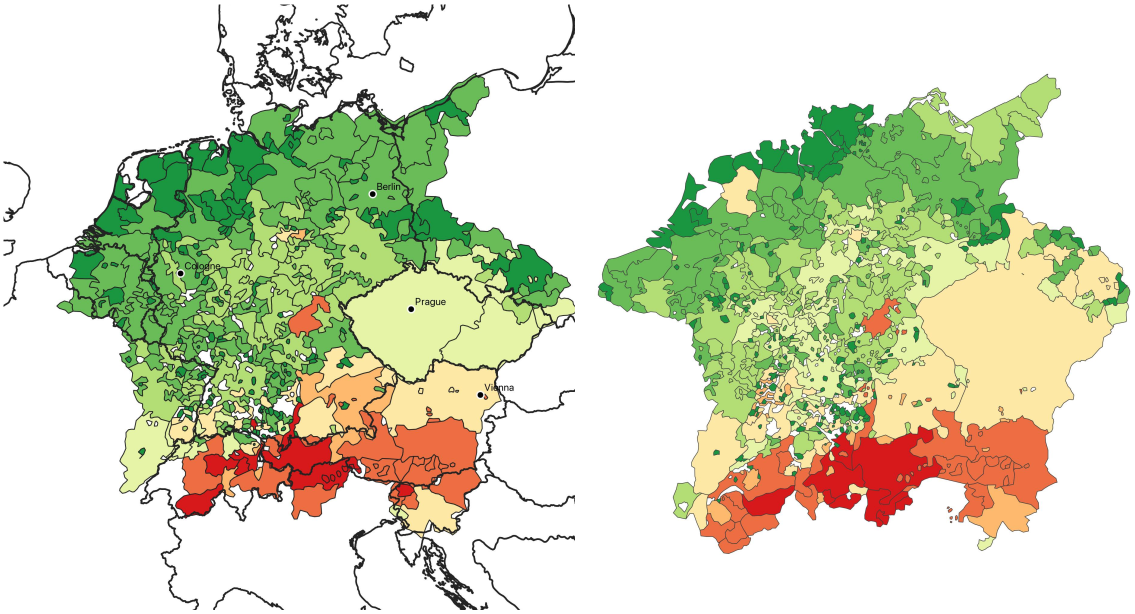
A state's contribution depended on its rank in the imperial hierarchy (e.g. electoral states paid more than others, duchies paid more than counties),[11] its estimated wealth, and its population. We match the territories mentioned in the Reichsmatrikel with the states in our data using their names and consulting historical literature.[12] Whenever we find a matching state in our data set in 1556, we assume that its geography was unchanged between 1521 and 1556. If a state ceased to exist between 1521 and 1556, we match it with the 1477 state from our data set, assuming it did not change in between.

9. The Handbook contains information for each of the 2,390 places that had city-rights at one point in their history and that are located within the borders of the German Empire as of 1937—which implies that not all the states of the Holy Roman Empire are covered (overall 362 of the 411 different states that existed in 1477 and 1556 are located within these boundaries).

10. There are Holy Roman Empire types of contributions: states had to contribute mounted and foot soldiers, and also a certain contribution in guilders. To monetize the whole contribution we also follow Cantoni (2012) and the historical literature and assume that a mounted soldier was paid 12 guilders and a foot soldiers were paid four guilders and multiply for the number of each type of soldier. Typically, not the population of the state was a restriction for the contribution of soldiers but rather its ability to pay them. This can also be seen by the fact that the average contribution was 70 soldiers on foot and just 15 on horse.

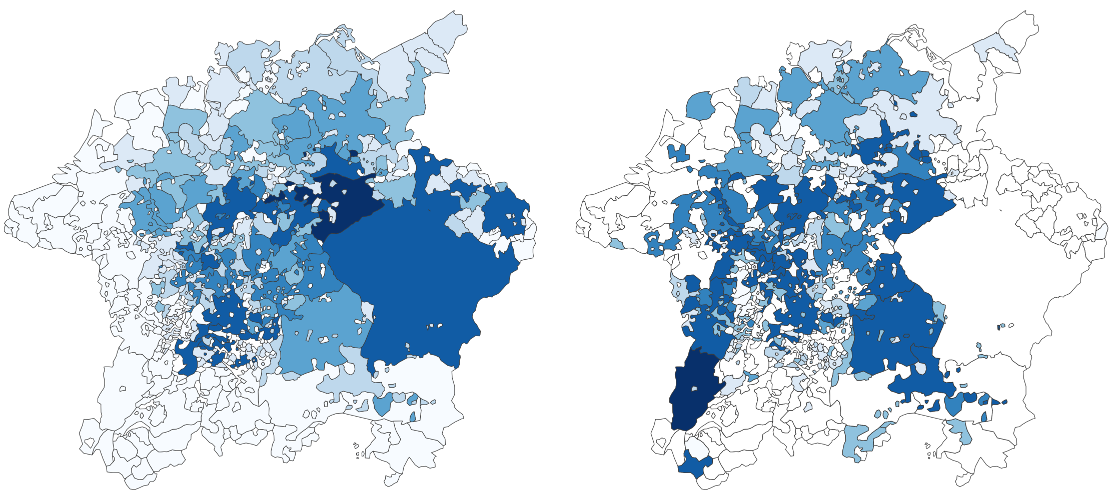
11. The electoral states on average paid 3465 guilder, duchies 2427, counties 252 and "Herrschaften" 147 guilders.

12. It is known that the Reichsmatrikel list has errors, i.e. it contains states that were not or no longer independent ("reichsunmittelbar") or for which this status is doubtful. Our maps also provide information on the states in 1477 and 1556, but not on 1521. Thus, we have to rely on information from Köbler (1988) and other sources to match the states in our maps to those of the Reichsmatrikel.



(a) *Caloric Observability and the states of the Holy Roman Empire in 1477*

(b) *Caloric Observability and the states of the Holy Roman Empire in 1556*



(c) *Administrative Buildings 1556*

(d) *Reichsmatrikel Contributions 1521*

Note: Panel (a) shows the average Caloric Observability Index in each of the territories of the Holy Roman Empire in 1556 alongside modern country borders and the location of important cities. Increasing caloric observability corresponds to increasingly darker shades of green; increasing shades of red denote decreasing caloric observability. Panel (b) shows the number of administrative buildings in each state of the Holy Roman Empire in 1556. The darker the blue the higher is the number of buildings. Panel (c) shows the Reichsmatrikel (Imperial Tax) contribution of each state in 1521 (in guilder). The darker the blue the higher is the contribution.

Figure 3: *Observability, State Presence and Tax Revenues in the Holy Roman Empire*

Overall, we match 236 states (which is around 80 % of the 305 states that existed in the Holy Roman Empire in 1477).[13]

Figure 3, Panels (a) and (b) provides an overview of the average observability for the caloric yields of each state of the Holy Roman Empire in 1477 and 1556. Panels (b) and (c) show the distribution of number of administrative buildings and the Reichsmatrikel contributions per state, respectively.

2.3. Wealth Taxation in the 1545 Duchy of Württemberg

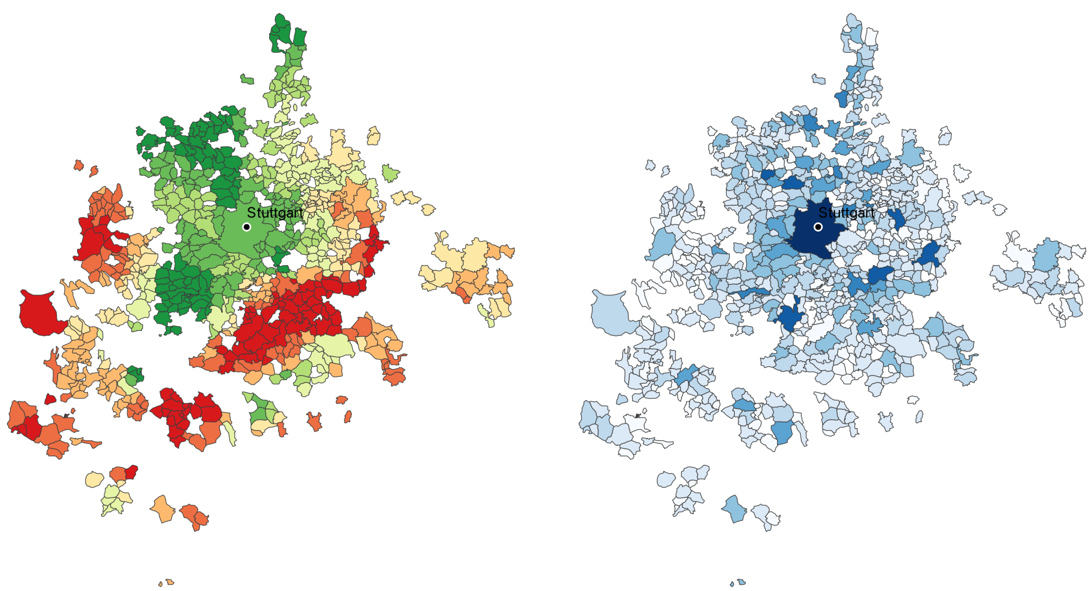
We consider differences in tax revenues within one particular state of the Holy Roman Empire, namely the Duchy of Württemberg as another way to test our hypotheses. The Duchy of Württemberg was located in the southwest of the Holy Roman Empire and was among the largest duchies of the Empire, as such it was homogeneous with respect to the political and institutional environment, but characterized by a relatively heterogeneous geography. As such it provides us with sufficient within-state variation in observability to conduct an empirical analysis. Württemberg was a large territorial state, very rural, with a predominantly agricultural economy (There was a single major urban center, its capital Stuttgart).

We collect municipality-level information on tax revenues from the imperial tax raised for the defense against the Turkish invasion 1545 ("Reichstürkenhilfe")—a tax similar to the Reichsmatrikel contribution introduced above. The tax had to be paid by the duke to the Emperor, and he advised his administration to collect taxes from the municipalities in his realm (Bull 1980). The tax rate was 0.5 % of taxable wealth. This consisted of real estate property, farm buildings and agricultural land (distinguished between fief and allodium), wood, stored crops, natural interest from all kinds of agricultural goods, money interest, livestock, and wine barrels. The tax had to be paid in coin rather than in kind, so the value of all taxable goods was monetized. A list with the taxable wealth of each municipality is available from the state archives and is printed in Bull (1980) alongside a map contained in the publication "Historischer Atlas von Baden-Württemberg" (Kommission für geschichtliche Landeskunde in Baden-Württemberg 1988), a series of maps on the history of the contemporary German state Baden-Württemberg (of which the historical duchy is part of) edited by an official, state-financed commission of historians. Bull aggregated the historical municipalities (so called "Ämter") to municipalities of the state of Baden-Württemberg in 1957. This allows us to connect the information on taxable

13. The average Reichsmatrikel contribution was 629.4 guilders with the minimum being zero and the largest contribution being 11,940 guilders (from the states controlled by the Habsburgs).

wealth (and tax revenue as 0.5 % of it) with our data set on municipality level variables for Baden-Württemberg in the 1950s from our studies on the origins and economic effects of agricultural inheritance traditions (Huning and Wahl 2021a, 2021b). This contributes a host of relevant historical control variables.

Figure 4(a) shows caloric observability among the municipalities that were part of the Duchy of Württemberg in 1545. Panel (b) indicates the wealth tax revenue in each municipality. With respect to observability we see that it is the highest in the southwest and north of the capital city Stuttgart and decreases towards the periphery. The pattern of wealth tax revenues appears similar.



(a) *Observability in the Duchy of Württemberg* **(b)** *Wealth Tax Revenues in 1545*

Note: Panel (a) shows the average Caloric Observability Index in those municipalities of Baden-Württemberg as of 195 which belonged to the Duchy of Württemberg in 1545 ("Altwürttemberg"). Increasing caloric observability corresponds to increasingly darker shades of green; increasing shades of red denote decreasing caloric observability. Panel (b) shows the wealth tax revenue per municipality (in 1000 guilders). The darker the blue the higher is the contribution.

Figure 4: *Observability and Wealth Taxation ("Türkensteuer") in the Duchy of Württemberg in 1545*

IV. Empirical Analysis and Results

In this section we introduce the empirical tests of our argument for medieval European states, the Holy Roman Empire, and the Duchy of Württemberg. We also present the results of the regressions and discuss their implications.

1. Observability and European States' Sizes

We start our analysis by looking at the relationship between state size and observability in cross-sections of historical European territories.

In line with our argument, we expect a significant and positive relationship between state size and observability of agricultural output across historical European states. To empirically test this, we calculated average caloric observability of each 2nd order administrative division included in the maps of historical European states by Nüssli (2008). Then, we estimate the relationship between caloric observability and the area of these territories–also calculated from the maps. We separately look a this relationship for the years 1200, 1300, 1400 and 1500. This is, we run the following cross-sectional OLS regressions for each of these years:

$$ln(STATEAREA)_i = \alpha + \beta ln(COI_i) + \gamma' \mathbf{X_i} + \epsilon_i, \tag{2}$$

where $ln(STATEAREA)_i$ is the natural logarithm of the area in km^2 of state i. $ln(COI_i)$ is the natural logarithm of a territory's average caloric observability index as defined above. $\mathbf{X_i}$ is a vector of basic control variables to account for factors that might have influenced both state size and observability. Among those variables is the maximum elevation of each territory. As suggested by Scott (2009, 2017), maximum elevation is highly positively correlated with state size. The rationale behind this is that states with high mountains (like Bohemia, or the Habsburg Lands) are harder to conquer. On the other hand, elevation is negatively correlated with observability. As such, our argument only works when accounting for the effect of mountains on state capacity. Our idea holds for states that differ in observability but are similar with respect to their maximum elevation. Other covariates include the average ruggedness of a territory's terrain, and the average caloric suitability of its soils. Both are related to agricultural productivity. Terrain ruggedness also serves as a proxy for the difficulty of defending the territory against foreign enemies and exerting control over it. To consider possible geographic patterns in state development and caloric observability, we also include the latitude and longitude of a territory's centroid.

Table 1: *Observability of Agricultural Output and State Size in Europe 1200–1500*

Dependent Variable	ln(Area)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1200		1300		1400		1500	
ln(Caloric Observability)	-0.356***	-0.211*	-0.387***	-0.205**	-0.580***	-0.346***	-0.510***	-0.367***
	(0.122)	(0.111)	(0.0966)	(0.0932)	(0.0867)	(0.108)	(0.110)	(0.0714)
Elevation (max)	0.000938***	0.00136***	0.000963***	0.00138***	0.00125***	0.00174***	0.00100***	0.00178***
	(0.000120)	(0.000256)	(9.85e-05)	(0.000182)	(9.35e-05)	(0.000221)	(0.000109)	(0.000125)
Terrain Ruggedness (mean)		-0.00632**		-0.00538***		-0.00769***		-0.00689***
		(0.00246)		(0.00135)		(0.00149)		(0.000790)
Latitude		0.0344		0.0584***		0.0335*		0.0364*
		(0.0278)		(0.0168)		(0.0184)		(0.0203)
Longitude		0.0128		0.0324***		0.0163*		-0.00610
		(0.0114)		(0.00840)		(0.00912)		(0.00866)
ln(Caloric Suitability)		-0.0601		0.200		0.0734		0.321**
		(0.424)		(0.188)		(0.196)		(0.139)
Market Potential		-2.74e-06***		-8.77e-07***		-1.76e-06***		-1.57e-06***
		(9.57e-07)		(2.12e-07)		(3.13e-07)		(2.21e-07)
Island		-1.004		-1.946***		-0.511		-0.275
		(0.656)		(0.626)		(0.733)		(0.696)
State Type Dummies	–	✓	–	✓	–	✓	–	✓
Observations	238	238	398	398	430	430	512	511
R^2	0.229	0.566	0.204	0.574	0.258	0.547	0.179	0.518

Notes. Standard errors clustered on the level of 2nd order administrative divisions are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. All regressions include a constant not reported.

To account for the extend of commercial activities as potential alternative source of state income and general measure of economic prosperity we include a territory's average market potential.[14] To capture the particularities of islands with respect to natural conditions but also sources of fiscal income, we include a dummy for island territories (like Sicily).

Finally, we add a set of state type dummies accounting for possible existing differences in unobserved factors connected to observability and state size.[15] ϵ_i is the error term.

Table 1 shows the results of the OLS regressions. For each of the respective years, the odd-numbered columns report the results of baseline regressions where we explain the natural logarithm of a state's area just by the logarithm of caloric observability and maximum elevation of each state. We find a highly statistically and economically significant positive coefficient of observability.

In the regressions in the even-number columns, the other covariates area added. The covariates reduce the estimated elasticity of state size with respect to observability to 0.20–0.35. The results show a statistically significant and qualitatively important relationship between both variables.

2. Observability and State Development in the States of the Holy Roman Empire

In this subsection we analyze the relationship between caloric observability, fiscal capacity and state presence among the states of the Holy Roman Empire in the 15$^{\text{th}}$ and 16$^{\text{th}}$ century.

2.1. Observability and Administrative Capacity in the Cities of the Holy Roman Empire

As a first step, we test whether caloric observability is significantly and positively related to the number of administrative buildings in cities of each state of the Holy Roman Empire in 1477 and 1556. Formally we estimate the following regression equation using OLS:

14. We calculate the market potential based on the Bairoch, Batou, and Chevre (1988) data set of historical city populations. We follow the approach of Crafts (2005). Market potential basically captures a state's market access and size (from a demand but also a supply perspective).

15. A descriptive overview of the different cross-sectional data sets is presented in Table A.1 in the Appendix.

$$ln(BUILDINGS)_{i,t} = \alpha + \beta ln(COI_{i,t}) + \gamma' \mathbf{X_{i,t}} + \delta_t + \epsilon_{i,t}, \tag{3}$$

where $ln(BUILDINGS)_{i,t}$ is the number of buildings in the cities of state i, in period t (and $t = 1477, 1556$). $X_{i,t}$ is a vector of different sets of controls. The motivation for including these control variables is to limit concerns about omitted variables bias. Therefore, we include a number of variables in our data set that should capture relevant historical and geographical confounders of fiscal and administrative capacity as well as observability as identified in the literature.

The set "Basic Geographic Controls" includes average distance to a major river, maximum elevation, and average terrain ruggedness. Variables controlling for soils and climate are caloric suitability, average temperature, and share of luvisol soils (the latter control for the effect of early plough adoption, see Alesina, Giuliano, and Nunn (2013) and Andersen, Jensen, and Skovsgaard (2016)). Because of its prominence in the literature on state capacity we include soil suitability in all regressions, and discuss it.

The set "Economic Factors and Resources" includes the average distance to the closest trade route, trade fair, Roman road, Imperial city, copper, gold, iron, lead, potassium salt, rock salt, or silver deposit. Several authors have argued that military conflicts were a driver for state capacity in Europe, because of competition between states fostering technological and organizational innovations (e.g. in taxation technologies) (Hoffman 2011; Karaman and Pamuk 2013; Tilly 1975). We construct a variable measuring the number of battles that had taken place within a state between our sampling years (i.e., between 1250 and 1378 or between 1556 and 1648), normalized by the area of the state. Additionally, a dummy variable "Boundary Location" measuring the share of a states' border that is an outer boundary of the Holy Roman Empire is also included to proxy for the more likely exposure of these regions to military conflicts or a higher presence of military there.

We also include a set of state type dummies (for Kingdoms, Electoral States, ecclesiastical territories, duchies, princedoms, margraviates, counties, republics, and "Herrschaften"), capturing unobserved shocks that might have affected different types of states differently and also unobserved historical factors that caused a certain state to become a kingdom and another one a county.[16] Finally, we add the number of cities per km^2 in a state as a

16. The base category remaining are states occupied by the Swedish after the Thirty Year's War, Imperial

control.δ_t is a 1556 dummy, and ϵ_{ic} is the error term.

The rationale for including each of these variables is explained in more detail in the Online Data Appendix (Appendix A.2.1). Exact definitions and sources of all the variables are given in Appendix section A.2.2. A descriptive overview of the variables in the data set can be found in Table A.2. The maps on which we base our geographic and historical variables are shown in section A.3 of the Appendix.

Table 2 reports the results. In columns (1) to (3), we include the basic geographic controls alongside a 1556 dummy, and cities per area as control variables. In column (3), we exclude city states as our argument, which is based on the taxation of agricultural output, might not apply to them. Finally, in columns (4) to (6) we add additional controls. The results imply a statistically and economically significant positive relationship between the observability of a state's agricultural output and the number of administrative buildings in its cities. The coefficients suggest that a 1% increase in caloric observability increases the number of administrative buildings by around 0.10%, which is sizable, but within a reasonable range. Caloric suitability is always positively and significantly associated with the number of administrative buildings, once again giving credit to the importance of soil quality itself.

Table 2: *Caloric Observability and the Number of Administrative Buildings in Cities*

Dependent Variable	ln(Number of Administrative Buildings)					
	(1)	(2)	(3)	(4)	(5)	(6)
Sample	All States		Without City States	All States		Without City States
ln(Caloric Observability)	0.136**	0.0980*	0.122*	0.131**	0.121**	0.133**
	(0.0534)	(0.0512)	(0.0725)	(0.0510)	(0.0497)	(0.0660)
ln(Caloric Suitability)	1.108***	1.146***	1.448***	1.154***	1.150***	1.315***
	(0.361)	(0.359)	(0.423)	(0.316)	(0.316)	(0.370)
1556 Dummy	✓	✓	✓	✓	✓	✓
State Type Dummies	–	–	–	✓	✓	✓
Basic Geographic Controls	✓	✓	✓	✓	✓	✓
Climate	–	–	–	✓	✓	✓
Economic Factors and Resources	–	–	–	✓	✓	✓
Battles per Area	–	–	–	✓	✓	✓
Cities per Area	–	✓	✓	–	✓	✓
Boundary Location	–	–		✓	✓	✓
Observations	362	362	269	362	362	269
R^2	0.162	0.196	0.218	0.439	0.442	0.508

Notes. Heteroskedasdicity robust standard errors are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a state. All regressions include a constant not reported. State Dummies are dummy variables indicating electoral states ("Kurfürstentümer"), kingdoms, margraviates, duchy, princedoms, counties, republics, "Herrschaften" and ecclesiastical states. The set of basic geographic controls comprises a variable measuring the average distance of 1,000 randomly distributed points within a state to the closest major river, its maximum elevation above sea-level, and its average ruggedness. Climate controls include the fraction of a state's area with luvisol soil that benefits most from plowing and a measure for the average temperature in a state. The control variables in "Economic Factors and Resources" include variables measuring the average distance of 1,000 randomly distributed points within a state to the closest Roman road, major medieval trade route, trade fair, gold, copper, silver, iron, lead, potassium salt or rock salt deposit.

territories directly controlled by the Emperor (i.e., bailiffs and Staufian territories) and Imperial cities.

2.2. Observability and Imperial Taxation in 1521

We continue with the evidence for a positive relationship between the fiscal capacity of states as measured by their contribution to the Imperial War Tax ("Reichsmatrikel") of 1521 and caloric observability. To do so, we estimate the following, cross-sectional OLS regression:

$$ln(IMPERIALTAX_i) = \alpha + \beta ln(COI_i) + \gamma' \mathbf{X_i} + \epsilon_i, \tag{4}$$

where ln($IMPERIAL\_TAX_i$) is the natural logarithm of the contribution of state i in the Reichsmatrikel of 1521. $ln(COI_i)$ is the natural logarithm of caloric observability of a state's agricultural output. X_{ic} is a vector of different sets of controls, identical to those used in Table 2.[17]

Table 3 reports the results of the regressions. As before, column (1) shows baseline regressions in which we include only a set of basic geographic controls and caloric suitability.

17. Table A.3 in the Appendix provides a descriptive overview of this data set and all the variables included in the regressions.

Table 3: *Caloric Observability and Financial Capacity of States in the Holy Roman Empire*

Dependent Variable	ln(Reichsmatrikel Contribution)					
	(1)	(2)	(3)	(4)	(5)	(6)
ln(Caloric Observability)	0.253***	0.265***	0.237***	0.212**	0.210**	0.174*
	(0.0969)	(0.0922)	(0.0913)	(0.102)	(0.102)	(0.101)
ln(Caloric Suitability)	0.366***	0.303***	0.272***	0.261**	0.254**	0.253**
Basic Geographic Controls	✓	✓	✓	✓	✓	✓
State Type Dummies	–	✓	✓	✓	✓	✓
Soil and Climate	–	–	✓	✓	✓	✓
Economic Factors and Resources	–	–	–	✓	✓	✓
Battles per Area	–	–	–	–	✓	✓
Boundary Location	–	–	–	–	–	✓
Observations	235	235	235	235	235	235
R^2	0.163	0.494	0.512	0.546	0.549	0.558

Notes. Heteroskedasdicity robust standard errors are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a state. All regressions include a constant not reported. State Dummies are dummy variables indicating electoral states ("Kurfürstentümer"), kingdoms, margraviates, duchy, princedoms, counties, republics, "Herrschaften" and ecclesiastical states. The set of basic geographic controls comprises a variable measuring the average distance of 1,000 randomly distributed points within a state to the closest major river, its maximum elevation above sea-level, and its average ruggedness. Climate controls include the fraction of a state's area with luvisol soil that benefits most from plowing and measure for the average temperature in a state. The control variables in "Economic Factors and Resources" include variables measuring the average distance of 1,000 randomly distributed points within a state to the closest Roman road, major medieval trade route, trade fair, gold, copper, silver, iron, lead, potassium salt or rock salt deposit.

The results are in line with our expectations. There is an economically sizable and statistically at least marginally significant relationship between caloric observability and the Reichsmatrikel contributions of each state. The most conservative estimate from column (6) implies that a one percent increase in caloric observability is associated with an increase in the Reichsmatrikel contribution of 0.17 percent, which is not only statistically significant but sizable from an economic point of view too. The results on soil suitability (not observability) suggest that it is relevant to the Reichsmatrikel contributions as well.

3. Observability and Taxation in 1545 Württemberg

We conclude the empirical analysis by exploring the association between caloric observability and (wealth) tax revenues in the 16th century Duchy of Württemberg by estimating the following OLS equation:

$$ln(TAX)_i = \alpha + \beta ln(COI_i) + \gamma' \mathbf{X_i} + \epsilon_i, \tag{5}$$

where $ln(TAX)_i$ is the natural logarithm of tax revenue of municipality i in 1545, or of the tax revenue per capita (taxable wealth per capita). $ln(COI_i)$ is the natural logarithm of a municipality's average caloric observability, and $\mathbf{X_i}$ is a vector of control variables. These variables include distance to the Rhine and Neckar (the major rivers in the area), and to the capital city Stuttgart, maximum elevation and average terrain ruggedness of each municipality, its average caloric suitability, Roman road density, foreign market potential in 1500, the length of trade roads through it, the share of a municipality's area settled already during Neolithic times, its exposure to the Black Death (calculated as distance-weighted average of the mortality rates of the cities around it during the Black Death epidemic in 1347/48), a dummy variable equal to one if historically equal partition was the dominant mode of inheriting agricultural property in the municipality and the number of water mills active during the 16th century in a municipality. These variables account for relevant differences in geography, economic prosperity—and thus, potentially alternative sources of taxable wealth— and settlement history of each of the municipalities.

Table 4: *Caloric Observability and Municipal Tax Revenues in Württemberg in 1545*

Dependent Variable	ln(Tax Revenue)						ln(Tax Revenue per capita)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(Caloric Observability)	0.443***	0.306***	0.318***	0.317***	0.271***	0.259***	0.0842**
	(0.0652)	(0.0733)	(0.0710)	(0.0724)	(0.0727)	(0.0718)	(0.0335)
Distance to Rhine or Neckar		-0.0148***	-0.0232***	-0.0290***	-0.0263***	-0.0258***	-0.00542**
		(0.00373)	(0.00417)	(0.00517)	(0.00519)	(0.00509)	(0.00231)
Elevation (max)		-0.000731***	-0.000783***	0.000272	0.000420	0.000762*	-0.000126
		(0.000259)	(0.000255)	(0.000377)	(0.000379)	(0.000397)	(0.000170)
Terrain Ruggedness (mean)		0.00231***	0.00179**	0.00164**	0.00113	0.000925	-0.000322
		(0.000777)	(0.000748)	(0.000736)	(0.000741)	(0.000746)	(0.000332)
Caloric Suitability		0.0367***	0.0394***	0.0328***	0.0283***	0.0297***	0.00409*
		(0.00497)	(0.00488)	(0.00522)	(0.00536)	(0.00531)	(0.00245)
Roman Road Density			1.133***	1.116***	1.063***	1.169***	0.277**
			(0.326)	(0.317)	(0.310)	(0.317)	(0.138)
No. of Water Mills			0.123**	0.111**	0.121**	0.124**	0.000528
			(0.0566)	(0.0546)	(0.0566)	(0.0576)	(0.0233)
Foreign Market Potential			1.239***	2.613***	3.025***	3.308***	-0.123
			(0.372)	(0.624)	(0.625)	(0.613)	(0.276)
Trade Roads (km)			0.190**	0.184**	0.179**	0.155*	0.133***
			(0.0801)	(0.0753)	(0.0766)	(0.0819)	(0.0457)
Share of Neolithic Settlement Area				0.997***	0.917***	0.829***	0.480***
				(0.289)	(0.290)	(0.286)	(0.128)
Black Death Potential				-0.672***	-0.816***	-0.756***	0.216**
				(0.226)	(0.225)	(0.222)	(0.0991)
Equal Partition					0.350***	0.276***	-0.0242
					(0.0883)	(0.0904)	(0.0461)
Distance to Stuttgart						-0.00907***	-0.000623
						(0.00264)	(0.00116)
Observations	662	660	660	660	660	660	660
R^2	0.069	0.168	0.228	0.255	0.268	0.280	0.151

Notes. Heteroskedasdicity robust standard errors are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a municipality in Baden-Württemberg in 1953. All regressions include a constant not reported.

Huning and Wahl (2021a) provide detailed information on all the variables and their sources.[18] ϵ_i is the error term.

Table A.4 in the Appendix reports descriptive statistics of the variables included in the regressions, and Table A.5 provides bivariate correlations. Figures A.8 and A.9 in the Appendix show scatter plots of the bivariate relationship between the natural logarithm of caloric observability, tax revenue, and tax revenue per capita. They show a clearly positive and statistically significant relationship to caloric observability for both variables. This is not driven by outliers.

Table 4 reports the results of the regressions. They suggest a robust and positive relationship between caloric observability and tax revenues within the Duchy of Württemberg. Reassuringly the estimated elasticity with all controls included is similar to the other estimates, suggesting that a one percent increase in observability increases tax revenues by around 0.25 percent.

These results confirm the relationship between financial capacity and caloric observability, also within large territorial states.

V. Conclusion

This paper studies the determinants of fiscal capacity in medieval Europe, the Holy Roman Empire and the Duchy of Württemberg. We are among the first to study the role of appropriability within the context of Europe. We present a theoretical argument linking observability of agricultural output to administrative and fiscal capacity. We provide empirical support for this idea using different data sets and by introducing a new, uniquely detailed data set on the states of the Holy Roman Empire. We conclude that observability of agricultural output, specifically via its impact on fiscal capacity was an important determinant of state capacity.

Our results provide evidence for the interaction of agriculture, climate, and geography in explaining political outcomes, such as fiscal capacity. This adds a new perspective to the

18. The number of water mills is the only variable not included in Huning and Wahl (2021a). It is based on a geo-referenced list of historical water mills in Germany from http://milldatabase.org/home, a gazetter of historical water and wind mills hosted and edited by the "Deutsche Gesellschaft für Mühlenkunde und Mühlenerhaltung" (German Foundation for Research and Maintenance of Mills). Furthermore, it builds on information in the mills data base of the International Molinology society http://gpsdatabase.molinology.org, the database of the blogus website www.blogus.de (a private website hosted by a paper mill enthusiast but reporting all the source of the information), various other websites on mills in certain areas like the south-east of Baden-Württemberg (http://www.muehlenstrasse-oberschwaben.de/muehlenuebersicht) and Bayerl (1987) a book on the history of paper mills in Germany.

influential literature that links geography, climate and agriculture to long-run differences in economic outcomes (Diamond 1999; Olsson and Hibbs 2005). We introduce a GIS measure of observability of agricultural output which calculates the degree of information asymmetry in an early society. As this index is well grounded in theoretical economic reasoning, it can be applied to other research in political and economic history, and long-run development.

The evidence suggests that our story holds across historical European states. Further exploration of this will require more detailed data, or different avenues of exploitable exogenous variation in observability. An especially interesting question is which specific historical developments link geography, observability, and the development of state capacity. Studying other European regions, focusing on the mechanisms, and the discovery of exogenous variation are promising avenues for future research. With this paper, we introduce a new, more comprehensive and detailed database on the states of the Holy Roman Empire from the Middle Ages until the French Revolution. It contains data on the location and borders of the historical states as well as the evolution of their status, and the reasons for their disappearance. We hope that this database can be used for a variety of future research in this and adjacent areas, for example for research concerned with the causes and consequences of political fragmentation and instability, or the location of borders.

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Appendix (For online publication only)

A.1. Dependent Variable

A.1.1. The Underlying Maps

The area of a state ("reichsunmittelbares Territorium") is calculated based on shapefiles created from maps of the non-Italian parts of the Holy Roman Empire printed in Wolff (1877). One of those maps, "Deutschland beim Tode Karl des IV. im Jahre 1378" ("Germany at the death of Charles IV. in the year 1378") is shown below in Figure A.1. Note that this map incorrectly includes the state of the Teutonic Order, so when digitizing the map we excluded this area.[1] To cross-validate the map of we consulted several other historical atlases, including those of Darby and Fullard (1978), Stier et al. (1956), and Andree (1886), or Baldamus, Schwabe, and Koch (1914).

Note: This figure shows the original map of the HRE as printed in Wolff (1877). For our empirical analysis we digitized this map using GIS software.

Figure A.1: *Germany at the Death of Charles IV. in the Year 1378 (Wolff 1877)*

1. The maps are available here: http://gei-digital.gei.de/viewer/javax.faces.resource/pdf-icon32.png.xhtml?ln=images/ (accessed on January 22, 2016).

A.1.2. Frequency and Type of Territories in the HRE

Overall, we identified 730 independent states, including 81 city states, 89 ecclesiastical territories (bishoprics, archbishoprics and monastic states), and 560 secular territorial states. The latter group consists of two kingdoms, Bohemia and Prussia, 48 duchies, 80 principalities[2], 16 republics (all of them in today's Switzerland), 217 counties[3] and 180 "Herrschaften" (territories ruled by "Freiherren" (barons)). Furthermore, there were seven Imperial territories (directly controlled by the Emperor), among them were six "Landvogteien" (Grand Bailiffs) and one territory, the Staufian lands, controlled by the Staufian Emperors during the 11^{th} to 13^{th} century. There are also four territories that were occupied by the Swedes after the Thirty Years' War. Finally, there are nine electorates (among them three archbishoprics already counted above), which are considered to be the most powerful states of the HRE and are treated as an own category.[4]

A.1.3. Historical Background to the Sampling Years

(i) 1250 was the year of the death of Frederick II., the last Emperor of the Staufer dynasty. The Staufer dynasty had ruled the Empire as kings and emperors for more than 110 years. The whole dynasty (and with them central power) collapsed soon after, in 1254, when his sole male heir Konrad IV., who was King of Germany but never Emperor, died. Following the collapse of the Staufer dynasty, a 20 year period called the "Great Interregnum" began, in which there was no elected Emperor, but four elected kings. The kings were not universally accepted by the powerful princes, and so did not rule the Empire. In this period, known as an age of insecurity, violence, and anarchy, many of the numerous city state (free and imperial cities) emerged and

2. Apart from principalities, we also classify the following states into this category: Nine "Landgrafschaften" (landgraviates), 17 "Markgrafschaften" (margraviates) and two Princely counties (the Princely county of Burgundy and the Princely County of Tyrol). The reason for this is that the rulers of those states (the margrave, the landgrave etc.) were considered to have the same rank as princes (although their names refer to their origins as counties).

3. The 217 counties subsume the following territories with "county" in the name: Four "Pfalzgrafschaften" (county palatinates). In general, the rulers of those territories (the palatinates) were considered to be of a higher rank than ordinary counts (in the case of a "Pfalzgraf" (Palatinate)). One of these county palatinates, the "Pfalzgrafschaft bei Rhein" (County Palatinate of the Rhine) had the status of an electorate from the middle of the 13^{th} century (and was thereafter called "Kurfürstentum Pfalz" (Electorate of the Palatinate)). Thus, it still was called a county palatinate but actually was one of the most influential and powerful states within the Empire. Then, there are also six burgraviates and 207 ordinary "counties". It is important to note that counties were fairly heterogeneous regarding their size, and political importance. The county of Württemberg, for example, for a long time the largest county of the Empire (before it became a duchy in 1495), was larger than some of the principalities or duchies of the time and also had higher tax revenues than some of those higher-ranked territories. Hence, one should not assume counties to be less important or smaller than duchies or principalities.

4. The official title of those states differed. Some of them were called "Kurfürstentümer" (electoral principalities) some are margraviates or county palatinates and the Habsburg monarchy called itself "Archduchy of Austria".

political fragmentation increased further.[5]

(ii) 1378 was the year Emperor Charles IV died. This year marks the peak of the political fragmentation of the Empire—a situation that was made permanent by the Golden Bull of 1356. Furthermore, while considered by some as one of the greatest and most influential medieval German Emperors, he failed to preserve the powerful position of his dynasty, the Luxembourgians, as he pledged away a lot of the territories under his control, in order to pay his large debts. This further weakened central authority and helped to increase the political fragmentation of the Empire.

(iii) 1477 was the year in which Charles the Bold, Duke of Burgundy died. With his death, the Duchy of Burgundy, one of the largest states in Europe, which could be considered an independent, middle-sized power (although de jure part of the HRE), collapsed and was split after violent hostilities. Some parts of the Duchy fell to France and the remainder was integrated into the HRE as smaller political entities (like the Duchy of Brabant). Furthermore, through marriage, the Habsburgs gained control over the remaining parts of Burgundy. Thus, the death of Charles the Bold was the decisive event in the ascent of the House of Habsburg to world power. A period with slowly declining political fragmentation began.

(iv) 1556, the year after the peace of Augsburg settled the confessional division of Germany for the next decades and ended the first wave of religious wars in the Holy Roman Empire. However, it also was the year when Charles V, probably the most powerful European monarch after the fall of Rome, abdicated from the throne due to his setback against the protestant princes and his lack of loyal vassals within the Empire. His reign marked the peak and turning point of the power of the House of Habsburg as his resignation from the throne and its defeat by the princes of the Empire commenced the slow decline of the Habsburg's power.

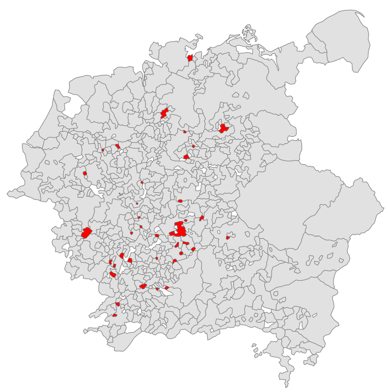
(v) 1648, the year the Thirty Years War ended, with the Peace Treaties of Westphalia. This lead to notable territorial changes, as some large and powerful states like Brandenburg and Hesse integrated smaller territories into their states. Furthermore, several imperial cities disappeared, becoming part of France or of Switzerland (whose independence was officially acknowledged). Finally, it settled the confessional question within the Empire.

(vi) 1789, the year when the French Revolution began and triggered a series of events and

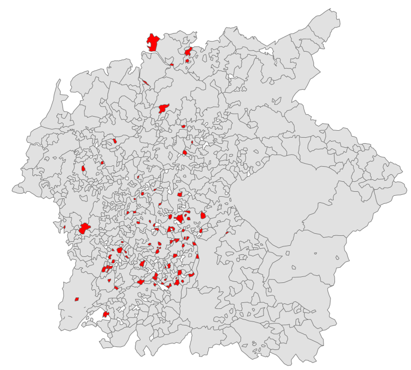
5. Political fragmentation in the 13^{th} century was already much higher than during the 12^{th} century. This was due to the fact that, as a consequence of the struggle between Henry the Lion, Duke of Saxony and Emperor Frederick I., the old and quite large stem duchies ("Stammesherzogtümer") were dissolved and partitioned into smaller (and even further divisible) territories. This should have weakened the position of dukes and princes towards the Emperor and hence strengthen central power, but in the long-run, had the opposite effect.

wars, resulting in the demise of the HRE and the most significant reshaping of the landscape of states in Central Europe since the dissolution of the stem duchies in the 12^{th} century.

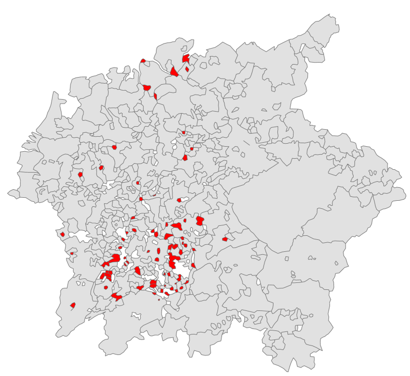
A.1.4. States in the Holy Roman Empire 1250–1789



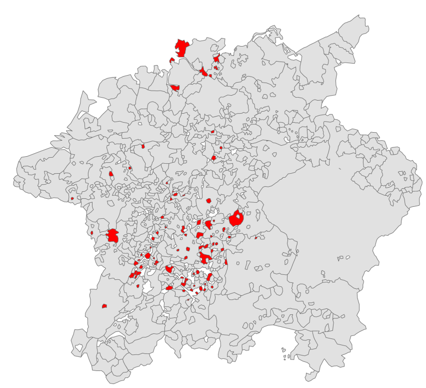
(a) *HRE 1250*



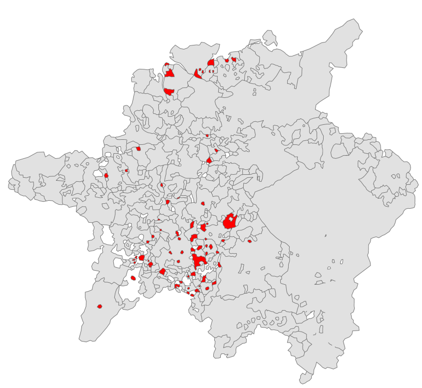
(b) *HRE 1378*



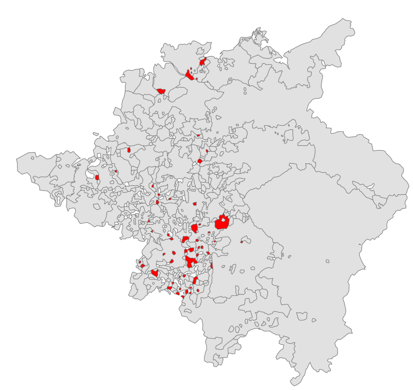
(c) *HRE 1477*



(d) *HRE 1556*



(e) *HRE 1648*



(f) *HRE 1789*

Figure A.2: *The Holy Roman Empire and its territorial states (gray) and city states (red) at our sampling years*

A.1.5. Coding Challenges and Discussion of Difficult Cases

Typical difficulties in the coding of the data originate from errors as to name, type of state or omission of an existing state. Such problems mostly arose in the case of small states on which information is limited even today (typically some “Herrschaften”, states ruled by a baron or an imperial knight), when there were several territories with the same name (e.g. “Limburg”) or for a few of Imperial cities in the Alsac-Lorrain region which Wolff forgot.[6] However, we were able to resolve almost all of these issues, sometimes by consulting additional sources such as books by local historians.

Another difficulty was determining the start and end point of a states’ independence. The latte was problematic, when, for example, a states was split up between the sons of a ruler and three family lines ruled over three different parts of the former territory. Here, Wolff not always correctly recorded the division of the state, which we resolved. Sometimes, after a ruling dynasty died out due to a lack of a male heir (or after a war about its heritage) a territory was partitioned between several other rulers. In this case, we decided whether to assign the territory to the state that had the majority of rights or whether it remained an independent state (when there was no clearly dominant party).

This was the case, for example, for the county of Sponheimwhich consisted at the beginning of the 14$^{\text{th}}$ century, of two separated territories, the “Vordere” and “Hintere” Grafschaft of Sponhein. When the dynasty ruling the “Vordere Grafschaft” (the front county) died out, one fifth of the County went to the Electoral Palatinate and four fifth to the Count controlling the “Hintere Grafschaft” (the back county). After 1437, the Margrave of Baden and the Count of Veldenz inherited both parts of the County. Both rulers decided not to split the County but to rule it together as a condominium. Another change occurred in 1559, when the Princedom of Pfalz-Simmern (who had inherited the part of the County of Veldenz) bought the Electoral Palatinate’s shares in the “Vordere Grafschaft”. Simultaneously, it decided to give away the half of the “Hintere Grafschaft” to the Duchy of Pfalz-Zweibrücken. This resulted in the following situation: the “Vordere Grafschaft” belonged three fifths to Pfalz-Simmern (since 1559 Electoral Palatinate) and two fiftha to Baden. The “Hintere Grafschaft” belonged half to Baden and half to Zweibrücken. Finally, in 1707, the Margraviate of Baden-Baden and Electoral Palatinate split up the “Vordere Grafschaft” and in 1776, the “Hintere Grafschaft” was split in half by the Margrave of Baden and the duke of Pfalz-Zweibrücken. After 1815 the territory was integrated into Prussia and disappeared. In 1477 and 1555, i.e.

6. Another case was that of the Imperial city of Friedberg and the burgraviate of Friedberg, located around a castle next to the city. The latter was a very small county around the castle of Friedberg that was involved in various conflicts with the nearby Imperial city. Wolff does not include both territories before the 1789 map, where he drew a territory called Friedberg and marked it as an Imperial city. We split this territory between the Imperial city and the burgraviate from 1250 to 1378. In 1477 the Imperial city lost its independence (it was under the control of the burgraviate then for most of the time) and thus, we assigned the whole territory to the burgraviate in the later maps—the burgraviate existed until 1806.

during the condominium, we decided to consider the whole territory as county of Sponheim. Wolff, in his 1556 map has assigned the four separate territories of the county to either Pfalz-Simmern or Baden-Baden, Pfalz-Zweibrücken and the Electoral Palatinate. One cannot be sure whether he has assigned it to Pfalz-Simmern or Baden-Baden as both have the same color. In addition, this does not reflect the actual situation in 1556 (according to our sources), rather this is the situation in 1559 (when one assumes that he has assigned the "Vordere Grafschaft" to Baden and not to Pfalz-Simmern). For 1648 and 1789 we follow Wolff, who no longer included the county of Sponheim but assigned its territory to Pfalz-Zweibrücken, Electoral Palatinate and Baden-Baden (or Baden, respectively).

A lack of clarity about when a territory ceased to be an independent state typically arose also because Wolff (and other historians) followed a tradition of drawing important states (like e.g., the duchy of Berg) as independent ("reichsunmittelbare") states even when they were de facto ruled by other nobles, as was the case for the united duchy of Kleve-Jülich-Berg which was split up again after armed hostilities over the different parts, with one part (the duchy of Kleve and the counties of Mark and Ravensberg) falling in the hands of the margrave of Brandenburg and another part (the duchies of Berg and Jülich) coming under the control of the duchy of Pfalz-Neuburg. In these cases we diverge from the map and make these territories part of Brandenburg or Pfalz-Neuburg, respectively.

Finally, city states are often among those territories for which it was not absolutely clear what degree of independence they had, regardless of their de jure status. It is well known that some cities had gained certain independence from their rulers, while never being officially considered as imperial cities. By the same measure, there were imperial cities that were never truly independent of their former ruler although they were granted "Reichsunmittelbarkeit" by the Emperor. We consulted standard sources on the history of German cities such as Köbler (1988) or Keyser and Stoob (1939–1974) and other studies on imperial cities, including Cantoni (2012) and followed their judgment about whether a city was de facto, and not just de jure, an imperial city. This is also an issue for several territories that were ruled by the Emperor or another high-ranked noble (like an elector) but where never part of their core territory. Two of these territories were the magraviates of Ober- and Niederlausitz (Upper and Lower Lusatia). Hence, some historians argue that the power of those rulers over the territory was limited if non-existent. Therefore, we decided to treat the Lausitz territories as independent states.

A.2. Control Variables

A.2.1. Relevant Explanatory Factors

Agricultural conditions. A vast body of literature has pointed at soil quality as an indicator for development (e.g., Diamond 1999; Olsson and Hibbs 2005) and decisive factor for the development of statehood Jones (1981). For example, von Thünen (1826) and more recently Lindert (1999) and Kopsidis and Wolf (2012) have pointed at the link between urban development and soil quality. Furthermore, the vast majority of the population was employed in agriculture and had to feed the growing urban population which produced all the innovations and proto-industrial activity. Thus, to account for the effect of the level of soil quality on state development and the tax basis, we use the caloric suitability index by Galor and Özak (2014, 2015) that we already have used to construct the observability index. A necessary prerequisite for crop farming was *deforestation*, which was mostly finished by the 12th century (Wilson 2016). We digitized data on areas still forested (or otherwse non-arable, for example, marsh land) during the Middle Ages, which is available for modern Germany from Schlüter (1952). With this variable we control for the share of a territory's area that was not deforested by the early Middle Ages. Finally, a growing body of literature is concerned with the *effects of specific crops*, such as the potato, on various economic outcomes (Nunn and Qian 2011) and more recently Berger (2017). We therefore employ both the pre-1500 and post-1500 specification of the caloric suitability index. Finally, we include the *average temperature* to account for climatic variations over time that could affect the agricultural output in each state.

Border States. Recently, economic research has found evidence that state capacity within historical and contemporary developing countries varies depending on the remoteness of a region (Olsson and Hansson 2011; Michalopoulos and Papaioannou 2014). Thus, in peripheral areas state capacity might be weaker. Looking at the HRE, it is evident that many of the border states were politically unstable and conflict-prone, and eventually gained independence from the Emperor (e.g. the Dutch Republic, Switzerland, the northern Italian cities etc.). Thus, we created a variable to identify countries that are located on the *outer border of the HRE* in each of our sampling years, to account for this. This also takes into account spatial effects of outward threats, especially the expansion of France and the Ottoman Empire (see (Iyigun 2008)).

Heavy Plough. Alesina, Giuliano, and Nunn (2013) and Anderson, Johnson, and Koyama (2016) document a profound impact of the introduction of the heavy plough on gender inequality and city development. Thus, it is very likely that it could also have affected state capacity, e.g. due to significantly increasing the productivity of agriculture within a state that adopted the plough (or adopted it earlier). Higher productivity of agriculture increased agricultural output and therefore the absolute tax basis of a state. We account for the effect of the heavy plough by a variable measuring the fraction of a states' area that was endowed with *luvisol soils*, a type of soil that particularly benefited from ploughing.

Natural Resources. It is well established that the availability of natural resources such as gold, silver, salt and copper was a decisive factor determining a country's state capacity and tax revenues. Where minerals could have been exploited, mining was an alternative to agriculture, and rulers could generate high revenues from mining activities (historically particularly true for the Harz area and Saxony). To account for differences in natural resource endowments, we digitized maps of the geographic location of *copper, gold, lead, salt (rock salt and potassium salt) and silver*. Based on these maps we calculated a variable giving the average distance from 1,000 randomly generated points within a state to the next deposit of those resources. Additionally, we have data on areas within contemporary Germany that were still forested in the Middle Ages and hence provided a supply of wood—one of the most important raw materials in the pre-modern economy.

Outmigration. As discussed above, outmigration to Imperial cities posed a vital threat to the financial base of medieval and early-modern states. Thus, we compute a variable that proxies the outmigration opportunities by the average distance from 1000 randomly generated points within a state to the next Imperial city.

Terrain Characteristics. We also control for the *maximum elevation* above sea level and average ruggedness of a states' territory, using the digital elevation model provided by thee U.S. Geological Survey's Center for Earth Resources Observation and Science (EROS). Both factors could affect state capacity because they have an influence on the defensibility of the area of a state and the appropriability of agricultural output (Scott 2009). Ruggedness could also have a direct influence on animal husbandry (see (Eder and Halla 2017)) other than agglomeration (Kopsidis and Wolf 2012). Taxation of animal husbandry could be different to taxation of crops.

Trade and Tariff Income. Trade affects our analysis in many different ways. First, trade was a source of revenue, as trading cities were usually wealthy and generated large tax revenues. Furthermore, trade took place along *trade routes, rivers and Roman roads* therefore rulers could impose tolls on trade routes and navigable rivers within their territories (Heckscher 1955).[7] Tariff income from such road tolls could be significant and made some territories e.g., those straddling both sides of the Rhine, very wealthy.[8] Finally, if a lot of rivers or trade routes were located within a state, it was easier for its citizens (and the ruler) to access commercial centers. Therefore, these states profited from better market access and lower transaction costs. We proxy for these advantages with variables measuring the average distance from 1000 randomly generated points within a state to the next Roman road, trade route or major navigable river. We also control for *trade fairs*, which were identified by Milgrom, North, and Weingast (1990), and more recently Edwards and Ogilvie (2012) as classic example of medieval trade institutions. With respect to access to *financial*

7. There is a growing literature documenting the importance of the Roman road network for the long-run development of Europe (e.g.Wahl (2017)). This makes it even more important to account for the Roman road network and its possible effects.

8. The small sizes of states introduce competition between them over trade routes, so that any single state can only raise its overall revenues from tariffs to the level that drives traders to change their routes (Huning and Wolf 2016).

markets, the results of Volckart and Wolf (2006) suggest that there is a strong correlation between the spatial pattern of the integration of commodity markets on the one side, and financial markets on the other. We therefore assume to have controlled for spatial variation of financial integration with the above.

War and Conflicts. Several authors have argued that war and conflicts were a driver for state capacity in Europe, e.g. because of competition between states fostering technological and organizational innovations (e.g. in taxation technologies) (Hoffman 2011; Karaman and Pamuk 2013; Tilly 1975). We construct a variable measuring the *number of battles* that had taken place within a state between 800 and 1378 AD, normalized by a state's area. Romer (2009) and Acemoglu et al. (2011) have pointed to the benefits of importing efficient political institutions, which in our historical setting is captured either via trade as a market for ideas, or conflicts. Radical modernization occurs well after the period in our study (also see Mokyr (2011)).

A.2.2. Definitions and Sources of the Variables

The spatial datasets were each converted into WGS 1984 UTM 32N projection. State type and "State in 1150" dummies are calculated from the shapefiles of Wolff's maps (1877). This is also the case for the variable "Outer Boundary" reporting the share of a states' border that is an outer boundary of the HRE.

Administrative Buildings in Cities. Number of administrative buildings constructed in a city included in the "Deutsche Städtebuch" (Handbook of German Cities) (Keyser and Stoob 1939–1974) between 1400 and 1477 and between 1477 and 1556. Data comes from Cantoni, Dittmar, and Yuchtman (2018).

Average Terrain Ruggedness. Following Riley, DeGloria, and Elliot (1999) average ruggedness of a states' territory is calculated as the negative value of the derivative of the ruggedness index of a digital elevation model. The calculations are based on the elevation raster of Nunn and Puga (2012) (see above). Terrain ruggedness was calculated using QGIS.

Average Temperature. Historical average temperature for a state is taken from the data set of Guiot and Corona (2010). They constructed a grid cell database of historical European temperatures and their deviations from the average temperature in 1960–1990. We use this data set to calculate, for each state, the average temperature deviation in the period from 800 to 1378. To calculate the average temperature deviations for each grid we follow the interpolation procedure of Anderson, Johnson, and Koyama (2016) by filling in missing values with the inverse distance weighted average temperature of the twenty-four nearest neighbor grid points.

Battles per Area. Number of battles per km^2 that have taken place in a state in the period between two of our maps (e.g. between 800 and 1250 between 1250 and 1378, between 1378 and 1477 etc.). Information of the date and location of the battles is taken from Bradbury (2004), Clodfelter (1992) and Darby and Fullard (1978).

Distance to Major Rivers. Distance to major rivers is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. In a second step, the Euclidean distance from each of the 1,000 points per state to the to the closest major river (see Figure A.4) was calculated. In a last step, these distances were aggregated by state. For the location of the rivers, we used the dataset for 'WISE large rivers' shapefile, which can be downloaded here: http://www.eea.europa.eu/data-and-maps/data/wise-large-rivers-and-large-lakes(last accessed May, 30th 2016).

Distance to Natural Resources. We have calculated seven variables reporting the distance to natural resources (copper, gold, iron, lead, potassium salt, rock salt and silver). Distance to natural resources is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. In a second step, the Euklidean distance from each of the 1,000 points per state to the closest deposit of the respective natural resource was calculated. In a last step, these distances were aggregated by state. The location of natural resource deposits is taken from Frenzel (1938) and Elsner (2009).

Distance to Roman Roads. Distance to (minor and major) Roman roads is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. In a second step, the Euclidean distance from each of the 1,000 points per state to the to the closest Roman road was calculated. These distances were aggregated by state. Locations of Roman roads (minor and major) originate from a shapefile included in the "Digital Atlas of Roman and Medieval Civilizations" (McCormick et al. 2013). The shapefile is based on the map of Roman roads in the Barrington Atlas of the Greek and Roman World (Talbert 2000). It can be downloaded here: http://darmc.harvard.edu/icb/icb.do?keyword=k40248&pageid=icb.page601659 (last accessed September, 24th 2015).

Distance to Medieval Trade Road. Distance to medieval trade routes is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. The Euklidean distance from each of the 1,000 points per state to the to the closest medieval trade route was calculated. In a last step, these distances were aggregated by state. Location of trade routes are obtained by digitizing a map on "Medieval Commerce" from Shepherd (1923). The map can be downloaded as pdf from here: https://www.lib.utexas.edu/maps/historical/shepherd/europe_mediaeval_commerce.jpg (last accessed July, 10th 2017).

Distance to Trade Fairs. Distance to trade fair is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. The Euclidean distance from each of the 1,000 points per state to the to the closest trade fair city was calculated. These distances were aggregated by state. The locations of the fairs were taken from Ditchburn and Mackay (2002).

Cities per Area. Number of cities per state that are included in the "Deutsche Städtebuch" (Handbook of German Cities) (Keyser and Stoob 1939–1974) between 1400 and 1477 and between 1477 and 1556. The number is divided by the area of a state in km^2 from our maps. Data on city locations comes from (Dittmar and Meisenzahl 2019).

Latitude. Minimum longitudinal coordinates a states' centroid (mid-point) in meters. Calculated using QGIS.

Longitude. Minimum longitudinal coordinates of a states' centroid (mid-point) in meters. Calculated using QGIS.

Market Potential in 1500. A state's market potential is calculated following the methodology of Crafts (2005). Unlike Crafts measure of regional economic potential, our measure is not based on the GDP of all other municipalities, but on the population size of the historical cities included in the database of Bairoch, Batou, and Chevre (1988).

Maximum Elevation. Maximum elevation of each state in meters. Data is based on the Digital Elevation Model (DEM) of the U.S. Geological Survey's Center for Earth Resources Observation and Science (EROS), namely the GTOPO30 dataset, which can be downloaded here https://lta.cr.usgs.gov/GTOPO30 (last accessed May, 30th 2016). The GTOPO30 has a spatial resolution of 30 arc seconds.

Plough Suitability. Plough suitability of a states' soils are measured by the share of its area which has luvisol soils. Data on location of luvisol soils is taken from the European Soil Database version 2 provided by the European Soil Data Center (ESDAC). We used the 1km*1km raster data set downloadable here[9]

Pre-Historic Settlement Area. We have computed the (natural logarithm of the) area within each state that was already settled in pre-historic times (in m^2). This information stems from Schlüter (1952).

9. http://esdac.jrc.ec.europa.eu/content/european-soil-database-v2-raster-library-1kmx1km (last accessed June, 20th 2017).

Table A.1: *Descriptive Overview of the Nüssli-based Data Set of European States*

Variable	Obs.	Mean	Std. Dev.	Min	Max
			1200		
Elevation (Max)	238	1,085	1,063	11	4,415
Island	267	0.0150	0.122	0	1
Latitude	267	47.21	6.047	28.34	59.30
ln(Area)	267	8.840	1.545	4.242	13.54
ln(Caloric Observability)	267	5.452	1.142	2.577	8.134
ln(Caloric Suitability)	267	7.548	0.330	5.105	7.940
Longitude	267	10.17	13.36	-15.66	46.46
Market Potential	298	269,553	139,757	61,928	625,262
Terrain Ruggedness (mean)	238	119.5	125.9	3.832	669.8
			1300		
Elevation (Max)	398	1,023	929.4	11	4,415
Island	426	0.0235	0.152	0	1
Latitude	426	47.49	5.706	28.34	59.33
ln(Area)	426	8.215	1.561	-0.145	12.30
ln(Caloric Observability)	426	5.519	1.184	2.335	8.134
ln(Caloric Suitability)	426	7.521	0.426	4.750	7.976
Longitude	426	8.735	11.44	-15.66	44.56
Market Potential	490	648,413	334,722	149,431	1.643e+06
Terrain Ruggedness (mean)	398	127.4	123.5	2.377	699.0
			1400		
Elevation (Max)	430	987.1	879.1	7	4,415
Island	465	0.0108	0.103	0	1
Latitude	465	47.47	5.644	28.34	59.01
ln(Area)	465	8.108	1.670	-2.745	13.38
ln(Caloric Observability)	465	5.538	1.147	2.593	7.920
ln(Caloric Suitability)	465	7.530	0.416	4.993	7.979
Longitude	465	8.561	11.77	-15.66	43.06
Market Potential	511	551,310	271,762	124,980	1.435e+06
Terrain Ruggedness (mean)	430	125.1	118.6	2.944	792.7
			1500		
Longitude	1	9.498	11.72	-16.94	42.80
Elevation (Max)	512	1,022	893.1	4	4,415
Island	550	0.0145	0.120	0	1
Latitude	550	47.59	5.486	28.34	60.11
ln(Area)	550	8.116	1.565	1.386	13.27
ln(Caloric Observability)	550	5.536	1.218	-2.216	7.985
ln(Caloric Suitability)	549	7.508	0.645	-3.599	8.002
Market Potential	611	729,998	323,468	164,837	1.669e+06
Terrain Ruggedness (mean)	512	130.7	136.3	2.431	868.9

Table A.2: *Descriptive Overview of Administrative Buildings in the States Data Set*

Variable	Obs	Mean	Std. Dev.	Min	Max
Average Temperature	362	0.200	0.0297	0.0846	0.334
Battles per km^2	362	0.0166	0.128	0	1
Cities per Area	362	0.0107	0.00925	0.000824	0.0703
City State	362	0.257	0.438	0	1
County	362	0.262	0.441	0	1
Distance to Copper Deposit	362	137,721	61,017	8,989	256,380
Distance to Gold Deposit	362	75,540	51,091	0	253,460
Distance to Iron Deposit	362	68,996	45,247	0	238,981
Distance to Large River	362	37.04	21.73	1.643	95.86
Distance to Lead Deposit	362	115,152	54,897	8,277	281,051
Distance to Pottasium Salt Deposit	362	98,767	66,971	4.956	306,831
Distance to Rock Salt Deposit	362	130,759	85,317	110.8	354,646
Distance to Roman Road	362	90.62	114.1	1.112	449.2
Distance to Silver Deposit	362	329,623	104,372	57,411	513,267
Distance to Trade Fair	362	195,392	90,173	6,041	577,655
Distance to Trade Route	362	35.86	25.20	1.366	119.4
Duchy	362	0.0359	0.186	0	1
Ecclesiastical State	362	0.227	0.419	0	1
Electorate	362	0.0166	0.128	0	1
Elevation (max)	362	527.6	254.5	36	1,170
Herrschaft	362	0.160	0.367	0	1
Kingdom	362	0	0	0	0
ln(Administrative Buildings)	362	0.383	0.646	0	3.219
ln(Caloric Observability)	362	2.910	0.766	1.235	5.386
ln(Caloric Suitability)	362	7.523	0.194	6.943	7.814
Markgraviate	362	0.00829	0.0908	0	1
Outer Boundary	362	0.00172	0.0214	0	0.373
Princedom	362	0.0304	0.172	0	1
Republic	362	0	0	0	0
Share of Luvisol Soils	362	5.157	2.422	0.0968	16.07
Terrain Ruggedness (mean)	362	72.78	45.03	5.427	263.4

Table A.3: *Descriptive Overview of the Reichsmatrikel Data Set*

Variable	Obs	Mean	Std. Dev.	Min	Max
Average Temperature	236	0.198	0.0274	0.104	0.300
Battles per $km2̂$	236	7.64e-11	9.68e-10	0	1.47e-08
City State	236	0.292	0.456	0	1
County	236	0.237	0.426	0	1
Distance to Copper Deposit	236	137,959	64,002	14,077	375,289
Distance to Gold Deposit	236	87,427	62,720	0	396,924
Distance to Iron Deposit	236	77,482	54,277	0	367,136
Distance to Large River	236	33.99	23.47	1.180	120.7
Distance to Lead Deposit	236	114,946	66,233	8,968	441,057
Distance to Potassium Salt Deposit	236	109,152	82,417	76.00	452,849
Distance to Rock Salt Deposit	236	122,534	83,754	106.3	354,670
Distance to Roman Road	236	77.57	117.8	1.108	629.9
Distance to Silver Deposit	236	387,944	131,578	57,511	804,887
Distance to Trade Route	236	43.81	32.85	1.373	199.7
Duchy	236	0.0297	0.170	0	1
Ecclesiastical State	236	0.288	0.454	0	1
Electorate	236	0.0297	0.170	0	1
Elevation (max)	236	704.0	637.7	20	3,602
Herrschaft	236	0.0636	0.244	0	1
ln(Caloric Observability)	236	2.593	0.879	0.256	5.249
ln(Caloric Suitaility)	236	7.337	0.540	0	7.766
ln(Reichsmatrikel Contribution)	235	5.772	1.153	2.890	9.388
Markgraviate	236	0.00424	0.0651	0	1
Outer Boundary	236	0.0237	0.0912	0	0.590
Princedom	236	0.0636	0.244	0	1
Republic	236	0.00424	0.0651	0	1
Share of Luvisol Soils	236	4.261	2.591	0.130	16.07
Terrain Ruggedness (mean)	236	99.58	113.2	3.068	685.7

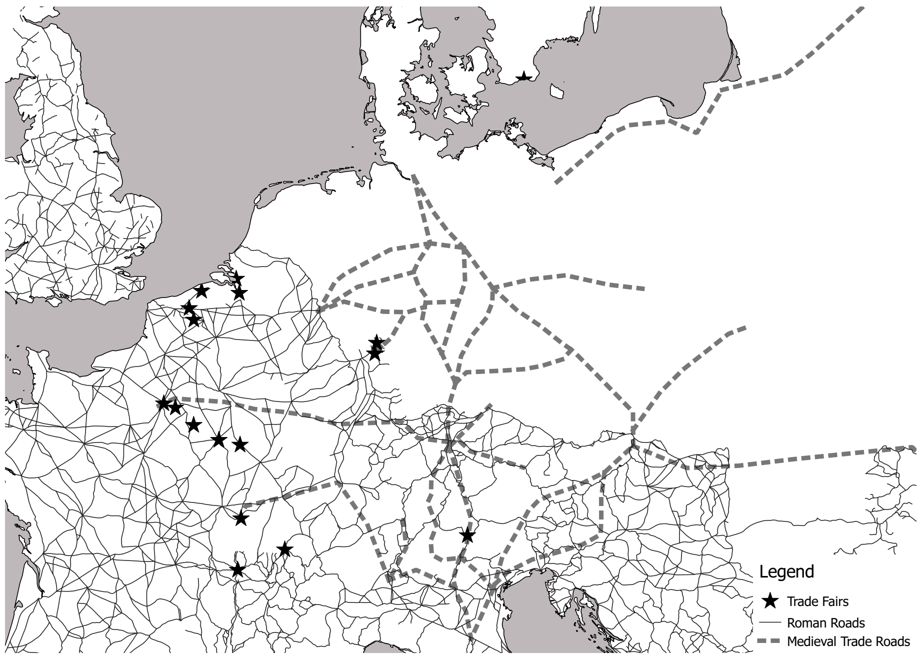
Table A.4: *Descriptive Overview of the Württemberg Municipal Tax Data Set*

Variable	Obs	Mean	Std. Dev.	Min	Max
Black Death Potential	662	18.799	0.377	18.130	20.237
Distance to Rhine or Neckar	662	14.483	11.655	0.000	64.445
Distance to Stuttgart	662	27.342	19.253	0.000	88.472
Elevation (max)	660	531.688	181.476	178.000	983.000
Equal Partition Area	662	0.733	0.443	0.000	1.000
Foreign Market Potential 1500	662	12.141	0.128	12.017	12.865
ln(Caloric Observability)	662	5.318	0.661	3.489	6.491
ln(Tax Revenue in 1545)	662	-1.141	1.119	-3.689	3.679
No. of Watermills	662	0.239	0.897	0.000	12.000
Roman Road Density	662	0.059	0.128	0.000	0.832
Share Neolithic Settlement Area	662	0.067	0.157	0.000	0.947
Soil Suitability (mean)	662	24.358	8.037	5.333	47.122
Terrain Ruggedness (mean)	660	100.380	56.492	17.768	354.297
Trade Roads (km)	662	0.117	0.800	0.000	14.648

Table A.5: *Bivariate Correlations of the Duchy of Württemberg Data Set (Table 1)*

Variables	ln(Tax Revenues per capita)	ln(Tax Revenue)	ln(Caloric Observability)	Distance to Rhine or Neckar	Elevation (max)	Terrain Ruggedness (mean)	Caloric Suitability	Equal Partition	Roman Road Density	Share of Neolithic Settlement Area	No. of Water Mills	Foreign Market Potential 1500	Black Death Potential	Trade Roads (km)	Distance to Stuttgart
ln(Tax Revenues per capita)	1.00														
ln(Tax Revenues)	0.60	1.00													
	(0.00)														
ln(Caloric Observability)	-0.18	-0.26	1.00												
	(0.00)	(0.00)													
Distance to Rhine or Neckar	-0.20	-0.22	-0.02	1.00											
	(0.00)	(0.00)	(0.25)												
Elevation (max)	-0.13	-0.23	0.60	0.22	1.00										
	(0.00)	(0.00)	(0.00)	(0.00)											
Terrain Ruggedness (mean)	-0.10	-0.03	0.46	-0.18	0.47	1.00									
	(0.01)	(0.43)	(0.00)	(0.00)	(0.00)										
Caloric Suitability	0.04	0.24	-0.23	0.13	-0.07	-0.27	1.00								
	(0.27)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)									
Equal Partition	0.12	0.28	-0.28	-0.57	-0.41	-0.07	0.10	1.00							
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)								
Roman Road Density	0.06	0.14	-0.02	-0.13	-0.14	-0.08	0.04	0.19	1.00						
	(0.10)	(0.00)	(0.25)	(0.00)	(0.00)	(0.00)	(0.04)	(0.00)							
Share of Neolithic Settlement Area	0.22	0.27	-0.18	-0.15	-0.22	-0.12	0.09	0.19	0.04	1.00					
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)						
No. of Water Mills	-0.00	0.09	0.06	0.06	0.08	0.09	-0.01	-0.06	0.02	-0.01	1.00				
	(0.98)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.42)	(0.00)	(0.32)	(0.57)					
Foreign Market Potential 1500	-0.08	-0.11	-0.01	-0.16	-0.21	-0.06	-0.23	0.11	0.14	-0.03	0.02	1.00			
	(0.05)	(0.01)	(0.69)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.06)	(0.16)				
Black Death Potential	-0.02	-0.20	0.40	-0.28	0.20	0.23	-0.28	0.03	0.06	-0.03	0.00	0.56	1.00		
	(0.58)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.09)	(0.00)	(0.05)	(0.95)	(0.00)			
Trade Roads (km)	0.23	0.15	-0.01	-0.03	0.02	0.03	-0.03	0.04	0.04	0.01	0.04	0.05	0.11	1.00	
	(0.00)	(0.00)	(0.72)	(0.07)	(0.17)	(0.06)	(0.09)	(0.02)	(0.03)	(0.57)	(0.01)	(0.00)	(0.00)		
Distance to Stuttgart	-0.14	-0.28	0.34	0.11	0.23	0.17	-0.19	-0.25	-0.07	-0.14	0.01	0.34	0.51	-0.10	1.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.45)	(0.00)	(0.00)	(0.00)	

A.3. Geographic Controls

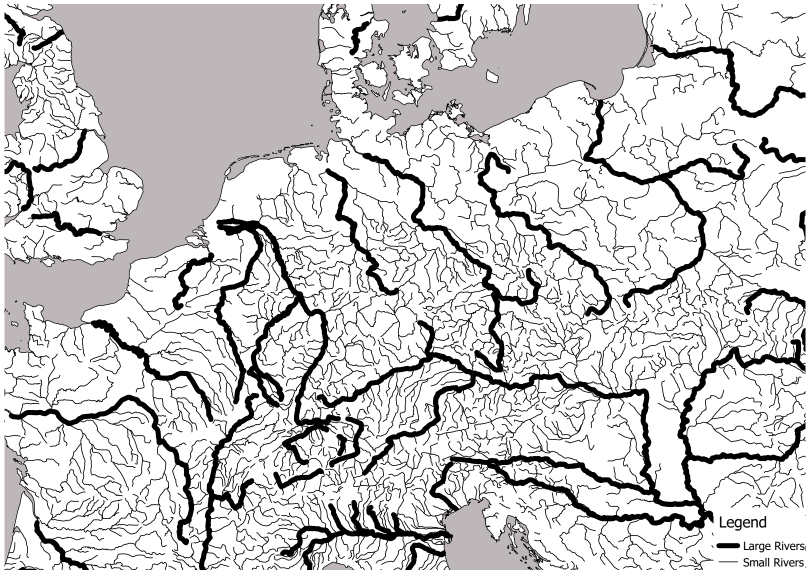


Note: Data on Roman Road was taken from McCormick et al. (2013), medeval trade routes were digitztized from Shepherd (1923). Trade fairs were digitized using modern positions and the towns from Ditchburn and Mackay (2002).

Figure A.3: *Roman & Medieval Roads, Trade Fairs, and Hanseatic Towns*

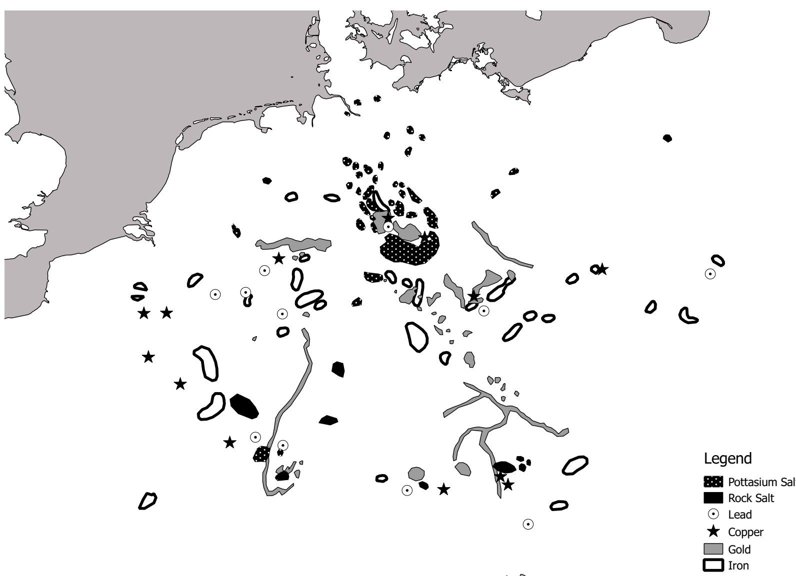
Table A.6: *Inclusion of the trade fairs*

Name	**1250**	**1378**	**1477**	**1555**	**1648**	**1789**
Antwerp	–	✓	✓	✓	✓	✓
Bar sur Aube	✓	✓	–	–	–	–
Bergen ob Zoom	–	✓	–	–	–	–
Bozen	–	–	✓	✓	✓	✓
Bruges	✓	✓	✓	✓	✓	✓
Chalons sur Saone	✓	✓	–	–	–	–
Frankfurt	–	✓	✓	✓	✓	✓
Friedberg	–	✓	–	–	–	–
Geneva	–	✓	✓	✓	✓	✓
Lagny	✓	✓	–	–	–	–
Leipzig	–	–	✓	✓	✓	✓
Lille	✓	✓	✓	✓	✓	✓
Lyon	–	✓	✓	✓	✓	✓
Provins	✓	✓	–	–	–	–
Skanes	✓	✓	✓	✓	✓	✓
St. Denis	✓	✓	✓	✓	✓	✓
Troyes	✓	✓	–	–	–	–
Ypres	✓	✓	✓	✓	✓	✓



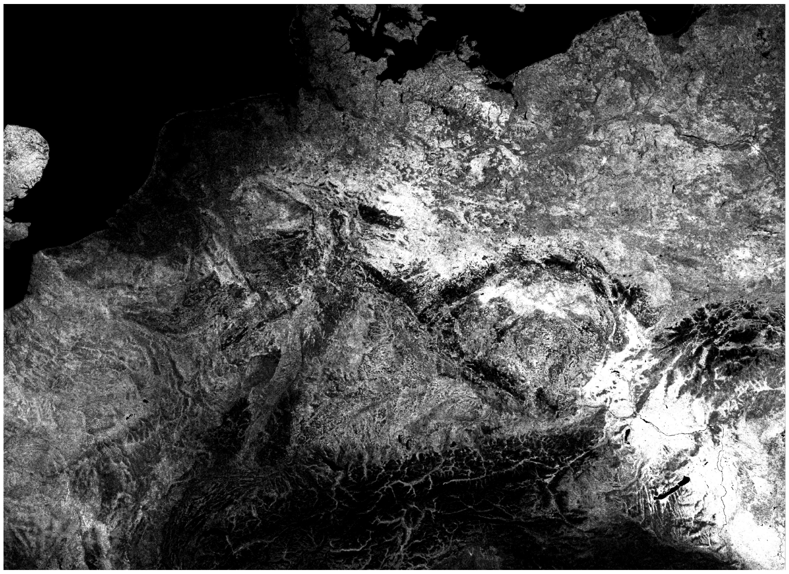
Note: Accessible via http://www.eea.europa.eu/data-and-maps/data/wise-large-rivers-and-large-lakes (last accessed May, 30th 2016)

Figure A.4: *Large and Small Rivers*



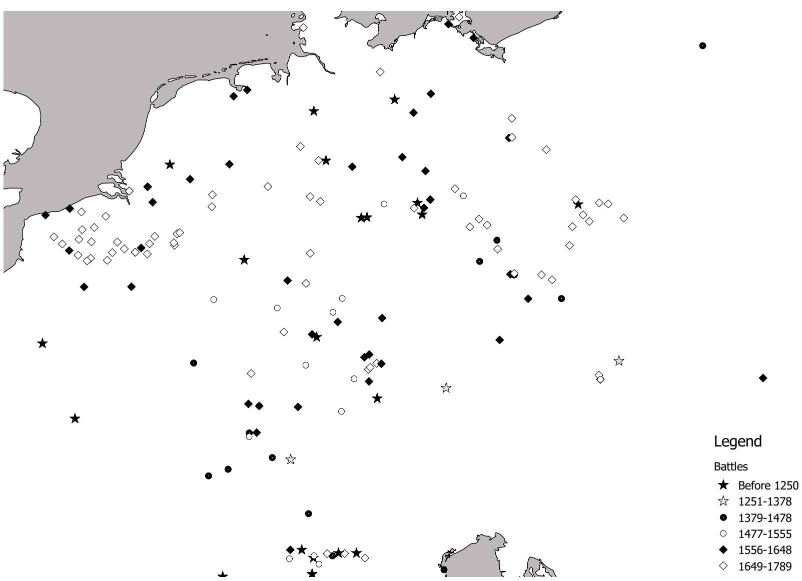
Note: These data were digitized from Frenzel (1938) and Elsner (2009)

Figure A.5: *Mineral Resources*



Note: The instrument from Alesina, Giuliano, and Nunn (2013) shows only minor variation within our sample. We employ the idea by Andersen, Jensen, and Skovsgaard (2016) based on data from Panagos (2006) and Van Liedekerke, Jones, and Panagos (2006).

Figure A.6: *Usage of the Heavy Plough Alesina, Giuliano, and Nunn (2013) and Andersen, Jensen, and Skovsgaard (2016)*



Note: Information of the date and location of the battles is taken from Bradbury (2004), Clodfelter (1992) and Darby and Fullard (1978).

Figure A.7: *Battles*

A.4. Additional Figures

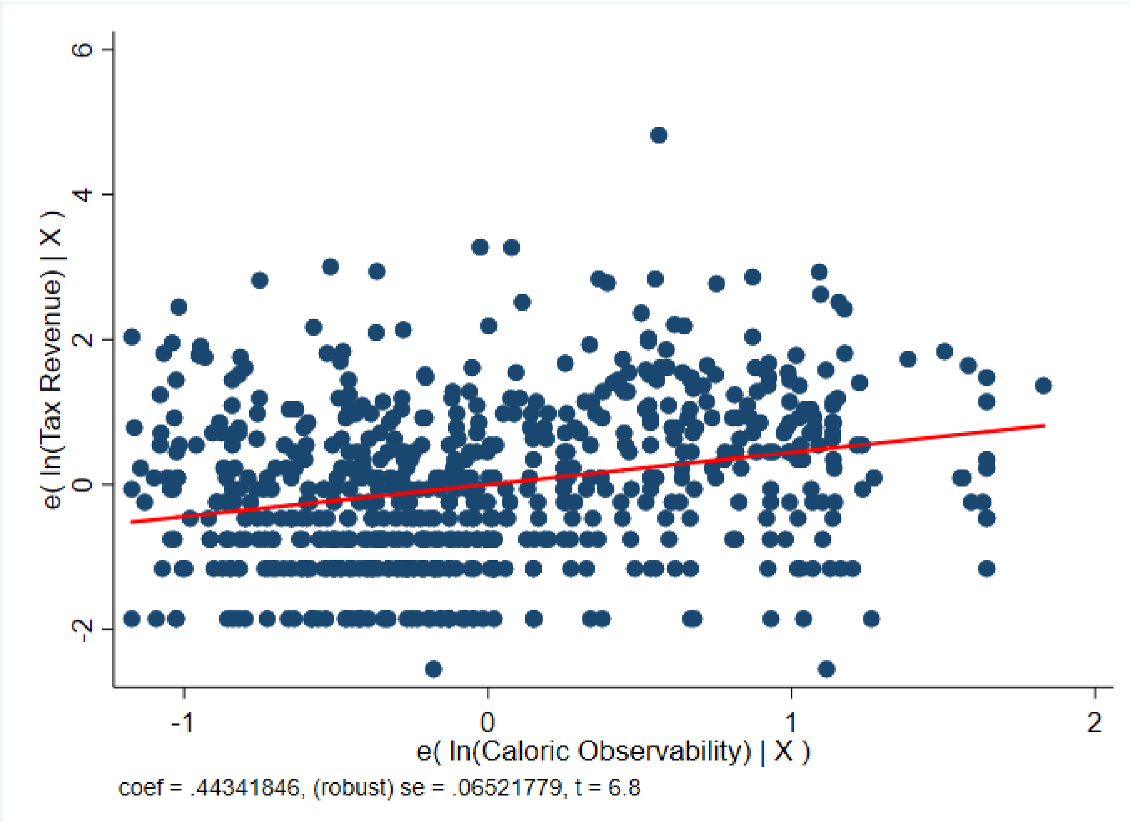


Figure A.8: *Bivariate relationship between ln(Caloric Observability) and ln(Tax Revenue) (as estimated in column (1) of Table (1)).*

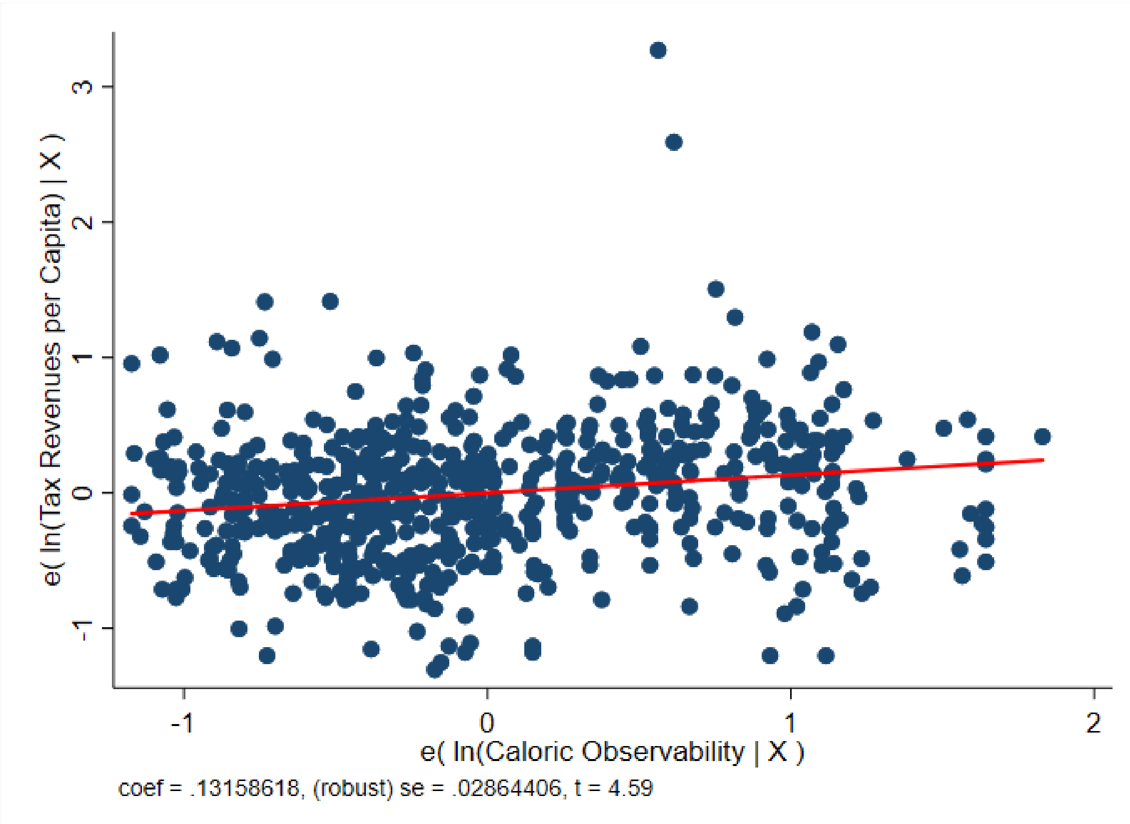


Figure A.9: *Bivariate relationship between ln(Caloric Observability) and ln(Tax Revenue per capita).*

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