The London School of Economics and Political Science

Historical Events and their Effects on Long-Term Economic and Social Development

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Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

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Abstract

This thesis uses econometric methods to examine the effects of historical events and developments on aspects of economic and social development. Its objective is two-fold: The thesis examines causes and effects of different historical events using econometric methods and newly constructed and newly available data sets. By studying these historical events, broader theoretical questions are addressed that are relevant and have implications for today.

The first chapter studies the economic effects of the Little Ice Age, a climatic period that brought markedly colder conditions to large parts of Europe. The theoretical interest of this study lies in the question whether gradual temperature changes affect economic growth in the long-run, despite people's efforts to adapt. This question is highly relevant in the current debate on the economic effects of climate change. Results show that the effect of temperature varies across climate zones, that temperature affected economic growth through its effect on agricultural productivity and that cities that were especially dependent on agriculture were especially affected.

The second chapter examines the role of adverse climatic conditions on political protest. In particular, it assesses the role of adverse climate on the eve of the French Revolution on peasant uprisings in 1789. Historians have argued that crop failure in 1788 and cold weather in the winter of 1788/89 led to peasant revolts in various parts of France. I construct a cross section data set with information on temperature in 1788 and 1789 and on the precise location of peasant revolts. Results show that adverse climatic conditions significantly affected peasant uprisings.

The third chapter examines the role of different Catholic missionary orders in colonial Mexico on long term educational outcomes. I construct a data set of the location of 1000 historical mission stations. I use OLS and instrumental variables estimation to show that only Mendicant mission stations have affected educational attainment while all orders affected conversion.

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I also dedicate this thesis to my husband Fabian. I thank you for your love and for introducing me to the exciting world of research.

Preface

This thesis examines econonometrically causes and effects of historical events. The purpose of this approach is two-fold: First, this thesis contributes to historical research, in particular by using econometric methods to analyse newly available or newly constructed data. Thereby, the thesis sheds new light on historical debates. At the same time, by studying historical events, each chapter also addresses theoretical questions that have important implications for today.

In the first chapter, I study the effects of climatic change during the Little Ice Age on economic growth in Early Modern Europe. Historians have provided anecdotal evidence that relatively cold temperature during the Little Ice Age had a negative effect on the economy (e.g Fagan, 2000; Behringer 2010). This is the first study to provide econometric evidence on the economic effects of the Little Ice Age studying all of Europe. It thereby contributes to research in climate history and to research on the economic growth experience of Early Modern Europe. At the same time, this chapter also addresses a broader theoretical question by providing econometric evidence on the economic effects of *long-term* climate change, when climate change spans several centuries and people have time to adapt. This question is highly relevant in the current debate on climate change and to date empirical evidence is scarce. The question of which rate of adaptation can be realistically assumed in current climate models is especially urgent. This chapter provides evidence that the effect of climate change is highly context-specific. Better access to trade, for example, decreases vulnerability to climate change.

The second chapter of this thesis examines the relationship between negative weather shocks and political uprisings. This question is examined by studying negative weather shocks in the year preceding the French Revolution on the probability of peasant uprisings. As in the previous chapter, this chapter identifies economic characteristics that make it more likely that adverse negative weather shocks are followed by political uprising, especially an economy's dependency on agriculture. Again, this question is highly relevant in the current debate on the effects of climate change. Climatologists predict that the current climate change will be accompanied by more frequent extreme weather events. At the same time, this study contributes to the well-known hypothesis that the drought summer of 1788 and the harsh winter of 1788/89 had a direct effect on peasant uprisings by causing food insecurity. I use newly available paleoclimatological data to shed new light on this question. This chapter is also the first econometric test of this hypothesis. The econometric approach allows to establish causality between temperatures and uprisings by exploiting variation in weather within France and variation in the outbreaks of peasant uprising across France and variation in their timing. As in the previous chapter, this chapter examines a historical research question while at the same time contributing to our understanding of the theoretical relationship between weather shocks and uprisings.

The third chapter studies the long-term effects of missionaries in colonial Mexico on educational and cultural outcome variables. It contributes to the strand of literature on the long-term effects of missionaries by refining the definition of missionaries that has been used in previous studies and by introducing instrumental variable estimation addressing the notorious identification problem that stems from the endogenous location of mission stations. At the same time, this chapter contributes to our knowledge on the long-term transmission of cultural values. By studying different missionary order separately, it shows that only those orders with corresponding values had lasting effects on educational outcomes.

To sum up, the current thesis contributes to our knowledge on historical events and shows that lessons can be drawn that are relevant and useful for today. It is crucial, in this respect, to take into account the political, economic, and social circumstances that differ considerable from circumstances today. To address this concern, it is useful to use within-sample comparison as a basis for extrapolation. Furthermore, it is indispensible to carefully discuss whether the underlying theoretical mechanisms are likely to be at work today.

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1.1. Introduction

Obtaining a realistic estimate of the long term effect of global warming on economic growth is crucial for identifying efficient policy responses. One strand of literature, e.g. the influential Stern Review (Stern, 2007) estimates the economic cost of climate change based on Integrated Assessment Models. They specify and quantify an array of mechanisms through which climatic change may affect national income. This approach has received considerable public attention and has informed important policy choices. A criticism of this approach is that the complex relationships between climate and the economy are extremely challenging to capture in its entirety (Dell et al., 2012: 67). Results depend on a large number of assumptions whose validity is very difficult to test. One source of uncertainty is the degree of adaptation that could realistically be assumed (Stern, 2007: 149).

Another strand of literature explores empirically the effects of year-to-year fluctuations in temperature on economic outcomes (Dell et al., 2012; Burgess et al., 2011; Deschenes and Greenstone, 2007, 2012). Yet, the authors point out that the effects of short-term temperature fluctuations are likely to be different than the effects of long-term temperature change because the empirical framework does not include the possibly important role of adaptation.

In this chapter, I assess the effects of long term gradual temperature change on economic growth in the past. In particular, I assess the effects of the Little Ice Age on economic growth in Europe between 1500 and 1750. The Little Ice Age was a climatic period between the High Middle Ages and the onset of the Industrial Revolution that brought markedly colder climate to Early Modern Europe (Fagan, 2000). Temperature in Europe fell by 0.5 to 1 degrees centigrade, changes that were not uniform across space or time (Aguado et al., 2007: 483). "[The] seemingly small decrease in mean temperature [during the Little Ice Age] had a considerable effect on living conditions throughout Europe [...] shortened growing seasons led to reductions in agricultural productivity [...]," (Aguado et al., 2007: 483). Famines became more frequent (Behringer, 2005: 226).

To assess the long term effect of temperature change on economic growth I construct a panel data set for over 2000 European cities. These data measure annual temperature between 1500 and 1750 and city size data for several points in time. The temperature data for each city come from a large temperature reconstruction effort that was undertaken by climatologists (Luterbacher et al., 2004). The data set contains gridded 'temperature maps' for each year since 1500 that cover all of Europe. Each grid cell measures ca. 50 by 50 kilometres which allows for a precise measurement of climatic change at the local level. The temperature data are reconstructed using directly measured temperature for later years, temperature indices from historical records as well as proxy temperature reconstructions from ice cores and tree ring series (Luterbacher et al., 2004: 1500). As a proxy for economic growth I use data on historical city sizes for over 2,000 European cities that are obtained from Bairoch (1988) and data on country-level urbanisation that are defined based on work by McEvedy and Jones (1978) and Bairoch (1988).

The main analysis investigates the effect of temperature on city size and on urbanisation proxies for economic growth. To control for other factors that may have affected long-run economic growth I control for city fixed effects and country times year fixed effects. City fixed effects control for each city's time invariant characteristics, such as geographic characteristics or persistent cultural traits.

While it is safe to assume that temperature changes are exogenous to economic growth, they are not necessarily randomly distributed across space. Likewise, city growth and urbanisation in Early Modern Europe has been unevenly distributed across space with especially strong growth in Northwestern Europe (e.g. Broadberry, 2013; van Zanden, 2009; Koot, 2013). If temperature changes were correlated with a third factor that also affects city size estimation results would be biased. I address this concern by directly controlling for a host of geographic and historical control variables. All geographic and historical control variables are interacted with a full set of time indicator variables to allow for flexible effects over time. I control for soil suitability for potato and wheat cultivation. As vegetation varies with elevation and terrain conditions such as ruggedness (Benniston et al. 1997) I also control for elevation and ruggedness. Then, I control for a number of historical determinants of city size in Early Modern Europe that have received particular attention in the literature: being part of an Atlantic trading nation (Acemoglu, Johnson, and Robinson, 2005), majority Protestant in 1600 (Becker and Woessmann, 2009), a history of Roman rule and access to Roman roads (Landes, 1998), being a university town (Cantoni et al. 2013), distance to battlegrounds (Dincecco et al. 2013), and distance to the coast. Finally, I show that the results are robust to the use of Conley (1999) standard errors that assume spatial autocorrelation between observations, to the inclusion of period-specific country border fixed effects, period-specific country border time trends, and city time trends.

Then, I investigate heterogeneity in the effect of temperature. Results show that temperature had a nonlinear effect on city size. During the Little Ice Age, when temperature was relatively low, temperature increases had an overall positive effect on city size, especially in cold areas. The effect of temperature changes on economic growth is heterogeneous across climate zones. In parts of Europe with a hot and dry climate, especially in southern Spain, further temperature increases led to lower growth.

I also investigate temperature's effect on agricultural productivity. I combine yearly temperature data with yearly wheat prices for ten European cities over a period of ca. 300 years starting in 1500 (Allen, 2003). As city level demand changes only gradually yearly fluctuations in wheat prices are likely to be a reflection of changes in supply. My analysis indicates that rising temperatures are associated with falling wheat prices in northern cities and with rising wheat prices in southern cities. This pattern of results suggests that temperature changes were related to changes in agricultural output which then affected city size. Then, I then introduce yield ratios as a direct measure of agricultural productivity (based on Slicher van Bath, 1963). Consistent with previous results,results show that higher temperatures increased yield ratios, and hence agricultural productivity.

To further test the hypothesis that temperatures affected city size through its effect on agricultural productivity, I assess whether the effect of temperature on city size is different for relatively small cities that are likely to depend on average more on agriculture than relatively large cities. "In grain-growing villages [...] demographic crises caused by harvest failure were most destructive [compared to those that could] cushion the blow through the existence of more varied economies [...]," (De Vries, 1976: 7f.). Results show that the effect of temperature was significantly larger in relatively small towns compared to relatively large towns. I also show that the effect of temperature changes is significantly smaller for cities that were part of the Hanseatic League, a long-distance trade network. These results show that the effect of long-run temperature changes on economic growth varies across climate zones and with the degree to which an economy depends on agriculture.

This study contributes to various strands of literature, in particular to the empirical literature on the effects of climate on economic growth. A number of studies have assessed the economic effects of short-term temperature fluctuations. Burgess et al. (2011), Dell, Jones, and Olken (2012) and Deschenes and Greenstone (2007, 2012) study the effects of sudden and temporary climatic events, such as droughts and excessive heat and of year-to-year temperature fluctuations. In these studies the authors emphasise that the effect of short-term temperature fluctuations are not the same as the effect of long term gradual temperature changes because it does not allow for adaptation. Burgess et al. (2011) find that rainfall shocks in India affects mortality in rural areas, but not in urban areas, through its effect on agricultural incomes. Based on extrapolation the authors estimate an increase in the Indian annual mortality rate of approximately 12% to 46% by the end of the century. These results are interpreted as an upper bound estimate as the authors "[...] fully expect rural Indians to adapt to an anticipated and slowly warming climate in various ways," (Burgess et al., 2011: 3). Dell, Jones, and Olken (2012) use worldwide temperature and precipitation data between 1950 and 2003 and find large, negative effects of higher temperature on growth in the short-term, but only in poor countries. Dell, Jones and Olken (2012: 68) emphasise that "[...] in the long run, countries may adapt to a particular temperature, mitigating the short run economic impacts that we observe." Deschenes and Greenstone (2007, 2012) use year-to-year temperature and agricultural data to conclude that warming will significantly decrease US agricultural output. "All of these estimates are derived under the unrealistic assumption of no technological progress and adaptation [...]. It seems reasonable to assume that these economic forces will contribute to reducing the predicted damages," (Deschenes and Greenstone, 2012: 3763). Barreca et al. (2008) find relatively modest effects of heat waves on health outcomes in the US, also because people are able to adapt their consumption of health-preserving goods such as air conditioning.

Another strand of literature assesses the effects of climatic events on political outcome variables. Brückner and Ciccone (2011) study the effects of negative rainfall shocks on democratic institutions to show that transitory economic shocks may lead to long term improvements in institutional quality. Dell, Jones, and Olken (2012) find that temperature shocks reduce political stability. Miguel et al. (2004) use rainfall as an instrument to estimate the effect of economic shocks on civil conflict. Dell (2012) finds that the severity of drought affected insurgency during the Mexican Revolution and subsequent land redistribution.

This chapter also contributes to the literature in economic history that examines the role of climate in the past. Oster (2004) shows that especially adverse weather conditions during the Little Ice Age led to economic stress and coincided with a higher number of witchcraft trials. Berger and Spoerer (2001) show that rising grain prices are related to the outbreak of the European Revolutions of 1848. Historians document a relationship between historical events and climatic trends. McCormick et al. (2007, 2012) show that the expansion of the Roman Empire and the reign of Charlemagne coincided with relatively benign weather conditions while the decline of the Roman Empire and the disintegration of Charlemagne's empire were accompanied by less favourable climatic conditions that decreased food security. Diamond (2005) illustrates that the extinction of the Norse people of Greenland occurred because stifle institutions hampered their adaptation to changing environmental conditions during the Little Ice Age.

The subsequent part of this chapter is structured as follows: In section 1.2, I provide historical background on the Little Ice Age, and its effect on agricultural productivity, city size, and urbanisation. Sections 1.3 and 1.4 describe the data set construction and empirical strategy used in this chapter. I present results in sections 1.5 to 1.8. Sections 1.9 and 1.10 discuss implications of results and external validity of results and conclude.

1.2. The Effect of the Little Ice Age on Agricultural Productivity and Urban Growth

1.2.1. The Little Ice Age

The Little Ice Age was a climatic period that lasted from ca. 1350 to 1750 and brought markedly colder and wetter climate to Europe. The cold conditions were interrupted a few times by short periods of relative warmth, e.g. around 1500 when it almost reached again temperature of the Medieval Warm Period (Fagan, 2000). It ends with the onset of the Industrial Revolution in the second half of the 18th century. "[The Little Ice Age] does represent the largest temperature event during historical times," (Aguado et al., 2007: 483).

While there is debate among climatologists about the causes of the Little Ice Age, different contributing factors have been identified: Besides increased volcanic activity and changes in atmospheric pressure fields over Europe, reduced amounts of solar energy emitted by the sun have contributed to colder temperatures in Europe (Cronin, 2010: 300ff., Mann et al. 2009:1259).

Historians have argued that climatic changes during the Little Ice Age had a negative effect on economic outcomes. „the unusually cold and damp seventeenth century [had a negative effect on] population, agricultural yields, and commerce," (Merriman, 2010: 363). One mechanism through which the Little Ice Age may have affected economic growth has received particular attention in the literature: agricultural productivity. In the following, I discuss whether agricultural productivity is a plausible mechanism. through which temperature changes may have affected economic outcomes, and in particular city size. I will first discuss how temperature decreases may have decreased agricultural productivity. Then, I will discuss how decreases in agricultural productivity may have affected economic outcomes, in particular city size. I will provide evidence from historical case studies (Baten, 2002; Pfister et al. 2006).

1.2.2. *Effect of the Little Ice Age on agricultural productivity*

"[D]uring [the Little Ice Age] temperatures fell by about 0.5 to 1 degree Celsius. Historical records indicate that this seemingly small decrease in mean temperature [during the Little Ice Age] had a considerable effect on living conditions throughout Europe, especially through its effect on agricultural productivity, as colder tempreatures led to shortened growing seasons," (Aguado et al., 2007: 483). The unusually wet and cold conditions had detrimental effects on the harvest in certain regions of Europe (De Vries, 1976: 12). In particular crops that are dependend on relatively warm temperatures, such as wine and wheat, were affected. During the relatively mild and stable temprature of the Middle Ages, the Medieval Warm Period, viticulture had existed as much north as England, but was abandoned during the Little Ice Age. The tree line in the high Alps fell and mountain pastures had to be abandoned (Behringer, 2005: 94). Later, "during the eighteenth century, Europe as a whole experienced warmer, drier weather [...] in stark contrast to the unusually cold and damp seventeenth century. This had a salutary effect on population, agricultural yields, and commerce," (Merriman, 2010: 363).

1.2.3. *Effect of agricultural productivity on economic and population growth*

How may the Little Ice Age's effect on agricultural productivity have translated into effects on economic growth in general, and city growth in particular?

The agricultural sector was by far the most important sector at the time. The majority of the labour force in early modern Europe worked in agriculture. Differences in agricultural productivity were the main determinant of differences in overall economic productivity (Dennison, 2010: 148f.). Changes in agricultural productivity were changes in productivity in the most important economic sector. It seems therefore plausible – as Fagan (2000) and Behringer (2010) argue – that these changes in productivity had a tangible effect on the economy as a whole.

Furthermore, a number of historians and climate historians have shown that changes in weather conditions and agricultural productivity during the Little Ice Age at the local level affected local economic and population growth. Pfister et al. (2006) provides interesting case studies to illustrate this point. The authors describe that local weather conditions during the Little Ice Age affected local economic conditions in Switzerland and the Czech Lands (1769-1779) by showing that differences in the local weather conditions translated into differences in local grain prices. „The amplitude of grain prices mirrors this difference in the magnitude of climate impacts [...]. Rye prices in Bern did not even double [while] average prices for rye tripled in Brno (Moravia) [and were] even more dramatic in Bohemia", (Pfister et al. 2006: 122). In a similar vein, using London as a case study Galloway (1985) identifies a relationship between adverse weather conditions, reduced harvest, increases in prices and increases in mortality for London. „Among people living at or near subsistence level [...] variation in food prices were primary determinants of variation in the real wage." Increases in food prices therefore decreased the poor population's food intake. Malnutrition then increased their susceptibility to diseases. Similarly, Baten (2002) finds an effect of climate on grain production in 18th century Southern Germany: relatively mild winters from the 1730s to the early 1750s led to increases in production while relatively cold winters between 1750s and 1770s reduced agricultural productivity. He finds an effect of temperatures and agricultural productivity on the nutritional status of the local population. Oster (2004) also finds an effect of adverse local weather conditions on the local economy for Switzerland.

At this time, potatoe cultivation became an attractive alternative to grain cultivation as the potatoe as a plant was less vulnerable to what Pfister et al. (2006) call 'Little Ice Age Type Impacts'.

These studies show empirical evidence that local changes in temperature that affected the local harvests and through this channel the local economy. If local decreases in agricultural productivity had not affected the local population then we would not expect to see famines in the aftermath of low agricultural yields as we see in Pfister et al. (2006).

At the same time, these studies also show that the local change in temperature is one among many determinants of economic and nutritional conditions at this time period.

Pfister et al. (2006) identify two mechanisms that further affected the adverse economic effects of climatic change during this period: local access to trade and local quality of political institutions. While „the grain-harvest led to higher food prices, mounting unemployment rates, and an increase in the scale of begging, vagrancy, crime and social disorder“ in all areas under study, the degree of these calamities varied with local access to trade and with the response of the local political institutions (Pfister et al. 2006: 123). In the canton of Bern, for example, social vulnerability was relatively low. From the late seventeenth century onwards, the Bern authorities had built a comprehensive network of grain stores. In addition, taxation was relatively low and was managed by a relatively efficient administration (Pfister et al., 2006: 124). The Bern authorities also systematically traded with adjacent territories. „In the event of bumper crops, Bern used to sell grain to the adjacent territories. In the event of deficient harvests, grain was usually imported by order of the administration from the surrounding belt of grainexporting territories such as the Alsace, Burgundy, Savoy and Swabia“, (Pfister et al., 2006: 124). Starting around 1750, the authorities augmented these short-term measures by improving the legal framework such that would promote agricultural productivity, e.g. by privatisation of communal land and introducing poor relief.

In comparison, the institutional framework of the Czech Lands made this area much more vulnerable to economic calamity caused by harvest failure. Heavy taxes and feudal dues were imposed on large parts of the population by the Austrian rulers. In addition, the authorities in Vienna reacted too slowly to the severe famine, at first only by prohibiting exports and grain distilling. When grain and flour were finally imported from Vienna and Hungary, it was not done in sufficient quantity. Bohemia had lost about 10% of its population during the third year of famine (Pfister et al., 2006: 125f.).

These case studies illustrate that climatic changes affect local agricultural productivity, while the effect of changes in local agricultural productivity are shaped by a society‘s institutional framework and its access to trade. Cities that were in a better position to compensate for agricultural losses, e.g. by importing food from other regions were likely to be less affected. Food tranpsortation within England, for example, was relatively efficient. „[...] it was this efficiency with which food could be brought from the countryside to the city which would play a major factor in determining the size of the city", (Dennison et al., 2010: 156). In other parts of Europe, food transportation was more costly. The physical costs of transportation, the institutional impediments, such as taxes or the need for official transport permits, or the prohibition of the movements of goods affected these costs (Dennison et al., 2010: 156). In sum, local temperature affected agricultural productivity which affected nutrition and economic conditions. Better institutions and low-cost access to trade, however, shaped this effect. Better institutions and better access to agriculture made regions more climate-resilient.

1.2.4. Effect of agricultural productivity on city growth and urbanisation

In this section, I describe how increased agricultural productivity lead to city growth and to urbanisation. I follow Nunn et al. (2011). In a paper on the effects of the introduction of the potatoe on economic growth (measured as urban population growth and urbanisation), they argue that agricultural productivity affects urban growth and urbanisation. They identify two specific channels through which this effect might have taken place (Nunn et al., 2011: 605ff.). First, a shock to agricultural productivity changes the relative prices of agricultural and manufacturing products as prices for agricultural produce decrease and more workers in the rural economy will migrate to the urban economy. This mechanism depends on the assumptions that labour is mobile and that demand for agricultural produce is inelastic (i.e. a one percent decrease in prices increases demand by less than one percent). This assumption is consistent with empirical findings on the price elasticity of food (e.g. Andreyeva et al. 2010). Labour mobility was high within most parts of Europe (e.g. de Vries, 1976: 157). It was restricted in parts of Eastern Europe where serfdom restricted labour mobility (e.g. Nafziger, 2011).

A second channel through which agricultural productivity might affect urbanisation is the effect of agricultural productivity on income per capita (Nunn et al., 2011: 607). When agricultural productivity increases workers in the rural economy have more to sell and earn more. An increase in income takes place if prices in the agricultural sector are not fully offset by rural-to-urban migration. The further above subsistence level rural per capita income rises, the more income is available for manufacturing goods. Hence, demand for manufacturing goods and prices for manufacturing products increase. This further incites rural workers to move to cities as manufacturing activities were typically concentrated in cities (Voigtlaender and Voth, 2013: 781). In sum, „cities emerge once peasants' productivity is large enough to provide above-subsistence consumption, such that agents also demand manufacturing goods," (Voigtlaender and Voth, 2013: 788).

A third mechanism through which agricultural productivity might have affected urban growth and urbanisation was its effect on the urban death rate. For a given rate of rural to urban migration a decrease in urban mortality will increase city growth. „Infectious diseases dominate the causes of death. These diseases generally thrive in towns, where people live at relatively high densities and interact at comparatively high rates," (Dyson, 2011: 39). If infectious diseases are a more important cause for death in cities compared to rural areas then decreased prevalence of infectious diseases will benefit the urban population more compared to the rural population. Galloway (1985) shows that temperature changes – through their effect on food prices – affect death from diseases in London in the 17th and 18th centuries. „[...] few persons actually died of starvation during poor harvest years. The increase in deaths was rather a function of the increased susceptibility of the body to various diseases as a result of malnourishment," (Galloway, 1985: 488).

Agricultural productivity affected city growth and urbanisation through its effect on rural-to-urban migration and rural-to-urban migration was an important determinant of urban growth and urbanisation because in early modern cities urban mortality was higher than urban fertility. Cities would have ceased to exist without migrant inflow from the countryside. „the urban sector is a demographic "sink"—that is, in the long run its population would not exist without rural-to-urban migration", (Dyson 2011: 39) and „migration from the countryside has, in past societies, been the immediate cause of urbanization", (Malanima, 2010: 250).

1.3. Data

The basic data set for this chapter is a balanced panel of 2115 European cities. It includes data on city size in 1600, 1700, and 1750 and data on annual mean temperature for Europe for each year since 1500 (see Table 1 for summary statistics).

I use data on the size of European cities from Bairoch (1988) as a proxy for economic growth. The data set includes 2191 European cities that had more than 5000 inhabitants at least once between 800 and 1850. I use a version of the data set that has been modified by and used in Voigtländer and Voth (2013). They use linear interpolation to fill missing values for time periods between non-zero values. City size is available every 100 years for the years 800 to 1800 and additionally for the years 1750 and 1850. Of these 2191 cities, I drop 67 because they are located east of 40°E longitude, an area for which temperature data is not available. I drop nine cities because they are not located on the European continent. The final data set for this chapter includes 2115 cities.

The temperature data is taken from Luterbacher et al. (2004). They contain annual gridded seasonal temperature data for European land areas. Each grid cell measures 0.5 by 0.5 degrees which corresponds to an area of about 50 by 50 km. The temperature in this data set has been reconstructed based on temperature proxies (tree ring series, ice cores), historical records, and directly measured temperature for later years (Luterbacher et al., 2004: 1500). The dataset covers European land area between 25°W to 40°E longitude and 35°N to 70°N latitude. It covers all European cities in the data set, except for Russian cities east of 40°E longitude.

I combine the two datasets as follows. City size is available in 1600, 1700, and 1750. For each time period, I calculate mean temperature over the preceding 100 or 50 years.

For t=1600 and t=1700:

$$\sum_{n=1}^{100} Temperature_{it-n}$$

For t=1750

$$\sum_{n=1}^{50} Temperature_{it-n}$$

Local mean temperature at city i in time period t is calculated by taking the mean temperature over the preceding 100 years for the years 1600 and 1700, and over the preceding 50 years for the year 1750.

I construct a second panel data set to explore the relationship between temperature changes and agricultural productivity. For this purpose, I combine yearly temperature data from Luterbacher et al. (2004) with yearly wheat prices for ten European cities from Allen (2001). Wheat prices are available for Amsterdam, London, Leipzig, Antwerp, Paris, Strasbourg, Munich, Florence, Naples, and Madrid. Yearly prices are available for these cities over a period of 200 to 250 years starting around 1500.

Data on control variables is obtained as follows: Data on local potatoe suitability, wheat suitability, and altitude are taken from the Food and Agriculture Organization (FAO)'s Global Agro-Ecological Zones (GAEZ) database (IIASA/FAO, 2012). Data on ruggedness is taken from Nunn and Puga (2012). Location of the Roman road network is taken from the Digital Atlas of Roman and Medieval Civilizations (McCormick et al., 2014). Data on country borders in Early Modern Europe, on the extent of the Roman Empire in year 0, and information on the location of small and big rivers in pre-modern Europe are taken from Nüssli (2012). Information on member cities of the Hanseatic League and on the spread of the Protestant Reformation in 1600 has been collected from Haywood (2000).

As an alternative indicator for agricultural productivity data on yield ratios is collected from Slicher van Bath (1963). As an alternative indicator for economic growth I use country-level urbanisation rates. Urbanisation rates are measured as a country’s population living in cities divided by the total population. Data on a country’s population living in cities is taken as before from Bairoch (1988). Data on a country’s total population has been collected from McEvedy and Jones (1978). The authors provide information on total population for land areas that correspond to country borders in 1978.

When assessing the effect of temperature on wheat prices and yield ratios I control for precipitation. I use reconstructed historical precipitation starting in 1500 which is taken from Pauling et al. (2006). The reconstruction is based on long instrumental precipitation series, precipitation indices based on documentary evidence and precipitation-sensitive natural proxies such as tree-ring chronologies, ice cores, and corals.

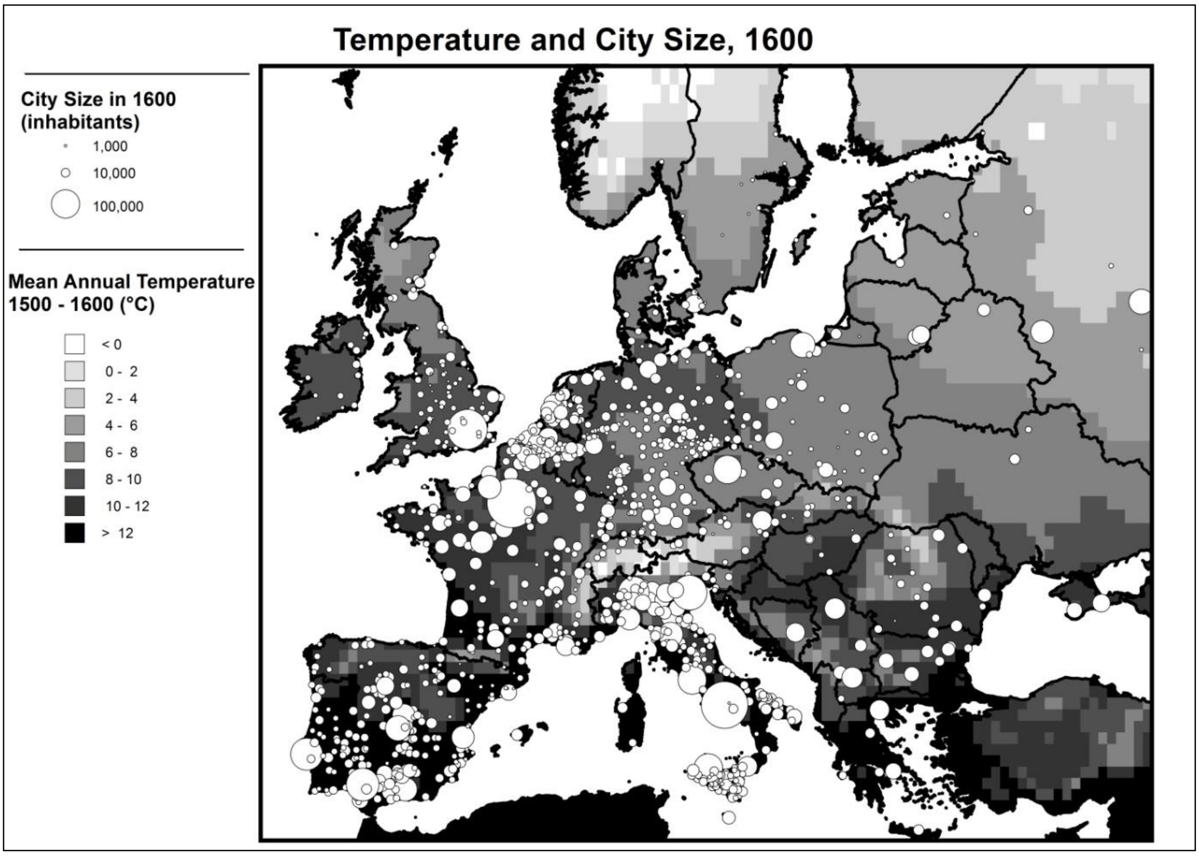

Figure 1 Temperature and City Size, 1600
Note: Map shows European year temperature averaged over 100 years, between 1500 and 1600. Data is taken from Luterbacher (2004). It shows location of cities in 1600 according to Bairoch (1988). Symbols are proportionate to city size.

Figure 2 shows European mean annual temperature between 1500 and 1750 according to Luterbacher (2004). Temperature generally decreases between 1550 and 1700 by ca. 0.6 degree Celsius. An increase in temperature of around 0.35 degree Celsius occurs around 1600. This is followed by an upwards trend in temperature after 1700.

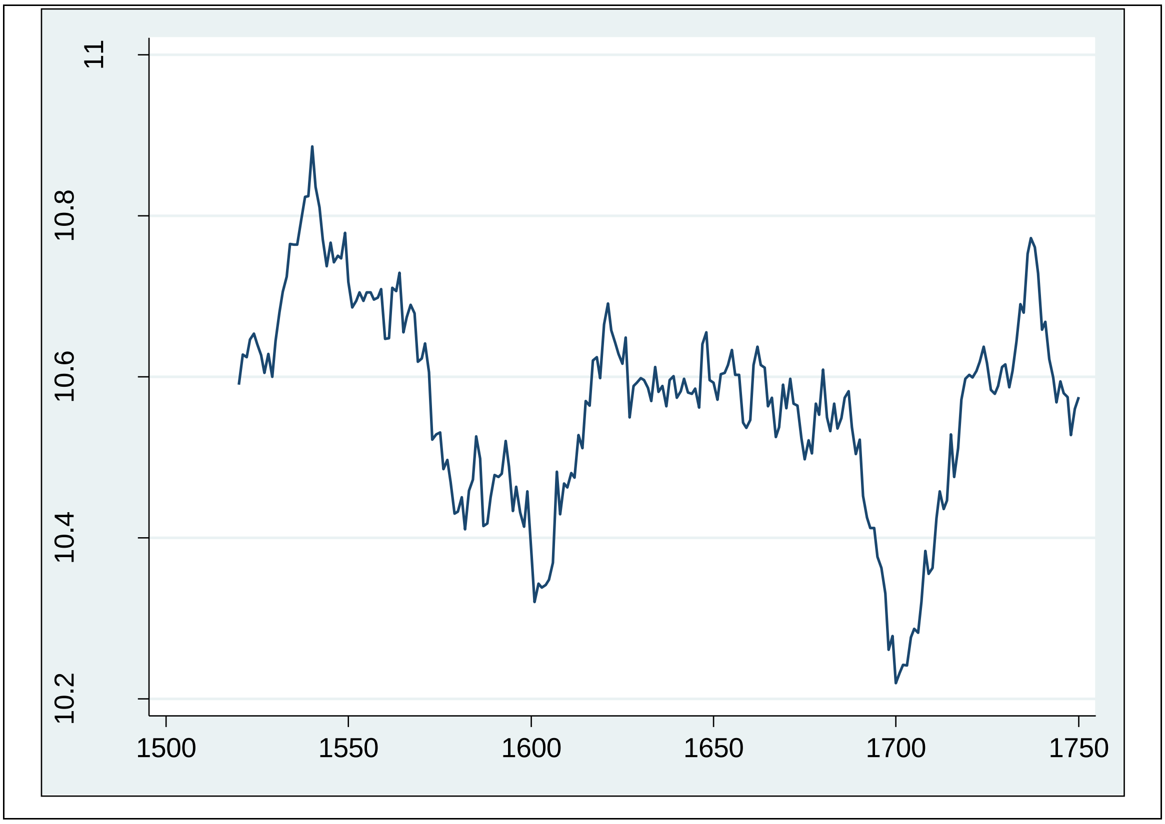

Figure 2 European annual mean temperature, 20 year moving average

Figure 3 shows variation in mean temperature over time for different parts of Europe: north of 59 degree latitude, between 51 and 59 degree latitude, between 43 and 51 degree latitude, and south of 43 degree latitude. The figures show that temperature changed differently over time in these different areas. In the northernmost area of Europe (north of 59 degree latitude, including Scotland, Scandinavia, and the Baltic states) the cooling trend is almost uninterrupted, with only a short warm period around 1650 during which temperatures increase slightly. In the area between 51 and 59 degree latitude (Ireland and Great Britain, the Netherlands, north Germany and Poland) a temperature decrease of more than 0.6 degree Celsius between 1550 and 1600 is followed by 50 years of temperature during which temperatures increase by less than 0.4 degree Celsius. Between 43 and 51 degree latitude (France, the Alpines region, Austria, the Czech Republic and Slovakia) the cooling trend after 1550 is completely interrupted by a relatively warm and stable period of close to 100 years after 1600. In southern Europe (south of 43 degree latitude, including Spain, Italy and Greece) a short period of cooler temperatures after 1550 is completely compensated for by the following increase in temperature.

Table 1 Summary Statistics

Temperature in °C

Year	***All***	***Region 1***	***Region 2***	***Region 3***	***Region 4***
1600	10.6	4.2	8	9.72	14.41
1700	10.51	3.95	7.84	9.62	14.4
1750	10.6	4.46	8.1	9.71	14.33

City Size (number of inhabitants)

Year	***All***	***Region 1***	***Region 2***	***Region 3***	***Region 4***
1600	5440	1600	4600	5507	6251
1700	6500	3700	6836	6722	6033
1750	8258	9167	9134	8338	7365

Note: Regions 1 to 4 are defined as in Figure 3. Region 1 includes all cities north of 59 degree latitude (Scotland, Scandinavian countries, and the Baltic states). Region 2 includes all cities between 59 and 51 degree latitude (Ireland, Great Britain, the Netherlands, Belgium, northern Germany and Poland). Region 3 includes all cities between 51 and 43 degree latitude (France, Switzerland, Austria, the Czech Republic, Slovakia, and Rumania) and region 4 includes all cities south of 43 degree latitude (Spain, Italy and Greece).

Figure 3 European annual mean temperature as 20 years moving averages, according to latitude

Note: The top left graph presents annual mean temperature for the area north of 59 degree latitude. Countries in this area include Scotland, Scandinavian countries, and the Baltic states (Region 1). The top right graph presents annual mean temperature for the area between 51 and 59 degree latitude. Countries in this area include Ireland, Great Britain, the Netherlands, Belgium, northern Germany and Poland. The bottom left graph presents annual mean temperature for the area between 51 and 43 degree latitude. The area includes France, Switzerland, Austria, the Czech Republic, Slovakia, and Rumania. The bottom right graph presents data for the area south of 43 degree latitude including Spain, Italy and Greece.

To investigate heterogeneity in the effect of temperature on city size I divide the sample according to climate groups (see Table 2). I define five climate groups based on the Köppen-Geiger climate classification for Europe. I use data on the extent of Köppen-Geiger's climate zones from Peel et al. (2007). The Köppen-Geiger climate classification divides the world into five major climate groups, denoted by the capital letters A to E. These climate groups are defined by temperature with A representing the warmest and E the coldest areas. An exception is climate group B whose defining characteristic is aridity. Subtypes of the groups are defined based on temperature and precipitation. In this chapter, I subdivide the sample into five climate groups. The climate group 'arid hot climate' represents Köppen-Geiger's climate group B. The climate groups 'temperate hot climate' and 'temperate warm climate' represent Köppen-Geiger's climate group C. The climate group 'temperate hot climate' represents a subgroup of Köppen-Geiger's climate group C: temperate climate with hot summers. The climate group 'temperate warm climate' represents another subgroup of Köppen-Geiger's climate group C: temperate climate with warm summers. The climate groups 'moderately cold climate' and 'cold and alpine climate' represent the Köppen-Geiger's climate groups D and E. The climate group 'moderately cold climate' represents a subgroup of Köppen-Geiger's climate group D: cold climate with hot or warm summers. The climate group 'cold and alpine climate' represents a subgroup of Köppen-Geiger's climate group D and climate group E: cold climate with cold summers and Alpine climate.

Table 2 Climate Groups & Corresponding Koeppen-Geiger Climate Groups

Climate group	*KG Climate Group*	*KG Climate Subgroups*	*N° of Observations*
Arid climate	B Arid	Arid hot steppe	1
		Arid cold steppe	140
		Arid cold desert	2
Temperate Hot Climate	C Temperate	Temperate climate with hot dry summer	396
		Temperate climate with hot summer	152
Temperate Warm Climate	C Temperate	Temperate climate with warm dry summer	81

		Temperate climate with warm summer	758
Moderately Cold Climate	D Cold	Cold climate with hot summer	26
		Cold climate with warm summer	491
Cold and Alpine Climate	E Polar	Cold climate with cold summer	47
		Polar Tundra	20

1.4. Empirical Strategy

I use the panel data set for 2120 European cities to test whether temperature changes during the Little Ice Age, between 1500 and 1750, have affected city size. In the baseline specification, I include city fixed effects and year fixed effects. I further include various control variables. Each control variable is interacted with a full set of time period indicator variables.

$$(1) \qquad City\ Size_{it} = \beta + \gamma Mean\ Temperature_{it} + y_t + i_i + c_{it} + \varepsilon_{ict}$$

City Size is the size of city i in time period t. $MeanTemperature_{it}$ is mean year temperature in city i, and time period t over the past 100 years (for the years 1600 and 1700) and past 50 years (for the year 1750, see also previous section for more detail). i_i are a full set of city fixed effects. The city fixed effects control for time-invariant city characteristics, e.g. distance to the sea and to waterways, permanent climatic or soil characteristics that may affect a city's access to trade or its agricultural productivity. y_t are a full set of year fixed effects that control for variation in temperature and in city size over time that is common to all cities in the data set. c_{it} are a number of control variables, each interacted with indicators for each time period. They will be described in more detail when introduced into the equation. ε_{it} is the error term. Standard errors are clustered at the city level.

The coefficient of interest is γ. It is the estimated effect of a one degree increase in long-run mean temperature on city size conditional on control variables. This specification estimates the effect of temperature on city size based on variation in both variables within each city conditional on year fixed effects and on control variables interacted with time period indicators. The identification relies on the assumption that temperature changes are not correlated with other determinants of city size besides those that are controlled for.

1.5. Baseline Results

1.5.1. Basic Results and Geographic Controls

Table 3 shows baseline results. The table reports results for five different specifications. The first specification in column 1 estimates the effect of mean temperature on city size including city fixed effects and year fixed effects. The relationship is positive and significant at the 1% level. This indicates that temperature decreases during the Little Ice Age had a negative effect on city size which is consistent with historical evidence on the negative economic effects of the Little Ice Age. While current climate change is concerned about temperature increases above the temperature optimum, temperatures during the Little Ice Age dropped below the optimal temperature for European agriculture. Actually, climate researchers have predicted that Northern European agriculture - but only in the short-term and only for very small increases - might benefit from mild temperature increases due to its relatively cold climate (European Environmental Agency 2012: 158).

In columns (2) to (6), I include one-by-one several geographic control variables: altitude, soil suitability for potato cultivation, for wheat cultivation, as well as terrain ruggedness. These geographic factors may have affected city size, for example through their effects on agricultural productivity. Local vegetation, for example, changes with higher altitudes and increased ruggedness (e.g. Beniston et al., 1997). Nunn and Qian (2011) show the importance of (soil suitability for) potato cultivation for population growth. If these variables are also correlated with temperature changes omitting them may lead to bias. Each variable is interacted with time indicator variables for each time period. Columns (2) to (6) in table 2 show that the point estimate remains stable.

***Table 3** The Effect of Temperature on City Size - Baseline Estimates and Geographic Controls*

	Ln City Size					
	(1)	(2)	(3)	(4)	(5)	(6)
Mean Temperature	0.567***	0.653***	0.624***	0.565***	0.490***	0.491***
	(0.127)	(0.142)	(0.143)	(0.139)	(0.144)	(0.144)
City Fixed Effects	yes	yes	yes	yes	yes	yes
Year Fixed Effects	yes	yes	yes	yes	yes	yes
Geographic Controls (× Year fixed effects)						
ln Elevation		yes	yes	yes	yes	yes
ln Wheat Suitability			yes	yes	yes	yes
ln Potatoe Suitability				yes	yes	yes
ln Ruggedness					yes	yes
precipitation						yes
Observations	6,360	6,360	6,360	6,360	6,360	6,360
R-Squared	0.885	0.886	0.886	0.886	0.887	0.887

Robust standard errors in parentheses, clustered at city level

*** p<0.01, ** p<0.05, * p<0.1

1.5.2. Controlling for Historical Determinants of Economic Growth

Results thus far show that temperature decreases of the Little Ice Age have had a negative effect on city size. This result is consistent with historical evidence on the negative effects of the Little Ice Age on economic conditions. In addition, I have controlled for a set of geographical variables that may have been correlated with both city size and temperature changes, each variable interacted with time indicator variables.

Yet, economic and urban growth has been uneven across Europe with especially high growth in Northwestern Europe. This pattern has been called by historians the Little Divergence. A number of factors have been held accountable for this divergence, e.g. the overseas trade expansion of the Atlantic powers and human capital accumulation. If temperature changes were correlated with these historical factors the estimated effect of temperature and city size would be biased. In the following, I therefore directly control for historical factors that have been identified as drivers of disparity in urban growth within Early Modern Europe.

Acemoglu, Johnson, and Robinson (2005) show that the overseas trade expansion of Western European countries had a positive effect on economic growth. I add an indicator for Atlantic traders, i.e. Great Britain, the Netherlands, Belgium, France, Spain, and Portugal.

As an additional measure for a country's natural openness for overseas trade I include an indicator variable for all cities located within 10 km of the coast.

Van Zanden (2009: 12) emphasises, among other factors, the importance of human capital accumulation for economic growth in Early Modern Europe. In the same vein, Cantoni and Yuchtman (2013) argue that the establishment of universities increased the number of people trained in law. This had a positive effect on economic activities in medieval Europe as it decreased the uncertainty of trade and. I include an indicator variable for cities that were university cities in 1500.

Becker and Woessmann (2008, 2009) argue that Protestantism had a positive effect on human capital due to its emphasis on people's ability of reading the bible. Weber famously argued that Protestantism introduced a stricter work ethic making Protestant countries better off. Besides, for most European rulers choosing a Protestant denomination was a highly political act. Rulers distanced themselves from the influence of the Roman Catholic Church that rejected, among other things, the newly developing ideas on scientific research (e.g. Merriman, 2010). As Protestantism may have affected economic development and hence city growth in these various ways I include indicator variables that are 1 if a city was majority Lutheran, Calvinist, Anglican, or Catholic in 1600.

Several studies identify war as an important factor in the development of Europe, e.g. through its effect on state-building (Tilly, 1990). Recently, Dincecco et al. (2013) argue that exposure to military conflict had a direct effect on urban growth as it induced people to seek protection from violence within city walls. I add a variable that measure the distance to the nearest battleground during the time period.

In column 6 of Table 4, I add an indicator variable that is 1 for all cities that were part of the Roman empire. In column 7 of table 3, I add an indicator variable for all cities that were located within one kilometer of a Roman road.

Table 4 shows estimates. Column 1 of Table 4 shows the baseline estimates including the geographic control variables. Columns 2 to 8 report estimates when including each alternative historical determinant of city size separately. Column 9 reports estimates when including all alternative historical determinants. Results show that the coefficient on temperature remains stable across these different specifications. These results suggest that, while important in their own right, the alternative determinants of city growth do not drive the relationship between temperature and city size.

Table 4 ***Robustness Additional Historical Control Variables***									
	Ln City Size								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mean Temperature	0.491***	0.740***	0.500***	0.426***	0.548***	0.411**	0.445***	0.336**	0.489**
	(0.144)	(0.185)	(0.144)	(0.151)	(0.158)	(0.160)	(0.150)	(0.156)	(0.208)
City Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Geographic and Historical Controls (× Year fixed effects)									
Geographic Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Protestant		yes							yes
University			yes						yes
Atlantic Traders				yes					yes
Battle					yes				yes
Part of Roman Empire						yes			yes
Access to Roman Roads							yes		yes
Distance to Coast								yes	yes
Observations	6,360	6,360	6,360	6,360	6,360	6,360	6,360	6,360	6,360
R-Squared	0.887	0.893	0.887	0.887	0.887	0.887	0.887	0.888	0.894

Robust standard errors in parentheses, clustered at city level

*** p<0.01, ** p<0.05, * p<0.1

1.5.3. The Effect of Temperature on Urbanisation

So far, city size has been used as an indicator of economic growth. In this section, I introduce urbanisationan as an alternative indicator of economic growth. In the absence of a direct measure, it has been widely used as a measure of historical per capita GDP by a number of studies (e.g. DeLong and Shleifer, 1993; Acemoglu, Johnson, and Robinson, 2002, 2005) and it has been shown that urbanisation has been strongly correlated with economic growth (e.g. Acemoglu, Johnson, and Robinson, 2002).

$$(2) \qquad Urbanisation_{ct} = \beta + \gamma Mean\ Temperature_{ct} + y_t + c_c + gc_{ct} + hc_{ct} + \varepsilon_{ct}$$

To estimate the effect of mean temperature on urbanisation I regress urbanisation in country c in time period t on a country's mean temperature, year fixed effects, country fixed effects, and the previously introduced geographic and historical controls, each of them interacted with time period indicator variables.

Urbanisation is defined at the country level as the number of inhabitants living in cities divided by the total population. Countries are defined as in McEvedy and Jones (1978). The measure of urbanisation is available for 22 European countries and three time periods. Table 5 reports results from seven specifications. The first specification does not include controls. Each of the following specifications introduces one or more new controls. Specification (2) introduces year fixed effects in, specification (3) region fixed effects. Region times year fixed effects are included in specification (4) and country fixed effects in specification (5). Finally, the geographic and historical control variables as introduced previously in Table 3 and Table 4 are included in specifications (6) and (7).

Results show a robust and positive relationship between mean temperature and urbanisation. With the introduction of new controls the size of the coefficient on mean temperature increases, except in the last specification where it decreases. These estimates confirm the earlier findings that showed a positive relationship between mean temperature and city size. The three specifications including country fixed effects are no longer statistically significant. This seems unsurprising given the small sample size. As the estimates are based on within-country variation in temperature and urbanisation, variation used for estimation is much reduced. One might be concerned that the insignificant results in column (5) to (6) signify that the country fixed effect, hence country-wide institutional, economic or political factors – had been driving results. In this case, however, we would have expected to see a drop in the size of the coefficient and not only reduced statistical significance. It is reassuring that the size of the coefficients remains positive and relatively large.

Table 5 The Effect of Temperature on Urbanisation

	Ln Urbanisation						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mean Temperature	0.134***	0.134***	0.188**	0.187**	0.598	0.445	0.288
	(0.0434)	(0.0441)	(0.0762)	(0.0823)	(0.474)	(0.517)	(0.633)
Year Fixed Effects		yes	yes		yes	yes	yes
Region Fixed Effects			yes				
Region*Year Fixed Effects				yes			
Country Fixed Effects					yes	yes	yes
Geographic Controls (× Year Fixed Effects)						yes	yes
Historical Controls (× Year Fixed Effects)							yes
Observations	66	66	66	66	66	66	66
R-squared	0.263	0.295	0.512	0.533	0.915	0.939	0.943

Robust standard errors in parentheses, clustered at country level
*** p<0.01, ** p<0.05, * p<0.1

1.6. Robustness

1.6.1. Alternative Samples

Table 3 has shown a positive and significant relationship between mean temperature and city size. This is consistent with historical accounts of the adverse economic effects of low temperatures in Europe during the Little Ice Age. In Table 6, I test the robustness of these results to the exclusion of potential outliers. Columns 1 and 2 show the result of the baseline specification (1) with year fixed effects and with country times year fixed effects. Columns 3 to 10 explore whether the results are robust to the exclusion of potential outliers to test whether results are driven by a small number of especially fast growing cities. Each time I provide estimates for two specifications, one including city fixed effects and year fixed effects, the other including city fixed effects and country times year fixed effects.

In the early modern period, capital cities have grown particularly fast. In non-democratic societies rulers were free to invest a disproportionate share of tax income into the capital, e.g. into infrastructure project or the state bureaucracy. In columns 3 and 4, I exclude capital cities from the sample. Coefficients remain largely unchanged.

Port cities have also grown especially fast because of their access to long distance trade. In columns 5 and 6, I exclude all potential port cities from the sample. Potential port cities are defined as cities that are located within 10 km of the Atlantic Ocean, Mediterranean Sea, North Sea, or Baltic Sea. Coefficients increase by 0.10 and 0.19 and increase in significance.

De Vries (1984: 140, see Table 7) provides a list of 34 cities that have been exceptionally successful because they were European capital cities, port cities or because they carried out industrial, commercial or administrative functions. In columns 7 and 8, I show that coefficient estimates decrease 0.03 and 0.02 and remain significant when excluding this group of cities.

Finally, in columns 9 and 10, I exclude cities located in Great Britain, Netherlands, France, Spain, and Portugal. Acemoglu et al. (2005) show that these countries, that were involved in long distance trade with the American colonies, were an especially successful region of early modern Europe. When excluding cities from these countries from the sample, the coefficient in column 9 decreases by 0.045 compared to the baseline specification and the coefficient in column 10 increases by 0.44. Results in columns 3 to 10 show that results are robust to the exclusion of potential outliers.

	Log CITY SIZE									
	Entire Sample		excl. capitals		excl. port cities		excl. successful cities		excl. Atlantic traders	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Mean Temperature	0.579***	0.540*	0.571***	0.557*	0.680***	0.733**	0.556***	0.519*	0.534***	0.981**
	(0.127)	(0.303)	(0.128)	(0.305)	(0.160)	(0.330)	(0.129)	(0.308)	(0.157)	(0.397)
City Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year Fixed Effects	yes		yes		yes		yes		yes	
Country*Year Fixed Effects		yes		yes		yes		yes		yes
Observations	6,345	6,345	6,291	6,291	5,037	5,037	6,246	6,246	3,711	3,711
R-Squared	0.885	0.899	0.881	0.895	0.878	0.897	0.880	0.895	0.892	0.907

Table 6 The Effect of Temperature on City Size - Different Samples

Notes: Data are a panel of 2215 European cities. The left-hand-side variable is the natural log of number of city inhabitants. Mean temperature is year temperature averaged over the periods 1500 to 1600, 1600 to 1700, and 1700 to 1750. Country times Year fixed effects use country borders in 1600. The sample in columns 3 and 4 is restricted to cities that were not capital cities between 1600 and 1750. Regressions 5 and 6 include cities that are located more than 10 km from the sea. Regressions 7 and 8 exclude cities that were listed by de Vries (1984:140) as especially successful, fast growing cities between 1600 and 1750. Regression 8 includes cities that were not located in one of the countries identified in Acemoglu et al. (2005) as Atlantic traders: Portugal, Spain, France, England, and the Netherlands.
Robust standard errors in parentheses, clustered at city level.
*** p<0.01, ** p<0.05, * p<0.1

Table 7 Fastest Growing Cities in Europe in 1600

Amsterdam	Clermont-Ferrand	Liege	Nimes
Berlin	Copenhagen	Liverpool	Norwich
London	Cork	Livorno	Prague
Madrid	Dresden	Lyon	Rotterdam
Paris	Dublin	Malaga	Stockholm
Turin	Glasgow	Nancy	Toulon
Brest	The Hague	Nantes	Versailles
Bristol	Leipzig	Newcastle	Vienna
Cadiz	Kaliningrad		

Note: The table contains a list of cities, especially capital cities, port cities, and cities that served as administrative or trade centres that were identified by de Vries (1984: 140) as especially successful, fast-growing cities in early modern Europe.

1.6.2. Alternative Fixed Effects and Time Trends

In this section, I test whether the estimated effect of mean temperature on city size is robust to the inclusion of alternative spatial fixed effects and time trends at different levels. Column 1 of Table 8 shows a specification including city fixed effect and year fixed effects. In column 2, I introduce a linear time trend at the country level. In column 3, the country level time trend is replaced by country level fixed effects. In column 4, a country level time trend is added to the specification. Then, the country level fixed effects are replaced by time-period specific fixed effects in column 4. Finally, a time-period specific country time trend is added in column 5 and a city specific time trend in column 6. For the period specific country fixed effects, each city is assigned to the country that it was located in in each time period. If city X was part of country A in time period t but was part of country B in time period t+1, then country A is assigned to city X in time period t and country B is assigned in time period t+1. This takes into account changing country borders over the course of the period under study.

Estimates in Table 8 show that the size of the coefficient are affected by the use of different fixed effects and time trends. However, they also show a positive and important relationship between mean temperature and city size across all specifications. The relationship is significant in most specifications, except in columns 4 and 7 that include city level time trends. For these specifications standard errors could not be estimated, possibly because the combination of city fixed effects, year fixed effects, period-specific country fixed effects and a city time trend is too demanding as the data contains three observations per city.

Table 8 Alternative Fixed Effects and Time Trends

	Ln City Size						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mean Temperature	0.564***	0.259**	0.526*	0.420	0.620***	0.345***	0.397
	(0.127)	(0.127)	(0.299)	n/a	(0.125)	(0.130)	n/a
Fixed Effects							
City FE	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes			yes	yes	yes
Country in 1600 × Year FE			yes	yes			
Period-Specific Country FE					yes	yes	yes
Linear Time Trend							
Country in 1600		yes					
Period-Specific Country						yes	
City				yes			yes
Observations	6,360	6,360	6,360	6,360	6,360	6,360	6,360
R-Squared	0.885	0.895	0.899	0.974	0.888	0.899	0.972

Robust standard errors in parentheses, clustered at city level
*** p<0.01, ** p<0.05, * p<0.1

1.6.3. Using Alternative Standard Errors

Table 9 shows the baseline estimates applying different standard errors. Column 1 and 2 of Table 9 is the baseline specification when clustered at city level when including geographical controls (column 1) and when including geographic and historical controls (column 2). Column 3 and 4 show the same two specifications when clustering at the grid cell level of the underlying temperature data set. Temperature data is provided by grid cell (see section 3 for more detail). Each city is assigned temperature data of the grid cell that the city is located in. Different cities can have been assigned the same temperature data if they are located in the same grid cell. All cities whose temperature data has been informed by the same observation in the temperature reconstruction dataset form a cluster. Finally, column 5 and show the two specifications using Conley standard errors. Conley standard errors assume spatial autocorrelation for cities located within 100 km from each other. Spatial autocorrelation is assumed to decrease with distance between cities and complete independence is assumed for cities located further than 100 km apart.

Table 9 Robustness Using Alternative Standard Errors

	Ln City Size					
	Clustered at…					
	City Level		***Grid Cell Level***		***Conley SE***	
	(1)	(2)	(3)	(4)	(5)	(6)
Mean Temperature	0.487***	0.483**	0.487***	0.483**	0.487***	0.483**
	(0.144)	(0.208)	(0.172)	(0.224)	(0.173)	(0.200)
City Fixed Effects	yes	yes	yes	yes	yes	yes
Year Fixed Effects	yes	yes	yes	yes	yes	yes
Geographic Controls (× Year fixed effects)	yes	yes	yes	yes	yes	yes
Historical Controls (× Year fixed effects)		yes		yes		yes
Observations	6,360	6,360	6,360	6,360	6,360	6,360
R-Squared	0.887	0.894	0.887	0.894	0.887	0.894

Robust standard errors in parentheses, clustered at different levels
*** p<0.01, ** p<0.05, * p<0.1

1.6.4. The Effect of Temperature in Different Climate Zones

The 2007 report of the Intergovernmental Panel on Climate Change (IPCC, Parry et al., 2007) predicts that the effect of temperature change on agricultural productivity will be different in different climate zones. "In mid- to high-latitude regions [far from the equator], moderate warming benefits cereal crop and pasture yields, but even slight warming decreases yields in seasonally dry and tropical region," (Parry et al., 2007: 38). Schlenker et al. (2009) find that increases in temperature up to a certain point lead to increases in yield. After reaching an optimum further increases lead to a steep decline in yield. In this section, I test whether the effect of temperature change on city size during the Little Ice Age is different for cities in different climate zones within Europe. Mean annual temperature varies significantly across Europe (see Figure 1 for mean annual temperature across Europe in 1600). The difference between the warmest and the coldest areas is more than 12 degrees. The question arises whether the effect of temperature on city size varies with initial climate.

For this purpose, I divide the sample into five subsamples based on the Köppen-Geiger climate zones for Europe (see section 1.3 for a detailed description). The five subsamples represent five climate groups: arid and hot climate, temperate hot climate, temperate warm climate, moderately cold climate, and cold, alpine climate (see Figure 4 for a map). The groups with arid, hot climate and cold, alpine climates are the smallest with 143 and 67 cities respectively. Arid, hot climate prevails in parts of Spain, and cold, alpine climate in parts of Scandinavia and Russia, and in the Alps. The groups with temperate, hot climate, temperate warm climate, and moderately cold climate comprise between 517 and 839 cities. Temperate, hot climate prevails in the area bordering on the Mediterranean Sea. Temperate warm climate prevails in large parts of north-western Europe, e.g. England, the Netherlands, and France, and in parts of Germany and Spain. Moderately cold climate prevails in large parts of Eastern Europe.

To examine whether the effect of temperature depends on a location's initial climate I divide the sample into five subsamples each containing all the cities within one climate zone. I split the sample according to climate groups and estimate specification (3).

$$(3) \qquad City\ Size_{ict} = \beta + \gamma Mean\ Temperature_{ict} + cy_{ct} + i_i + \varepsilon_{ict}$$

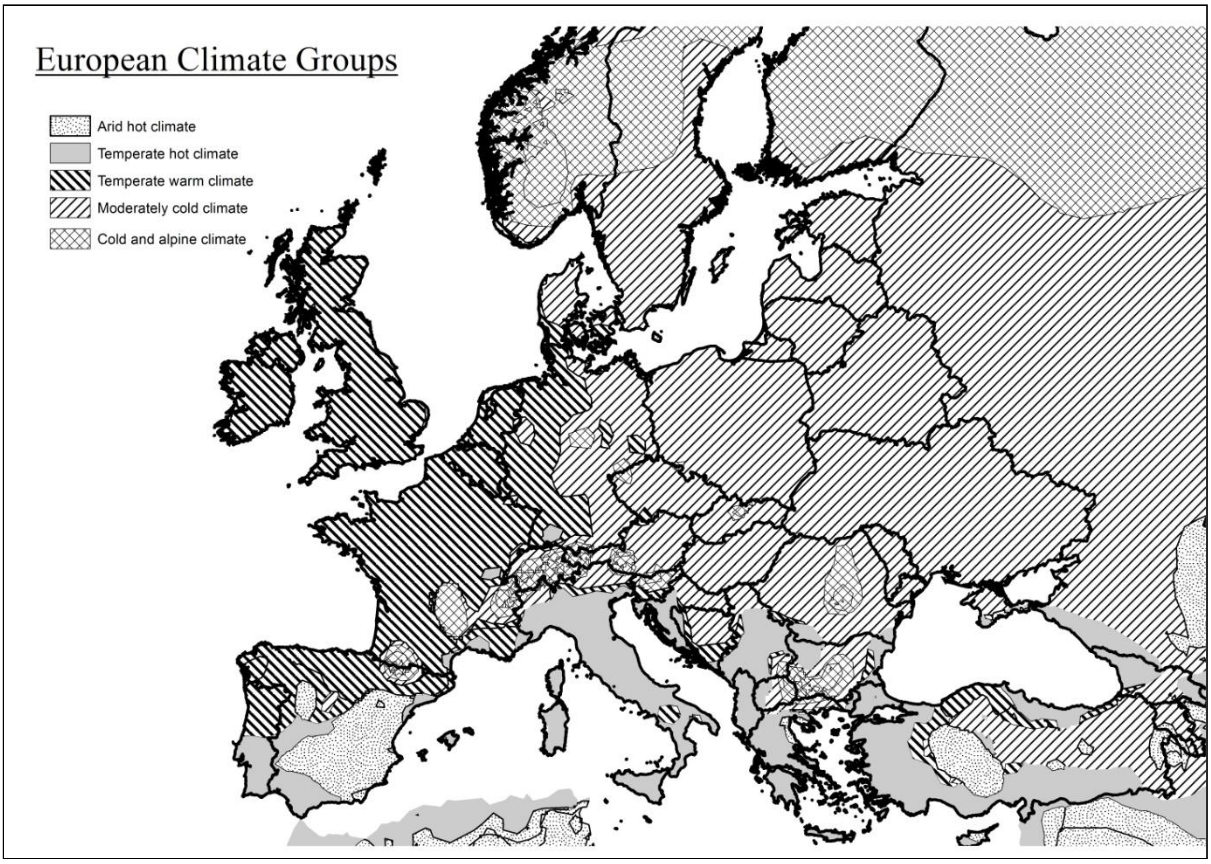

Figure 4 European Climate Groups
Note: This map shows the distribution of climate groups across Europe. The definition of climate groups follows the Koeppen-Geiger definition (Peel et al., 2007). Arid hot climate corresponds to Koeppen-Geiger climate group B. Temperate hot climate corresponds to Koeppen-Geiger climate groups Csa and Cfa. Temperate warm climate corresponds to Koeppen-Geiger climate groups Csb and Cfb. Moderately cold climte corresponds to Koeppen-Geiger climate groups Dfa and Dfb, and Cold and alpine climate corresponds to Koeppen-Geiger climate groups Dfc and ET.

The coefficient of interest is γ, the estimated effect of temperature on city size. The specification also contains a full set of country times year fixed effects, cy, and a full set of city fixed effects, i. ε denotes an error term. The subscripts i, c, and t denote city, country and time period respectively.

Table 10 shows regression results for specification (1) and samples of cities in different climate groups. Column 1 includes the complete sample. Columns 2 to 6 shows the estimated effect of a one degree Celsius increase in temperature on city size for cities of each climate group. Results show a steady increase in the coefficient size from warm to cold areas. For cities with arid and hot climate, the coefficient is negative and significant. For cities with temperate hot climate the coefficient is also negative but substantially closer to 0 and insignificant. The coefficient is very close to 0 for cities in temperate warm climate. It is positive for cities with moderately cold climate and positive and relatively large for cities with cold and alpine climate. The increase in coefficient size from hot to cold areas indicates that the effect of long-term temperature change on city size varies with initial climate. It is also consistent with the IPCC's predictions for the effect of current climate change that different climatic zones will be differently affected by temperature changes.

Table 10 The Effect of Temperature in Different Climate Zones

	LOG City Size (inhabitants)					
	Entire Sample	***Arid Hot Climate***	***Temperate Hot Climate***	***Temperate Warm Climate***	***Moderately Cold Climate***	***Cold and Alpine Climate***
Latitude (°N)	46.63	39.01	40.72	49.12	50.63	49.18
Longitude (°E)	8.87	-2.05	10.6	9.97	20.38	12.48
Temperature (°C)	10.71	14.39	14.15	9.99	7.7	7.48
	(1)	(2)	(3)	(4)	(5)	(6)
Mean Temperature	0.540*	-4.222***	-0.0485	-0.00134	1.011	1.367
	(0.303)	(1.120)	(0.881)	(0.532)	(0.662)	(1.550)
Country*Year Fixed Effects	yes	yes	yes	yes	yes	yes
City Fixed Effects	yes	yes	yes	yes	yes	yes
Observations	6,345	429	1,644	2,517	1,551	201
R-squared	0.899	0.947	0.947	0.879	0.872	0.919

Note: Data are a panel of 2215 European cities. The left-hand-side variable is the natural log of number of city inhabitants. Mean temperature is year temperature averaged over the periods 1500 to 1600, 1600 to 1700, and 1700 to 1750. The definition of climate groups follows the Koeppen-Geiger definition (Peel et al. 2007). Arid hot climate corresponds to Koeppen-Geiger climate group B. Temperate hot climate corresponds to Koeppen-Geiger climate groups Csa and Cfa. Temperate warm climate corresponds to Koeppen-Geiger climate groups Csb and Cfb. Moderately cold climate corresponds to Koeppen-Geiger climate groups Dfa and Dfb, and Cold and alpine climate corresponds to Koeppen-Geiger climate groups Dfc and ET.
Robust standard errors in parentheses, clustered at city level
*** p<0.01, ** p<0.05, * p<0.1

1.7. The Role of Agricultural Productivity

1.7.1. The Effect of Temperature on Wheat Prices

The results have shown that the effect of temperature on city size varies across climate zones. The question arises through which channel this effect occurs. Historians have argued that the Little Ice Age affected agricultural productivity. Fruit blossoming, haymaking and grape ripening were delayed because of cold weather (Behringer, 2010: 93). "Shortened growing seasons [during the Little Ice Age] led to reductions in agricultural productivity, especially in northern Europe," (Aguado, 2007: 483). The overwhelming importance of agriculture for the economy at the time also makes it plausible that temperature may have affected city size through its effect on agricultural productivity. "The growth rates of agricultural outputs and productivity within each country were the primary determinants of overall growth rates in each [European] country," (Dennison, 2010: 148). It is therefore plausible that a negative effect of disadvantageous weather conditions during the Little Ice Age on agricultural productivity may have translated into an effect on city size and on the economy overall.

To test this hypothesis, I combine yearly temperature data from Luterbacher et al. (2004) with annual data on wheat prices for ten European cities from Allen (2001). Data is available for Amsterdam, London, Leipzig, Antwerp, Paris, Strasbourg, Munich, Florence, Naples, and Madrid. In this section, I use wheat prices as a proxy for agricultural productivity. As city level demand changes only gradually yearly fluctuations in wheat prices are likely to be a reflection of changes in supply. Determinants of agricultural productivity, other than temperature, such as certain institutions or technologies, are unlikely to change immediately from year to year in response to temperature changes. The immediate effect of temperature on wheat prices is therefore likely to depend primarily on temperature's effect on agricultural productivity. As people are likely to reduce consumption when prices increase the result may be seen as a lower bound estimate. I propose the following specifications to assess the effect of temperature on agricultural productivity:

$$(4) \qquad Wheat\ Price_{irt} = \beta + \gamma Mean\ Temperature_{irt} + i_i + c_i + \varepsilon_{irt}$$

I regress the wheat price in city *i* and time period *t* on temperature in city *i*, and time period *t*. *c* denotes a number of additional control variables I also include a full set of city fixed effects *i*. The coefficient of interest here is γ. It describes the relationship between changes in temperature and changes in wheat price in city *i* and time period *t*.

Table 11 reports results. Columns 1 to 5 contain estimates of the effect of temperature on wheat prices when including city fixed effects and year fixed effects. Columns 6 to 10 contain estimates of the effect when including city fixed effects and region times year fixed effects. In columns 2 to 5 and 7 to 10 four additional control variables are introduced that may have affected wheat prices. Omitting them from the equation may lead to biased results if these variables are also correlated with mean temperature. It is therefore important to include them in the specification. I include reconstructed precipitation data. I then include a variable that counts the number of battles that were fought in a country in a given year. It is likely that wars in a country may have increased the costs of trading which could have affected wheat prices. I also control for whether a country has access to the Sea and whether it is an Atlantic trader. These two variables are proxies for access to trade. Access to trade and lower transportation costs may have affected wheat prices. If these variables were also correlated with mean temperature omitting them from the specification would bias results. The two variables, Access to Ocean and Atlantic Trader, are interacted with a full set of year fixed effects to account for the possibility that these characteristics may have had affected differently at different points in time.

The coefficient on mean temperature in column 1 is negative and significant. This indicates that a one degree increase in temperature leads to an average decrease in wheat prices of 11 percent. This suggests that an increase in temperature may have led to an average increase in wheat yields and therefore to a decrease in prices. This results is consistent with results in Table 3 showing that, overall, an increase in temperature had a positive effect on city size. This result is robust to the inclusion of the control variables described above (columns 2 to 5). The coefficient decreases only very slightly and remains significant.

The specification in columns 6 to 10, when replacing year fixed effects by region times year fixed effects, show the same pattern as regressions 1 to 5. The coefficient size is smaller. It remains robust to the inclusion of the aforementioned control variables.

Then, I estimate specification (2) for each of the ten cities separately. I regress *Wheat Price* in time period *t* on mean temperature in time period *t*. Previous results have indicated that the effect of temperature on city size varies with initial climate. It is therefore interesting to test whether the effect of temperature on wheat prices varies with initial climate. The ten cities in the data set are located in different climate zones within Europe. An increase in temperature might affect agricultural productivity differently in northern Europe, where it is relatively cold, than in southern Europe, where it is relatively warm.

Columns 1 and 2 of Table 12 contain specifications as estimated in columns 1 and 6 of ***Table 11***. Columns 3 to 12 of show results of regressions for each city separately. Results are shown according to latitude, showing the northernmost city, Amsterdam, first and the southernmost city, Madrid, last. For the seven northernmost cities results coefficients on temperature are negative indicating that an increase in temperature in these areas improves agricultural productivity and lowers wheat prices. For the three southernmost cities, Florence, Naples and Madrid, the coefficient on temperature is positive indicating that an increase in temperature reduced agricultural productivity and lead to an increase in wheat prices. These results are consistent with previous results that have shown variation in the effect of temperature on city size across Europe.

Table 11 The effect of yearly temperature on yearly wheat prices - all cities

	Ln Wheat Prices (grams of silver per kg)									
	Year Fixed Effects					***Region×Year fixed Effects***				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Mean Temperature	-0.110***	-0.104***	-0.106***	-0.106***	-0.103**	-0.0626**	-0.0646**	-0.0681**	-0.0681**	-0.0864
	(0.0215)	(0.0219)	(0.0217)	(0.0217)	(0.0351)	(0.0272)	(0.0279)	(0.0256)	(0.0256)	(0.0762)
City Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year Fixed Effects	yes	yes	yes	yes	yes					
Region×Year fixed Effects						yes	yes	yes	yes	yes
Control Variables (×Year Fixed Effects)										
Precipitation		yes	yes	yes	yes		yes	yes	yes	yes
Battle			yes	yes	yes			yes	yes	yes
Access to Ocean				yes	yes				yes	yes
Atlantic Trader					yes					yes
Observations	2,111	2,111	2,111	2,111	2,111	2,111	2,111	2,111	2,111	2,111
R-Squared	0.663	0.666	0.666	0.666	0.736	0.745	0.747	0.748	0.748	0.799

Robust standard errors in parentheses, clustered at city level

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 12 The effect of yearly temperature on yearly wheat prices – by city

	Ln Wheat Prices (grams of silver per kg)											
	All Cities	***All Cities***	***Amsterdam***	***London***	***Leipzig***	***Antwerp***	***Paris***	***Strasbourg***	***Munich***	***Florence***	***Naples***	***Madrid***
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mean Temperature	-0.110***	-0.0626**	-0.0908**	-0.140**	-0.0214	-0.110	-0.126***	-0.0354	-0.0401	0.118**	0.251***	0.0276
	(0.0215)	(0.0272)	(0.0373)	(0.0575)	(0.0315)	(0.0707)	(0.0413)	(0.0462)	(0.0428)	(0.0552)	(0.0530)	(0.0771)
City Fixed Effects	yes	yes										
Year Fixed Effects	yes											
Region×Year fixed Effects		yes										
Observations	2,111	2,111	282	425	215	133	355	361	316	307	248	278
R-Squared	0.663	0.745	0.021	0.014	0.002	0.018	0.026	0.002	0.003	0.015	0.084	0.000

Robust standard errors in parentheses, clustered at city level

*** p<0.01, ** p<0.05, * p<0.1

1.7.2. The Effect of Temperature on Yield Ratios

In this section, I introduce historical yield ratios as an alternative, more direct measure of agricultural productivity. Yield ratio is defined as ratio of the amount of harvested crop grains over the amount of crop grains used for sowing. The data is taken from Slicher van Bath (1963). The author provides crop yields by year and city during the 16^{th}, 17^{th} and 18^{th} century for European countries. For each city, the number of years for which crop yield data is available varies between one and several hundred years. For certain years, information on crop yields is available from various cities within one country. For other years, data is available from only one city or not at all. I aggregate the yield ratio data at the country level (following Slicher van Bath (1963)'s classification of countries). For each year, I take the mean yield ratio of cities for which this information is available. This has the advantage that cities for which crop yields are available for only one year are not omitted. The estimates are reported in Table 13. In column 1, the relationship between yearly mean temperature and yield ratio is estimated with no further controls. Then, year fixed effects (column 2) and region fixed effects (column 3) are introduced into the specification. In column 4 country fixed effects are introduced into the specification following Silcher Bath's information on the country in which each city is located. In columns 5 to 8, I add additional control variables to clarify whether it is really the link between yield ratios and weather that is of relevance here or whether other variables that were not included before could explain the estimated relationship. As described in the previous section, I control for precipitation, for the number of battles fought within one country during each year, and for a country's access to an ocean and its status as an Atlantic Trader.

$$(5) \qquad Yield\ Ratio_{crt} \ = \ \beta + \gamma Mean\ Temperature_{crt} + countryFE_c + c_i + \varepsilon_{irt}$$

Table 13 presents results. I estimate the effect of mean temperature on yield ratios without any control variables (column 1) and then including year fixed effects (column 2). The relationship is positive but not significant. Then, I add country fixed effects and region fixed effects in columns 3 and 4. The size of the coefficient increases and it is significant. In columns 5 to 8, as in the previous section, I control for various control variables: precipitation, how many battles took place in a country in each year, whether a country had access to the ocean or was an Atlantic trader. The coefficient size is robust to the inclusion of these controls. The standard errors also increase and the significance of the coefficient lies at 10 percent.

Table 13 The effect of yearly temperature on yearly yield ratios

	Yield Ratios							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean Temperature	0.182	0.139	0.499**	0.430***	0.459***	0.451***	0.434**	0.543*
	(0.285)	(0.282)	(0.162)	(0.111)	(0.112)	(0.112)	(0.142)	(0.259)
Year Fixed Effects		yes	yes	yes	yes	yes	yes	yes
Region fixed Effects			yes					
Country Fixed Effects				yes	yes	yes	yes	yes
Control Variables (×Year Fixed Effects)								
Precipitation					yes	yes	yes	yes
Battle						yes	yes	yes
Access to Ocean							yes	yes
Atlantic Trader								yes
Observations	702	702	702	702	702	702	702	702
R-Squared	0.017	0.321	0.732	0.802	0.803	0.803	0.820	0.847

Robust standard errors in parentheses, clustered at country level
*** p<0.01, ** p<0.05, * p<0.1

1.8. Heterogeneity in the Effect of Temperature

1.8.1. The Effect of Temperature on Small and Large Cities

If temperature affects city size through its effect on agricultural productivity we would expect cities that depend especially on agriculture to be more affected by temperature changes than cities whose economies are more diverse. De Vries (1976: 7f.) finds that grain-growing villages were more affected by harvest failure than places with more diverse economies. Burgess et al. (2011) find that short-term temperature shocks in India only affected rural, not urban, areas because the former depended on agriculture. To test this hypothesis, I propose specification 4.

$$(6)\ City\ Size_{ict} = \beta + \gamma MeanTemperature_{ict} + \theta MeanTemperature{*}BigCity_{ict} + cy_{ct} + i_i + \varepsilon_{ict}$$

In the following, I estimate specification 5. I regress city size on mean temperature and on an interaction term of mean temperature and the dummy variable *BigCity*. *BigCity* is a dummy variable that is 1 for all cities that were larger than the median city in 1500. The subscripts *i*, *c*, and *t* denote city, country, and time. The specification includes country times year fixed effects, *cy*, and city fixed effects, *i*.

Table 14 shows results. Columns 1 and 2 contain results for the entire sample. The first column excludes, the second column includes the interaction term. The coefficient on mean temperature in column 1 is the estimated effect of temperature on city size in all cities. The coefficient on mean temperature in column 2 is the estimated effect of temperature on city size in cities that were smaller than the median city in 1500. The coefficient of the interaction term estimates the difference in the effect of temperature on city size between small cities and large cities. The coefficient on mean temperature is larger in column 2 compared to column 1. It is larger for small cities than for the entire sample. The coefficient estimate on the interaction term is negative and significant. This indicates that the effect of temperature on large cities is significantly smaller compared to the effect of temperature on relatively small cities.

One interpretation of this finding is that the economy of big cities depended on average less on agriculture and is therefore less affected by temperature changes. Table 10 has shown that the effect of temperature on city size varies across climate zones. If this is true then we would expect to see the same pattern of heterogeneity here. We would expect that the effect of temperature on city size is always closer to 0 for large cities compared to small cities. For areas where the effect of temperature on city size is positive, such as in relatively cold climates, we would expect the interaction term to have a negative sign. For areas where the effect of temperature on city size is negative, such as in relatively warm climates, we would expect the interaction term to have a positive sign.

Columns 3 to 7 in Table 14 show results for different climate areas. As expected, we see that the coefficient on the interaction term always has the opposite sign compared to the coefficient on mean temperature. The only exception is the result in column 3 for arid and hot climates. Despite its small sample, one might still be worried that the result in column 2 is mainly driven by this climate group. In column 8, I therefore estimate the specification including all cities except those in arid, hot climate. As can be expected the coefficient on mean temperature increases compared to column 2. This is not surprising because the average climate of cities included in this regression is cooler compared to cities included in the regression of column 2. The coefficient on the interaction term is slightly smaller but remains significant at the 10 percent level. This result indicates that the effect of temperature on city size is different for small and large cities.

Table 14 The Effect of Temperature in Small and Large Cities

	LOG City Size (inhabitants)							
	Entire Sample	***Entire Sample***	***Arid Hot Climate***	***Temperate Hot Climate***	***Temperate Warm Climate***	***Moderately Cold Climate***	***Cold and Alpine Climate***	***All Cities excl. Arid Hot Climate***
Latitude (°N)	46.63	46.63	39.01	40.72	49.12	50.63	49.18	47.18
Longitude (°E)	8.87	8.87	-2.05	10.6	9.97	20.38	12.48	9.66
Temperature (°C)	10.71	10.71	14.39	14.15	9.99	7.7	7.48	10.45
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean Temperature	0.540*	0.760**	-2.617*	-1.23	0.432	1.285*	1.991	0.961***
	(0.303)	(0.334)	(1.414)	(0.999)	(0.536)	(0.694)	(1.918)	(0.342)
Big City* Mean Temperature		-0.457**	-3.260**	2.555***	-0.955***	-0.554	-1.28	-0.393*
		(0.21)	(1.308)	(0.666)	(0.269)	(0.378)	(1.672)	(0.213)
Country*Year Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes
City Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	6,345	6,345	429	1,644	2,517	1,551	201	5,916
R-squared	0.899	0.899	0.949	0.948	0.88	0.873	0.92	0.897

Note: Data are a panel of 2215 European cities. The left-hand-side variable is the natural log of number of city inhabitants. Mean temperature is year temperature averaged over the periods 1500 to 1600, 1600 to 1700, and 1700 to 1750. Big City is a dummy variable that is 1 for all cities whose size was below the median in 1600. Big City*Mean Temperature is an interaction of the dummy variable big City and the variable Mean Temperature. The definition of climate groups follows the Koeppen-Geiger definition (Peel et al. 2007). Arid hot climate corresponds to Koeppen-Geiger climate group B. Temperate hot climate corresponds to Koeppen-Geiger climate groups Csa and Cfa. Temperate warm climate corresponds to Koeppen-Geiger climate groups Csb and Cfb. Moderately cold climte corresponds to Koeppen-Geiger climate groups Dfa and Dfb, and Cold and alpine climate corresponds to Koeppen-Geiger climate groups Dfc and ET

Robust standard errors in parentheses, clustered at city level *** p<0.01, ** p<0.05, * p<0.1

1.8.2. The Effect of Temperature on Trade Cities

In section 1.7.2 we have seen that the effect of temperature on city size is significantly smaller for large cities whose economies are likely to depend less on agriculture than the economy of small cities. In this section, I want to add to this by testing temperature's effect on cities that were part of long distance trade networks. In particular, I test whether the effect of temperature is different for cities that were part of the Hanseatic League, a network of independent trading towns in Medieval Europe. It had been established as an alliance between two trading cities in north Germany, Hamburg and Lübeck, that joined forces to fight piracy in the North and Baltic Sea (Merriman, 2010: 24). Later, more than 30 other cities joined it as members or as *kontor* cities that had constant offices of the Hanseatic league. The League granted each member trading privileges, provided nautical charts and waged war. The Hanseatic cities were located in the German states or in North and Eastern Europe. Most member cities were directly located at the North and Baltic Sea, others, such as Cologne and Dortmund, were not. At its peak in the 14th century it controlled the sea routes of the North and Baltic Sea from London to Novgorod. In the period under study the Hanseatic League was beyond its most influential time. Yet, its members were still likely to be on average more involved in trading activities than the other European cities.

$$(7)\ City\ Size_{ict} = \beta + \gamma MeanTemperature_{ict} + \theta MeanTemperature*HanseCity_{ict} + cy_{ct} + i_i + \varepsilon_{ict}$$

To test whether cities with access to long distance trade were affected differently by temperature change than cities that engaged less in trading activities I estimate specification 5. I regress city size on mean temperature and an interaction term of mean temperature and the variable *HanseCity*. *HanseCity* is a dummy variable that is 1 for all cities that were member or *kontor* cities of the Hanseatic League according to Haywood (2000; see Table 15). The subscripts *i*, *c*, and *t* denote city, country, and time period. The specification also includes country times year fixed effects *cy* and city fixed effects *i*.

Table 15 Cities of the Hanseatic League

Berlin	Cologne	Elblag	Deventer	Kaliningrad	Russia
Braunschweig	Lübeck	Gdansk	Groningen	Riga	Latvia
Bremen	Magdeburg	Kolobrzeg	Kampen	Tallin	Estonia
Dortmund	Osnabrueck	Szczecin	Nijmegen	Tartu	Estonia
Hamburg	Rostock	Torun		Visby	Sweden
Kiel	Stralsund	Wroclaw			
Wismar					

Notes: This list of cities contains members cities and *kontor* cities of the Hanseatic League in 1500. *Kontor* cities were cities in which the Hanseatic League held permanent offices. The data is taken from Haywood et al. (2000).

Table 16 shows results. Columns 1 and 2 contain results for the entire sample, the first column without, the second with the interaction term. The coefficient on mean temperature in column 2 shows the estimated effect of temperature on cities that were not Hanseatic cities. The coefficient on the interaction term in column 2 shows the difference in the effect of temperature on city size between cities that were and cities that were not part of the Hanseatic League. It shows that the effect of temperature on cities that were part of the Hanseatic League is significantly smaller than the effect of temperature on cities that were not.

Columns 3 to 7 show results for climate groups separately. As the Hanseatic League existed mainly in the North and Baltic Sea region I only estimate the effect separately for cities in temperate warm and moderately cold climate. In both climate groups, the effect of temperature on city size is significantly smaller for cities that were part of the Hanseatic League compared to cities that were not part and the difference is larger in colder areas. While the combined estimated effect of temperature for trade cities with moderately cold climate is almost zero, it is negative for trade cities in temperate warm cities. This is somewhat surprising. While we would expect the combined coefficient to be smaller, we would not expect it to become negative indicating a negative effect of temperature increases in an area where temperature increases have generally a positive effect. One explanation for this pattern could be that temperature increases in the temperate warm climate zone has positive effects on agriculture and increases in temperature therefore incite people working in in trade to relocate to the agricultural sector. This could have a direct negative effect on city size. It might also have long-run negative effects on economic growth. In the short-run, they might enjoy a higher income. In the long run, however, for example because trading activities might be easier to scale up compared to agricultural activities if costs of scaling up are higher in agriculture – e.g. buying land – compared to scaling up in trade which is possible to do in a more step-by-step way, e.g. by expanding the trading stock stepwise.

Table 16 The Effect of Temperature on Cities of the Hanseatic League

	LOG City Size (inhabitants)						
	Entire Sample	***Entire Sample***	***Arid Hot Climate***	***Temperate Hot Climate***	***Temperate Warm Climate***	***Moderately Cold Climate***	***Cold and Alpine Climate***
Latitude (°N)	46.63	46.63	39.01	40.72	49.12	50.63	49.18
Longitude (°E)	8.87	8.87	-2.05	10.6	9.97	20.38	12.48
Temperature (°C)	10.71	10.71	14.39	14.15	9.99	7.7	7.48
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mean Temperature	0.540*	0.658**	-4.222***	-0.0485	0.0708	1.307*	1.367
	(0.303)	(0.308)	(1.120)	(0.881)	(0.536)	(0.687)	(1.550)
HanseCity* Mean Temperature		-1.114***			-0.969**	-1.307***	
		(0.307)			(0.407)	(0.443)	
Country*Year Fixed Effects	yes	yes	yes	yes	yes	yes	yes
City Fixed Effects	yes	yes	yes	yes	yes	yes	yes
Observations	6,345	6,345	429	1,644	2,517	1,551	201
R-squared	0.899	0.899	0.947	0.947	0.879	0.873	0.919

Note: Data are a panel of 2215 European cities. The left-hand-side variable is the natural log of number of city inhabitants. *Mean Temperature* is year temperature averaged over the periods 1500 to 1600, 1600 to 1700, and 1700 to 1750. *HanseCity* is a dummy variable that is 1 for all cities that were part of the Hanseatic League, as members or *kontor* cities in 1500 according to Haywood et al. (2000). *HanseCity*Mean Temperature* is an interaction of the dummy variable *HanseCity* and the variable *Mean Temperature*. The definition of climate groups follows the Koeppen-Geiger definition (Peel et al. 2007). Arid hot climate corresponds to Koeppen-Geiger climate group B. Temperate hot climate corresponds to Koeppen-Geiger climate groups Csa and Cfa. Temperate warm climate corresponds to Koeppen-Geiger climate groups Csb and Cfb. Moderately cold climte corresponds to Koeppen-Geiger climate groups Dfa and Dfb, and Cold and alpine climate corresponds to Koeppen-Geiger climate groups Dfc and ET.
Robust standard errors in parentheses, clustered at city level
*** p<0.01, ** p<0.05, * p<0.1

1.8.3. The Effect of Temperature Conditional on City Size and Trade Estimated Using Interaction Terms

In this section, I estimate the effect of temperature conditional city size and access to trade. In this sense it is identical to sections 1.8.1 and 1.8.2. It is different from these sections as I am using interaction terms here while I have used split samples in the previous sections. The advantage of using interaction terms is that the complete sample instead of a subset is included in the regression which increases precision of estimates.

Ideally, to estimate the effect of temperature conditional on another variable, we would introduce interaction terms of this variable with all other variables in the equation. To estimate the effect of temperature conditional on city size, for example, we would introduce an interaction term of temperature and city size, and also interaction terms of city size with all other variables in the equation, i.e. other control variables and all fixed effects. I follow this ideal as closely as computing power limitations permit.

In Table 17, I summarise the regression equations as they should be ideally specified and as they are specified in Table 18. Column 1 estimates the effect of temperature on city size conditional on climate group. The specification estimates the main effects of mean temperature, country times year fixed effects and city fixed effects. The indicator variables for each climate group are not included here as they are constant within each city and are part of the city fixed effects. Then, it contains interaction terms of the indicator variables for each climate group with all other variables (Climate Groups × Mean Temperature, Climate Groups × Country Times Year Fixed), except city fixed effects. The group of interactions in the catgory Climate Groups × City Fixed Effects could not be included due to computing power limitations. For column 1, I also sketch out the various combinations of the indicator variables that constitute each category.

Column 2 estimates the effect of temperature on city size conditional on climate group and city size. As in column 1, the specification estimates the main effects of mean temperature, country times year fixed effects and city fixed effects. It also includes interactions of the variable Big City and of the indicator variables for each climate group with these baseline variables. The only exceptions are the interactions of climate groups and Big City with city fixed effects due to computing power limitations. Finally, the specification contains three-way interaction term of the indicator variables for each climate group, the variable Big City, and the baseline variables (Climate Groups × Big City × Mean Temperature and Climate Groups × Big City × CY Fixed Effects).

The regression specification for column 3 is identical to the specification for column 2 with main effects, two way interactions and three way interactions, except that the variable Big City is replaced by the variable Hanseatic League.

Table 18 reports regression results. Column 1 estimates the effect of temperature conditional on climate group. Column 2 estimates the effect of temperature conditional on climate group and city size. Column 3 estimates the effect of temperature conditional on climate group and Membership in the Hanseatic League. The results of the regression are summarised in Table 18 where the coefficients of the relevant main effects and interaction terms are added up to effect of the categories of interest.

The first section of Table 18 shows the resulting estimated effect of temperature on cities conditional on climate zone. Results indicate that the effect of a one degree increase in temperature is most positive for areas with cold climate while the effect is negative in places with hot and arid climate.

The second section of Table 18 presents the estimated effect of temperature on cities conditional on being a relatively big city (above the median city in 1600) and on climate zone. The estimated effects are largest for small cities with cold and alpine, moderately cold, and temperate hot climate. For these climate zones, the effect of temperature on city size is substantially smaller for big cities. For the climate zone of temperate warm climate, the estimated effect is similar. It is substantially larger for cities with hot and arid climate.

The third section of Table 18 reports the estimated effect of temperature on cities condition on being a member of the Hanseatic League. Member cities of the Hanseatic League are all located in areas with moderately cold or temperate warm climate. For cities of the Hanseatic League with moderately cold climate the effect of temperature on city size is smaller than for non-Hanseatic League members. For cities with temperate warm climate the estimated coefficient is substantially smaller, such that it is negative even though the overall estimated effect of temperature in this climate zone in this specification is close to zero. For the non-Hanseatic cities the coefficient is negative in hot arid areas indicating a negative effect of further temperature increases while it is large and positive in moderately cold and cold and alpine areas.

The patterns of the estimated effects are very similar to the estimated effects in Table 10, but they are not identical. A plausible reason for this are the missing interaction terms between variables (e.g. climate zone indicator variables, big city indicator variable, and Hanseatic League indicator variable) with city fixed effects.

Table 17 Regression Equations and Interaction Terms For Table 18

Column 1

Main Effect	***Interaction Terms***					
	Included				***Not included***	
Mean Temperature	***Climate Groups × Mean Temperature***		***Climate Groups × Country Times Year Fixed Effects***		***Climate Groups × City Fixed Effects***	
	hot arid climate	mean temperature	hot arid climate	CY FE1, CY FE2, CY FE3…	*hot arid climate*	*city FE1, city FE2, city FE3…*
	temperate hot climate	mean temperature	temperate hot climate	CY FE1, CY FE2, CY FE3…	*temperate hot climate*	*city FE1, city FE2, city FE3…*
	temperate warm climate	mean temperature	temperate warm climate	CY FE1, CY FE2, CY FE3…	*temperate warm climate*	*city FE1, city FE2, city FE3…*
	moderately cold climate	mean temperature	moderately cold climate	CY FE1, CY FE2, CY FE3…	*moderately cold climate*	*city FE1, city FE2, city FE3…*
	cold and alpine climate	mean temperature	cold and alpine climate	CY FE1, CY FE2, CY FE3…	*cold and alpine climate*	*city FE1, city FE2, city FE3…*

Column 2

	Included		***Not Included***
Mean Temperature	***Climate Groups × Mean Temperature***	***Climate Groups × Country Times Year Fixed Effects***	*Climate Groups × City Fixed Effects*
	Big City × Mean Temperature	***Big City × Country Times Year Fixed Effects***	*Big City × City Fixed Effects*
	Climate Groups × Big City × Mean Temperature	***Climate Groups × Big City × CY Fixed Effects***	*Climate Groups × Big City × City Fixed Effects*

Column 3

	Included		***Not Included***
Mean Temperature	***Climate Groups × Mean Temperature***	***Climate Groups × Country Times Year Fixed Effects***	*Climate Groups × City Fixed Effects*
	Hanse × Mean Temperature	***Hanse × Country Times Year Fixed Effects***	*Hanse × City Fixed Effects*
	Climate Groups × Hanse × Mean Temperature	***Climate Groups × Hanse × CY Fixed Effects***	*Climate Groups × Hanse × City Fixed Effects*

Table 18 ***The Effect of Temperature on Cities Conditional on Climate, City Size, and Hanseatic League Membership***

	LOG City Size (inhabitants)			
	Climate	***Climate and Big City***	***Climate and Hanseatic League***	
	(1)	(2)		(3)
Mean Temperature	-4.203*** (1.104)	-2.531 (2.230)	***Mean Temperature***	-4.203*** (1.106)
Mean Temperature *Arid Hot Climate	omitted category	omitted category	***Mean Temperature *Arid Hot Climate***	omitted category
Mean Temperature *Temperate Hot Climate	4.345*** (1.369)	4.374 (2.883)	***Mean Temperature *Temperate Hot Climate***	4.345*** (1.373)
Mean Temperature *Temperate Warm Climate	4.145*** (1.222)	2.377 (2.409)	***Mean Temperature *Temperate Warm Climate***	4.770*** (1.263)
Mean Temperature * Moderately Cold Climate	5.206*** (1.285)	5.246** (2.433)	***Mean Temperature * Moderately Cold Climate***	6.076*** (1.484)
Mean Temperature *Cold and Alpine Climate	5.570*** (1.828)	6.195* (3.267)	***Mean Temperature *Cold and Alpine Climate***	6.972*** (2.186)
Mean Temperature *BigCity		-3.32 (92.538)	***Mean Temperature *Hanseatic League***	0.606 (8.171)
BigCity *Arid Hot Climate		omitted category	***Hanseatic League *Arid Hot Climate***	
BigCity *Temperate Hot Climate		1.676 (3.196)	***Hanseatic League *Temperate Hot Climate***	
BigCity *Temperate Warm Climate		3.282 (2.717)	***Hanseatic League *Temperate Warm Climate***	-5.424 -8.601
BigCity * Moderately Cold Climate		0.618 (2.758)	***Hanseatic League * Moderately Cold Climate***	-2.005 (8.310)
BigCity *Cold and Alpine Climate		0.602 (3.605)	***Hanseatic League *Cold and Alpine Climate***	
Observations	6,360	6,360		6,360
R-squared	0.904	0.920		0.905

Note: The same notes as in Table 14 and Table 16 apply.
Robust standard errors in parentheses, clustered at city level
*** p<0.01, ** p<0.05, * p<0.1

Table 19 The effect of temperature on city size in…

Conditional on climate zone			
cities with hot arid climate	-4.203		
cities with temperate hot climate	0.142		
cities with temperature warm climate	-.058		
cities with moderately cold climate	1.003		
cities with cold and alpine climate	1.367		
Conditional on city size and climate zone			
big cities with hot arid climate	-5.851	-2.531	small cities with hot arid climate
big cities with temperate hot climate	0.199	1.843	small cities with temperate hot climate
big cities with temperate warm climate	-0.192	-.154	small cities with temperate warm climate
big cities with moderately cold climate	0.013	2.715	small cities with moderately cold climate
big cities with cold and alpine climate	0.946	3.664	small cities with cold and alpine climate
Conditional on city size and climate zone			
Hanseatic cities with hot arid climate		-4.203	non - Hanseatic cities with hot arid climate
Hanseatic cities with temperate hot climate		0.142	non- Hanseatic cities with temperate hot climate
Hanseatic cities with temperature warm climate	-4.251	0.567	non- Hanseatic cities with temperature warm climate
Hanseatic cities with moderately cold climate	0.474	1.873	non- Hanseatic cities with moderately cold climate
Hanseatic cities with cold and alpine climate		2.769	non- Hanseatic cities with cold and alpine climate

1.9. Comparability to Current Economic Situation

Economic characteristics of Early Modern and present-day Europe are clearly very different. One among many indicators of these changes has been the declining importance of the agricultural sector and the structural transformation of the European economy as a whole. While in 1600 and 1700 43.2 and 26.8 percent of UK GDP came from agriculture, this number has shrunk to 1 percent in 2012 (Broadberry et al., 2011; World Bank, 2014). At the same time, the importance of the service sector has increased dramatically from 24.3 and 34 percent in 1600 and 1700 to 78 percent in 2012. Other indicators, such as the share of the work force employed in agriculture, also speak of the same transformation (see Table 20).

The same indicators today for countries in the developing world, however, are more similar to those from the Early Modern European economy. Between 35 and 56 percent of GDP in countries such as Burkina Faso, Chad, and Mali come from the agricultural sector. These West African economies are of course still very different from the Early Modern European economy in many respects (e.g. the shares of GDP from services are mostly higher than in Early Modern economies). These numbers show, however, their heavy economic reliance on agriculture. Agricultural productivity, e.g. in Chad, Burkina Faso and Mali, are extremely low, even lower than the agricultural productivity in England (Broadberry et al., 2011). This chapter and previous research (e.g. Burgess et al., 2011) have identified temperature's effect on agricultural productivity as an important channel through which temperature may affect economic growth. This could suggest that vulnerability to adverse climate change of developing countries' economies might be similar as in Early Modern Europe. Climate researchers predict strong effects of adverse climate change on developing countries' economies (e.g. Parry et al., 2007).

Another important economic characteristic, especially for economies with an important agricultural sector, is farm size. Over past centuries, larger farms have usually been correlated with higher economic growth, e.g. because of economies of scale and higher investment into technological innovation. In Early Modern Europe a large part of the agricultural labour force worked on small landholdings (e.g. 52.4 percent in Savoy, 35.7 percent in Bohemia). Of course, this varied very much within Europe. Currently, the share of small holdings has decreased very much (e.g. 5.6 percent of holdings in England and 15 percent in France are smaller than 2 hectares). In developing countries, e.g. Senegal, Ethiopia, or Uganda the share of small holdings (< 2 hectares) is still relatively high (37.5 percent in Senegal, 87.1 percent in Ethiopia, 73.4 percent in Uganda).

Another important indicator of an country's economic potential is the literacy rate. Literacy is a fundamental pre-condition for training people to move to higher value added activities, e.g. in services or to open up businesses. Literacy remains very low in countries such as Burkina Faso, Chad, or Mali, where only about one third of the population can read. This is comparable to the values for literacy between 1500 and 1800.

The European economies have developed dramatically since the Early Modern period in every respect. They exhibit very different characteristics today than in the past. While developing countries' economies are also clearly different from Early Modern European economies, they are more comparable, e.g. in their high dependence on agriculture, their low farm size, and low levels of human capital.

Table 20 Economic characteristics of Countries in Early Modern Europe and Today

	Today			***Early Modern Europe***		
Indicator	***Country***	***Year***	***Value***	***Country***	***Year***	***Value***
Sectoral Shares in GDP, (%): Agriculture	United Kingdom	2012	1	England	1600	*43.2*
	France	2012	2	England	1700	*26.8*
	Burkina Faso	2012	35.0			
	Chad	2012	56.0			
	Mali	2012	42.0			
	Senegal	2012	17.0			
Sectoral Shares in GDP, (%): Industry	United Kingdom	2012	21	England	1600	*32.5*
	France	2012	19		1700	*39.2*
	Burkina Faso	2012	24			
	Chad	2012	13			
	Mali	2012	22			
	Senegal	2012	25			
Sectoral Shares in GDP, (%): Services	United Kingdom	2012	78	England	1600	*24,3*
	France	2012	79		1700	*34.0*
	Burkina Faso	2012	42.0			
	Chad	2012	34.0			
	Mali	2012	38.0			
	Senegal	2012	59.0			
Share of Workforce employed	United Kingdom	2012	1.0	England	1705	*35*
in Agriculture (%)	France	2013	3.0		1775	*29*
	Burkina Faso	2014	90.0	Prussia	1705	*80*
	Chad	2015	80.0		1775	*70*
	Mali	2016	80.0	Spain	1705	*71*
	Senegal	2017	77.5		1775	*66*
				France	1705	*70*
					1775	*65*
Farm Size(% of holdings of certain size)	Burkina Faso	1993	< 2 ha.: 32.4	Savoy	1600	<1 ha.: 52.4%
	Senegal	1993	< 2 ha.: 37.5	Hochberg, Germany	1788	<1 ha.: 45%
	England	1993	< 2 ha.: 5.6	Bohemia	1725	<1.5 ha.: 35.7%
	France	1988	< 2 ha.: 15			
	Ethiopia	2001	< 2 ha.: 87.1			

	Uganda	1991	< 2 ha.: 73.4			
Literacy	United Kingdom	2014	99.0	England	1500	*6*
	France	2014	99.0	Netherland		*10*
	Burkina Faso	2007	28.7	France		*7*
	Chad	2011	35.4	Spain		*9*
	Mali	2011	33.4	England	1800	*53*
	Senegal	2009	49.7	Netherland		*68*
				France		*37*
				Spain		*20*
Agricultural Productivity (crop yields in kg per hectar)	France	2012	6831	England	1550-59	1593.2
	United Kingdom	2012	6213		1600-10	2028.3
	Burkina Faso	2012	1230		1650-60	2411.8
	Chad	2012	1282		1700-10	2461.4
	Mali	2012	1667.0		1750-60	2890.7
	Senegal	2013	1310.0			

1.10. Conclusion

This chapter studies a historical research question in order to contribute to our understanding of the historical period while also shedding light on a theoretical question with implications for today. In this chapter, I study the effects of the Little Ice Age on city size in Early Modern Europe. Historians have documented both the Little Ice Age and its adverse economic effects in certain areas of Europe (e.g. Fagan, 2000; Behringer, 2010; Pfister et al., 2006). In this chapter, I econometrically test the hypothesis the Little Ice Age affected economic growth in Europe. This research contributes to the strand of literature that examines the effects of climatic changes in history. Results show that the temperature decreases during the Little Ice Age had adverse effects on city size. This is consistent with the historical evidence on the adverse economic effects of the Little Ice Age. This research also contributes to research on the economic effects of climate change in general. It is one of the first studies to provide econometric estimates of the economic effects of *long-term* climate change, when climate change spans several centuries. Previous research used year-to-year temperature changes (e.g Deschenes and Greenstone, 2007, 2012; Dell et al., 2012). The effects of year-to-year temperature changes, however, are unlikely to capture the effects of climate change, a long-term process to which people may adapt to. This chapter shows that - in the given setting - societies were not adapting sufficiently to the climatic changes in order to avoid negative long-term consequences. Results also show that the effect of temperature changes varied significantly with climatic and economic characteristics. Cities in already cold areas were especially affected by further temperature decreases. Cities that had better access to trade were significantly less affected.

What can be learnt from these results about the likely effects of the current climate change? While studying a historical episode of climate change provides the opportunity of studying the economic effects of climate change in the long-run it also brings with it certain interpretative challenges. The economic circumstances of Early Modern Europe are clearly different from present-day Europe. The robust effects of temperature changes found in this study suggest that - in the context of very low levels of political and economic institutional quality, with very little technological change, and especially in areas with already extreme climate and with limited access to trade - the mitigating force of adaptation is not sufficient to overcome the adverse effects of climate change.

Another interpretative challenge is that the period under study was exposed to temperature decreases, yet current climate change leads to temperature increases. Is the effect of temperature decreases likely to be similar to the effect of temperature increases? The literature on temperature and agircultural productivity shows that a one degree decreases in temperature away from the optimum has a smaller effect compared to a one degree increase in temperature (Schlenker et al., 2009). Besides, the magnitude of climate change is likely to be larger in the current climate change compared to the Little Ice Age. For both reasons, the direction and magnitude of the studied temperature changes it is very well possible that the estimated effects are underestimating the effects of the current climate change.

Following Dell et al. (2014) an alternative way of drawing lessons from past climate experiences is to examine heterogeneity in the estimated economic effects of temperature changes along relevant economic and climatic dimensions. These within-sample comparisons draw lessons based on variation in economic and political characteristics. In this chapter, for example, I compare cities with better access to trade to cities with less access to trade showing that the effect of climate is smaller for better-connected cities. The underlying mechanisms that have led to heterogeneous effects of temperature changes in the past can be expected to be still at work. Today, it is still likely that countries with better access to trade are in a better position to compensate for economic losses from adverse effects of climate change by specialising in non-affected sectors and increasing trade. These results are also consistent with evidence from short-term temperature changes (e.g. Dell et al., 2012).

2. Drought and the French Revolution: The effect of economic downturn on peasant revolts in 1789

2.1. Introduction

Recent research has shown that recessions may trigger revolutions because they decrease people's opportunity costs of contesting power (Acemoglu and Robinson, 2001, 2006; Berger and Spoerer, 2001, for the European Revolutions in 1848; Brueckner and Ciccone, 2011, for regime change in Africa; Dell, 2012, for the Mexican Revolution). People have "nothing to lose" and protest against the government, even if the recession's causes are known to be exogenous and transitory (Burke and Leigh, 2010: 126, Acemoglu and Robinson, 2006). Protesters will uphold the threat of revolution until institutional changes ensure more redistributive policies in the future (Acemoglu and Robinson, 2006: 31f.)

In 1788, on the eve of the French Revolution, a drought hit France and caused severe crop failure (Neumann, 1977). By 1789, grain prices had increased steeply and common people spent 88 percent of their income on bread compared to 50 percent in normal times (Neely, 2008: 72f.). The dry and hot summer was followed by a particularly cold winter. Ice blocked navigable rivers and prevented the transportation of cereals. Heating material became scarce and expensive. Living costs soared. The share of famished people grew rapidly. "On the eve of the Revolution, hunger was the great enemy for the majority of Frenchmen," (Lefebvre, 1973: 7). Famished peasants turned to protest and violence. Their anger was especially directed against the feudal system that imposed heavy cash and labour obligations on the common population and severely reduced their incomes (Lefebvre, 1973: 118). After weeks of persistent and violent protests, in August 1789, "[...] in an effort to appease the peasants and to forestall further rural disorders, the National Assembly formally abolished the "feudal regime," including seigneurial rights," (Merriman, 2010: 447; Neely, 2008: 80).

I use variation in climatic conditions in the summer of 1788 and in the winter of 1788/89 to test whether economic downturn on the eve of the French Revolution triggered political protest. I study two variables to measure weather variability: temperature levels and deviations in temperature from the long-term mean. To my knowledge, this study provides the first econometric test of the role of adverse weather conditions in the year preceding the French Revolution on peasant uprisings.

Economic theory predicts that adverse climatic conditions affect the probability of revolt if adverse climatic conditions affect income (Acemoglu and Robinson, 2001, 2006). To test this hypothesis, I construct a community level data set that contains information on the precise locations of peasant revolts (Lefebvre, 1973) and gridded data on temperatures in the summer of 1788 and the winter of 1788/89 (Luterbacher et al., 2004). I digitise and geo-reference information on the locations of peasant revolts, where they first broke out, which areas they later spread to and which areas remained completely untouched.

Results indicate that a one degree increase in summer temperatures during the drought summer 1788 significantly increased the probability of revolt by about 2.5 percentage points. A one degree decrease in temperatures in the severe winter of 1788/89 significantly increased the probability of revolt by about 2.7 percentage point. Temperature also affected the revolt's timing. Conditional on having a revolt, areas with higher summer temperatures in 1788 and lower winter temperatures in 1788/89 experienced earlier uprisings. These results are robust to the inclusion of county (*département*) level fixed effects. Results from temperature deviations from the mean show the same pattern. Summer temperature deviations *above* the long-term mean summer temperature and winter temperature deviations *below* the long-term mean winter temperature both increase the probability of revolt. This set of results indicates that summer temperature deviations had a larger effect on revolt compared to witner temperature devations.

I also show evidence that temperature affected the probability of peasant revolt through its effect on peasant's income as the effect of temperature on the probability of revolt was significantly higher in areas with a higher share of agriculture.

I also investigate the effect of adverse conditions on revolt in manufacturing areas. Adverse weather conditions should only affect income from agriculture but not from manufacturing.[1] Historians have documented that a crisis in the French manufacturing sector in the 1780s added to the economic crisis (Lefebvre 1973: 12). My results indicate a positive correlation between the share of manufacturing and the frequency of revolts which is consistent with the crisis in manufacturing. Adverse weather conditions, however, did not increase the probability of revolt in manufacturing areas. This suggests that the effect of climate on the probability of revolt operates primarily through its effect on the living conditions of farmers.

To test temperature's effect on crop failure more directly, I construst a dataset of summer temperatures between 1780 and 1790 and wheat prices for the same time period based on date from Labrousse (1939). Estimates show that increases in summer temperature increased wheat prices. This suggests a negative effect of summer temperature increases on agricultural productivity.

As a placebo test, I estimate the effect of summer and winter temperature deviations from the long-term mean in various years preceding the French Revolution. Estimates show that temperature in these previous years do not affect the probability of revolt in the way that theory would suggest. Instead, higher summer temperatures are mostly associated with a lower probability of peasant revolts.

Overall, the empirical results suggest that the mechanisms highlighted in theoretical models on the economic origins of political protest, such as Acemoglu and Robinson (2001, 2006), played an important role in the outbreak of peasant revolts across France during the French Revolution. Adverse negative economic shocks in the form of adverse climatic conditions decreased people's incomes, especially income from agriculture. They decreased people's opportunity costs of contesting power and increased the incidences of political protests, especially in areas with a high share of agriculture. Persistent violent peasant protests formed a credible threat of revolution. In response to this threat feudal obligations and privileges of the nobility, the fundamental characteristics of the ancient regime, were abolished.

This chapter contributes to various strands of literature, especially to the literature on the effect of negative economic shocks on political protest and subsequent institutional change. A study that is especially relevant to this chapter is Dell (2012). The author

[1] Burgess et al. (2011) show that adverse weather conditions in present-day India only affect income from agriculture, not income from manufacturing.

studies the effect of within-state variation in drought severity on municipality-level insurgency during the Mexican Revolution. She shows that municipalities that were more affected by drought also experienced more insurgency. After the Mexican Revolution, more land was redistributed in municipalities with more uprisings which had long-term negative effects on economic development Other studies have shown that within country variation in climatic conditions had effects on the development of democratic institutions (see Brückner and Ciccone, 2011 for sub-Saharan; Burke and Leigh, 2010, for a study on 150 countries). Analysing another historical episode, Berger and Spoerer (2001) provide evidence that the European Revolutions of 1848 were triggered by economic crisis and a shortfall in food supply. Others have estimated the effects of climate on other political outcome variables, such as civil conflict (Miguel et al., 2004; Hsiang et al. 2013), and historical uprisings in China (Jia, 2013).

A related strand of literature examines the effects of climatic events on economic growth (Burgess et al., 2011 and Dell, Jones, and Olken, 2012), agricultural output (Deschenes and Greenstone 2007, 2012) and health (Barreca et al., 2012).

This chapter also contributes to the historical literature that assesses the role of climate as a trigger of the French Revolution. Various historians have documented the relationship between adverse climatic conditions and the outbreak of the French Revolution (Neumann, 1977; Dettwiller, 1990; Le Roy Ladurie, 1972; Fagan, 2000). To my knowledge, this chapter is the first to provide an econometric assessment of this hypothesis.

The chapter proceeds as follows: Section 2.3 provides useful background to the outbreak of the French Revolution. Section 2.3 introduces the theoretical and historical framework. The empirical strategy and data set construction are described in section 2.4 I present results in section 2.5 and conclude in section 2.6.

2.2. Political, Economic, and Intellectual Context before 1789

An understanding of the political, economic, and intellectual context of pre-revolutionary France in crucial to an adequate interpretation of results. The estimated effect of weather shocks have to be interpreted as the effect of weather shocks *conditional* on accompanying characteristics, such as political, institutional, and social conditions of the time and place. While it is possible to take some of these factors explicitly into account as control variables and to test empirically whether the effect of weather shocks is affected by them, this is not possible for factors that do not vary within France because they are national level conditions or for factors that are unobservable. The estimated effect of weather shocks on uprisings has to be interpreted as an effect conditional on these underlying conditions. In other words, the same weather conditions may not have had an effect on uprisings at all in countries with different underlying political, economic and social conditions. England, for example, was also affected by the same adverse weather conditions in the 1780s. As their economy depended less on agriculture and had already moved more into manufacturing the general population was economically less affected by these weather conditions and riots did not take place. It is therefore important to interpret the effect of weather shocks in the context in which they appeared. In this section, I will therefore present the broader historical context of the period under study, in particular those factors that historians have discussed as causes of the French Revolution.

In the 1780s, a financial crisis severely weakened the political and economic power of the French king. Three main reasons, Bossenga (2011: 38) argues, lead up to this financial crisis. First, over the 18th century the French monarchy had been involved in several expensive wars to strengthen their position in Europe: the War of the Austrian Succession (1740-48), the Seven Years' War (1756-63), and the American War of Independence. Maintaining the French military and fighting these wars were very costly. Three-fourths of the money spent by the French monarchy in the 1780s was to maintain the military or to pay off war debts. Second, the French monarchy had to borrow money at relatively high interest rates. One reason for this was that it had defaulted several times on their debts in the past and lenders demanded compensation for the risk of default (Rosenthal, 1992: 11). Another reason was that – unlike the English monarchy – the French monarchy lacked a financial institution such as the Bank of the England from where it could have borrowed at lower interest rates (Norberg, 1994: 270; Bossenga, 2011: 38 ; Hoffman and Rosenthal, 2000: 442).

Thirdly, the French tax system was inefficient and did not generate enough income to repay debts.

The limited financial means made it impossible for the French King during the Revolution to either appease or subdue the uprisings. Formerly, the French kings had provided free grain in times of harvest crisis. As protests during the French Revolution were also partly motivated by food shortages (e.g. Neumann, 1977) the king might have had a chance to take momentum out of the protests if he had been able to feed the population. This was, however, beyond his financial scope. Furthermore, in the past, the French kings had also used military force to subdue uprisings. During the French Revolution, however, members of the military deserted in droves as the King was no longer able to pay their salaries. The lack of food and payment were of course only part of the motivation for uprisings. The King's ability to limit the scope of uprisings by providing food and using military force as French kings had formerly done was severely limited by the financial crisis.

Before the outbreak of the French Revolution the financial crisis already put the French king in a politically difficult situation vis-à-vis the French political elite. One option would have been to default as the French kings had done several times before. "[...] it had become a long-standing tradition for French monarchs to use default to solve, so to speak, the financial woes," (Bossenga, 2011: 38). However, the French king decided against this option. Declaring bankruptcy had always been a sign of political weakness and it was feared that France would lose investors' confidence entirely and would no longer be able to borrow, thereby making its financial situation even worse (Bossenga, 2011: 60). Instead, the French king chose to attempt a reform of the French public finances in order to improve French financial viability. "[...] if France was to maintain its position in Europe, tax revenues would have to rise [but] attitudes had changed and the traditional solution, raising taxes without a change in the distribution of power, was no longer acceptable even to the aristocracy," (Rosenthal 1992: 11). The monarchy depended on the wealthy elite to reform the tax system and to agree to tax raises, but the elite had no intention to agree unless more power was distributed to them (Hoffman, and Rosenthal, 2000). As a result, the Estates General were called. "It was this act, the calling of the Estates-General [...] that was novel in French history. This fateful decision opened the way to a whole new era in politics, in fact, to revolution," (Bossenga, 2011: 38).

The financial crisis of the Revolution were tightly interwoven with political and institutional conditions (Bossenga, 2001: 66). As mentioned above, one of the reasons of the financial crisis was the inefficient French tax system. It was inefficient because the right to raise taxes had been sold to individuals in return for short-term loans. Many powerful groups within the French society, especially the aristocracy and the church, had also been exempt from taxes in return for their loyalty, and their political and military support. In the French political tradition, these privileges were irrevocable. Each new king was accepted by the provincial nobility based on his promise to respect the existing privileges. "[...] the French king got the support of the important people in the kingdom by promising to preserve their power and privileges" (Neely 2008: 2, 4). In the long-term, the money that French kings had raised in return for tax exemptions and other privileges did not generate as much income as taxes. "Fiscal immunities, whether inherited or purchased, undermined French finances and put the king in the apparently ridiculous situation of taxing those who had nothing to tax. They also made it impossible for the Crown to reform the fiscal system and render it more equitable and more efficient," (Norberg, 1994: 256). In sum, the King's inability to raise taxes was at the heart of his inability to address the crisis adequately (Hoffman and Rosenthal, 2000: 443).

The manifold privileges and tax exemptions did not only render the French tax system inefficient and unresponsive they also lead to a highly unequal distribution of the tax burden across the French population. The poorest part of the population paid taxes to the King and had feudal obligations toward their local land lords (Neely 2008: 7). The high tax burden was among the main grievances of the French population at the eve of the French Revolution. Many nobles could still administer the law over peasants. Forests, lakes, and streams were controlled by the landlord and peasants did not have the right to hunt and fish (Merriman 2010: 438).

The hypothesis that an economic crisis was one of the causes of the French Revolution was pioneered by Labrousse (e.g. 1939, 1944). Labrousse argued that France experienced a broad economic crisis in the 18th century with rising population and grain prices, stagnant agricultural sector and falling real wages accompanied by falling demand in manufacturing products. More recently, this aggregate view of the 18th century French economy has been refined (Goldstone, 2001: 73). “Agriculture made only slow advances in yields in most areas during the century, but seaborne trade, especially through the Atlantic ports, was a great success story. The expansion of textile manufacturing and the beginnings of a chemical and metallurgical industry also helped France to have similar overall growth figures to Britain [...],” (Campbell, 2006: 18). It was not so much the absence of growth, but the failure to tax this growth sufficiently that left French finances strained. Instead, “French finances were overdependent upon internal tariffs (which inhibited trade) and the large but undynamic agricultural sector,” (Campbell, 2006: 18). Furthermore, growth of the urban and trade sector benefited only a relatively small proportion of the population, while modest increases in food production lead to only limited surpluses in some years and serious national food shortages in others resulting in the long-term in an increase in grain prices (Goldstone, 2001: 74). As one reason for stagnant agricultural productivity, Rosenthal (1992) identifies poorly defined property rights. He shows evidence that incentives for long-term investment in agricultural productivity, for example through investments in irrigations facilities, were limited because poorly defined property rights made it uncertain that the person investing would be able to benefit from the investment in the long-term. In sum, institutional short-coming were underlying causes of low economic growth in the agricultural sector and hindered the French state to take advantage of relatively high economic growth in the manufacturing sector.

Besides the long-term growth trajectory of the French economy, the implications of the economic crisis of the late 1780s, in particular of the manufacturing crisis of 1787/9 and the harvest failure of the year 1788/9, for the events of the French Revolution has received considerable attention. First, this crisis directly exacerbated the financial crisis. “[...] the unemployment of textile workers caused by France’s commercial treaty with England [...] or the famine resulting from the catastrophic harvest of 1788 bore directly on the fiscal crisis since they cut into the precious flow of tax revenues.” (Kaiser et al. 2001: 6)

Besides, the economic crisis of the 1780s has come to be seen not so much as a long-term development that caused, but as an event that triggered uprisings. This did not lessen the political importance of such uprisings. “Economic factors adversely affecting the most populous classes of the nation may not have generated the revolutionary crisis on their own. But surely they came to weigh heavily in the calculations of established authorities once hungry crowds in search of bread began to surge through the capital and countryside early in 1789, thereby posing increasingly ominous threats to public order," (Kaiser et al., 2011: 5). This interpretation of the economic crisis of the 1780s as a trigger that developed political effects in interaction with other factors chimes with Rosenthal (1992: 10)'s observation that "short-term food shortages far worse than those of 1788-9 had been weathered before without precipitating a Revolution. The subsistence crisis may indeed have fuelled the Revolution, because over the previous half-century expectations had changed and individuals had demanded state intervention to reduce the impact of food shortages." This observation is also corroborated by temperature data for the year preceding and following the Revolution. The temperatures in 1788 were not exceptional. They were soon after followed by similar temperatures. By this time, however, the underlying political, economic, and social conditions had already changed.

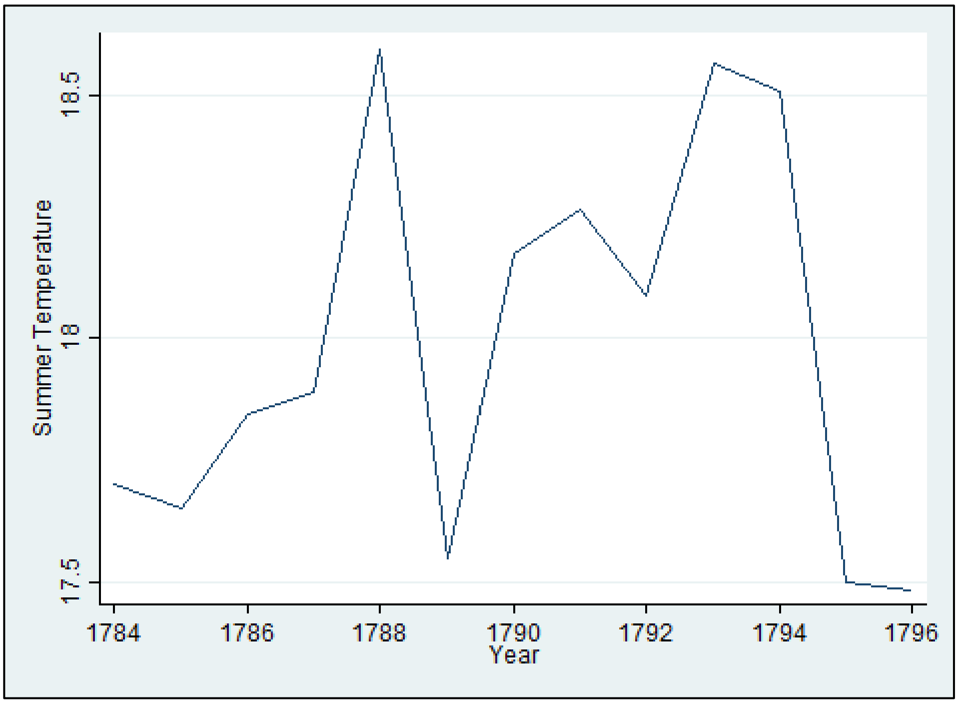

Figure 5 Mean summer temperature for France between 1784 and 1796

Or in Campbell (2006: 32)'s words: "As the price of bread rose to its highest points (actually on July 14 in Paris), the interaction between subsistence problems and the stimulated popular awareness of politics became explosive."

Another institutional feature exacerbated the effects of harvest failure in 1788. A large part of the agricultural sector consisted of small peasant cultivators with little financial cushion living just above self-sufficiency. While landlords of larger estates could often rely on financial reserves the small scale workers could not. In addition, many small peasants depended on revenue from wine harvest, but the 1780s had seen several years of very low vintage thereby reducing even this income source (Doyle, 1980: 160).

Finally, as already mentioned above, the intellectual origins of the French Revolution have received considerable attention. Again, the intellectual origins can only be understood in interaction with the political, economic and social conditions at the time.

"Intellectual origins also played an essential role in transforming a fiscal crisis into a revolution. [...]," (Kaiser et al., 2011: 6). The behaviour and insistence of the third estate in the Estates-General can hardly be understood without new ways of thinking about the constitution of the importance on the nation. This was helped by an increasing number of pamphlets that raised political awareness among growing parts of the population. (Kaiser et al., 2011: 6; Neely, 2008: 23; Bossenga, 2011: 37).

Also the drawing up of the cahiers de doleances incited political debates in towns and villages. Many parts together led to increased political awareness and to confidence of the general population that demanding an overhaul of the entire French political system was in their right.

2.3. Theoretical and Historical Framework

As the previous section makes clear, many factors affected the outbreak of the French Revolution. In this chapter, I examine one of these factors, the effect of adverse weather conditions in the year leading up to the French Revolution on the probability of peasant revolt. This analysis is guided by a theory on political transitions by Acemoglu and Robinson (2001, 2006). In the model, a nondemocratic society consists of two groups, a small rich elite and a large group of the poor and disenfranchised. The rich elite controls society and possesses all de jure political power.

The poor and disenfranchised do not hold any de jure political power, but they are the majority and hold de facto political power if they can solve the collective-action problem in a moment when the elite is “unable to use the military to effectively suppress the uprising,” (Acemoglu and Robinson, 2006: 25).

The disenfranchised population gains de facto political power if they overcome collective-action problem and are able to “create significant social unrest and turbulence, or even pose a serious revolutionary threat,” (Acemoglu and Robinson, 2006: 25).

The theory predicts that revolutions are more likely during times of economic crises, for example after harvest failure (Acemoglu and Robinson, 2006: 31f.). During economic crises, people’s opportunity costs. They have less to lose and are more likely to contest power. As a result, economic recession increases the probability of uprisings even if the crisis’ causes are known to be exogenous and transitory.

If the poor are able to overcome collective action problems and pose a credible revolutionary threat that the elite is unable to suppress, then the elite has to make concessions to avoid costs of revolution. The elite is likely to promise more redistributive policies in the future. Yet, the poor are aware of the transitory nature of their revolutionary threat. They will not be able to enforce such policies in the future, once their threat has passed. If possible, the poor will uphold the revolutionary threat until institutional changes are made that will ensure more redistributive policies in the future and are costly to reverse (Acemoglu and Robinson, 2006: 25f.).

2.3.1. The elite and the disenfranchised in French society in 1789

In French society in 1789 the rich, small elite consisted of the king, the nobility, and part of the clergy. The formed the first two privileged estates and comprised about two percent of the population. The vast majority of the population, about 98 percent of the population, consisted of people with limited economic means (Neely, 2007: 7). Many of them had difficulties reaching subsistence level (Lefebvre, 1973: 8). The part of society consisted of rural and urban wage-labourers, free peasants, the urban bourgeoisie, craftsmen, and others.

The political power of the king and the first two estates was reflected in the highly inequitable tax system. The king exempted the nobility and the church from most taxes while imposing a crushing tax burden on the third estate that normally did not have enough power to negotiate exemptions (Neely, 2008: 7). The third estate paid taxes to the king and had feudal obligations in cash and labour towards their local landlord.

2.3.2. Collective action by the disenfranchised

In 18th century France, the third estate formed the vast majority of the population, but did not hold any de jure political power. Bread riots in larger towns sometimes led to state provision of bread, but these riots were never coordinated and strong enough to enforce more profound institutional changes. In the 1780s, however, a severe financial crisis occurred in France and changed the balance of power. After decades of constant warfare and high military expenditure the government had exhausted its resources. To raise further taxes the king was compelled to convoke the Estates-General, an assembly of representatives of the first two estates, the clergy and the nobility, and of the third estates, the common people (Merriman, 2010: 441). It was an opportunity for the third estate to coordinate and to unify their political power. In preparation of the Estates-General, they had been asked by the king to democratically elect representatives and list their requests in *cahiers de doléances* (Merriman, 2010: 443). Their representatives advocated these requests at the Estates-General in Paris starting in May 1789.

2.3.3. The de facto political power of the disenfranchised vs. the elite's military force

The king was unable to simply suppress these requests because his military power had been limited by the severe financial crisis. Parts of his troops defected in 1789 after not being paid and joined popular protests. Meanwhile, people of the third estate demonstrated violently in support of their representatives on the streets of Paris. When the population noticed an increase in royal troops in mid-July 1789, they feared that the king intended to subdue their representatives by force. In response, they stormed the Bastille (Neely, 2008: 66f). The people of the third estate gained de facto political power through their representatives at the Estates General in Paris and their own protests. They demanded in particular reform of the highly inequitable tax system and the abolition of the feudal regime.

Since May 1789, after three months, the representatives in Paris had still not been able to enforce changes in the feudal system that had been one of the main requests of the rural population in the *cahiers de doléances*. The population of rural France was disappointed with the slow progress. In July 1789, shortly after the fall of the Bastille, they organised armed protests against their landlords and against the feudal obligations that they owed them. "'none of them was moved by any motive other than that of the pillage and the licence which the exaggeration of their so-called rights appeared to allow them: they seem to have gathered by common consent with the intention of laying waste chateaux and houses and freeing themselves from their rents by burning their charters [...]'," (cited in Lefebvre, 1973: 118). Their anger against the feudal system had been a concern of the rural population for a long time. An immediate trigger of the peasant protests in July and August 1789 was the population's economic hardship that the drought of 1788 and the harsh winter of 1789 had still exacerbated. Besides, rumours had spread that the aristocracy planned to exploit the fact their economically difficult situation to make them give up on their political requests. The rumour said that the aristocracy had sent out brigands to destroy the much needed harvest of 1789 to "[starve] the country people into submission," (Merriman, 2010: 447). These rumours quickly spread from one village to the next, via messengers, travellers, or official circulars sent out by the authorities (Lefebvre, 1973: 14).

To defend themselves against increased number of brigands and the supposed aristocratic plot, in July 1789, villages and rural towns in various parts of France started organising groups of armed men. After the storming of the Bastille in July 1789, landowners' estates were stormed (Merriman, 2010: 438, 446).

2.3.4. Revolution during Recession

Historians have argued that peasant revolts in revolutionary France against the aristocracy were spurred by severe economic crisis (e.g. Lefebvre, 1973; Merriman, 2010). Hot and dry weather in the summer of 1788 had caused crop failure and especially cold weather in the winter of 1788/89 further increased people's survival costs. In normal years, people spent about 50 percent of their income on bread. After the crop failure of 1788, the share rose to 88 percent in 1789 (Neely, 2008: 72f.). The number of famished people rose. The harsh winter conditions of 1788/89 further increased food prices and living costs in general because navigable rivers froze and prevented the transportation of cereals. Heating material also became scarce and expensive. The situation was made worse by the peasants' obligations and the nobility's rights that were enshrined in the feudal system. The peasants' owed cash and labour to their local landlords. The nobility's exclusive rights to exploit forests, streams, and lakes made it illegal for common people to augment their diets with fish and game and to collect fire wood. (Merriman, 2010: 438). They were not even allowed to protect their fields from deer or from the lord's pigeons that trampled on their fields or fed on the seeds. Besides, many nobles still held judiciary rights over peasants. Feudal obligations had always been a heavy burden for the peasants but especially after the crop failure of 1788 and the harsh conditions of the following winter.

2.3.5. Peasant Revolt and Institutional Reform

The king tried to calm the revolts by promising tax reform but insisted on feudal obligations and privileges of the first estates. "To the radicalised members of the third estate, [these] concessions were not enough," (Merriman, 2010: 444).

In August 1789, after weeks of persistent and violent peasant revolts, all members of the National Assembly, that comprised representatives of the nobility, the clergy, and the third estate, were concerned about the situation and wished to re-establish public order. Many sympathised with the peasants' request to abolish feudal obligations and nobles' privileges. But even the privileged members of the assembly who did not sympathise with the peasants requests' were willing to make concessions in order to end the revolts because many of them owned property that the peasants were attacking (Neely, 2008: 80). The persistent revolts and the scale of the violence had shown the peasants' ability to organise resistance and to do lasting damage. "On August 4, 1789, in an effort to appease the peasants and to forestall further rural disorders, the National Assembly formally abolished the "feudal regime," including seigneurial rights," (Merriman, 2010: 447). In particular, personal labour and cash obligations were eliminated. Afterwards, the freedom of worship, the nobles' judiciary rights, and their exclusive right to hunt were also eliminated. Provinces and cities also had to give up privileges. "The members of the National Assembly thus renounced privilege, the fundamental organizing principle of French society," (Merriman, 2010; 447).

2.4. Empirical Strategy and Data

2.4.1. Data Description

The basic dataset is a cross section of 3596 cantons. They cover the entire territory of mainland France in 1789. The canton is a territorial subdivision of the French state, one level above the communes, the lowest administrative division. The main components of the data set are the geographic locations of rural uprisings in 1789 and gridded temperature data for the summer of 1788 and the winter of 1788/89.

I collected information on the locations of rural uprisings in 1789 from Lefebvre (1973: 4). I digitised a map of all localities in France that had rural revolts in the summer of the French Revolution. I also collected information on the starting points of revolts and their gradual spread to other localities. I define two outcome variables. The main outcome variable describes the probability of revolt. It is a dummy variable that is 1 if an uprising took place in a canton and 0 otherwise. The second outcome variable measures the timing of revolt. The baseline map by Lefebvre (1973: 4) indicates that uprisings originally broke out in only about five different towns. From there, uprisings spread to surrounding towns. Lefebvre (1973: 4) uses arrows pointing from town A to one or more towns to indicate that uprisings in town A spread from there to one or more towns. Eventually, the uprisings had spread to most parts of France. To proxy for how early a town joined the uprisings, I count how many stages (stages equal arrows in Lefebvre's map) lie between one town and the town of original uprising. It is a measure of revolt delay in that a higher numbers indicate that a town's towns is further removed from the original uprising and that uprising have been likely to have started later. In Figure 6, I indicate the number of stages and thereby the delay with which towns joined uprisings with a colour code (darker colours indicate between a town's uprisings I define the variable *revolt delay* as a number between 0 and 20. I assign a value of 0 for localities where uprising first broke out (indicated in Figure 6 by the star symbol). I assign a value of 1 to a locality if only one stage separates a town from the original uprising. A value of 2 is assigned if two stages (two arrows in Lefebvre's map) lie between a locality and the locality where uprisings first broke and so forth.

The map below illustrates the distribution of localities with uprisings across France and the gradual spread of uprising over France. As mentioned above, the star symbol represents localities where the first original uprisings broke out. Darker colours indicate that a locality started uprising relatively quickly after the first uprising took place.

Information on temperature in 1788/89 is taken from Luterbacher et al. (2004). The data is reconstructed seasonal and gridded temperature. It provides yearly 'temperature maps' that show variation within France for grid cells of about 50 by 50 kilometres. For this data set, climatologists have reconstructed temperatures based on proxy indicators such as tree ring series and ice cores and based on historical records. For the years 1788/89, directly measured monthly temperature from ten weather stations in France is available (Garnier, 1974). Summer temperature 1788 is the average temperature in the months June, July, and August of the year 1788. Winter temperature 1789 is the average temperature in the months December 1788, January 1789, and February 1789.

I also collected information on population density in 1789, the routes of communication in 1789, on salt tax rates in 1789, the share of the labour force that works in agriculture in 1789 and the share of the population that works in manufacturing in 1789. I digitised these data and assign to each canton the value of the area that applies to the largest part of the canton.

Information on population density in 1789 (Clout, 1977: 217) is provided in the unit 'population density per square league'. It is provided in seven categories: below 500 inhabitants per square league, between 500 and 750 inhabitants per square league, between 750 and 1000 inhabitants per square league, and so forth, until above 1750 inhabitants per square league.

Information on the routes of communication in 1789 (Bonin et al., 1987: 15) is available for four categories: postal routes, navigable rivers, canals, and other important routes. I digitise the map and assign to each canton the routes that intersect it. I create a variable that counts the number of routes that intersects a canton.

I obtain information on the salt tax rate in 1789 from Shepherd (1926). Tax rates varied substantially across provinces within France in 1789. The highest tax rate applied to the northern centre of France. Other provinces, such as Brittany, were exempt from tax rate. These tax rates are reflected in the salt prices that are about thirty times higher in northern central France compared to Brittany.

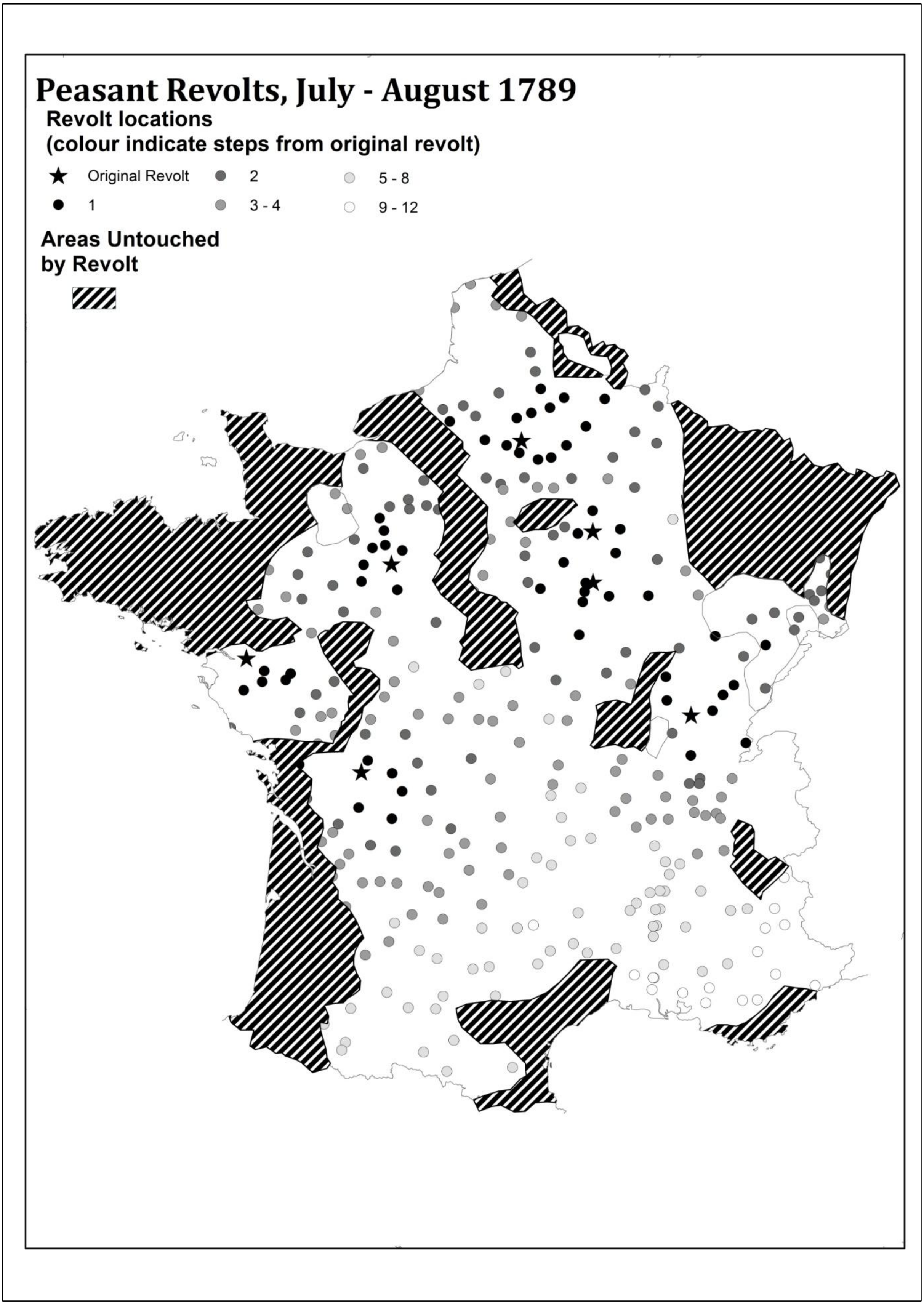

Figure 6 Peasant Revolts, July - August 1789

I collect data on the share of the labour force that works in agriculture in 1789 from Planhol (1994: 157f.) is provided in five categories. The lowest category is assigned to areas where less than 43.4% of men are employed in agriculture. The next category is assigned to areas where between 43.4 and 51.57% of men are employed in agriculture. Each higher category is assigned to areas with an increase in the share by about 10 percentage points. The highest categories assigned to areas with more than 72.85% of men working in agriculture.

The share of the population that works in industry in 1789 (Planhol, 1994: 157f.) comprises workers in the manufacturing of leather, wood, iron and other metals. These categories range from the lowest (under 11.88%) to the highest (over 21.74%) with three categories in between (11.88-15.39%, 15.40-18.29%, and 18.3-21.74%)

In my dataset, I create variables for population density, share of workers in agriculture, and share of workers in manufacturing. The average of the highest and lowest value of the relevant category is assigned to the canton.

Table 21 Summary Statistics

	Cantons with uprisings	***Cantons without uprisings***	***Untouched areas***
Number	298	3,298	1317
Population density	1115	1147	1184
Share of Labour Force in Agriculture	0.52	0.48	0.48
Share of Labour Force in Industry	0.10	0.11	0.11
Share of canton in heavily taxed area	0.41	0.36	0.27
canton area	4.26	3.95	3.95
distance to communication routes	2.45	2.13	1.73

Table 11 shows summary statistics for cantons with and without uprisings, and for cantons in areas that Lefebvre (1973: 4) described as completely untouched by insurgency. These untouched areas systematically experienced no peasant revolts (see Figure 6 for a map, the striped areas are areas that experienced no peasant revolts). The table shows that population density in cantons with uprisings is lower than in cantons without uprisings. The share of labour force in agriculture is slightly higher and the share of labour force in manufacturing is slightly lower. 41 percent of cantons with uprisings lie in areas with especially high taxes compared to 36 percent of cantons without uprisings. Distance to communication routes is slightly larger than in the other cantons. In sum, the table shows some but rather small differences between cantons with and without uprisings.

Information on froment (wheat) prices are collected from Labrousse (1939). The paper provides froment prices for the years 1782 to 1790 for 35 French *Generalites,* that correspond to historical French provinces. The data are provided in the form of graphs from which I collect the prices.

2.4.2. Empirical Strategy

In this chapter, I test the theory's prediction that uprisings are more likely to occur during economic downturn. The model predicts that areas with worse economic conditions are more likely to experience uprisings. Economic conditions in France in 1789 were affected by the drought in the summer of 1788 and by the cold winter of 1788/89. The theory's prediction in this case is that areas with especially hot temperatures during the summer of 1788 and with especially cold temperatures during the winter of 1788/89 are more likely to experience uprisings.

To investigate this hypothesis, I use cross-section data set for 3596 French cantons (see section 2.4.1 for a detailed description). It contains information on the locations of peasant uprising in the summer of 1789, on mean temperature in the summer of 1788, and on mean temperature in the winter of 1788/89. I test whether uprisings were more likely in areas with especially high summer temperature in 1788 and especially low winter temperature 1788/89.

I propose the following regression specification:

$$(8)\ PeasantRevolt_{cr} = \alpha + \beta\ SummerTemp1788_{cr} + \gamma\ WinterTemp1789_{cr} + f_r + \varepsilon_{cr}$$

$PeasantRevolt_{cr}$ is a dummy variable that is 1 if canton *c* in region *r* has experienced peasant revolt during the French Revolution. $SummerTemp1788_{cr}$ is the mean temperature in canton *c* and region *r* during the months June, July, and August in 1788. $WinterTemp1789_{cr}$ is the mean temperature in canton *c* and department *r* during the months December 1788, January 1789, and February 1789. f_r is a full set of region fixed effects; and ε_{cr} is the error term. Standard errors are adjusted for 94 clusters at the department level.

The main coefficients of interest are β and γ. β captures the effect of a one degree increase in summer temperature on the probability that a canton experiences peasant revolt. γ captures the effect of a one degree increase in winter temperature on the probability that a canton experience peasant revolt. Both coefficients are estimated based on variation in temperature and peasant revolt *within* each region. In other words, they estimate whether a canton with different summer and winter temperatures compared to the other cantons in the *same* region also has a different probability of experiencing peasant revolt. The main prediction of the model is that β should be positive and that γ should be negative.

An alternative measure of environmental stress are deviations of summer temperature 1788 and winter temperature 1788/89 from the long-term summer and winter temperature means. While high summer and low winter temperature per se could lead to economic stress it is also likely that the population are to a certain extent adapted to the long-term temperature mean, e.g. through the establishment of irrigation systems during summer or the adoption of transportation technology such as Pferdeschlitten in winter that could at least partially and possibly fully offset the negative effects of adverse temperatures. In this case, deviations from mean temperature are a better measure of environmental stress. Following Dell (2012), the variable summer temperature deviation from long-term mean temperature is defined as the ratio of summer temperature in 1788 over the mean summer temperature between 1700 and 1788. The variable winter temperature 1789 deviation from mean temperature is defined accordingly.

$$(9)\quad PeasantRevolt_{cr} = \alpha + \beta\ Summer\ Temp\ 1788\ Deviation\ from\ Mean\ Temp_{cr} + \gamma\ WinterTemp1789\ Deviation\ from\ Mean\ Temp_{cr} + f_r + \varepsilon_{cr}$$

The model would predict that β should be positive and that γ should be negative. In other words, as economic stress from summer temperatures stems from excessive heat summer temperatures above the long-term mean would put the economy under stress. The more the summer temperature of 1788 exceeds the long-term mean the larger would be the economic stress and – according to the model – the larger should be the probability of revolt.

Accordingly, economic stress from winter temperatures stems from excessive cold winter temperatures below the long-term mean would put the economy under stress. The more the winter temperature 1788/89 lies below the long-term mean the more likely are negative economic consequences.

2.5. Empirical Results

2.5.1. Basic Specifications

Table 22 contains basic results. I estimate the baseline regression without region fixed effects in column 1, with region fixed effects in column 2, and with department fixed effects in column 3. Results in column 1 of Table 22 show that the coefficient β on $SummerTemp1788_{cr}$ is positive and significant at the ten percent level. The coefficient γ on $WinterTemp1789_{cr}$ is negative and significant at the five percent level. This is consistent with the model's prediction. It indicates that cantons with higher temperatures during the summer 1788 and with lower temperatures during the winter of 1788/89 are more likely to have peasant revolts.

The specification in column 1 estimates the relationship between temperature and peasant revolt based on variation in both variables within all of France. One might be concerned that areas in France with relatively extreme temperatures share certain characteristics that also affect the probability of revolt. If areas with extreme temperature are on average worse off than areas with more moderate temperature these results could reflect that particularly poor areas were more likely to revolt. In the following column, I therefore introduce region fixed effects and estimate specification (1).

Column 2 shows results. This time, region fixed effects control for unobserved regional characteristics that may affect temperature's effect on the outbreak of peasant revolt. They capture, for example, the effects of any geographic, political, or economic characteristics that cantons within one region share. The main coefficients of interest β and γ are estimated based on variation in temperature and peasant revolt *within* each region. In other words, they estimate whether a canton with different summer and winter temperatures compared to the other cantons in the *same* region has a different probability to experience peasant revolt.

The main coefficients of interest β and γ are about three times larger as in the previous estimation. Both are significant at the one percent level. This result indicates that cantons with higher summer temperature 1788 and lower winter temperature 1789 are more likely to experience peasant revolt than the other cantons in their region.

Table 22 Peasant Revolts and Extreme Temperatures – Basic Results

	Probability of Peasant Revolt			***Revolt Delay***			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Summer Temperature	0.00762*	0.0245***	0.0474***	-0.107	-0.439***	-0.790***	-0.885*
	(0.00451)	(0.00857)	(0.0139)	(0.0719)	(0.145)	(0.222)	(0.450)
Winter Temperature	-0.00709**	-0.0271***	-0.0491***	0.121**	0.454***	0.777***	0.727*
	(0.00345)	(0.00760)	(0.0140)	(0.0592)	(0.132)	(0.221)	(0.416)
Sample	All	All	All	All	All	All	Revolt
Region Fixed		yes			yes		
Department			yes			yes	yes
Observations	3,596	3,596	3,596	3,596	3,596	3,596	298
R-squared	0.003	0.024	0.102	0.002	0.027	0.103	0.971

Robust standard errors in parentheses, clustered at department level

*** p<0.01, ** p<0.05, * p<0.1

In column 3, I estimate the baseline specification but replace region fixed effects with department fixed effects. The department fixed effects control for all department level characteristics that affect the probability of revolt and are correlated with temperature. Results could be biased if a department within a region has a certain economic structure because of its climatic conditions and also experiences more peasant revolt because of this economic structure. I therefore introduce department fixed effects into the regression.

Column 3 of Table 22 shows that the coefficient on summer temperature remains positive and highly significant. The coefficient on winter temperature also remains negative and highly significant. These results indicate a significant effect of temperature on peasant uprisings even when only taking into account variation in temperatures and uprisings within each department.

In columns 4 to 7, I use an alternative outcome variable to indicate revolt delay. *Revolt delay* is an indicator of revolt timing. It is a number between 0 and 20. The higher the value the longer it took a revolt to break out compared to the first revolt. The value 20 is assigned to cantons that were untouched by revolt. The value is assigned based on information on revolt delay from Lefebvre (1973: 4) that provides detailed information on the spread of revolt across France.

Results in column 4 to 6 indicate that higher summer temperature in 1788 and lower winter temperature 1789 decreased a canton’s delay in joining the revolts. The higher summer temperature and the lower winter temperature the sooner revolt broke out.

One might be concerned that these results are driven by certain systematic differences between towns that revolted and the others that did not. To investigate this concern I limit the sample in column 7 to those towns that were affected by peasant revolts. Results show that, conditional on having a revolt, summer and winter temperature affected a town’s revolt delay.

In Table 23, I estimate the effects of temperature deviations from the long-term mean on peasant revolts (columns 1 and 2) and on revolt rank (columns 3 and 4). Results for both outcome variables indicate that deviations of summer temperature above the long-term mean and deviations of winter temperature below the long-term mean increase the probability of revolt. The size of the coefficients indicate that a one degree increase in summer temperature above the long-term mean had a substantially larger effect on revolt probability than a one degree decrease in winter temperature. Then, after the introduction of region fixed effects the estimated coefficients become both substantially larger and are significant. This indicates the importance of regional characteristics in determining incidences of revolts. Once, these are controlled for the estimates become more precise and significant. The increase in all coefficients after the introduction of region fixed effects (columns 2 and 4) compared to the previous specification (columns 1 and 3) indicates that omitting regional characteristics from the specification tended to bias results downwards.

Table 23 Peasant Revolts and Deviations from Long-Term Mean Temperature – Basic Results

	Peasant Revolt		***Revolt Rank***	
	(1)	(2)	(3)	(4)
1788 Deviation from Mean Summer Temperature	0.629	2.585**	-7.844	-38.26**
	(0.564)	(1.097)	(9.804)	(18.65)
1788/89 Deviation from Mean Winter Temperature	-0.000349	-0.000564**	0.00576	0.0102**
	(0.000434)	(0.000281)	(0.00776)	(0.00490)
Region Fixed Effects		yes		yes
Observations	3,596	3,596	3,596	3,596
R-squared	0.001	0.022	0.000	0.024

Robust standard errors in parentheses, clustered at department level
*** p<0.01, ** p<0.05, * p<0.1

2.5.2. Augmented Specifications

In this section, I introduce further controls to specifications (1) and (2). Column 1 of Table 24 is the estimate of the baseline regression equation (1) and identical to column 2 of Table 22. Likewise, column 1 of Table 25 is identical to the baseline estimation reported in column 2 of Table 23. I start by adding the control variables population density and canton area to the equations (columns 2 and 3 of Table 24 and Table 25). In preindustrial times, population density is a useful proxy for an area's affluence. It is also important to control for a canton’s area. It is thinkable that larger cantons are located in more agricultural areas with lower population density. Besides, if population size was larger in larger cantons, then larger cantons could be more likely to experience revolt. In column 2 and 3 of Table 24 and Table 25 show that including these control variables affects the coefficients very little.

News availability, it has been argued, was pivotal to the spread of uprisings to other areas. The historian Georges Lefebvre (1973) argues that the fear of an aristocratic plot broke out in seven points across France and then spread from there to other localities. Lefebvre suggests that messengers were sent out to warn other communities, that travellers transmitted the rumours on their journey and that the postal service distributed warnings of an aristocratic plot to other regions (Lefebvre, 1973: 150-152). To test this hypothesis, I add the variable *News Availability* to the specification. It is defined as the number of news routes that intersected a canton in 1789. News routes include postal routes, navigable rivers, canals, or other important routes like well-paved roads. Results in column 4 of Table 24 and column 4 of Table 25 show a highly significant positive relationship between news routes and peasant uprisings. This supports Lefebvre’s hypothesis that peasant revolts spread through France via news routes. At the same time, *News Availability* is also an important control variable for a place’s economic situation. Relatively affluent areas are likely to be better connected than relatively poor areas. Results show that adding this control variable hardly affects the estimated effects of summer and winter temperature on peasant uprisings. Both coefficients remain highly statistically significant with only a slight decrease in size.

As mentioned before, the high tax burden was a main concern of the protesting French people. In column 5 of Table 24 and Table 25 , I add a dummy variable to the equation that is 1 for all cantons with the highest tax rates. This tax rate was around 30 times as high as the lowest tax rate and around double the rate of the second highest tax rate. The high tax rates might have further reduced the economic resources of the population. Adverse temperature changes here might have had different effects compared to less heavily taxed areas. Coefficients in columns 5 of both tables show insignificant effects of being located in the heavily taxed region. The sign of the coefficients are differ with a positive sign of the main effect and negative signs of the interaction term in Table 24 and a negative sign of the main effect and positive signs of the interaction term in Table 25. The interpretation of these results is not clear. They could indicate that high taxes did not spur revolt, e.g. because the tax regime was correlated with other institutional characteristics that compensated for the economic constraints of high taxes. It could also be the case that the effect of taxes, that were determined at the regional level, on revolt are already captured by the region fixed effect. The main coefficients of summer and winter temperature levels and deviations do not change substantially.

Table 24 Peasant Revolts and Extreme Temperatures – Augmented Specifications

	Probability of Peasant Revolt				
	(1)	(2)	(3)	(4)	(5)
Summer Temperature	0.0245***	0.0242***	0.0249***	0.0188**	0.0188**
	(0.00857)	(0.00869)	(0.00868)	(0.00848)	(0.00871)
Winter Temperature	-0.0271***	-0.0269***	-0.0268***	-0.0234***	-0.0231***
	(0.00760)	(0.00770)	(0.00766)	(0.00764)	(0.00768)
News Availability				0.0263***	0.0263***
				(0.00493)	(0.00494)
Heavy Tax					0.0635
					(0.182)
Heavy Tax*Summer Temperature					-0.0115
					(0.0109)
Heavy Tax*Winter Temperature					-0.00220
					(0.0100)
Region Fixed Effects	yes	yes	yes	yes	yes
Population Density		yes	yes	yes	yes
Canton Area			yes	yes	yes
Observations	3,596	3,596	3,596	3,596	3,596
R-squared	0.024	0.024	0.026	0.036	0.036

Robust standard errors in parentheses, clustered at department level

*** p<0.01, ** p<0.05, * p<0.1

Table 25 Peasant Revolts and Deviations From Long-Term Mean Temperature - Augmented Specifications

	Peasant Revolt				
	(1)	(2)	(3)	(4)	(5)
1788 Deviation from Mean Summer Temp	2.585**	2.579**	2.473**	3.073***	3.092***
	(1.097)	(1.097)	(1.100)	(1.037)	(1.010)
1788/89 Deviation from Mean Winter Temp	-0.000564**	-0.000562*	-0.000596**	-0.000506*	-0.000483*
	(0.000281)	(0.000284)	(0.000287)	(0.000268)	(0.000267)
News Availability				0.0280***	0.0279***
				(0.00510)	(0.00511)
Heavy Tax					-2.781
					(1.731)
Heavy Tax*Summer Temperature					2.685
					(1.659)
Heavy Tax*Winter Temperature					0.0284
					(0.0298)
Region Fixed Effects	yes	yes	yes	yes	yes
Population Density		yes	yes	yes	yes
Canton Area			yes	yes	yes
Observations	3,596	3,596	3,596	3,596	3,596
R-squared	0.022	0.022	0.024	0.035	0.036

Robust standard errors in parentheses, clustered at department level

*** p<0.01, ** p<0.05, * p<0.1

2.5.3. Testing for an Effect of Temperature Deviations in Earlier Years

The question arises whether the observed relationships between extreme temperatures, temperature deviations from the long-term mean and peasant revolts is due to temperature volatility during the specific year preceding the French Revolution. An alternative possibility is that areas that experienced temperature volatility in the year preceding the French Revolution have generally been exposed to a higher degree of temperature volatility. If this is the case than we would expect to observe a similar relationship between temperature deviations from the long-term mean and peasant revolts for earlier years long-preceding the French Revolution. If this was the case one possible explanation would be that temperature volatility caused economic hardship in certain areas that accumulated over time. Another possible explanation would be that temperature volatility is systematically higher in certain areas that might systematically differ from other areas with respect to other observable or unobservable characteristics.

In Table 26, I test whether summer and winter deviations from the long-term mean temperatures in earlier years predict the outbreak of peasant revolts in 1789. I test whether temperature deviations in the years 1700, 1720, 1730, 1750, and 1770 from the long-term mean predict peasant revolts. For each specification, temperature deviations from the long-term mean are defined, as before, as the ratio of summer and winter temperature in a given year over the long-term mean temperature between 1700 and 1782 (see section 2.4.1. for more detail). For each year I show results for two specifications: the baseline specification including region fixed effects and the augmented specification including the control variables introduced in section 2.5.2. Results show that summer and winter deviations from the mean in these years do not predict peasant revolts in 1789. The pattern of coefficients differ strongly from the estimated effects of summer and winter temperature deviations in 1788/89. Summer temperature deviations are always negative and some of them significant. This suggests that peasant revolts arose more often in areas with especially low summer temperatures in the years 1700, 1720, 1730, 1750, and 1770. Likewise, deviations from mean winter temperature are mostly positive and sometimes significant. This indicates that peasant revolts were more likely in areas with especially warm winters in these early years. These results indicate that temperature deviations in 1788/89 played a decisive role in stimulating revolt and that temperature deviations in 1788/89 were not preceded by a history of temperature volatility.

Table 26 Testing for an Effect of Temperature Deviations on Peasant Revolts in Earlier Years

	YEAR =									
	1700		***1720***		***1730***		***1750***		***1770***	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Deviation from Mean Summer Temperature	-1.799	-2.708**	-2.106**	-2.438***	-1.481	-1.983**	-1.672	-2.445	-5.001***	-6.417***
	(1.266)	(1.160)	(0.854)	(0.766)	(0.901)	(0.868)	(2.831)	(2.801)	(1.817)	(1.714)
Deviation from Mean Winter Temperature	-0.0101	-0.00854	0.00392*	0.00348*	0.00152***	0.00135**	0.00121**	0.00111**	0.00600	0.00570
	(0.00613)	(0.00648)	(0.00213)	(0.00204)	(0.000567)	(0.000553)	(0.000467)	(0.000448)	(0.00498)	(0.00486)
Control Variabls										
News Availability		yes		yes		yes		yes		yes
Heavy Tax		yes		yes		yes		yes		yes
Population Density		yes		yes		yes		yes		yes
Canton Area		yes		yes		yes		yes		yes
Region Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	3,596	3,596	3,596	3,596	3,596	3,596	3,596	3,596	3,596	3,596
R-squared	0.021	0.035	0.022	0.035	0.021	0.035	0.020	0.033	0.022	0.036

Robust standard errors in parentheses, clustered at department level

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

2.5.4. Temperature, Peasant Revolt, and Different Economic Sectors

Previous research has shown that the agricultural sector compared to the industrial sector is normally especially affected by adverse weather changes as weather can be an important determinant of agricultural productivity, in particular in the absence of mitigating technology such as irrigation systems (e.g. Burgess et al., 2011). In the following, I therefore examine heterogeneity in the effect of temperature on peasant uprisings in different economic sectors. ***Table 27*** reports results. Columns 1 to 3 report results for summer and winter temperature levels, columns 4 to 6 for summer and winter temperature deviations from the long-term mean temperature. Columns 1 and 4 contain estimates for the augmented specifications on the effect of summer and winter temperature levels and deviations on peasant revolts when including region fixed effects and control variables introduced in section 2.5.2. These are identical to columns 5 of ***Table 24*** and Table 25.

Then, I introduce a variable that measures the share of the labour force that works in agriculture in1789 into the specification. Columns 2 and 5 report a positive relationship between this share and the probability of peasant revolt. Areas with a higher share of workers in agriculture had on average more peasant uprisings.

Motivated by the observation that agricultural productivity may be especially affected by temperature changes, I test whether the effect of a temperature change varies depending on an economy’s dependence on agriculture. I introduce interaction terms of the share of the labour force that works in agriculture and summer and winter temperature levels and deviations from the mean.

Columns 3 and 6 show results. Interestingly, results change substantially with the introduction of these interaction terms. In column 3, the main coefficients on summer temperature, winter temperature and the share of the labour force in agriculture become much smaller and insignificant while the coefficients on the interaction terms are significant and higher than the estimated coefficients on the summer and winter temperature variables in Table 22. The coefficients on the first interaction term indicates that the effect of a one degree increase in summer temperature in areas with a high share of labour force in agriculture is significantly higher compared to the effect of a one degree increase in summer temperature in non-agricultural areas. The effect of a one degree increase in summer temperature on the probability of peasant revolts in non-agricultural areas is close to zero and insignificant. The coefficient on the second interaction term indicates that the effect of a one degree increase in winter temperature is significantly lower in agricultural areas compared to non-agricultural areas. In other words, a decrease in winter temperature increases the probability of peasant revolt in agricultural areas but not in non-agricultural areas.

In column 6, that estimates the effect of temperature deviations on peasant revolt, the patterns of the coefficients in terms of the signs and sizes of the main variables and interaction terms behave similarly to those in column 3. They are, however, not statistically significant as the standard errors increase in size.

Finally, in ***Table 28***, I investigate the relationship between the share of the labour force that works in manufacturing and peasant revolt. On the one hand, the French manufacturing sector was hit by a crisis in the years after 1786 because it was outcompeted by English manufacturing imports. As a result, unemployment in manufacturing rose steeply and decreased people's incomes. One could expect an effect of manufacturing on peasant revolt on this basis. On the other hand, one would not expect a significant interaction effect of manufacturing and temperatures because productivity and income in manufacturing depends relatively little on weather conditions (see e.g. Burgess et al., 2011).

Table 28 reports results. Columns 1 and 4 are identical to columns 5 in ***Table 24*** and ***Table 25***. It is the baseline specification with control variables. In columns 2 and 4 of ***Table 28***, I add a variable for the share of the labour force that works in manufacturing and interaction terms of summer and winter temperature (both levels and deviations) and the share of the labour force in manufacturing. The coefficient on the main effect of the share of manufacturing is large and positive in both specifications (columns 2 and 5). It is significant only in the specification of column 2. The interaction terms of summer temperature and manufacturing are negative for both measures, temperature levels and temperature deviations. The interactions of winter temperature and manufacturing are positive for both measures. While there is a strong positive relationship between manufacturing and peasant revolt, there is no indication that adverse weather conditions such as high summer temperatures and low winter temperatures increase the probability of revolt in manufacturing areas. This is consistent with the historical evidence on an economic crisis in the manufacturing sector which could incite the population to revolt. It is also consistent with research that shows that weather does not have a negative effect on industrial production. In stark contrast led to the corresponding results for agriculture (columns 3 and 6 in ***Table 27***) the introduction of the manufacturing variables leads to an increase in the estimated effect of temperature on peasant revolt.

Finally, I also include the variables on the share of the work force in agriculture and the corresponding interaction terms to the specification. For the specification using temperature levels in column 3, the coefficients have the same signs and patterns compared to column 6 in ***Table 27***. The sign of the variable on agriculture is negative while the interaction between agriculture and summer temperature deviation is positive and about the same absolute size. They are not significant. The coefficient on the interaction between agriculture and winter temperature deviation is negative and small. It is also insignificant.

The manufacturing variable and interactions with summer and winter temperature deviations have unexpected signs. In contrast to results in column 5 using temperature deviations (while excluding agricultural variables) and to columns 2 and 3 using levels of temperature (excluding and including agricultural variables), the coefficients on share of the labour force in manufacturing is negative, and the coefficients on the interaction terms between summer temperature, winter temperature and manufacturing are positive. Except for the interaction between winter temperature and manufacturing these coefficients are not significant. It is nevertheless puzzling that the sign of the coefficients describing the relationships between manufacturing, temperature deviations and revolts are so little consistent with neither economic theory nor previous results.

Table 27 Peasant Revolts, Temperature and Agriculture

	Outcome Variable =					
	Temperature Levels			***Deviations from Mean Temperature***		
	(1)	(2)	(3)	(4)	(5)	(6)
Summer Temperature	0.0188**	0.0231**	-0.0129	3.092***	2.681**	-2.180
	(0.00871)	(0.00889)	(0.0206)	(1.010)	(1.122)	(2.980)
Winter Temperature	-0.0231***	-0.0250***	0.0142	-0.000483*	-0.000451	0.00469
	(0.00768)	(0.00787)	(0.0150)	(0.000267)	(0.000279)	(0.00352)
Share of Labour Force in Agriculture		0.126***	-1.011*		0.0995**	-8.440
		(0.0383)	(0.564)		(0.0406)	(5.513)
Summer Temperature * Agriculture			0.0661**			8.209
			(0.0311)			(5.301)
Winter Temperature * Agriculture			-0.0712***			-0.0104
			(0.0207)			(0.00758)
News Availability	yes	yes	yes	yes	yes	yes
Heavy Tax	yes	yes	yes	yes	yes	yes
Population Density	yes	yes	yes	yes	yes	yes
Canton Area	yes	yes	yes	yes	yes	yes
Region Fixed Effects	yes	yes	yes	yes	yes	yes
Observations	3,596	3,596	3,596	3,596	3,596	3,596
R-squared	0.036	0.039	0.042	0.036	0.037	0.039

Robust standard errors in parentheses, clustered at department level

*** p<0.01, ** p<0.05, * p<0.1

Table 28 Peasant Revolts, Temperature and Manufacturing

	Outcome Variable =					
	Temperature Levels			***Deviations from Mean Temperature***		
	(1)	(2)	(3)	(4)	(5)	(6)
Summer Temperature	0.0188**	0.0514***	0.0150	3.092***	3.700**	-3.453
	(0.00871)	(0.0141)	(0.0242)	(1.010)	(1.699)	(4.080)
Winter Temperature	-0.0231***	-0.0410***	0.0105	-0.000483*	-0.0152**	-0.00968
	(0.00768)	(0.0105)	(0.0209)	(0.000267)	(0.00636)	(0.00784)
Share of Labour Force in Agriculture			-0.713			-9.293
			(0.539)			(5.906)
Summer Temperature * Agriculture			0.0507*			9.027
			(0.0297)			(5.684)
Winter Temperature * Agriculture			-0.0688***			-0.00393
			(0.0227)			(0.00726)
Share of Labour Force in Manufacturing		6.593***	4.356*		8.105	-7.643
		(2.324)	(2.374)		(14.76)	(17.17)
Summer Temperature * Manufacturing		-0.373***	-0.236*		-7.891	7.346
		(0.132)	(0.134)		(14.10)	(16.42)
Winter Temperature * Manufacturing		0.175*	0.0149		0.109**	0.0819*
		(0.0932)	(0.0962)		(0.0459)	(0.0446)
News Availability	yes	yes	yes	yes	yes	yes
Heavy Tax	yes	yes	yes	yes	yes	yes
Population Density	yes	yes	yes	yes	yes	yes
Canton Area	yes	yes	yes	yes	yes	yes
Region Fixed Effects	yes	yes	yes	yes	yes	yes
Observations	3,596	3,596	3,596	3,596	3,596	3,596
R-squared	0.036	0.039	0.044	0.036	0.037	0.039

Robust standard errors in parentheses, clustered at department level

*** p<0.01, ** p<0.05, * p<0.1

2.5.5. *Exploring Temperature's Direct Effect on Agricultural Productivity*

The previous sections have shown evidence that temperature levels as well as deviations from temperature in the year preceding the French Revolution affected the probability of peasant revolts. We have also seen evidence that this effect of temperature on peasant revolts was especially strong for areas where a relatively large share of the labour force worked in agriculture. These results, together with economic theory (Acemoglu and Robinson, 2006) and previous research on the economic effects of adverse temperature changes (Burgess et al. 2011) suggest that temperature's effect on peasant uprising operates also through temperature's effect on agricultural productivity. In this section, I use froment (wheat) prices from Labrousse (1939) as a more direct measure of agricultural productivity to estimate whether temperatures had a direct effect on agricultural productivity. As the froment prices are available in each region for several years I construct a panel data set with information on froment prices, winter and summer temperature information for the years 1780 to 1790. The panel structure of the data allows me to include region and year fixed effects. I estimate the effect of deviations from the temperature mean within each region and specify the following equation.

$$(10) \quad \textit{Wheat Price}_{ry} = \alpha + \beta \textit{ Summer Temperature}_{ry} + \gamma \textit{ Winter Temperature}_{ry} + \textit{yearFE}_t + \textit{regionFE}_r + c_r + \varepsilon$$

I regress wheat price in region r and year y on summer temperature within this region in the year 1788 and on winter temperature in the year 1788/89. I additionally include the control variables for the tax regime, population density, average canton area, and news availability. As these variables are stable over time each control variable is interacted with both temperature variables. This allows exploring whether a relationship between temperature and prices might be driven by one or more of these variables that can be seen as proxies for local institutional or economic conditions.

Table 29 reports results. In column 1, I estimate the effect of within-region year-to-year changes in summer and winter temperature on froment prices at the regional level without any controls except year fixed effects. Then, I introduce region fixed effects (column 2), a variable on whether the region is part of the heavily taxed area (column 3), and finally the remaining control variables population density, canton area, and news availability.

Results show a positive relationship between summer temperatures and froment prices. This is consistent with evidence on the importance of growing season temperatures for agricultural productivity. The coefficient on winter temperatures is either positive, insignificant and small compared to the coefficient on summer temperature or relatively large, significant and negative. This is consistent with historical arguments stating that waterways blocked by ice and roads blocked by snow often hindered the transportation of crops and thereby lead to increases in food prices.

This assessment of the effect of temperatures on agricultural productivity suggests a direct effect of temperature on agricultural productivity and possibly, may have reduced the population’s financial resources and through this channel lead to increases in incidences of revolt.

Table 29 Effect of Temperature Deviations on Froment (Wheat) Prices				
	Froment Price			
	(1)	(2)	(3)	(4)
Summer Temperature	1.581***	1.321***	1.004**	3.329**
	(0.456)	(0.379)	(0.430)	(1.234)
Winter Temperature	0.354	-1.780***	-1.147*	0.206
	(0.250)	(0.462)	(0.567)	(1.777)
Heavy Tax			0.535	0.899**
****Summer Temperature***			(0.405)	(0.365)
Heavy Tax			-0.948***	-0.816***
****Winter Temperature***			(0.330)	(0.289)
Year Fixed Effects	yes	yes	yes	yes
Region 1798 Fixed Effects		yes	yes	yes
Control Variables (Interacted with Summer and Winter Temp.)				
Population Density				yes
Canton Area				yes
News Availability				yes
Observations	361	361	361	361
R-squared	0.583	0.829	0.838	0.847

Robust standard errors in parentheses, clustered at region 1789 level
*** p<0.01, ** p<0.05, * p<0.1

2.6. Conclusion

As laid out in the Preface to this thesis, this chapter has the two-fold objective of examining the impact of a historical event using by applying econometric methodology to newly available data while learning from this examination about a broader theoretical question.

The historical event in this case is the French Revolution and the question which forces lead to its outbreak. This has been a much debated question for a long time and the importance of different political, financial, institutional, and social factors (e.g. Norberg 1994; Kaiser and Kley, 2001; Doyle, 1980) has been shown. In this chapter, I examine the hypothesis that the drought of 1788 followed by crop failure and an especially harsh winter in 1788/89 contributed to economic hardship and the outbreak of peasant revolts during the French Revolution. I econometrically test the effect of weather conditions on the probability of peasant uprisings. This effect is thought of as a trigger that worked in interaction with an array of other variables, such as the financial crisis of the French state, limited growth in agricultural productivity and limited crop reserves, an inefficient and irresponsive tax system as well as an unequal distribution of the tax burden among the population. First introduced by Labrousse (1943), the hypothesis that economic factors affected the outbreak of the French Revolution and its timing has been subject to considerable debate. This chapter contributes to this work by providing the first econometric analysis of the question by combining newly available weather data as well as economic data on France during the French Revolution that has been collected by historians. The main advantage of using econometric methods in comparison to other methods lies in the ability to estimate the effect of one factor on revolts *conditional* on a number of other factors. By incorporating data on political and economic conditions into the dataset I find evidence that the effect of adverse weather is different for areas with different political and economic conditions. This chapter also contributes to the debate by establishing causality by estimating an effect of economic factors on the outbreak of revolt based on within-country variation in the economic factors.

Third, this chapter sheds new light on the old question on the economic origins of the French Revolution by using newly available weather data. These weather data were reconstructed by a group of climatologists and have not been used before in the context of this research question. The results of this chapter provide evidence in support of the hypothesis that the drought of 1788 and the harsh winter of 1788/89 affected the outbreak of peasant uprisings during the French revolution. As mentioned above, these results do not negate at all the importance of other political, financial and social factors that contributed their part to the outbreak of the revolution. Instead they have to be interpreted as the effect of weather on peasant uprising *conditional* on all these factors.

This chapter also contributes to the literature that explores the relationship between adverse weather shocks and political uprisings in general (e.g. Dell, 2012). It shows that historical events – and even exogenous events such as weather shocks – can have long-term effects conditional on societal circumstances (Dell, 2012: 1).

It is also relevant to the current debate on the economic and political effects of climate change in the course of which extreme weather events are likely to become more frequent. Why is it that in some cases adverse weather shocks lead to political uprising while in other cases it does not? Results of this chapter show a very context-specific effect of weather shocks: It matters for areas that depend on agriculture whereas it does to a significantly less in areas with a strong manufacturing sector. Consistent with this evidence, historical evidence suggests that adverse weather conditions in 1788/89 also brought drought to England. In this case, it did not lead to a revolution. The reason for this non-effect might be England's advanced manufacturing sector that secured weather-independent income for parts of the population.

3. Missionaries and Development in Mexico

3.1. Introduction

When the Spanish came to America in 1492 Catholic missionary orders accompanied the conquest to convert the native population to the Christian faith. These missionary orders represented different monastic traditions and obeyed different sets of rules. In colonial Mexico, the Franciscan, Dominican and Augustinian order followed the Mendicant tradition, whereas the Jesuit order did not. In contrast to the Jesuits, Mendicant orders shared a strong commitment to poverty. They argued that wealth inevitably corrupts Christians and leads them away from a lifestyle pleasing to God. Life in poverty makes Christians free to live a holy life and to gain salvation in the afterlife. According to these values, Mendicant orders were strongly committed to the poor. They cared for the urban poor in Europe, before coming to America, (Lawrence, 1994). In colonial Mexico, they advocated social equality between the native population and the colonial elite. In particular, they "sought equality between Indians and Spanish through education," (MacLachlan, 1980: 126). Mendicant orders opened the first school for natives in colonial Mexico (Ricard, 1966: 207). They regularly denounced the miserable living conditions of the native population, as did Bartolomé de las Casas in his book "A Short Account of the Destruction of the Indies" in 1552 (Griffin, 1992).

The Jesuit order, in contrast, was not defined by its commitment to poverty and to the poor. It was founded in 1540 shortly after the Protestant Reformation in Europe with the purpose of strengthening the position of the weakened Roman Catholic Church. Jesuits endorsed economic wealth and influence as valuable means to this end. "If God has given you an abundance of this world's goods it is to help you to earn those in heaven," (Worcester, 2008: 33). In colonial Mexico, they established a "close connection [with] the *criollo* elite [that] rested on the order's educational contributions," (MacLachlan, 1980: 137). They strengthened the position of the Catholic elite in the colony and contributed to the strong position of the Catholic Church in the country. To them, social inequality was justifiable as "the Spanish were the instrument chosen by God to incorporate the Indies into Christian society through subjecting their inhabitants to Spanish dominion," (Liss, 1973: 458).

This study examines the effects of Mendicant and Jesuit mission stations in colonial Mexico on educational and cultural outcomes. For this purpose, I construct the first comprehensive data set of the locations, founding years and founding orders of all historical mission stations in colonial Mexico between 1524 and 1810. I combine this information with current locality level information on literacy, schooling, employment, and conversion. To address the potential endogeneity of mission locations I use an instrumental variable strategy.

Upon arrival, missionary orders first went to Mexico City because only central Mexico had been conquered at the time. From there, missionary expeditions departed in different directions. The orders tended to maintain these early directions for the rest of the colonial period even though geographic and ethnic characteristics of the environment varied along the way. I use the directions of each order's ten earliest missions from Mexico City as instruments for their final distribution across Mexico. The Mendicant orders established 942 and the Jesuit order 203 mission stations between 1524 and 1810.

I further control for factors that may have influenced both the settlement patterns of missionaries and outcome variables today: geographic conditions (climate, altitude, longitude and latitude, distance to the nearest river and lake), location (distance to Mexico City, to the ocean, and to the USA), and pre-colonial characteristics, in particular, pre-colonial settlements, political and cultural conditions, and the number of years before a place got under Spanish control, a useful proxy for native resistance.

Results show that people in a locality that had a Mendicant mission station during the colonial period have significantly higher educational attainment today compared to places without a mission. Literacy rates are higher, the population has on average more years of schooling, and more people have received secondary and higher education. The Jesuit coefficients are negative in the IV regressions. These results are consistent with the strong emphasis that Mendicant orders put on educating the native population. In contrast, Jesuits focused on educating the Spanish and Creole youth in the city centres, rather than the native population in rural areas. Mendicants and Jesuits both have affected conversion to Catholicism.

This chapter contributes to the strand of literature that assesses the long term effects of missionary orders by examining heterogeneous effects of Catholic orders and by instrumenting for the endogenous location of mission stations. My findings corroborate results by Woodberry (2004) and Gallego and Woodberry (2010) who show that missionaries in colonial Africa matter for a country's long term development, mostly through its effect on people's education. Results are also similar to Nunn (2010) who shows missionaries' long term effects on conversion in Africa. Descendants of Africans who have been more exposed to missionaries are more likely to be Christians today. This shows the missionaries' role in shaping religious beliefs and the historic origins of cultural norms.

The study also adds to the strand of literature that assesses the effect of religion in general on people's education and economic well-being. Becker and Woessmann (2008, 2009) find that religious denomination affected current economic outcomes through its effect on educational institutions in 19th-century Prussia. McCleary and Barro (2006) document that religious beliefs are "the main channel through which religion matters for economic and other outcomes" (McCleary and Barro, 2006: 51) and that religious norms alter people's behaviour (McCleary, 2007).

The chapter proceeds as follows. Section 3.2 provides historical background. Section 3.3 presents data sources and the construction of the data set. OLS and IV results are shown in sections 3.4 and 3.6 and section 3.7. concludes.

3.2. Historical Background

3.2.1. Mexico in 1524

In 1524, when the first missionaries came to the territory that constitutes Mexico today, it encompassed distinct regions with different political and economic. The Aztec empire covered central Mexico. Small kingdoms surrounding its capital Tenochtitlan were obliged to pay tribute, mostly in kind. The area's extensive agriculture permitted the growth of urban settlements that were political, economic, and religious centres. A centralised political structure and a complex social order had evolved under the Aztecs. Pre-colonial settlements existed primarily in this part of Mexico. Mexico's south was organised in small, independent kingdoms. It had been home to the Maya civilization that had reached its height long before the Aztecs, before AD 900. At the Spanish arrival, it still had an elaborate system of exchange. The north of Mexico was inhabited by nomadic or semi-sedentary independent groups that were more loosely organised. The area was called Chichimeca ("barbarian") by the Spanish. The majority of them lived as hunters, gatherers, or fishermen (Solanes Carraro et al., 2000). Population density here was low compared to central and south Mexico.

The Spanish first conquered the Aztec empire, then South Mexico and finally North Mexico. After they had captured its capital Tenochtitlan the centralised Aztec empire collapsed and came quickly under Spanish control. The more decentralised Mayan south fought back longer. It was conquered 25 years later in 1546 (Clendinnen, 1982: 32). North Mexico, the so-called Chichimeca, resisted the longest. The independent tribes in Mexico's north posed great challenges to the Spanish military conquest "as guerrilla tactics in modern warfare today," (Deeds, 2011: 101, 122). Its conquest took more than 70 years. Even after 1590, Spanish military expeditions departed regularly from central Mexico towards the south and especially the north to put down uprisings.

When examining the role and long term effects of missionaries it is crucial to take these differences into account. Each place's political, economic, and cultural conditions may well have influenced both the missionaries' decision to settle and educational attainment today. When estimating the effect of missionaries I therefore include fixed effects for each of the pre-colonial regions. I further control for the number of years before an area was under Spanish control. This is a useful proxy for native resistance to conquest and for geographic characteristics that may have facilitated it. It further measures how long a place has been exposed to Spanish institutions, including missions, before Mexican independence. I further include a locality's distance to pre-colonial settlements as a proxy for pre-colonial population density. Its effect on the establishment of missions is not entirely clear. Nunn (2012: 2) suggests for Africa that "the general effect [of population density] is ambiguous. Some missionaries and societies intentionally built missions in more remote locations, where the word of God otherwise would not have reached, while others recognized the benefits and efficiencies associated with dense populations, and targeted these groups."

Mexico is also very diverse in terms of its geographic conditions. Climate and altitude, access to rivers and lakes vary within the country and are relevant factors for the establishment of mission stations and for a locality's economic potential. The same is true for its location within the country, its distance from Mexico City, the sea, and from the USA. Rivers, lakes, and access to the sea, for example, may well have attracted both missionaries and trade by providing relatively low cost transport infrastructure. If omitted from the regression, one

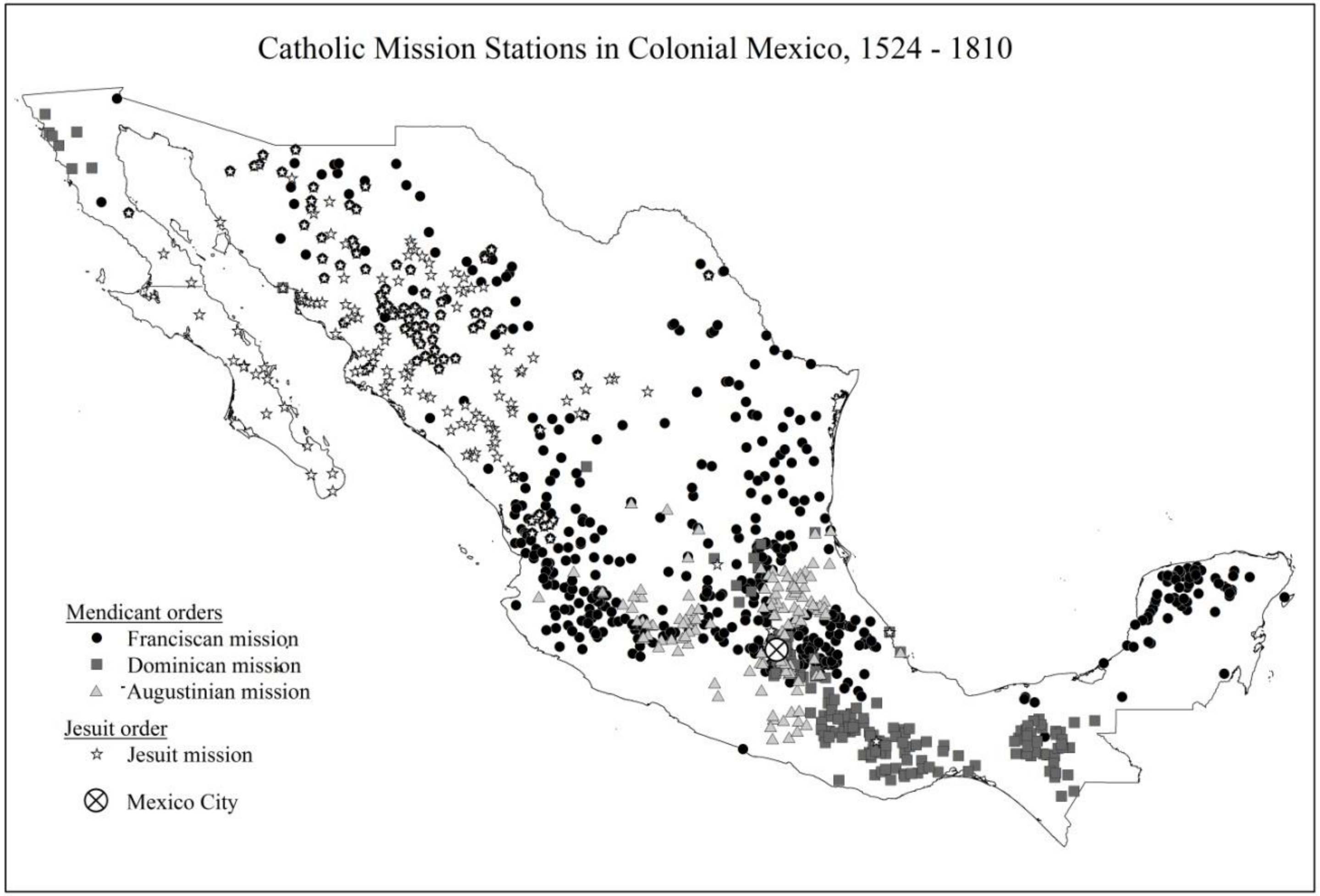

Figure 7 Catholic Mission Stations in Colonial Mexico by Order 1524 – 1810 Catholic

might mistake a positive effect of waterways for the effect of missionaries who were merely attracted by waterways. I therefore include these geographic factors into the regression. Shortly after conquering Tenochtitlan, Cortés asked for missionaries and specifically for Mendicant orders to be sent to Mexico. Unlike other orders, Mendicant friars had the advantage that their rules did not prescribe to remain in one monastery. Besides, they had already proven their worth as missionaries in the Reconquista of Spain. Finally, other orders, such as the Benedictines, owned large land estates across Europe and were in Cortes' opinion too powerful to give them a say in colonial affairs. The Mendicant orders, in contrast, had in principle renounced all worldly goods and were less likely to compete with Spanish conquerors for land and resources. The three Mendicant orders, the Franciscans, Dominicans and Augustinian, arrived in Mexico in 1524, 1526, and 1533. The Jesuit order was founded in 1540 and sent its first missionaries to Mexico in 1571. Figure 7 shows the locations of all mission stations that are part of my data. The missions were established during the colonial period between the arrival of the first missionaries in 1524 and the start of the war of Independence in 1810 in Mexico.

The Mendicant orders established 942 missions of which the Franciscan order established 610, the Dominican order 192 and the Augustinian order 140. The Jesuit order established 203 missions.

In the Americas, the Spanish Crown was the administrative head of the Catholic Church. The Spanish state, not the pope nor the religious orders, funded missionary activities. Spain paid for the journey of missionaries to America, for missionary expeditions within America and a yearly stipend for the maintenance of mission stations. The financial and administrative dependence of the Catholic Church in colonial Mexico on the Spanish Crown made the church an arm of the colonial state (Deeds et al., 2011: 142).

The Spanish Crown invested in the evangelization of overseas territories for various reasons, also because it provided legitimation for its conquest and the subjugation of its population. In return for Spain's pledge to convert the American peoples to Catholicism Pope Alexander VI officially approved of the conquest of America by the Spanish (Colegio de México, 2009: 249). Both sides benefited. Spain’s undertaking was declared to be legitimate by what was then Europe’s highest moral authority and the

Roman Catholic Church gained an unimagined number of new adherents at a time when the Reformation dramatically challenged its influence in Europe.

Missionaries proved useful in the conquest of territory and people. Their status as religious men sometimes granted them easier access to native groups. Missions were cheap to maintain and, "played a critical role in the colonization of frontier areas, which in many cases held little or no economic attraction for settlers," (Langer et al., 1995). Because of their importance as "pioneering agencies" Bolton describes Mexican missions in Mexico as "frontier institution" of Spanish conquest (Bolton, 1917). Establishment of Missions and of Spanish Military Control in 1540, 1580 and 1700 illustrates this aspect of missions in the conquest of Mexico. It shows the spread of mission at three points in time: shortly before the conquest of southern Mexico, shortly before the conquest of northern Mexico, and before the completion of the conquest. The darker areas indicate which parts of Mexico were not yet under Spanish control. The spread of mission stations closely accompanies and at times precedes Spanish military conquest. Missions in Latin America "[...] were characteristically and designedly frontier institutions [...]. They served [...] to aid in extending, holding, and civilizing [the frontier] [...]" (Bolton, 1917: 47). This sometimes made them the only Spanish institution in peripheral areas (Langer et al., 1995; Bolton, 1917: 50).

Once mission stations were established they served multiple purposes. They were centres of conversion and also contributed to the economic and cultural conquest of the native population. The resettlement of natives in missions permitted missionaries to regularly gather children and adults for religious service and indoctrination. Religious teaching took a prominent role in mission life because conversion remained at the heart of missionary work (Bolton, 1917). Missionaries regularly assembled mission inhabitants, on a daily or weekly basis, to teach them doctrines of the Roman Catholic Church and how to lead lives pleasing to God. At the same time, it facilitated the use of the native labour force by Spanish land owners (Langer et al., 1995; Cushner, 2006; Knight, 2002). Furthermore, missionaries contributed to the cultural assimilation of the natives. "The importance of the [missions] goes beyond conversion to Christianity. They represent the attempt to change not only a belief system but fixed, traditional ways of behaving," (Cushner, 2006). Missionaries forced natives to give up polygamous relationships and to cover their entire body with clothes. They also

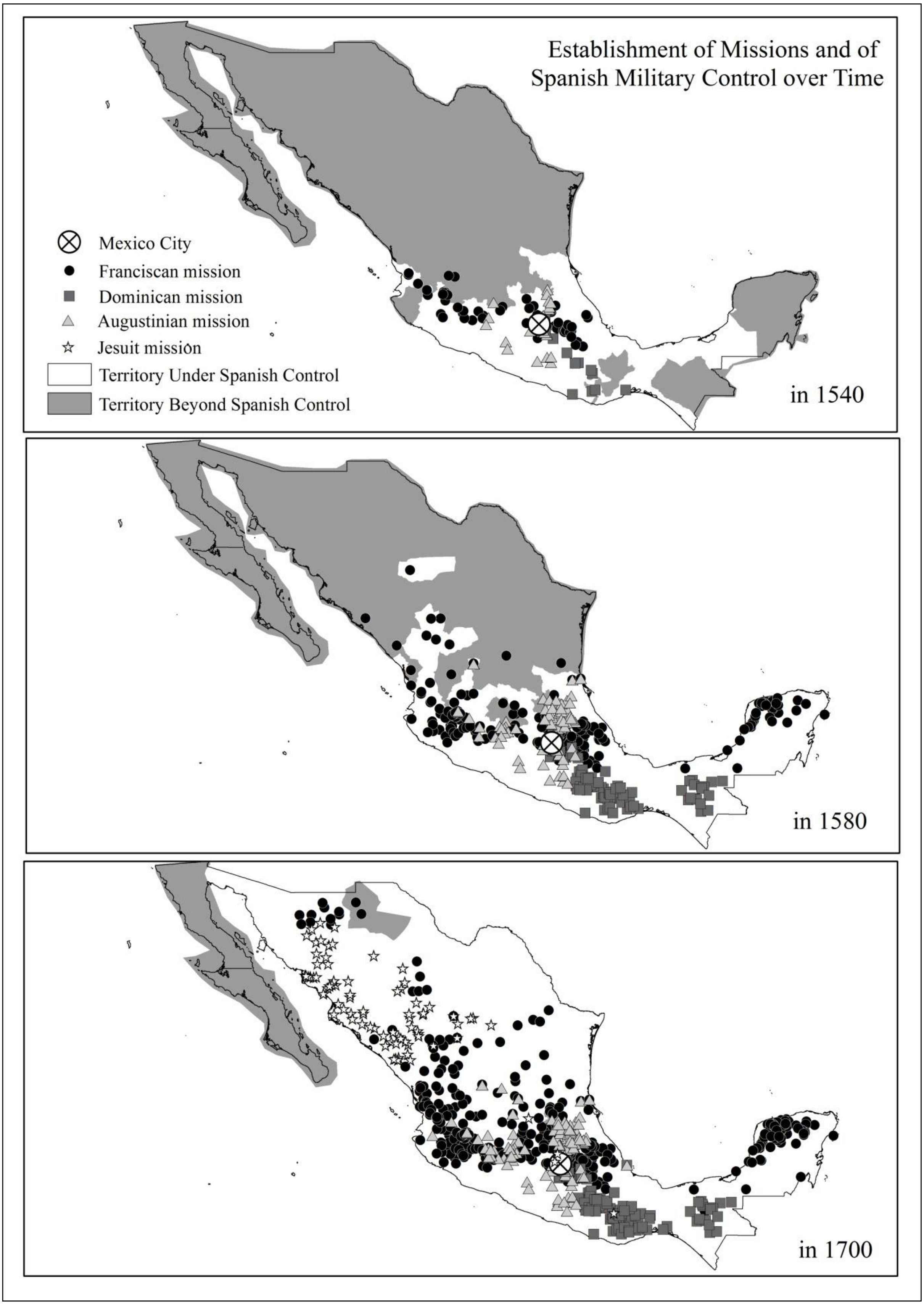

Figure 8 Establishment of Missions and of Spanish Military Control in 1540, 1580 and 1700

imposed a strict daily schedule of work and prayer to assure the mission's sustenance and missionaries' control over the natives. Besides, the friars believed that life as a good Christian naturally included a disciplined life style of work and prayer (Ricard, 1966: 212). It introduced the European perception of time and work, of dividing time into hours and minutes and splitting the day into work and leisure time. Conversion, cultural assimilation and economic exploitation went hand in hand (Langer et al., 1995).

3.2.2. Differences between Mendicant Orders and Jesuits

The early histories of missionary orders "shaped their approaches to conversion and their views of the people they wished to convert," (Wade, 2008: XIV). The Mendicant orders, i.e. the Franciscan, Dominican and Augustinian order, were founded in the 13^{th} century by men who rejected the opulent and decadent lifestyles of Catholic churchmen and their lack of education (Lawrence, 1994: 3, 9). Mendicant orders took the stance that wealth inevitably corrupts Christians and leads them away from a lifestyle pleasing to God. To become a good Christian one should therefore imitate the *Vita Apostolica*, "the life of the disciples of Jesus as it was revealed in the Gospels: a life of poverty devoted to evangelising the unconverted in which the missionaries were supported by alms," (Lawrence, 1994: 32). The key idea of the Mendicant way of life is that poverty makes Christians free to lead better lives and gain salvation in the afterlife. Unlike other orders, mendicant orders as a whole, not only the individual members, commit to poverty. The Mendicant orders had also an egalitarian organisation at their heart. While friars owed obedience to their superior, all superiors were democratically elected and could be dispelled by the friars or their elected representatives. Certain friars were elected to visit monasteries and judge the wrongdoings of their fellow monks and superiors.

The Jesuit order was founded in a different context and with different values. It was founded shortly after the Protestant Reformation in 1540 to help maintain the influence of the Roman Catholic Church in Europe. The founder Ignatius of Loyola intended to build a group of well-trained priests that stood in the pope's service and served his purposes. Jesuits were directly answerable to the pope and unlike any other order, its

Table 30 The Orders' Principles and Excerpts from their Rules

Subject	***Rules of the Mendicant orders***	***Constitution of the Jesuits***
Founding Principle	<u>Life in poverty</u> "The brothers shall appropriate nothing to themselves, neither a place nor anything; but as pilgrims and strangers in this world, serving God in poverty and humility, they shall with confidence go seeking alms. Nor need they be ashamed, for the Lord made himself poor for us in this world. This is that summit of most lofty poverty which made you, my most beloved brothers, heirs and kings of the kingdom of heaven" (Lawrence, 1994: 33)	<u>Obedience to the Pope</u> "the society as a whole, and each of them, owes obedience to our most holy lord, the pope […]. For the greater humility of our society, and toward the complete self-mortification of each one, and in order to aid the abnegation of our own wills to the greatest extent, let each one, besides that common obligation, be devoted to this by special vow."
Internal organisation	<u>Egalitarian Principles</u> "The election shall be conducted as follows: [they] shall ascertain and faithfully record the will of each member, one by one, in the same house and in the presence of all the members; then they shall publicly announce the result in the same place before the brethren leave or confer with one another."	<u>Concentration of Power</u> "let the deciding of the grade of each, of the offices, and whole arrangement be in the hands of the general or prelate selected through us, in order that the harmony so necessary in all well-governed institutions may be preserved"
	"[The *visitadores*] visit the province [and] are to hear the accounts of transgressions	"The right of carrying out laws, however, belongs only to the general."

	committed by conventual priors or the brethren and correct them without changing the constitution and status of the house.”	
	“The *difinitores* have plenary power with respect to correcting any transgressions of the Master of the Order and even of removing him from office.”	

members vowed direct obedience to him. The individual Jesuits vowed to have no private property, but - unlike Mendicant orders - the order as a whole did not commit to remain poor. It endorsed economic wealth and influence as important means to serve the interests of the Church. “If God has given you an abundance of this world's goods it is to help you to earn those in heaven,” (Worcester, 2008: 33). The Jesuit order became an important land owner in Mexico. All founding members of the Jesuit orders held degrees from the renowned university in Paris (Hoepfl, 2004: 9). Their excellent education allowed them to mix in the best society. Jesuits soon gained influence in the political and economic spheres of society. They acquired positions as confessors to Catholic princes and leading figures of the society (Hoepfl, 2004: 16).

Whilst Mendicant orders argued that wealth prevents people from leading a truly Christian life Jesuits saw economic means as a help to reach salvation. Whereas the Mendicant orders were organised on egalitarian principles, the Jesuit order concentrated power in the hands of few. The *padre general* was elected for life and could then not be held accountable (Aviles et al., 1997). He had the power to staff all other positions of importance and had power to carry out laws.

Differences between the orders’ attitudes shaped the way that they carried out missionary work in colonial Mexico (Wade, 2008: XIV). The Mendicant emphasis on poverty led these orders to esteem, sometimes to romanticise, the simple living conditions of the native population. In the beginning, they considered their way of life superior to Spanish culture because it seemed to be uncorrupted by money and greed, in perfect harmony with their own ideal of poverty. In the beginning, mendicant orders had naively cherished utopian hopes of creating the perfect Christian egalitarian community among them (Phelan, 1970). These hopes dissipated soon in the realities of the Spanish conquest and native resistance to conversion. Nevertheless, Mendicant orders still advocated equal opportunities between colonisers and colonised. They saw their educational institutions as a means to achieve “equality between Indians and Spanish through education” (MacLachlan, 1980: 126). In 1523, Franciscans opened the first school for natives in Texcoco. Later, a school in Mexico City was opened for native and Spanish orphans (Ricard, 1966: 207). The Dominican Bartolomé de las Casas was among the most important defenders of native rights. His book “A Short Account of the Destruction of the Indies”, published in 1552, was the first serious attempt to draw attention to the miserable living conditions of the native population in the Spanish land holdings (Griffin, 1992).

The Jesuits also established missions but their main focus was the establishment of educational institutions in cities providing education for the colonial elite and the administration of large land estates for their maintenance. They collected money from wealthy Mexican land owners, supposedly for the establishment of missions, but these assets might have been invested elsewhere. “The fund’s relative abundant assets contrasted with the poverty in which the missionaries lived who had to use all their energy and imagination to make ends meet [...]. The administration of the Fund turns out to be, at least, suspicious,” (Negro et al., 2005: 152) The Jesuits sought to strengthen the position of the Roman Catholic Church in Mexico. They gained influence in Mexican society through the provision of high quality education to the Spanish and Creole youth. “The close connection between the Society of Jesus and the *criollo* elite rested on the order’s educational contributions,” (MacLachlan, 1980: 137). This was in line with “the [general Jesuit] educational vision [...] to offer capable and zealous leaders to the social order,” (Cesareo, 1993: 26).

3.3. Data Sources and Data Set Construction

The main source of information on the locations of mission stations in colonial Mexico is a series of three volumes on political, economic and pre-colonial characteristics of colonial Mexico by historical geographer Peter Gerhard (Gerhard, 1972, 1982, 1993). The author systematically describes in text format all historical municipalities of Mexico (New Spain). In this text, he provides names of missions, the respective order in charge of the mission, and the mission's start and end year.

The exact locations of the historical mission stations are not provided. Based on the names I find the geographic coordinates of historical missions with the help of various sources. If the mission had become a present-day locality I could find its coordinates in locality level census data published by the Mexican Institute of Statistics and Geography (INEGI, 2000). Oftentimes, former mission stations had changed names or ceased to exist. In this case, I consulted the Illustrated Atlas of Indian Villages of New Spain in 1800 (Tanck de Estrada, 2005) which includes maps and geographic coordinates of Indian villages. Some of these had originally been mission stations. I also consulted the Historical Archive of Localities (INEGI, 2011), an online resource provided by the Institute of Statistics and Geography of Mexico, with lists of locality names that have ceased to exist and former names of current localities. If these options failed, an internet search helped to find details about a specific mission's history and its coordinates. In total, I have been able to geo-reference 95% of the mission stations compiled by Gerhard (1972, 1982, 1993). The data set contains 1145 mission stations in total.

A list of all localities in Mexico is taken from census data of the year 2000 (INEGI, 2000). The dummy variable *Mission of Any Order* is one for all localities that were located within five kilometres of a mission station of any of the orders. The dummy variable *Mendicant mission* is 1 for all localities that were located within five kilometres of a mission station of one of the Mendicant orders. The dummy variable *Jesuit mission* is defined accordingly. I obtain locality level information on outcome variables from census data on Mexico for 2000 (INEGI, 2000).

Table 31 Summary Statistics

		Localities With			
	All	No Mission	Mission of Any Order	Mendicant mission	Jesuit mission
# of missions	1,145	0	1,145	942	203
# of localities	104,439	86580	17859	16573	2330
% of localities	100%	82.90%	17.10%	15.87%	2.23%
Years of Schooling	4.21	4.13	5.00	4.98	4.68
Literacy	76.03%	75.73%	79.07%	78.55%	77.37%
Secondary Education	19.86%	19.01%	28.35%	28.26%	24.93%
Higher Education	1.48%	1.33%	3.00%	2.99%	2.76%
Employment	42.17%	41.90%	44.83%	45.09%	40.06%
Catholic	85.31%	84.94%	89.06%	89.09%	88.24%

I take information on a locality's climate from the database "Climate Project" (INEGI, 2009). I assign one of 13 climate zones to each locality. Climate zones are defined based on a locality's average temperature, rainfall frequency, and overall humidity. I calculate a locality's distance to the nearest river or lake based on GIS data. I further take information on a locality's altitude, and its latitude and longitude from locality level census data from 2000 (INEGI, 2009). I use the locality's coordinates to calculate each locality's distance from Mexico City. I use GIS data on Mexican boundaries to calculate each locality's distance from the sea, and from the USA.

The location of prehispanic settlements in Mexico are taken from Solanes Carraro (2000). *Precolonial settlement* measures a locality's distance from the nearest pre-colonial settlement. Information on the extent of Aztec territory in central Mexico, of the Maya region in Mexico's south and the northern zone that was home to nomadic and semi-sedentary groups is taken from three maps in Gerhard (1972, 1982, 1993). I further define the region non-nomadic north, which is an area in the north of Mexico that was neither part of the Aztec empire nor of the nomadic north. I likewise define the non-Mayan south as the south of Mexico that was neither part of the Mayan kingdoms nor of the Aztec empire. I assign each locality to one of these five pre-conquest zones: Aztec centre, Mayan South, nomadic north, non-nomadic north, and non-Mayan south. Finally, I include the variable *conquest delay*, the number of years between Cortés' arrival in Mexico in 1519 and the establishment of Spanish control. This information has been collected at the municipality level from Gerhard (1972, 1982, 1993).

A main concern in the identification strategy is the endogenous location of mission stations. In the next section, I will therefore introduce an array of control variables that are likely to affect both the location of mission stations and current outcome variables. Not accounting for these could bias results. ***Table 32*** provides a table of summary statistics that underlines the importance of controlling carefully for such factors. It reports means and differences in means of these control variables between localities with and without any mission station, and between localities with and without mission stations of each missionary order. All differences are highly statistically significant. If they are also correlated with outcome variables omitting these from the specification would bias results.

Table 32 Summary Statistics - Comparision of Differences in Means of Pre-Colonial Variables

		Mission Type									
	Complete Sample	**_FRAN_**	**_No FRAN_**	**_DOM_**	**_No DOM_**	**_AUG_**	**_No AUG_**	**_JES_**	**_No JES_**	**_Mission_**	**_No Mission_**
Number of Observations	110379	4866	105513	1971	108408	1611	108768	1269	109110	8767	101612
Average Temperature	17.828	17.653	17.836	19.092	17.805	17.561	17.83	18.77	17.81	18.086	17.806
Difference in Means		0.183***		-1.286***		.27136***		-.9562***		.2802***	
Altitude	1084.7	1379.7	1033.7	1266	1045	1421.3	1043.4	916.7	1050.4	1305.8	1026.79
Difference in Means		-345.94***		-221***		-377.95***		133.78***		279.0***	
Distance from river	2.719	.14670	2.8380	.112	2.7667	.1451	2.757	.0773	2.750	.134	2.942
Difference in Means		2.6913***		2.6546***		2.612***		2.672***		-2.808***	
Distance from lake	3.439	.71241	3.565	.88468	3.485	.6514	3.480	.8027	3.470	.7497	3.671
Difference in Means		2.8527***		2.601***		2.829***		2.667***		-2.921***	
Distance from ocean	5.72	1.6733	5.9087	1.253	5.80	1.603	5.783	1.390	5.772	1.523	6.084
Difference in Means		4.2353***		4.5500***		4.1793***		4.381***		-4.560***	
Latitude	19.76	21.479	19.702	17.795	19.81	20.109	19.77	25.98	19.708	20.80	19.693
Difference in Means		-1.7762***		2.0215***		-.3332**		-6.279***		1.108***	
Longitude	-95.12	-100.594	-94.739	-96.047	-94.978	-99.471	-94.931	-107.329	-94.85	-99.99	-94.56
Difference in Means		5.8544***		1.0681***		4.539***		12.475***		-5.426***	
Distance from prehispanic settlements	4.90	0.499	5.1038	.3107	4.984	.3584	4.9682	1.250	4.943	.4947	5.281
Difference in Means		4.604***		4.673***		4.6097***		3.693***		-4.786***	

3.4. Results

In the following, I use this data set to assess the question whether missionaries in colonial Mexico have had long term effects on educational and cultural outcomes, whether these effects vary across orders and whether they are robust to instrumental variable estimation. I first estimate the average effect of mission stations of *any* order on outcome variables.

$$
\begin{aligned}
(11)\ \ & Outcome_i = \\
& \beta_0 + \beta_1 \, Mission\ of\ Any\ Order_i \\
& + \beta_2 \, climate_i + \beta_3 \, altitude_i + \beta_4 \, latitude/longitude_i + \beta_5 \, river/lake_i \\
& + \beta_6 \, distance\ to\ capital_i + \beta_7 \, distance\ to\ sea_i + \beta_8 \, distance\ to\ USA_i \\
& + \beta_9 \, pre\text{-}colonial\ political\text{-}cultural\ zone_i + \beta_{10} \, pre\text{-}colonial\ settlements_i \\
& + \beta_{11} \, conquest\ delay_m + \varepsilon_i
\end{aligned}
$$

The variable Mission of Any Order is a dummy variable that is 1 for all localities located within less than 5 kilometres of a historical missions station. The main coefficient of interest is β_1. It indicates whether outcomes in locality i with a mission station of *any* of the orders are significantly different from outcomes in localities without mission station. To control for a location's geographic characteristics I include measures for a locality's climate and altitude, latitude and longitude, and distance to the nearest river and lake. I further control for a locality's distance to Mexico City, to the USA, and to the sea as these may affect a locality's economic potential. Finally, I include a place's pre-colonial characteristics: distance to pre-colonial settlements, a set of dummy variables for its pre-colonial political-cultural region, and the number of years between the arrival of the Spanish in 1519 and an area's conquest. I cluster standard errors at the municipality level. The outcome variable *Years of Schooling* measures the average years of schooling of the population above 15 years. *Literacy rate* is the share of the population above 15 years that is able to read. *Secondary Education* and *Higher Education* is the share of the population above 15 that has received secondary and higher education. The outcome variable *Catholic* is the share of Catholics in the population.

Table 33 The Aggregate Effect of Orders on Outcomes

	(1)	(2)	(3)	(4)	(5)
VARIABLES	***Years of Schooling***	***Literacy***	***Secondary Education***	***Higher Education***	***Catholic***
All Orders	0.83***	0.04***	0.09***	0.02***	0.01***
	(0.05)	(0.01)	(0.00)	(0.00)	(0.00)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Observations	107,743	107,227	107,227	107,227	107,229
R-squared	0.17	0.16	0.15	0.04	0.23

Robust se clustered at municipality level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

OLS results in Table 33 indicate that the populations of localities with a historical mission of any order have significantly more years of schooling; a higher share of the population is able to read, has received secondary and higher education, and is catholic. As described before, the missionary orders of colonial Mexico prescribed to different values which have influenced their activities in Mexico. Hence, the results in Table 33 may hide heterogeneity in the effects of missionary orders. In the next specification, I therefore compare localities with mission stations run by Mendicant orders and by the Jesuit order to localities without mission stations. Again, I include the full set of control variables as in regression equation 1.

$$\text{(12)} \quad Outcome_i = \beta_0 + \beta_1 \, Mendicant\ mission_i + \beta_2 \, Jesuit\ mission_i + \beta_3 \, climate_i + \beta_4 \, altitude_i + \beta_5 \, latitude/longitude_i + \beta_6 \, river/lake_i + \beta_7 \, distance\ to\ capital_i + \beta_8 \, distance\ to\ sea_i + \beta_9 \, distance\ to\ USA_i + \beta_{10} \, pre\text{-}colonial\ political\text{-}cultural\ zone_i + \beta_{11} \, pre\text{-}colonial\ settlements_i + \beta_{12} \, conquest\ delay_m + \varepsilon_i$$

The variable *Mendicant mission* is a dummy variable that is 1 for all localities within less than 5 kilometres of a historical mission station of the Mendicant orders, 0 otherwise. The variable *Jesuit mission* is defined accordingly. The main coefficients of interest are β_1 and β_2. β_1 compares the average outcome variables in localities with missions of Mendicant orders to localities without a mission. β_2 compares the average outcome variables in localities with missions of the Jesuit order to localities without a mission.

Results in Table 34 show that people in localities with Mendicant missions have on average more schooling, a higher share of the population is able to read, has received secondary and higher education, and is catholic. The coefficient of *Jesuit mission* for literacy is significantly negative. For *Years of Schooling*, *Secondary Education*, and *Higher Education* the coefficient is always insignificant and zero or negative. For a locality's shares of Catholics, the Jesuit coefficient is positive, significant and larger than the Mendicant coefficient.

Table 34 The Effect of Mendicant and Jesuit Orders on Outcomes

	(1)	(2)	(3)	(4)	(5)
VARIABLES	***Years of Schooling***	***Literacy***	***Secondary Education***	***Higher Education***	***Catholic***
Mendicant Mission	0.59***	0.03***	0.06***	0.01***	0.01***
	(0.04)	(0.00)	(0.00)	(0.00)	(0.00)
Jesuit Mission	0.08	0.00	0.01	0.00	0.03***
	(0.10)	(0.01)	(0.01)	(0.00)	(0.01)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Municipality Fixed Effects	yes	yes	yes	yes	yes
Observations	107,743	107,227	107,227	107,227	107,229
R-squared	0.41	0.45	0.36	0.14	0.39

Robust se clustered at municipality level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Even though I control for geographic factors, a locality's location and pre-colonial characteristics one might still be worried that other factors that are not explicitly controlled for explain the results In the next specification, I therefore include municipality fixed effects. This specification estimates coefficients only based on variation *within* each municipality.

$$(13) \quad Outcome_i = \\ \beta_0 + \beta_1 \, Mendicant\ mission_i + \beta_2 \, Jesuit\ mission_i \\ + \beta_3 \, climate_i + \beta_4 \, altitude_i + \beta_5 \, latitude/longitude_i + \beta_6 \, river/lake_i \\ + \beta_7 \, distance\ to\ capital_i + \beta_8 \, distance\ to\ sea_i + \beta_9 \, distance\ to\ USA_i \\ + \beta_{10} \, pre\text{-}colonial\ settlements_i + \beta_{11} \, conquest\ delay_m \\ + \beta_{12} \, municipality\ fixed\ effects + \varepsilon_i$$

Table 35 The Effect of Mendicant and Jesuit Orders Including Municipality Fixed Effects

	(1)	(2)	(3)	(4)	(5)
VARIABLES	***Years of Schooling***	***Literacy***	***Secondary Education***	***Higher Education***	***Catholic***
Mendicant Mission	0.59***	0.03***	0.06***	0.01***	0.01***
	(0.04)	(0.00)	(0.00)	(0.00)	(0.00)
Jesuit Mission	0.08	0.00	0.01	0.00	0.03***
	(0.10)	(0.01)	(0.01)	(0.00)	(0.01)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Municipality Fixed Effects	yes	yes	yes	yes	yes
Observations	107,743	107,227	107,227	107,227	107,229
R-squared	0.41	0.45	0.36	0.14	0.39

Robust se clustered at municipality level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results in Table 35 show that the previous results are robust to the inclusion of municipality fixed effects. We see positive and highly significant coefficients for Mendicant missions. The coefficients of Jesuit missions are close to zero and insignificant. The only exception is that localities with a Jesuit mission stations has significantly more Catholics than a locality without a mission station. The coefficient is larger than the respective coefficient for Mendicant mission. This indicates that Jesuits have affected conversion but not educational attainment.

We have seen that three Mendicant orders were present in colonial Mexico, the Franciscan, Dominicans, and Augustinians. These orders are part of the same monastic tradition and share many values. In the following I test whether their estimated effect is similar, too. I therefore replace the dummy variable *Mendicant mission* by three dummy variables: *Franciscan mission*, *Dominican mission* and *Augustinian mission*. *Franciscans mission* is a dummy variable that is 1 for a locality if a mission station of the Franciscan order is located less than 5 kilometres from this location. *Dominican mission* and *Augustinian mission* are defined accordingly. Specification (14) includes the four dummy variables, one for each order, the full set of control variables and fixed effects for the pre-colonial political-cultural zones described in section 2. Specification (15) is identical to specification (4) except that municipality fixed effects replace the pre-colonial zones fixed effects.

$$\begin{aligned}
&(14)\ Outcome_i = \\
&\quad \beta_0 + \beta_1\, Franciscan\ mission_i + \beta_2\, Dominican\ mission_i \\
&\quad + \beta_3\, Augustinian\ mission_i + \beta_4\, Jesuit\ mission_i \\
&\quad + \beta_5\, climate_i + \beta_6\, altitude_i + \beta_7\, latitude/longitude_i + \beta_8\, river/lake_i \\
&\quad + \beta_9\, distance\ to\ capital_i + \beta_{10}\, distance\ to\ sea_i + \beta_{11}\, distance\ to\ USA_i \\
&\quad + \beta_{12}\, pre\text{-}colonial\ settlements_i + \beta_{13}\, conquest\ delay_m \\
&\quad + \beta_{14}\, pre\text{-}colonial\ political\text{-}cultural\ zone\ fixed\ effects_i + \varepsilon_i
\end{aligned}$$

$$\begin{aligned}
&(15)\ Outcome_i = \\
&\quad \beta_0 + \beta_1\, Franciscan\ mission_i + \beta_2\, Dominican\ mission_i \\
&\quad + \beta_3\, Augustinian\ mission_i + \beta_4\, Jesuit\ mission_i \\
&\quad + \beta_5\, climate_i + \beta_6\, altitude_i + \beta_7\, latitude/longitude_i + \beta_8\, river/lake_i \\
&\quad + \beta_9\, distance\ to\ capital_i + \beta_{10}\, distance\ to\ sea_i + \beta_{11}\, distance\ to\ USA_i \\
&\quad + \beta_{12}\, pre\text{-}colonial\ settlements_i + \beta_{13}\, conquest\ delay_m \\
&\quad + \beta_{14}\, municipality\ fixed\ effects + \varepsilon_i
\end{aligned}$$

Table 36 and Table 37 show results. We see that results are similar for the three Mendicant orders. Their estimated effect is positive and most of the time significant. We can see that the Franciscan order has in some cases a larger coefficient than the Dominican and Augustinian order. Results for the Dominican order tend to be relatively weak compared to the other Mendicant orders.

Table 36 The Effect of Each Order Separately on Outcomes

	(1)	(2)	(3)	(4)	(5)
VARIABLES	***Years of Schooling***	***Literacy***	***Secondary Education***	***Higher Education***	***Catholic***
Franciscan Mission	0.89***	0.05***	0.09***	0.02***	0.01*
	(0.07)	(0.01)	(0.01)	(0.00)	(0.00)
Dominican Mission	0.58***	0.03**	0.06***	0.01***	0.00
	(0.12)	(0.01)	(0.01)	(0.00)	(0.01)
Augustinian Mission	0.64***	0.03***	0.08***	0.01***	-0.00
	(0.09)	(0.01)	(0.01)	(0.00)	(0.01)
Jesuit Mission	-0.12	-0.04**	-0.00	0.00	0.03***
	(0.18)	(0.02)	(0.02)	(0.00)	(0.01)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Observations	107,743	107,227	107,227	107,227	107,229
R-squared	0.17	0.16	0.15	0.04	0.23

Robust se clustered at municipality level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 37 The Effect of Each Order Separately Including Municipality Fixed Effects

	(1)	(2)	(3)	(4)	(5)
VARIABLES	***Years of Schooling***	***Literacy***	***Secondary Education***	***Higher Education***	***Catholic***
Franciscan Mission	0.62***	0.03***	0.06***	0.02***	0.01***
	(0.05)	(0.00)	(0.00)	(0.00)	(0.00)
Dominican Mission	0.29***	0.01	0.03***	0.01***	0.01
	(0.09)	(0.01)	(0.01)	(0.00)	(0.01)
Augustinian Mission	0.53***	0.03***	0.06***	0.01***	0.01
	(0.08)	(0.01)	(0.01)	(0.00)	(0.00)
Jesuit Mission	0.07	0.00	0.01	0.00	0.03***
	(0.10)	(0.01)	(0.01)	(0.00)	(0.01)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Municipality Fixed	yes	yes	yes	yes	yes
Observations	107,743	107,227	107,227	107,227	107,229
R-squared	0.41	0.45	0.36	0.14	0.39

Robust se clustered at municipality level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 38 OLS Results Within Mission Areas

	(1)	(2)	(3)	(4)	(5)
VARIABLES	***Years of Schooling***	***Literacy***	***Secondary Education***	***Higher Education***	***Catholic***
Mendicant Mission	0.88***	0.04***	0.09***	0.02***	0.01**
	(0.06)	(0.01)	(0.01)	(0.00)	(0.00)
Jesuit Mission	-0.22	-0.04**	-0.01	0.00	0.05***
	(0.15)	(0.02)	(0.01)	(0.00)	(0.01)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Observations	57,133	57,111	57,111	57,111	57,113
R-squared	0.16	0.16	0.15	0.04	0.14

Robust se clustered at municipality level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 39 OLS Results Within Mission Areas Municipality Fixed Effects

VARIABLES	(1) *Years of Schooling*	(2) *Literacy*	(3) *Secondary Education*	(4) *Higher Education*	(5) *Catholic*
Mendicant Mission	0.58***	0.03***	0.06***	0.01***	0.01***
	(0.05)	(0.00)	(0.00)	(0.00)	(0.00)
Jesuit Mission	0.07	0.01	0.01	0.00	0.04***
	(0.11)	(0.01)	(0.01)	(0.00)	(0.01)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Municipality Fixed Effects	yes	yes	yes	yes	yes
Observations	57,133	57,111	57,111	57,111	57,113
R-squared	0.40	0.45	0.35	0.14	0.30

Robust se clustered at municipality level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 40 OLS Results Per Order Within Mission Areas

VARIABLES	(1) *Years of Schooling*	(2) *Literacy*	(3) *Secondary Education*	(4) *Higher Education*	(5) *Catholic*
Franciscan Mission	0.78***	0.04***	0.08***	0.02***	0.02***
	(0.08)	(0.01)	(0.01)	(0.00)	(0.00)
Dominican Mission	1.00***	0.06***	0.09***	0.02***	-0.01
	(0.15)	(0.01)	(0.01)	(0.00)	(0.01)
Augustinian Mission	0.55***	0.02	0.06***	0.01***	0.00
	(0.11)	(0.01)	(0.01)	(0.00)	(0.01)
Jesuit Mission	-0.18	-0.04**	-0.01	0.00	0.05***
	(0.14)	(0.02)	(0.01)	(0.00)	(0.01)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest	yes	yes	yes	yes	yes
Observations	57,133	57,111	57,111	57,111	57,113
R-squared	0.16	0.17	0.15	0.04	0.14

Robust se clustered at municipality level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 41 OLS Results Per Order Within Mission Areas Municipality Fixed Effects

VARIABLES	(1) Years of Schooling	(2) Literacy	(3) Secondary Education	(4) Higher Education	(5) Catholic
Franciscan Mission	0.55***	0.02***	0.06***	0.01***	0.01**
	(0.07)	(0.01)	(0.01)	(0.00)	(0.01)
Dominican Mission	0.33***	0.01	0.04***	0.01***	0.00
	(0.10)	(0.01)	(0.01)	(0.00)	(0.01)
Augustinian Mission	0.51***	0.04***	0.05***	0.01***	0.01
	(0.09)	(0.01)	(0.01)	(0.00)	(0.01)
Jesuit Mission	0.09	0.01	0.01	-0.00	0.04***
	(0.11)	(0.01)	(0.01)	(0.00)	(0.01)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Municipality Fixed Effects	yes	yes	yes	yes	yes
Observations	57,133	57,111	57,111	57,111	57,113
R-squared	0.40	0.45	0.35	0.14	0.30

Robust se clustered at municipality level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

3.5.2. Altonji-Elder-Taber statistics

In this section, I use the Altonji-Elder-Taber statistic to explore whether the omission of variables from the regression, either because they are unobservable or because data is not available at present, is likely to bias results (Oster, 2013). The basic idea behind this test is that coefficients movements in combination with changes in R-squared values as control variables are introduced into the specification are informative of relevant omitted variables under the assumption that selection on observables is proportional to selection on unobservables. The test statistic δ is a test of "how important the unobservables would need to be relative to the observables to eliminate the estimated effect. [...]". (Oster, 2013: 9). Oster (2013: 13) tests the validity of the test statistic and finds that "estimates which require a higher δ to produce β = 0 are more likely to have been confirmed in randomised trials."

Table 42 shows results for different explanatory variables used in this studies. For the explanatory variable Franciscan mission the δ -value is large and positive. This suggests that unobservable variables in the model would have to facto 2.3 or factor 7.6 as large as observable characteristics so that the coefficient on this explanatory variable would be 0. For the other explanatory variables Dominican, Augustinian, Jesuit and Mendicant mission, however, the coefficients on δ are negative. This suggests that if unobservable variables could we controlled for the estimated effect of the explanatory variable would be 0. Further research would be needed to investigate what the implications of this test result are. A starting point would be to examine the relationships between the introduction of specific control variables and corresponding changes in R-Squared values. Another important pathway would be to test the relevance of control variables for the outcome variable, to include more control variables to increase R-Squared values and to be able to get a better sense of the importance of the unobservable variables.

Table 42 Altonji-Elder-Taber statistics δ-values

Outcome Variable	***Franciscan mission***	***Dominican mission***	***Augustinian mission***	***Jesuit mission***	***Mendicant mission***
Years of Schooling	2.341	-0.161	-0.696	-0.043	-0.729
Secondary Education	7.66	-0.223	-0.87	-0.015	-0.669

3.6. Instrumental Variable Estimation – Early Directions and Missionary Momentum

In the past section I have presented OLS results on the effects of missionary orders on educational attainment and conversion. I have been careful to control for factors that may have affected both the location of historical mission stations and the outcome variables. In this section I propose an instrumental variable estimation strategy. The missionary orders left Mexico City very early onwards in different directions. These initial directions substantially affected the final distribution of mission stations across Mexico. I use the orders' early directions as a source of exogenous variation in their final locations of missions.

Upon arrival, all missionary orders first went to Mexico City. From there, they sent out missionary expeditions in different directions to establish mission stations among the native population[2]. Then, the orders tended to maintain this direction for the rest of the colonial period even though geographic and ethnic characteristics of the environment varied along the way. There were two reasons for this behaviour. The first reason was the presence of the other orders. Once an order had taken up a direction the other orders generally accepted that this order had earned the right and responsibility to establish missions in this direction. This code of conduct prevented orders from encroaching on each other's territory and minimised tensions between orders over territory. The second reason is the persistent support that missionary expeditions received from their sending orders in Europe. At first, the early directions of the missionary orders consisted of only a handful of mission stations established by a relatively small number of missionaries. Yet, these missionary expeditions received powerful backing by their order in Europe which had the human and financial resources to pursue these initial directions and to persevere even in the face of difficulties. The powerful organisations of the religious orders lent momentum to their members' early missionary expeditions. As a result these early beginnings partly predict the final distribution of missionary orders across colonial Mexico (Figure 7, Figure 9 to Figure 12).

[2] In the colonial period, Mexico and present-day Guatemala together formed the administrative entity New Spain. Unlike Mexico, the more peripheral Guatemala was later divided among missionary orders to ensure its evangelization. This did not occur in Mexico.

The Franciscan order left Mexico City towards the northwest, northeast and southeast. Their main ambition was to reach the “uncivilized territories of the north”, (Ricard, 1966: 66). The second order to arrive in Mexico, the Dominicans, headed south because their “expansion [...] was limited and conditioned by that of the Franciscans” (Ricard, 1966: 66). The Augustinian order left Mexico City in several directions that were still unoccupied by the Franciscan and Dominican order and “squeezed their missions into the gaps left by the Franciscans and Dominicans” (Ricard, 1966: 68). They went into the northwest, northeast and southwest while remaining in the centre. The Jesuits left Mexico City in north western direction because this region was yet untouched by the other missionary orders.

I propose the initial directions of each missionary order to instrument for their final locations. More specifically, I identify each order’s 10 earliest establishments in the context of a missionary expedition and identify initial directions based on Ricard (1966, see Table 43). I draw two lines for each direction, each starting at Mexico City and going through the outermost mission station of each direction until the limits of the Mexican territory (Figure 9 to Figure 12). The area between the lines is then used to instrument for the final distribution of mission stations.

The Dominican and Jesuit order left Mexico City in one direction only. The Augustinians and Franciscans went into three directions each. I determine which missions constitute one direction based on a classification of early missionary directions by Ricard (1966).

Table 43 The Orders' Early Directions

	Number of Initial Directions	***Names of Directions in Ricard 1966***	***Identifier in map***
Dominican Directions	1	Southern Direction	
Augustinian Directions	3	Southern Thrust	A1
		Northern Thrust	A2
		Westward Thrust	A3
Franciscan Directions	3	Puebla-Tlaxcala group	F1
		Hidalgo Querétaro group	F2
		Michoacán group	F3
Jesuit Directions	1	North-western Direction	

For the Franciscan order, Ricard (1966) identifies three early directions: the southeast (the Puebla-Tlaxcala group), the northeast (the Hidalgo Querétaro group), and the northwest (the Michoacán group) (Ricard, 1966: 76). For the Augustinian order, he lists the "southern thrust, [...] the northern thrust [...], [...] the westward thrust," (Ricard, 1966: 77). Geographic names for the Franciscan directions corroborate that the 10 earliest mission stations were part of the early missionary expeditions. I only include establishments that lie outside a 40 miles zone around Mexico City because establishments in the vicinity of Mexico City were not part of the orders' missionary expeditions. They consisted of more than one mission station. In some cases more than one mission station was established in the same year as the 10^{th} mission station. As it was not possible to determine which of the mission stations has been built earlier in the year I include them all.

I define the dummy variable *Jesuit area* that is one for all localities that lie within the direction lines of the Jesuit order. The dummy variable *Mendicant area* is one for all localities that lie within the direction lines of one of the Mendicant orders. I use *Jesuit area* as an instrumental variable for the variable *Jesuit mission* that is one for a locality if a historical mission station of the Jesuit order was located less than 5 kilometres away. I use *Mendicant area* to instrument for *Mendicant mission* that is one for a locality if a historical mission station of one of the Mendicant orders is located less than 5 kilometres away. Due to the spatial nature of the instrument it is not possible to include control variables that describe areas within Mexico. I replace dummy variables for climate groups within Mexico with measures for rainfall and average temperature. I also omit the dummy variables for the pre-colonial political-cultural zones. To see the small impact of these changes on regression I compare OLS specifications with the full set of control variables and with the reduced set of control variables for all outcome variables in Table 44. The precision of the estimates decreases, but the coefficient estimates remain the same or are very similar.

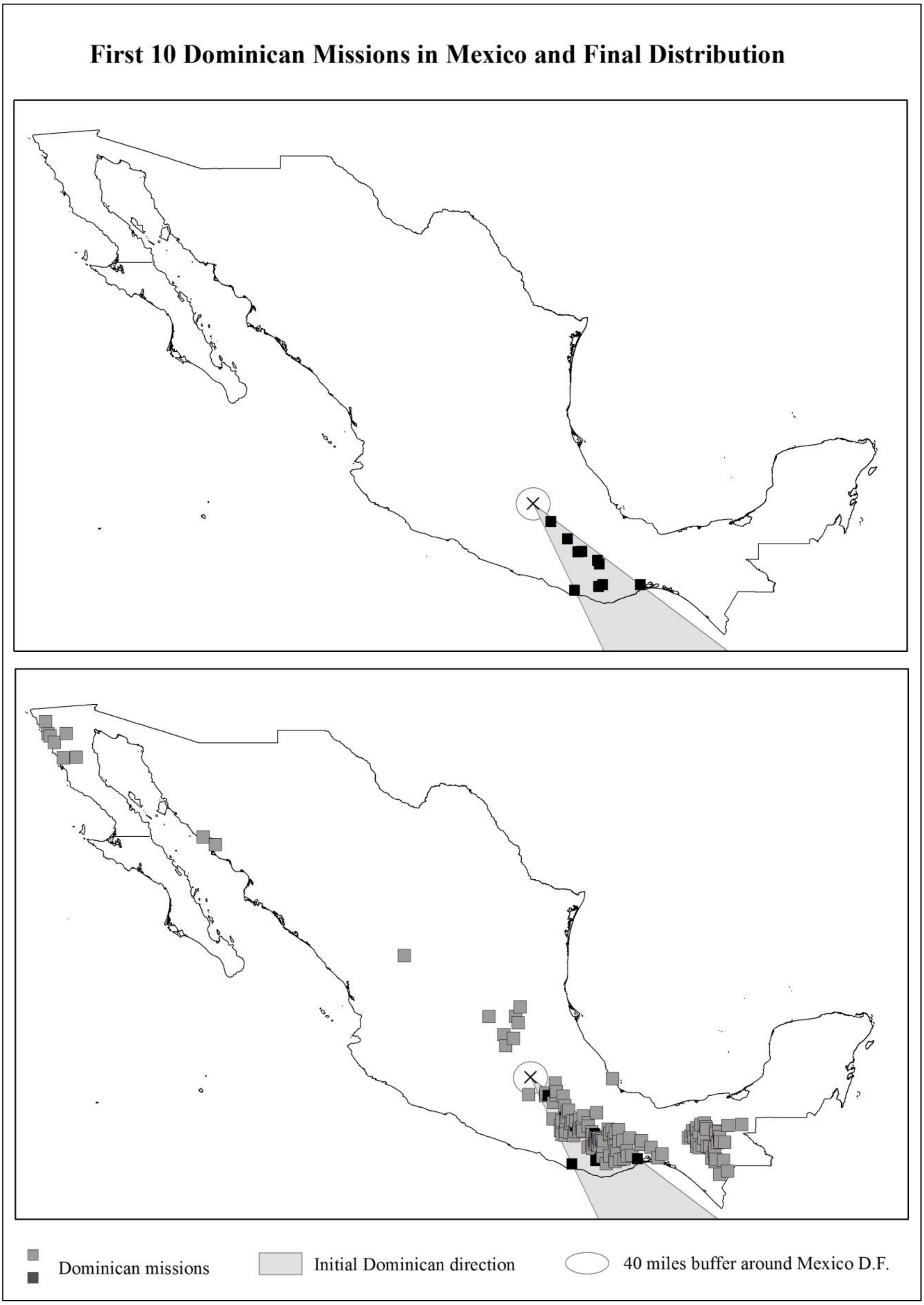

Figure 9 First 10 Dominican Missions in Mexico and Final Distribution

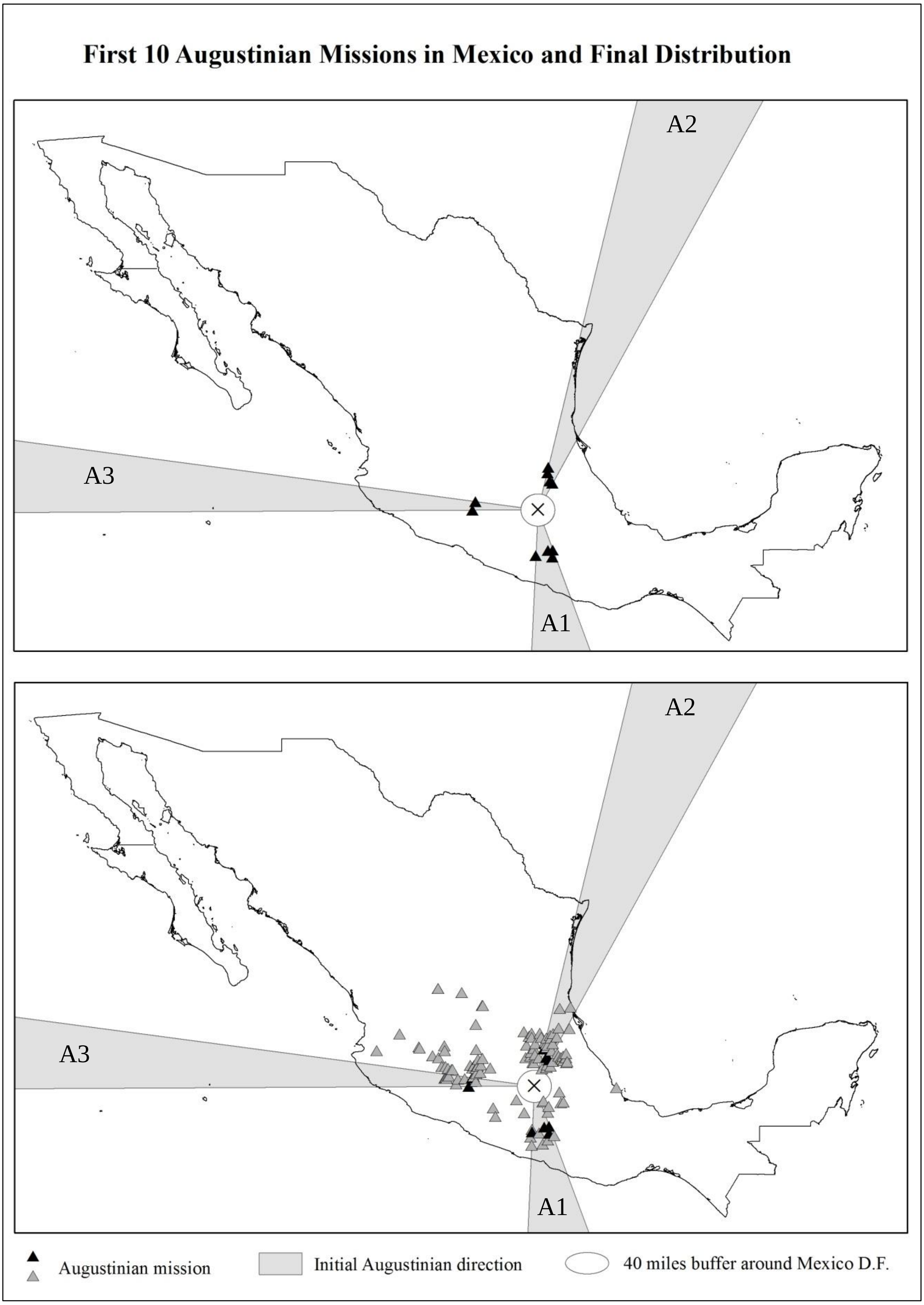

Figure 10 First 10 Augustinian Missions in Mexico and Final Distribution

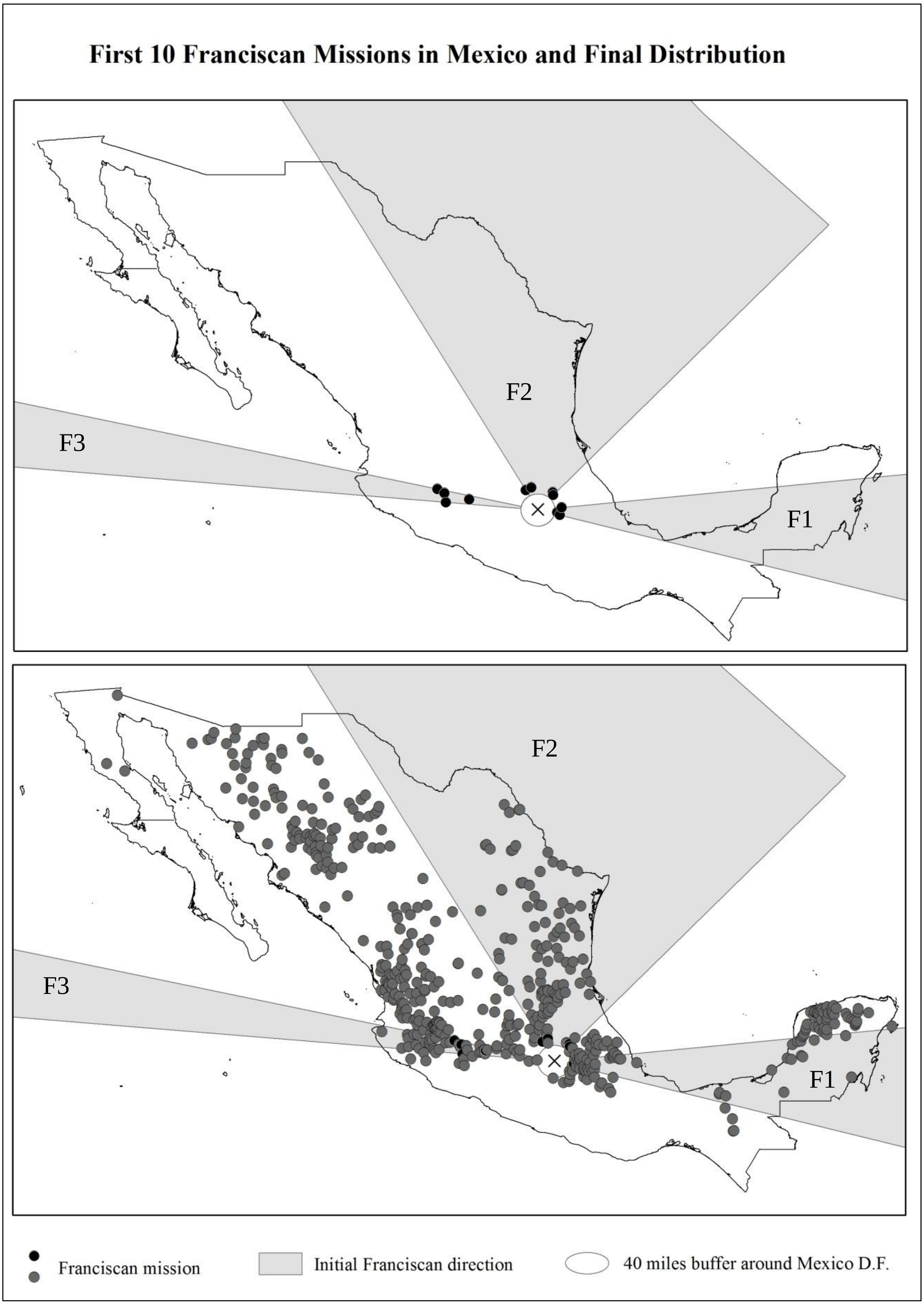

Figure 11 First 10 Franciscan Missions in Mexico and Final Distribution

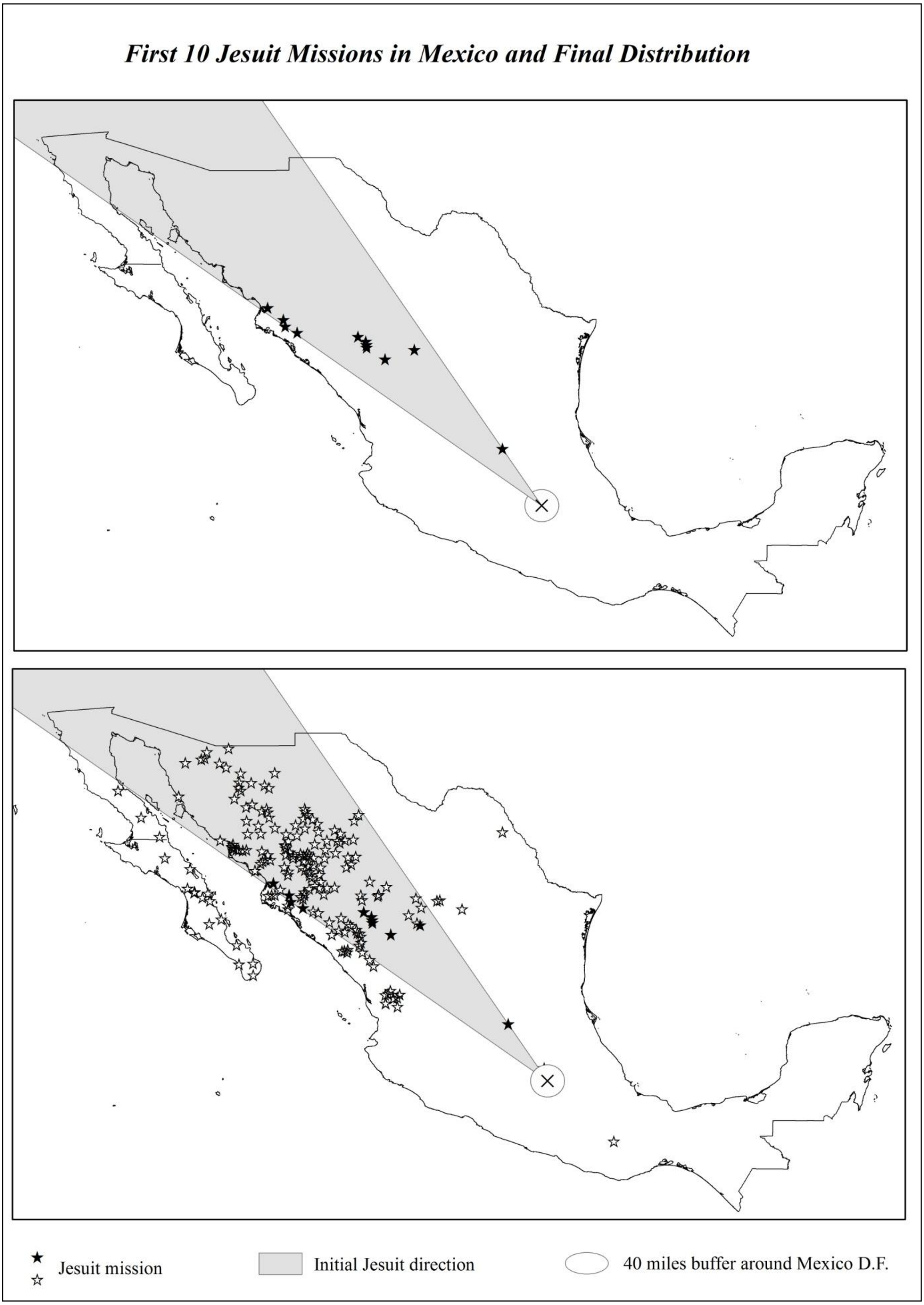

Figure 12 First 10 Jesuit Missions in Mexico and Final Distribution

Table 44 The Effect of Mendicant and Jesuit Orders with Different Control Variables

	(1)		(2)		(3)		(4)		(5)	
VARIABLES	***Years of Schooling***		***Literacy***		***Secondary Education***		***Higher Education***		***Catholic***	
Mendicant Mission	0.84***	0.93***	0.04***	0.04***	0.09***	0.10***	0.02***	0.02***	0.01**	0.01***
	(0.06)	(0.07)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Jesuit Mission	-0.11	-0.13	-0.04**	-0.06***	0.00	0.00	0.00	0.00	0.03**	0.03**
	(0.18)	(0.22)	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)	(0.00)	(0.01)	(0.01)
Full Set of Control Variables	yes		yes		yes		yes		yes	
Reduced Set of Control Variables		yes		yes		yes		yes		yes
Observations	107,743	107,743	107,227	107,227	107,227	107,227	107,227	107,227	107,229	107,229
R-squared	0.16	0.09	0.16	0.10	0.15	0.08	0.04	0.02	0.23	0.21

Robust se clustered at municipality level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

I propose the following First Stage regressions:

$$(16) \quad Mendicant\ mission_i = \gamma_0 + \gamma_1\, Mendicant\ area_i + \gamma_2\, Jesuit\ area_i + \gamma_3\, rainfall/average\ temp_i + \gamma_4\, altitude_i + \gamma_5\, latitude/longitude_i + \gamma_6\, river/lake_i + \gamma_7\, distance\ to\ capital_i + \gamma_8\, distance\ to\ sea_i + \gamma_9\, distance\ to\ USA_i + \gamma_{10}\, pre\text{-}colonial\ settlements_i + \gamma_{11}\, conquest\ delay_m + \varepsilon_i$$

$$(17) \quad Jesuit\ mission_i = \delta_0 + \delta_1\, Mendicant\ area_i + \delta_2\, Jesuit\ area_i + \delta_3\, rainfall/average\ temp_i + \delta_4\, altitude_i + \delta_5\, latitude/longitude_i + \delta_6\, river/lake_i + \delta_7\, distance\ to\ capital_i + \delta_8\, distance\ to\ sea_i + \delta_9\, distance\ to\ USA_i + \delta_{10}\, pre\text{-}colonial\ settlements_i + \delta_{11}\, conquest\ delay_m + \varepsilon_i$$

Table 45 First Stages Regressions

	(1)	(2)
VARIABLES	***Mendicant Mission***	***Jesuit Mission***
Mendicant Area	0.05***	0.01***
	(0.01)	(0.00)
Jesuit Area	-0.04***	0.02***
	(0.01)	(0.01)
Geographic Controls	yes	yes
Climate	yes	yes
Location	yes	yes
Pre-Conquest Controls	yes	yes
Observations	107,743	107,743
R-squared	0.04	0.06

Robust se clustered at municipality level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The First Stages regressions show a positive and highly significant coefficient of each instrument for its respective endogenous variable. Additionally, the instrumental variable *Jesuit Area* is negative and highly significant for the endogenous variable Mendicant Mission. The instrumental variable *Mendicant Area* is positive and significant for the endogenous variable *Jesuit Mission*. The size of the coefficient, however, is only half of the coefficient of *Jesuit Area* in the same regression. As I instrument with two instruments for two endogenous variables, I do not use the usual F-test to test for weak instruments. Instead I use a test proposed by Stock and Yogo (2005) based on the Cragg-Donald Eigenvalue statistic. The value of the Cragg-Donald minimum eigenvalue lies at 127.98, well above the critical value of 7.03. Weak instruments should not bias the results.

Table 46 reports IV regression results. They confirm the patterns of the OLS results. In localities with Mendicant missions, educational attainment is higher and a higher share of the population is Catholic. The Mendicant coefficient on employment is negative but it remains insignificant. For Jesuit missions, the coefficients on educational outcomes are negative and mostly insignificant except for *Higher Education*. The Jesuit coefficient on the share of Catholics is larger than the Mendicant coefficient but remains insignificant. The same results pattern emerges from OLS regressions with and without municipality fixed effects and IV estimation.

A striking feature of the results is that the estimated effect of missionary orders is substantially larger in the IV specification compared to the OLS specification. It is important to understand why this could be the case. Possible explanations include the presence of measurement error in the endogenous variables and that the Local Average Treatment Effects (LATE) does not equal the Average Treatment Effect. Measurement error in the endogenous variables biases results towards zero in the OLS specification. If the instrumental variables are not affected by measurement error and are uncorrelated with the residuals of the endogenous variables, then using IV estimation will produce unbiased results. If the variables on the locations of mission stations suffer from measurement error, then OLS results will be biased towards zero. If the instrumental variables are truly exogenous they will produce unbiased results that are not biased towards zero and hence produce larger estimates. A second explanation refers to the concept of the Following Imbens and Angrist (1993), I interpret IV estimates Local Average Treatment Effects (LATE), the effect of the treatment on those that would not have received treatment in the absence of the instrument. In the present case, this implies that the IV specification estimates the effect of missions on those localities that would not have had a mission if they had not been located within the mission areas defined above. It is thinkable that when missions were erected in remote and insignificant places, these were chosen because of their location, to a lesser extent because of their characteristics. The increase in probability of becoming a mission site by being located within a mission area might have been much higher for remote, insignificant places compared to larger settlements that might still have attracted missionaries by their socio-economic characteristics. If this is the case then the IV specification captures primarily the effect of missions on remote places, and to a lesser extent the effect of missions on relatively large places. It is thinkable that, in the case of smaller localities, missions might have had a particular strong effect because the probability of obtaining alternative educational institutions in the absence of missions might have been especially low. Hence, exploring heterogeneity in the effect of missions on outcome variables depending on localities' initial characteristics could be an interesting direction for future research. One explanation for the discrepancy between IV and OLS estimates is a potential discrepancy between the Average Treatment Effect (ATE) estimated by standard OLS regression and the Local Average Treatment Effects (LATE) estimated by IV regression. The LATE is defined as the effect of the treatment on those that would not have received treatment in the absence of the instrument (Imbens and Angrist, 1993). In the present case, this implies that the IV specification estimates the effect of missions on those localities that would not have had a mission if they had not been located within the mission area "triangles". It is thinkable that when missions were erected in remote and insignificant places, these were chosen because of their location, to a lesser extent because of their characteristics. The increase in probability of becoming a mission site by being located within a mission area might have been much higher for remote, insignificant places compared to larger settlements that might still have attracted missionaries by their socio-economic characteristics. If this is the case then the IV specification captures primarily the effect of missions on remote places, and to a lesser extent the effect of missions on relatively large places. It is thinkable that, in the case of smaller localities, missions might have had a particular strong effect because the probability of obtaining alternative educational institutions in the absence of missions might have been especially low. Hence, exploring heterogeneity in the effect of missions on outcome variables depending on localities' initial characteristics would be an interesting direction for future research.

Table 46 Instrumental Variable Regression Results

	(1)	(2)	(3)	(4)	(6)
VARIABLES	***Years of Schooling***	***Literacy***	***Secondary Education***	***Higher Education***	***Catholic***
Mendicant Mission	5.05***	0.40***	0.41***	0.04**	0.40***
	(1.14)	(0.12)	(0.10)	(0.02)	(0.12)
Jesuit Mission	-5.62	-1.17	-0.46	-0.24**	0.97
	(7.06)	(0.79)	(0.61)	(0.12)	(0.79)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Observations	107,743	107,227	107,227	107,227	107,229

Robust se clustered at municipality level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The validity of these results depends on the assumption that the orders' early directions have only affected the outcome variables through their impact on the orders' settlement patterns. An important concern is that early directions of orders were not random but driven by factors that are themselves related to long term development outcomes. Orders might have systematically chosen directions that allowed them to claim territory with particularly advantageous conditions. Alternatively, orders might have deliberately gone to "more remote locations, where the word of God otherwise would not have reached," (Nunn, 2012: 2). If the missionaries' first concern was to establish easily accessible and maintainable missions we would expect to see that missionaries first established missions around Mexico City, within the former Aztec empire. It was the most advantageous area at the time. Unlike the rest of Mexican territory, it was already under Spanish control, politically stable and the Aztec empire boasted the highest pre-colonial living standards of Mexico. If missionaries had set up missions in this area until the whole population there was exposed to missions this would be evidence for missionaries systematically choosing certain areas to secure particularly advantageous conditions. It would have led to an upward bias in the results we have seen.

Alternatively, the settlement patterns might have been driven by ambition to spread the Christian faith to "where the word of God otherwise would not have reached" (Nunn, 2012: 2). This attitude has been attested by Bolton (1917): "From the standpoint of the Church, and as viewed by [the missionaries] themselves, their principal work was to spread the Faith, first, last, and always".

In addition, the simple living conditions of the native population evoked in the Mendicant orders the dream of creating the perfect Christian egalitarian community among the natives of Mexico. "After [...] three hundred years of frustration in Europe, the Indians presented them with the unique opportunity of applying on a large scale the doctrine of evangelical poverty" (Phelan, 1970: 49). From their point of view, the native societies of the more remote areas of America had not yet been exposed to the evil influence of money, greed and corruption but lived in simplicity and poverty, values advocated by Mendicant orders throughout the world. In the creation of such a society, however, the contact to corrupt and greedy Spanish colonisers would have been disruptive. This incited missionaries to seek undivided control over the natives in remote areas (Phelan, 1970: 46).

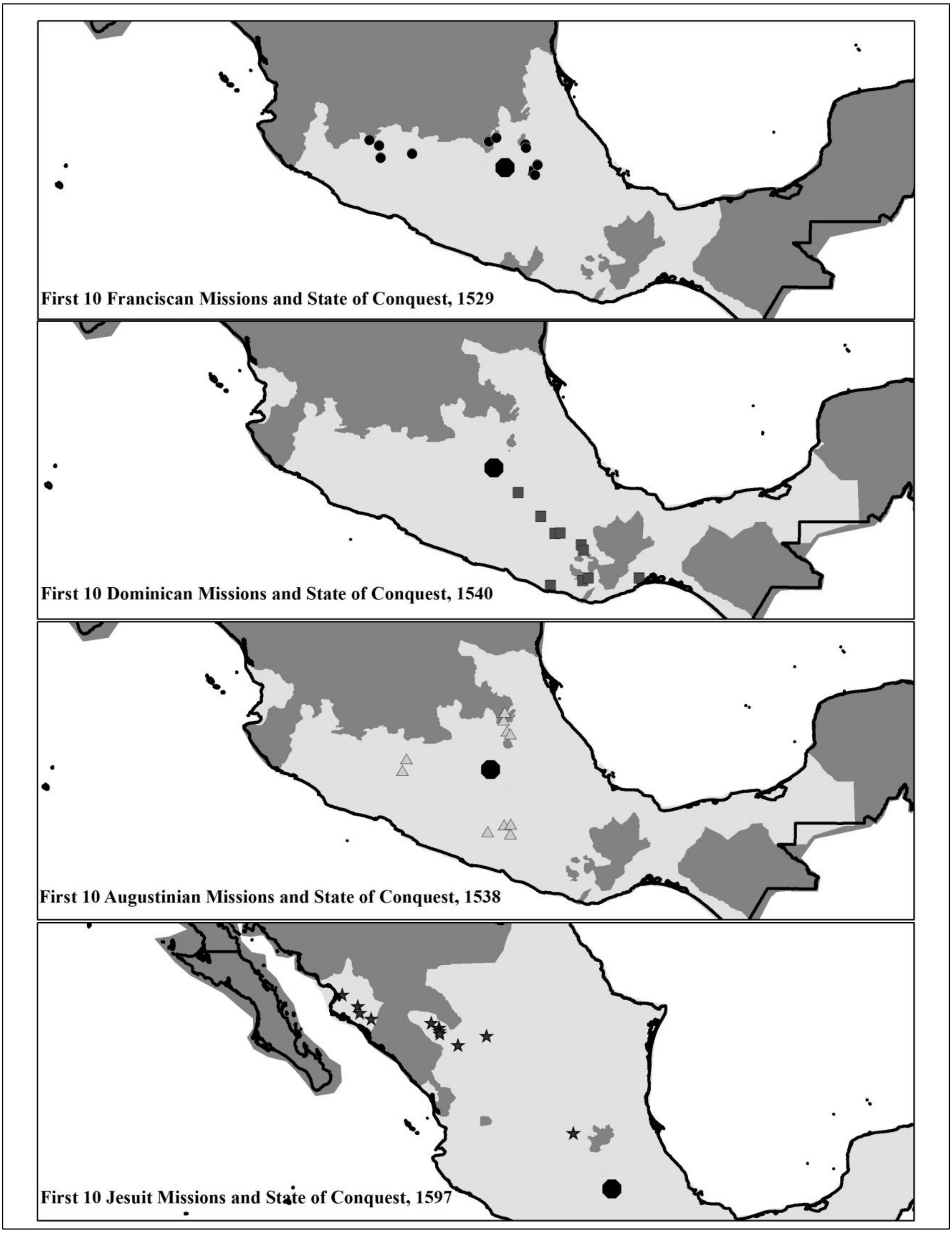

Figure 13 First 10 Missions and State of Conquest

The Spanish Crown further encouraged the missionaries' push towards the yet unsettled regions because "missions were a cost-effective form of colonization: in exchange for a small annual stipend [...] missionaries ran the evangelization and assimilation programs that pacified many frontier Indian groups and contributed to the economic development of frontier regions," (Langer et al., 1995). Missions "[...] were characteristically and designedly frontier institutions and [...] pioneer agencies [...]. They served not alone to Christianize the frontier, but also to aid in extending, holding, and civilizing it," (Bolton, 1917: 47). As a result, "missions played a critical role in the colonization of frontier areas, which in many cases held little or no economic attraction for settlers," (Langer et al., 1995). If settlement patterns of religious orders were primarily driven by these considerations we would expect to see missions spreading quickly to the periphery of Spanish control.

My data sets allows us to see whether the missionary orders pushed towards the unknown territories beyond Spanish control or rather set up missions in the heartland of Spanish control. The map below shows the location of the 10 first mission stations of each order and the state of Spanish conquest at the time when these missions were established. All orders had missions in the centre but then left the centre for more remote areas. All orders touched on areas that were not yet under Spanish control. Mission historian Robert Ricard classifies such missions as "mission of penetration [situated in] zones of difficult relief, unpleasant climate, not yet pacified, or on the border of unsubjugated territories," (Ricard, 1966: 78).

While missionaries did not avoid central Mexico the map shows us that the locations of early missions reflect the missionaries' push to remote areas, be it to spread God's word everywhere, to create communities in remote areas according to their own values, or because of encouragement by the Spanish Crown to establish missions as frontier institutions. This evidence makes it likely that the direction of the earliest missions was not chosen strategically to assure the easiest possible conditions. As the territory lying ahead of the missions was not yet under Spanish control its development trajectory under Spanish control was still unknown. If the direction of the early missions were chosen irrespective of the development potential of the territory ahead than, the results show the causal effect of missionaries rather than of other variables omitted from the equation.

3.6.1. Pseudo-Overidentification Tests

Finally, I conduct a pseudo-overidentification test as an indicator of the validity of the instruments. The test consists of regressing the outcome variables of interest on both the instruments (here: *Mendicant area* and *Jesuit area)* as well as the endogenous variables (here: *Mendicant mission* and *Jesuit mission*) as well as control variables. The basic idea behind the test is that the instrumental variables should not have explanatory power beyond the explanatory power of the endogenous variables. Hence, we would expect that the coefficient of the instrumental variables in this equation is insignificant and substantially smaller in size compared to the endogenous variables. To conduct the test, I estimate the following regression for each of the outcome variables:

$$(18) \qquad Outcome\ Variable_i = \gamma_0 + \gamma_1\, Mendicant\ missions + \gamma_2\, Mendicant\ area_i + \gamma_3\, Jesuit\ mission_i + \gamma_4\, Jesuit\ area_i + \gamma_5\, rainfall/average\ temp_i + \gamma_6\, altitude_i + \gamma_7\, latitude/longitude_i + \gamma_8\, river/lake_i + \gamma_9\, distance\ to\ capital_i + \gamma_{10}\, distance\ to\ sea_i + \gamma_{11}\, distance\ to\ USA_i + \gamma_{12}\, pre\text{-}colonial\ settlements_i + \gamma_{13}\, conquest\ delay_m + \varepsilon_i$$

Table 47 reports results. For each outcome variable – except in column 4 – the coefficient size of the instrumental variable *Mendicant area* is significant. The sizes of the coefficients are substantially smaller in most specifications compared to the coefficients on the endogenous variable *Mendicant mission* except in column 5. The coefficient size of the instrumental variable *Jesuit area* is substantially smaller compared to the coefficients on the endogenous variable *Jesuit mission*. They are not significant.

What do these results tell us about the validity of the instruments? Following the interpretation of the test, the significance of the instrumental variable Mendicant area is a concern, while the relatively small coefficient sizes of the instrumental variables in these specifications shows that the explanatory power of the instrumental variable over and above the endogenous variables is limited.

Table 47 Pseudo-Overidentification Tests

	(1)	(2)	(3)	(4)	(5)
VARIABLES	***Years of Schooling***	***Literacy***	***Secondary Education***	***Higher Education***	***Catholic***
Mendicant Mission	0.68***	0.03***	0.07***	0.02***	0.02***
	(0.05)	(0.01)	(0.00)	(0.00)	(0.00)
Mendicant Area	0.24***	0.01*	0.02***	0.00	0.03***
	(0.06)	(0.01)	(0.00)	(0.00)	(0.01)
Jesuit Mission	-0.17	-0.04**	-0.01	0.00	0.03**
	(0.16)	(0.02)	(0.01)	(0.00)	(0.01)
Jesuit Area	0.09	-0.00	0.01	-0.00	0.02
	(0.11)	(0.01)	(0.01)	(0.00)	(0.01)
Geographic Controls	yes	yes	yes	yes	yes
Climate	yes	yes	yes	yes	yes
Location	yes	yes	yes	yes	yes
Pre-Conquest Controls	yes	yes	yes	yes	yes
Observations	104,950	104,437	104,437	104,437	104,439
R-Squared	0.15	0.16	0.13	0.04	0.23

Robust se clustered at municipality level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

3.7. Conclusion

As in the previous two chapters, the interest of this chapter lies in examining the long-term effects of a historical event while also contributing to our knowledge on a theoretical question with implications for today. In this chapter, I examine the long-term economic effects the important missionary efforts of Catholic Missionaries in colonial Mexico while also contributing to our knowledge on the persistent effect of the transmission of values and the provision of educational institutions by missionaries.

Seminal papers in this field of research that use econometric methods to estimate the long-term effects of missionaries have been Woodberry (2004) and Nunn (2010, 2012). Their results indicate significant and long-term effects of missionary orders, especially on educational and cultural outcome variables.

The present piece of research is similar to these recent studies in the use of econometric methods. Quantitative data on missions located over a large territory have been collected and econometric methods have been applied to estimate the effects of missionaries. It also extends the scope of this literature in several ways. First, it extends the geographical scope of the existing research on missionaries. Previous papers have focused on the role of missionaries in colonial Africa (Woodberry, 2004; Nunn, 2010, 2012). Since it is the aim of this literature to improve our understanding of the effects of missionaries as part of the colonisation process the role of missionaries in colonial Latin America should not remain unexamined as it has been one of the most important missionary undertakings in history. The fact that until today the majority of the population in Latin American countries is Catholic bears witness to the importance of the penetration of Latin America by missionaries.

Second, this chapter refines the perspective on missionaries and how they can be usefully defined. Previous research has identified missionaries as Protestant or Catholic missionaries (e.g. Nunn, 2012), but this is a simplified view of the structures of the Protestant and Roman Catholic Church. Both churches are characterised by a multitude of sub-groups, e.g. in the form of different religious orders, that – while remaining firmly anchored in their respective church – differ in their specific values that motivate many of their actions. In this chapter, I recognize this heterogeneity within the Roman Catholic Church and use it for the purpose of the analysis. One important motivation of studying the effect of missionaries is their role in transmitting values. By estimating the effects of missionaries by order, and not by church (e.g. Catholic vs. Protestant), I can exploit interesting variation in missionary values to show that different orders that adhered to different values had also different long-term effects.

Finally, it is the first study to propose an instrumental variable strategy to address the notorious identification problem that stems from the endogenous locations of mission stations. Previous papers have acknowledged the identification problem addressed it by including an array of control variables. I also follow this strategy and carefully control for relevant control variables. In addition, I estimate the effects of missionaries using instrumental variable estimation. The richness of the collected data on historical mission stations – in particular information on each mission's starting year – allow me to trace the spread of mission across Mexico and to identify the importance of early missionary directions for the final distribution of mission stations. I exploit this source of exogeneity in the final distribution of mission stations. That results remain robust using IV estimation corroborates previous results on the effect of missionary orders for educational and cultural outcomes.

4. Bibliography

Acemoglu, D. and J. Robinson. 2001. A Theory of Political Transitions. American Economic Review 91: 938-963.

Acemoglu, D., S. Johnson, and J. Robinson. 2002. Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution. *Quarterly Journal of Economics*, 117 (2002), 1231–1294.

Acemoglu, D., S. Johnson and J. Robinson. 2005. The Rise of Europe: Atlantic Trade, Institutional Change, and Economic Growth. *American Economic Review* (95), 3: 546-579.

Acemoglu, D. and J. Robinson. 2006. *Economic Origins of Dictatorship and Democracy*. New York: Cambridge University Press.

Aguado, Edward and James. E. Burt. 2007. Understanding Weather & Climate. Upper Saddle River, NJ: Pearson Education.

Allen, R. C. 2001. The Great Divergence in European Wages and Prices from the Middle Ages to the First World War. *Explorations in Economic History* (38): 411-447.

Allen, R. C. 2003. Progress and Poverty in Early Modern Europe. 2003. *Economic History Review* 56 (3): 403-443.

Andreyeva T., M. Long, K. Brownell. The Impact of Food Prices on Consumption: A Systematic Review of Research on the Price Elasticity of Demand for Food. American Journal of Public Health. February 2010, Vol 100, No. 2.

Aviles, Brian. A. And R. Hoover. 1997. Two Californias, Three Religious Orders and Fifty Missions: A Comparison of the Missionary Systems of Baja and Alta California. *Pacific Coast Archaeological Society Quarterly* 33: 3.

Barreca, A., K. Clay, O. Deschenes, M. Greenstone, J. S. Shapiro. 2012. Adapting to Climate Change: The Remarkable Decline in the U.S. Temperature-Mortality Relationship over the 20th century. MIT Mimeo.

Bairoch, Paul. 1988. *The population of European cities, 800-1850: data bank and short summary of results*. Geneva: Droz.

Baten, J. 2002. Climate Climate, Grain Production and Nutritional Status in Southern Germany During the 18th Century. Journal of European Economic History 30(1): 9-47.

Becker, S. O. and L. Woessmann. 2008. Luther and the Girls: Religious Denomination and the Female Education Gap in Nineteenth-Century Prussia. *Scandinavian Journal of Eocnomics* 110 (4): 777-805.

Becker, S. O. and L. Woessmann. 2009. Was Weber Wrong? A Human Capital Theory of Protestant Economic History. *Quarterly Journal of Economics* 124 (2): 531-596.

Behringer, Wolfgang. 2010. *A Cultural History of Climate*. Cambridge: Polity.

Beniston, M., H. F. Diaz, R. S. Bradlez. 1997. Climatic Change at High Elevation Sites: An Overview. Climatic Change 36: 233-251.

Berger, H. and M. Spoerer. 2001. Economic Crises and the European Revolutions of 1848. *Journal of Economic History* 61(2): 293-326.

Bolton, Herbert. 1917. The Mission as a Frontier Institution in the Spanish-American Colonies. *The American Historical Review* 23: 42-61.

Bonin, S. and C. Langlois. 1987. *Atlas de la Révolution française, Nr. 1, Routes et communications*. Paris: École des Hautes Études en Sciences Sociales.

Bossenga, Gail. 2011 "Financial Origins of the French Revolution." In *From Deficit to Deluge – The Origins of the French Revolution,* edited by Kaiser, Thomas E. and Dale K. Van Kley. Stanford: Stanford University Press.

Broadberry, S., B. Campbell, A. Klein, M. Overton, B. van Leeuwen. 2011. British Economic Growth, 1270-1870. Mimeo London School of Economics.

Broadberry, Stephen. 2013. Accounting for the Great Divergence. Mimeo London School of Economics.

Brückner, M. and A. Ciccone. 2011. Rain and the Democratic Window of Opportunity. *Econometrica* (79), 3: 923-947.

Burgess, R., O. Deschenes, D. Donaldson, and M. Greenstone. 2011. Weather and Death in India. Mimeo, MIT.

Burke, P. and A. Leigh. 2010. Do Output Contractions Trigger Democratic Change? *American Economic Journal: Macroeconomics* (2): 124 – 157.

Campbell, P. R. 2006. The Origins of the French Revolution: Problems in Focus. Palgrave Macmillan.

Cantoni, Davide and Noam Yuchtman. 2013. Medieval Universities, Legal Institutions, and the Commercial Revolution. *CESifo Working Paper* No. 4452.

Cesareo, Francesco C. 1993 "Quest for Identy: The Ideals of Jesuit Education in the Sixteenth Century" in: The Jesuit tradition in education and missions: a 450-year perspective. Christopher Chapple (ed.), associated University Press, Inc.

Clendinnen, Inga. 1982. Disciplining the Indians: Franciscan Ideology and Missionary Violence in Sixteenth-Century Yucatan. *Past and Present*. Boston: Oxford University Press 94: 27-48.

Clout, Hugh D. 1977. *Themes in the Historical Geography of France*. London: Academic Press.

Colegio de México. 2009. *Historia general de México/Version 2000*. El Colegio de México, Centro de Estudios Históricos, Mexico D.F.

Conley, Timothy. 1999. GMM Estimation with Cross-Sectional Dependence. Journal of Econometrics, 92 (1999), 1-45.

Cronin, Thomas M. 2010. Paleoclimates – Unterstanding Climate change Past and Present. New York: Columbia University Press.

Cushner, Nicholas P. 2006. Why have you come here? : The Jesuits and the first evangelization *of native America*. Oxford: Oxford University Press.

Deeds, Susan M., M.C. Meyer, W.L. Sherman. 2011. *The Course of Mexican History*. Oxford University Press, New York Oxford.

Dell, M. 2012. Path dependence in development: Evidence from the Mexican Revolution. Mimeo Harvard University.

Dell, M., B. F. Jones, B. A. Olken. 2012. Temperature Shocks and Economic Growth: Evidence from the Last Half Century. *American Economic Journal: Macroeconomics*, 4 (3): 66-95.

Dell, M. B. F. Jones, B. A. Olken. 2014. What do We Learn from the Weather? The New Climate-Economy Literature. *Journal of Economic Literature*.

DeLong, J. Bradford, and Andrei Shleifer, "Princes andMerchants: City Growth Before the Industrial Revolution," Journal of Law and Economics, 36 (1993), 671–702.

Dennison, T. and J. Simpson "Sectoral analysis: Agriculture" in Broadberry, S. and K. H. O'Rourke (eds.). 2010. *The Cambridge Economic History of Modern Europe Volume 1: 1700-1870*.Cambridge: Cambridge University Press.

Deschenes, O., M. Greenstone.2007. The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather. *American Economic Review* 97 (1): 354-385.

Deschenes, O., M. Greenstone. 2012. The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Reply. *American Economic Review* 102 (7): 3761-3773.

Dettwiller, J. and J. Neumann. 1990. Great Historical Events that were Significantly Affected by the Weather : Part 9, the Year Leading to the Revolution of 1789 in France (II). *Bulletin American Meteorological Society*.

De Vries, Jan. 1976. Economy of Europe in an age of crisis. Cambridge: Cambridge University Press.

De Vries, Jan. 1984. European Urbanization, 1500 – 1800. London: Methuen and Co. Ltd.

Diamond, Jared. 2005. *Collapse: How Socities Choose to Fail or Succeed*. New York: Viking.

Dincecco, Mark and Massimiliano Gaetano Onorato. 2013. Military Conflict and the Economic Rise of Urban Europe. Mimeo University of Michigan.

Doyle, William. 1980. Origins of the French Revolution. Oxford: Oxford University Press.

Dyson, T. 2011. The Role of the Demographic Transition in the Process of Urbanization. Population and Development Review 37 (Supplement): 34-54.

European Environmental Agency. 2012. Climate Change, impacts and vulnerability in Europe 2012 - an indicator-based report. EEA Report no 12/2012.

Fagan, Brian. 2000. *The Little Ice Age: how climate made history, 1300-1850*. Basic Books: New York.

Gallego, F. A. and R. Woodberry. 2010. Christian Missionaries and Education in former African Colonies: How Competition Mattered. *Journal of African Economies* 19 (3): 294-329.

Galloway, P. 1985. Annual Variations in Deaths by Age, Deaths by Cause, and Weather in London 1670 to 1830. Population Studies (39) : 487-505.

Garnier, M. 1974. Longues Séries de Mesures de Précipitations en France. Zone 1, Zone 2, Zone 3, Zone 4. Mémorial de la Météorologie Nationale, No. 53, Fascicules No. 1, No. 2, No. 3, No. 4. Paris: Météorologie Nationale.

Gerhard, Peter. 1972. *A Guide to the Historical Geography of New Spain*. Cambridge: AT The University Press.

Gerhard, Peter. 1982. *The North Frontier of New Spain*. Princeton, Guildford: Princeton University Press.

Gerhard, Peter. 1993. *The Southeast Frontier of New Spain*. Norman and London: University of Oklahoma Press.

Goldstone, J. A. 2001. The Social Origins of the French Revolution Revisited. in Eds. Kaiser, T. E. and Van Kley, D. K. “From Deficit to Deluge – The Origins of the French Revolution”. Stanford: Stanford University Press.

Griffin, Nigel, ed. 1992. A Short Account of the Destruction of the Indies/ Bartolome de las Casas. London, UK; New York, N.Y.: Penguin Books.

Haywood, John, S. Hall, A. Jotischky, S. McGlynn, J. Swift. 2000. *The Cassell Atlas of World History – The Medieval & Early Modern Worlds Vol. II*. Oxford, London: Andromeda and Cassell & Co.

Hoepfl, Harro. 2004. Jesuit Political Thought – The Society of Jesus and the State, c. 1540-1630. Cambridge University Press.

Hoffman, P. T. and J. L. Rosenthal. 2000. New Work in French Economic History. *French Historical Studies* (23) 3: 439-453.

Hsiang, S. M., M. Burke and E. Miguel. 2013. Quantifying the Influence of Climate on Human Conflict. Science 341, 1235367.

Imbens, G.W. and Angrist, J.D. 1994. Identification and estimation of local average treatment effects. Econometrica, 62(2): 467–75.

Instituto Nacional de Estadística y Geografia. [INEGI]. Estados Unidos Mexicanos. 2000. Censo General de Poblacion y Vivienda 2000. Principales Resultados pro Localidad (ITER).

Instituto Nacional de Estadística y Geografia. [INEGI]. Estados Unidos Mexicanos. 2009.
Climas Serie I en Informacion Referenciada geoespacialmente Integrada en un Sistema (IRIS).

Instituto Nacional de Estadística y Geografia. [INEGI]. Estados Unidos Mexicanos. 2011. Archivo Historico de Localidades, Consulta de Localidades. http://mapserver.inegi.org.mx/AHL/ (accessed July 14, 2011).

Jia, Ruixue. 2013. Weather shocks, sweet potatoes and peasant revolts in historical China. *Endonmic Journal*.

Kaiser, T. E. and Van Kley, D. K. 2011. From Deficit to Deluge – The Origins of the French Revolution. Stanford: Stanford University Press.

Koot, Gerard. 2013. The Little Divergence and the Birth of the first Modern Economy, or when and why did northwestern Europe become much richer than southern and eastern Europe. Mimeo University of Massachusetts Dartmouth.

Labrousse, C.-E. 1939. Prix et Structures Regionale: Le froment dans les regions francaises 1782-1790.Annales d'histoires sociale (1939-1941), 1, (4), Oct. 1939: 382-400.

Labrousse, C. –E. 1944. La crise de l'economie francaise a la fin de l'ancien regime et au debut de la revolution. Paris : Presses universitaries de France.

Langer, E. and R. H. Jackson. 1995. The New Latin American Mission History. Lincoln, Neb.; London: University of Nebraska Press.

Lawrence, C.H. 1994. *The Friars – The Impact of the Early Mendicant Movement on Western Society*. London and New York: Longman.

Le Roy Ladurie, Emmanuel. 1972. Times of Feast, Times of Famine: A history of climate since the year 1000. London: George Allen & Unwin Ltd.

Lefebvre, Georges. 1973. The Great Fear of 1789 – Rural Panic in Revolutionary France. London: NLB.

Liss, Peggy K. 1973. Jesuit Contributions to the Ideology of Spanish Empire in Mexico: Part I. The Spanish Imperial Ideology and the Establishment of the Jesuits within Mexican Society. *The Americas* 29 (3): 314-333.

Luterbacher, J., D. Dietrich, E. Xoplaki, M. Grosjean, and H. Wanner. 2004. European seasonal and annual temperature variability, trends, and extremes since 1500, *Science* 303, 1499-1503.

Malanima, P.2010. Urbanisation. In Eds. Broadberry, S. and K. O'Rourke. The Cambridge Economic History of Modern Europe, Vol. 1: 1700-1870. Cambridge: Cambridge University Press.

Mann, Michael E., Zhihua Zhang, Scott Rutherfor, Raymond S. Bradley, Malcolm K. Hughes, Drew Shindell, Caspar Ammann, Greg Faluvegi, Fenbiao Ni. 2009. "Global Signatures and Dynamical Origins of the Little Ice Age and Medieval Climate Anomaly," *Science* (326): 1256-1260.

MacLachlan, Colin M. 1980. *The Forging of the Cosmic Race : A Reinterpretation of Colonial Mexico*. Berkeley: University of California Press.

McCleary, R. and Robert Barro. 2006. Religion and Economic Growth. *Journal of Economic Perspectives* 20 (2): 49-72.

McCleary, R. 2007. Salvation, Damnation, and Economic Incentives. *Journal of Contemporary Religion* 22 (1): 49-74.

McCormick, M., P.E. Dutton, P.A. Mayewski. 2007. Volcanoes and the Climate Forcing of Carolingian Europe, A.D. 750-950. *Speculum* 82: 865-895.

McCormick, Michael, Ulf Büntgen, Mark A. Cane, Edward R. Cook, Kyle Harper, Peter Huybers, Thomas Litt, Sturt W. Manning, Paul Andrew Mayewski, Alexander F. M. More, Kurt Nicolussi, Willy Tegel. 2012. Climate Change during and after the Roman Empire: Reconstructing the Past from Scientific and Historical Evidence. *Journal of Interdisciplinary History*, XLIII: 2 (Autumn): 169-220.

McCormick, Michael et al. Digital Atlas of Roman and Medieval Civilizations. Website: http://darmc.harvard.edu/icb/icb.do, last accessed (04/07/2014).

McEvedy, Colin, and R. Jones. 1978. Atlas of World Population History. NewYork, NY: Penguin Books.

Merriman, John. 2010. *A History of Modern Europe: from the Renaissance to the present*. New York and London: W. W. Norton & Company.

Miguel, E.,S. Satyanath, and E. Sergenti. 2004. Economic Shocks and Civil Conflict: An Instrumental Variable Approach. *Journal of Political Economy* 112 (4): 725-753.

Nafziger, S. 2011. Serfdom, Emancipation, and Economic Development in Tsarist Russia. Mimeo Williams College.

Neely, Sylvia. 2008. *A Concise History of the French Revolution*. Plymouth: Rowman & Littlefield Publishers.

Negro, Sandra y Manuel M. Marzal. 2005. Esclavitud, Economia y Evangelizacion – Las Haciendas Jesuitas en la America Virreinal. Pontificia Universidad Catolica del Peru, Fondo Editorial.

Neumann, J. 1977. Great historical events that were significantly affected by the weather: 2, The year leading to the Revolution of 1789 in France. *Bull. Amer. Meteor. Soc*. 58: 163-167.

Norberg, K. 1994. "The French Fiscal Crisis of 1788 and the Financial Origins of the Revolution of 1789." In *Fiscal Crises*, *Liberty and Representative Government* edited by Hoffman, P. T. and K. Norberg. 1450-1789. Stanford: Standford University Press.

Nunn, N. 2010. Religious Conversion in Colonial Africa. *American Economic Review: Papers & Proceedings* 100 (May 2010): 147-152.

Nunn, N. and N. Qian. 2011. The Potato's Contribution to Population and Urbanization: Evidence from a Historical Experiment. *Quarterly Journal of Economics* 126: 593-650.

Nunn, N. 2012. Gender and Missionary Influence in Colonial Africa. Mimeo Harvard University.

Nunn N. and D. Puga. 2012. Ruggedness: The Blessing of Bad Geography in Africa. Review of Economics and Statistics 94(1):20-36.

Nüssli, Christos. 2012. *Euratlas Periodis Historical Atlas of Europe*. Yverdon-les-Bains, Switzerland: Euratlas.

Oster, Emily. 2004. Witchcraft, Weather and Economic Growth in Renaissance Europe. *Journal of Economic Perspectives* (18), 1: 215-228

Oster, Emily. 2013. Unobservable Selection and Coefficient Stability: Theory and Validation. NBER Working Paper, No. 19054.

Parry, M.L., O.F. Canziani, J.P. et al. 2007. Technical Summary. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 23-78.

Pauling, A., J. Luterbacher, C. Casty, H. Wanner. 2006. Five hundred years of gridded high-resolution precipitation reconstructions over Europe and the connection to large-scale circulation. Climate Dynamics Vol. 26 (4): 387-405.

Peel, M.C., B.L. Finlayson, and T. A. McMahon. 2007. Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences* (11): 1633-1644.

Pfister, C. and R. Brazdil. 2006. Social vulnerability to climate in the "Little Ice Age": an example from Central Europe in the early 1770s. *Climate of the Past* (2): 115–129.

Phelan, John Leddy. 1970. *The Millenial Kingdom of the Franciscans in the New World*. Berkeley and Los Angeles: University of California Press.

Planhol, Xavier de, Claval, Paul and Janet Lloyd. 1994. An historical geography of France. Cambridge: Cambridge University Press.

Ricard, Robert. 1966. *The Spiritual Conquest of Mexico – An Essay on the Apostolate and the Evangelizing Methods of the Mendicant Orders in New Spain: 1523-1572*. Berkely & Los Angeles: University of California Press.

Rosenthal, Jean-Laurent. 1992. The Fruits of Revolution: Property rights, litigation, and French agriculture, 1700-1860. Cambridge: Cambridge University Press.

Schlenker, W. W. M. Hanemann, A.C. Fisher. 2005. Will U.S. Agriculture Really Benefit from Global Warming? Accounting for Irrigation in the Hedonic Approach. *American Economic Review* 95 (1): 395-406.

Schlenker W., M. J. Roberts. 2009. Nonlinear Temperature Effects indicate Severe Damage to U.S. Crop Yields under Climate Change. *Proceedings of the National Academy of Sciences* 106(37): 15594-15598.

Shepherd, William R. 1926. *Historical Atlas*. Holt: New York.

Slicher van Bath, B. H. 1963. The agrarian history of Western Europe, A. D. 500-1850. London: E. Arnold.

Solanes Carraro, María del Carmen and Enrique Vela Ramírez. 2000. *Atlas del México prehispanico: mapas de periodos, regiones y cultura*. México D.F.: Editorial Raíces: Instituto Nacional de Antropología e Historia.

Stern, Nick. 2007. The Economics of Climate Change – The Stern Review. Cambridge: Cambridge University Press.

Stock, J. and M. Yogo. 2005. Testing for Weak Instruments in Linear IV Regression. In: Andrews DWK Identification and Inference for Econometric Models. New York: Cambridge University Press: 80-108.

Tanck de Estrada, Dorothy. 2005. *Atlas Ilustrado de los Pueblos de Indios – Nueva Espana, 1800*. Mexico D.F.: El Colegio de Mexico, El Colegio Mexiquense, A.C., Comision Nacional para el Desarrollo de los Pueblos Indigenas, Fomento Cultural Banamex.

Tilly, C. 1990. Coercion, Capital, and European States, 990-1990. Cambridge, UK: Blackwell.

Van Zanden, Jan Luiten. 2009. The long road to the Industrial Revolution: the European economy in a global perspective, 1000-1800. Kininklijke Brill NV: Leiden, Netherlands.

Voigtländer, N. and J. Voth. 2013. The Three Horsemen of Riches: Plague, War, and Urbanization in Early Modern Europe. Review of Economic Studies 80 (2): 774-811

Wade, Maria F. 2008. *Missions, Missionaries, and Native Americans – Long-Term Processes and Daily Practices.* Gainesville: University Press of Florida.

Woodberry, R. 2004. The Shadow of Empire: Christian Missions, Colonial Policy, and Democracy in Postcolonial Societies. Ph.D. thesis, University of North Carolina, Chapel Hill.

Worcester, Thomas. 2008. *The Cambridge Companion to the Jesuits*. Cambridge: Cambridge University Press.

World Bank. 2014.World Bank Website - Data. http://data.worldbank.org/ (last accessed 25/06/2014).