European Economic Growth and Conflict during the Little Ice Age

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Abstract of Dissertation

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Recent studies on global warming have focused on how climate change will impact economic growth and conflict in the long run. This dissertation empirically measures the long run effects of climate change on economic growth and during the Little Ice Age in Europe. The Little Ice Age is a period of temperature cooling from the 16th century to the 19th century. The current literature has associated this temperature cooling with a decrease in economic growth and an increase likelihood in violent conflict. This paper utilized a new dataset of urbanization, conflict, and weather data from eight European countries to measure the impact of climate change from 1520 to 1770. Results on economic growth and temperature confirm the current literature by revealing the negative impact temperature cooling has on economic growth. The results on temperature cooling and conflict show that there is an increased probability of violent conflict with a decrease in temperature. However, these results were not supported with statistical significance.

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1. The Little Ice Age

"The sun is only one of a multitude – a single star among millions – thousands of which, most likely, exceed him in brilliance. He is only a private in the host of heaven. But he alone … is near enough to affect terrestrial affairs in any sensible degree, and his influence on them … is more than mere control and dominance."
- Charles Young, Old Farmers Almanac, 1766

Current climate change is a ubiquitous topic found in academic literature and popular news outlets. Climate change has numerous effects that is not limited to a change in temperature. The amount of rainfall that has occurred in the past will change in varying degrees for different regions into the future. This change in rainfall will cause there to be an increase in rainfall expectations, droughts, and floods. The consensus will support the claim that global warming needs to be addressed or there will be perilous consequences. These consequences have typically been referenced to be directly associated with shortages in agricultural commodities and increased scarcity of vital natural resources. The effect of these consequences will have a strain on existing institutions in the form civil unrest or conflict.

The Economist has cited climate change as being a cause for modern conflict.[1] Baga, a market town in Nigeria could be considered a coastal town of Lake Chad 50 years ago. Since then the size of Lake Chad has shrunken by half. According to locals, the erosion of this oasis has caused violence and disease in this region. Even though developing countries will feel the effects of climate change the worst, advanced countries should not ignore the inevitable effects. As the temperatures continue to increase, Greenland and

[1] Full article can be found at (How climate change can fuel wars 2019).

Antarctica will continue to melt revealing strategic passages to the other side of the world. In addition, natural resources that were once not possible to extract in Antarctica will be revealed as the ice melts. Military conflict can arise between advanced nations such as the United States and Russia or China for these resources in Antarctica. The factors ultimately leading to conflict are not as trivial as solely human climate change. However, this article shows that climate change is a threat that needs to be studied to further motivate policies that will address it.

Modern literature on the effects of current climate change on society are limited to a small time frame relating to the climate warming that began in the 20th century. To gain a larger time series to observe climate change's impact on society one must look at history. During the 16th century to the 19th century there was a period of global cooling that parallels in the rate of climate change that global warming is anticipated to create in the future. This era of global cooling is defined by researchers as the Little Ice Age (LIA).

The LIA in medieval Europe is the focus of this dissertation. The first two sub-sections will provide an overview the LIA and medieval Europe respectively. The broad effects of the global cooling of this period will be explained and I will provide emphasis on what periods will be focused in later sections. Historical evidence is provided to give context to medieval Europe and highlight major events during these time periods. Emphasis will be placed on the effects of global cooling of these events, but the array of other elements that could cause a change in the primary points of consideration will not be discounted. An analysis of government response will conclude the first section. The remaining portion of the thesis will be dedicated to sections of quantitative analysis that studies temperature variability during the LIA relation to economic growth, and conflict. In

Sections 2 will observe the effect of temperature cooling on early European society. This section will contain existing literature on this topic, the relevance of the dataset that will be utilized, and quantitative analysis covering the methods and results. Section 3 will explore the impact of temperature variability on violent conflict in Europe during the LIA. This section will explain the existing literature on this topic, a description of relevant data, and a quantitative analysis presenting methods and results of this topic.

1.1. A Period of Temperature Cooling

As mentioned in the prior section, the LIA began in the 16th century and ended in the 19th century. However, some scholars consider the LIA to begin in the 13th century and ended in the 19th century.[2] The cause of the conflicting time frames for the LIA is largely due to the lack of consensus on the necessary degree of variation in temperature. Those who study the LIA including 1200-1400 have a lower threshold for what is classified as an appropriate change in temperature. The researchers who exclude 1200-1400 from their analysis require more variation in temperature to consider the period the LIA.[3] The majority of LIA experts follow the prior interpretation, and this will be followed for this thesis.

From the 16th to the 19th century the greatest cooling of temperature was experienced across the world. A variety of paleoclimatology methods are utilized to support this claim. Common methods that have been utilized in the economic history literature include but are not limited to tree rings series, ice core series, marine coral series, documentary series, speleothem series, lacustrine series, and marine sediment series performed by climatologist (Mann 2009). The raw data from these methods are collected by paleoclimatologists and then applied to formulas to create accurate temperature reconstruction data. This reconstruction data is what will be primarily be utilized in this thesis and will be further explained in the later data sections. The paleoclimate methods of collecting raw data and the algorithms used in association with this reconstruction data is be beyond the scope of this thesis.

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[2] Lamb (1982) catalogs the history of the Little Ice Age time span debate.
[3] Iris.

Despite the variety of extraction methods in the paleoclimate research, the resulting temperature reconstruction variability for the past remains relatively constant. Figure 1 is a time series of a typical temperature reconstruction. This reconstruction was created from sea surface temperatures from North Iceland.

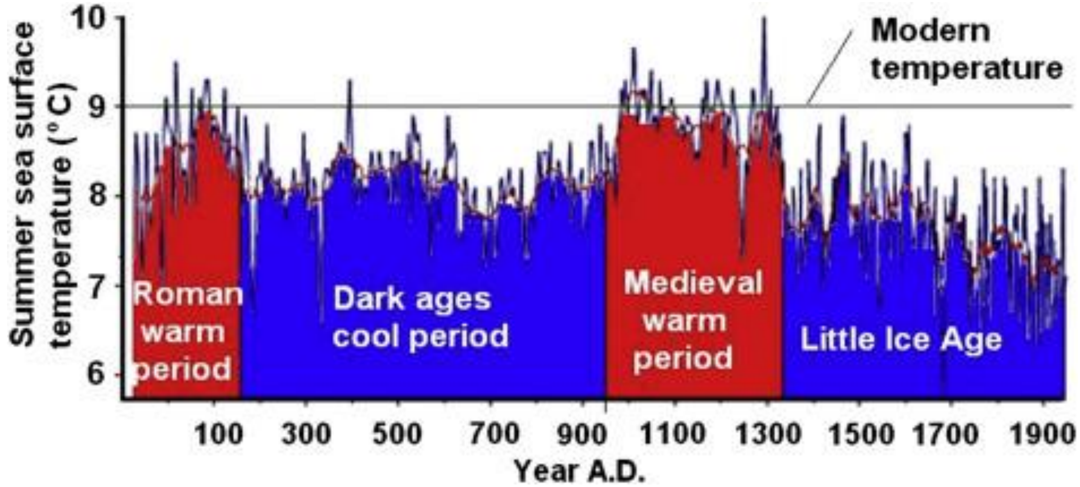

Figure 1- Sicre et al., 2008.

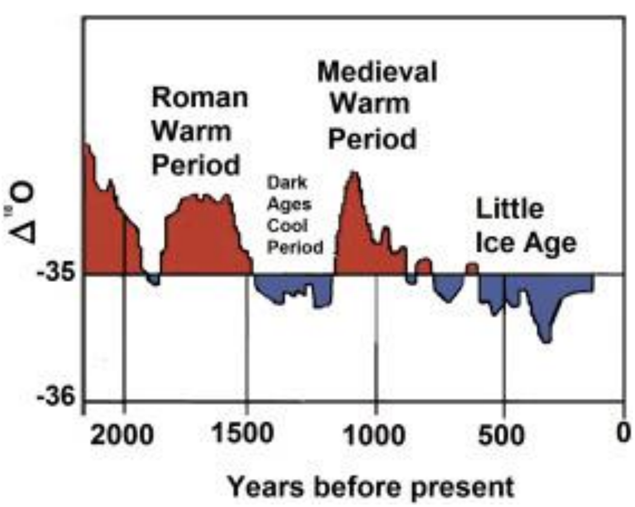

Figure 2- D.J. Easterbrook, in Evidence-Based Climate Science (Second Edition), 2016, Plotted from data by Grootes, P.M., Stuiver, M., 1997.

Figure 1 illustrates warm and cool periods of the past 2000 years, as defined by climatologists. The temperature variability experienced a significant drop from the

Medieval warm period around 1300. A more drastic change in cooling temperature can be seen from the 16^{th} to 19^{th} century. Figure 2 is a more simplistic temperature reconstruction extracted from an ice core in Greenland. From this figure is should be evident the most severe cooling occurred during the late 16^{th} century to the early 19^{th} century. The sharper change in temperature cooling will provide the most fruitful analysis of this period. For this thesis the focus will for this time duration during the LIA.

The cause of the LIA is currently being debated among climatologists, (Waldinger 2015) summarizes the cause with the following,

> There is debate among climatologists about the causes of the Little Ice Age, but different contributing factors have been identified, in particular decreases in energy emitted by the sun and increases in volcanic activity.
>
> Among the causes of the Little Ice Age were low levels solar energy and high volcanic activity. Low levels of solar energy were caused by reduced number of sun spots during the period. Sun spots are dark spots on the surface of the sun caused by magnetic fields. The energy levels in the areas surrounding sun spots are especially high (Eddy, 1976: 1189). Volcanic eruptions were especially frequent during the Little Ice Age. They can cool the surface of the earth by sending large quantities of sulfate gases into the atmosphere. These scatter solar radiation back to space (Cronin 2010: 305f.).[4]

From this description, climate change during the LIA was created by nature and had no human influence like current global warming. Regardless of the reason for the climate cooling, medieval society still needed to address the issues that the LIA presented to them.

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[4] Any further scientific discussion of the cause of climate cooling during the LIA is beyond the scope of this thesis.

1.2. Global Cooling and Early Civilization

The core of the LIA societal crisis revolved around poor harvests.[5] The supply shock in agricultural commodities had a rippling effect that was spread throughout early civilizations. The effects of the LIA were not equal or constant between regions or even countries. Indeed, Geoffrey Parker states,

> Even within Spain, different areas suffered at different times. Galicia in the northwest and Valencia in the southeast experienced population decline from about 1615 to the 1640s; but in the centre, although the decline around Toledo also began in 1615, it lasted until the 1670s, while around Segovia, where the decline also ended in the 1670s it began only after 1625 (Parker 56).

The disparities between damages experienced during the LIA were primarily caused by economic endowments and characteristics of a region. During the medieval warm period, new lands became available for agriculture. Once the effects of the LIA started to occur, some newly settled areas experienced changes from what was expected in previous growing seasons. The cooling of the temperatures and variability of rainfall changed the biology of venerable soil that was not recognized in the prior climate period. Ultimately, this led to crops not ripening, dying, or not yielding the necessary amount to live. Desperate farmers and others in rural locations began to abandon their villages in order seek work for food.

Cities during this time have generally experienced drops in their populations during the LIA.[6] However, there were some cities that recorded the opposite happening to their population. This growth in population can be explained by the inflow of migrants from

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[5] Parker (2013) supports this claim with a variety of examples spanning across the world during the LIA.
[6] McEvedy and Jones (1978) catalog the medieval population values of cities and states during the LIA.

rural farmland to cities. Cities often did not have the resources to support their existing population, so this influx of migrants was a burden. If cities were to efficiently contain the influx of migrates, it is estimated that city populations would have risen dramatically (Parker 59). Instead a dampening effect is reflected in the population data. City populations will be revisited in the data analysis section on economic growth during the LIA.

During the era of the LIA, macro-regions were beginning to have more of a presence in early civilization. Macro-regions had susceptibilities in the way they function in association with the changing climate. The development of macro-regions led farmers to specialize in cash crops with the intention to sell rather than to provide as sustenance. When the weather causes there to be a poor harvest for these cash crops the farmers who depend on selling this crop starve.[7] This phenomenon would repeat itself and would ultimately attribute to the decreasing populations during the period of the LIA.

Additional factors that influenced the decreasing populations during LIA included suicide, rebellions, emigration, disease, armed conflict, scapegoating, and migration.[8] Crediting climate change as the primary driver of armed conflict during this era would be a misrepresentation. However, to completely dismiss its role would also be an error. Determinants of conflict during this era were vast, but highly cited determinants include economic downturns and religious scapegoating.[9] Climate change can be measured as an individual factor in influencing conflict, but it's influence in economic downturns and

[7] Examples of this phenomenon would include Germany wine crop in 1622 and Chinese sugar, tea, silk, and cotton during the 17th century.
[8] Iris.
[9] Oster (2004) makes the claim that climate change during the LIA positively impacted the rate of witch persecution.

religious scapegoating should not be discounted. As food stock increased in scarcity, populations had a lower opportunity cost for violent conflict. The weather can be attributed to scapegoating seen in religious groups during the LIA. Common scapegoats that have been tied to the change in weather included women for witchcraft and Jews.[10]

Being accused of witchcraft was not the only burden women had to endure. Since men were the only participants in warfare, women would find themselves alone or widowed in a society not accommodating to independent women (Parker 91). The social standing for a woman in either of these positions made life difficult for them.[11] Ultimately, this led to poor working conditions, increase in nuns, poverty, and suicide for women during the LIA. Women who were married were more likely to abort children and expect a higher likelihood of their infant dying young. This is largely because many regions faced shorter growing seasons and general economic hardship. Women would find themselves struggling to feed themselves, so terminating pregnancies was not uncommon.

Another factor to account for when observing population data during the LIA is the influence of deadly disease. The plague and smallpox were notable diseases during the LIA and caused threatening morality crisis across Europe. Parker comments on the LIA influence on these epidemics,

> Plague and smallpox, together with typhus, measles, and fever, belong to a cluster of deadly diseases that correlate closely with harvest yields: that is, the number of victims in each epidemic to some extent reflected the food supply. It is therefore not surprising to find that both the frequency and intensity of these diseases increased amid the famines caused by the Little Ice Age (Parker 83).

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[10] Oster (2004) and Anderson et al. (2015) analyze witch and Jewish persecution respectively in more detail.

[11] Case studies of Swedish and German instances can be seen in (Parker 91).

Additional diseases had increased rates of infection during the LIA besides the plague and smallpox. Coal, a fossil fuel with a high concentration of toxins, was commonly used during this era for fires to warm houses. Since there were longer periods of cold temperatures there was a high rate of consumption for coal. This led to susceptible populations to contract raspatory illness such as asthma and bronchitis. Essentially, climate change during the LIA compromised populations immune systems through the change in weather and food supplies.

The temperature cooling and changes in rainfall had an influence on the flow of populations during the LIA. Migrations during this period left their home voluntarily and involuntarily. Those who left voluntarily were seeking better economic opportunities. Economic opportunities came primarily in the form enlisting in the military and seeking work in cities.[12] Migrants who left involuntarily were forced to leave their home due to unjust laws under their jurisdiction. Common policies that governments would impose were military drafts and high tax policies. The justification for the draft and tax policies was due to the frequency of armed conflict during this era. Governments pursued policies where there was essentially no limit on the tax rate and where all men, regardless of age, were forced to participate in the military draft. A notable instance of poor crisis response was in Anatolia, a city in the Ottoman empire. Here, it was recorded that 75% of the city's population departed between the 1570s and the 1640s to pursue illegal or legal opportunities to supply themselves with sustenance that was otherwise not available.[13]

[12] Again, women struggled greater than men when migrating to new areas. Typically, women were not allowed to enlist in the military and they were given limited economic opportunities in cities (most being servants until marriage) (Parker 101).
[13] Iris.

Government activity should not be marginalized when observing the climate's effect on medieval Europe during the LIA. This is line of reasoning is theoretically justified because an active government would be able to address economic issues that are caused by climate change than a government that does not meet regularly or at all. Annual governmental data is not available during the LIA, but Van Zanden et al. (2012) provide century level data of parliamentary activity. Van Zanden et al. (2012) follow Marongiu's definition of parliament with the following:

> an independent body, representing various social groups of the realm, containing members of three estates (the clergy, the nobility and the cities—in a few cases also the peasantry was represented as well), whose main functions are the granting of taxes and the participation in realm-binding legislation, while sometimes its functions might include the high court of justice, foreign relations (decisions on war and peace) or the appointment or abdication of a sovereign.

This definition leads them to define parliamentary activity as the following:

> … the number of calendar years per century in which for various areas a parliament (or estates-general, cortes, corts, diet, sejm, rik Generallandtag, or Reichstag) assembled for official sessions during shorter or longer periods in a year. This measure can vary from zero, when no parliament w convened (or none existed), to 100, when a meeting took place in every year of the century.

From this activity index they claimed to have a proper proxy for the influence of parliaments of medieval Europe. They do not claim that the index measures the quality of decision making for these parliaments. A full summary of the parliament activity data can be found in Appendix A.

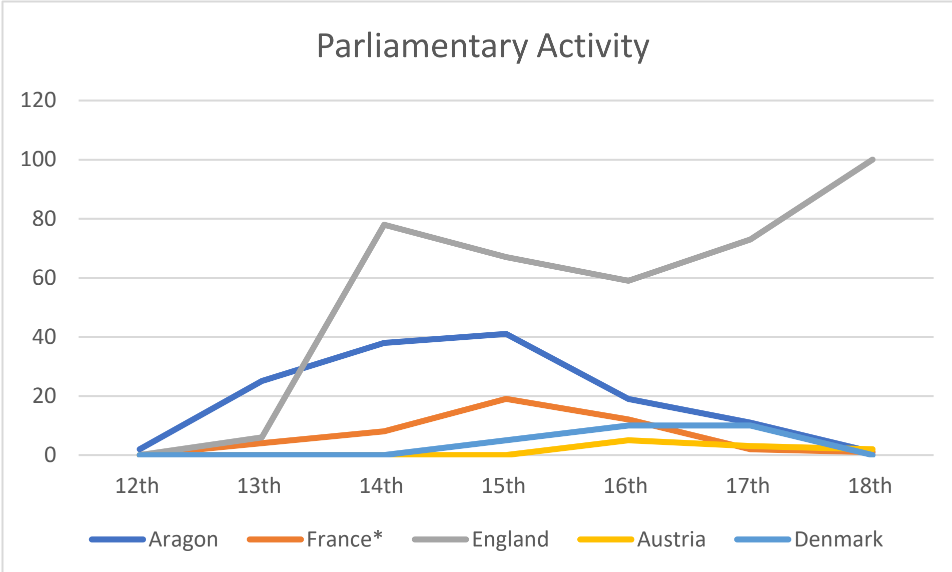

Figure 3 - Parliamentary Activity Index.

Figure 3 illustrates the parliamentary activity of Aragon (Spain), France, England, Austria, and Denmark. Except for England after the 16th century, the other countries shown in Figure 3 had declining parliamentary activity after the 15th century. This decline in activity coincides with the harshest conditions during the LIA. The declining trends in the activity index and temperatures can leave ambiguity when analyzing economic growth and conflict. Unfortunately, the activity index cannot be considered in the data analysis sections of this thesis because it is only reported at a century level. The extent that parliament activity effects economic growth and conflict in comparison to temperature will be left for future research. Similarly, how temperature effected the frequency of meetings for parliaments in medieval Europe will an area of research worth exploring.

Climate change during the LIA had a negative effect on society in a variety of dimensions. However, there is limited quantitative measurements illustrating the extent of its impact. This thesis will measure the impact of climate cooling that occurred during the LIA on economic growth and conflict in medieval Europe.

2.0. European Economic Growth during the Little Ice Age

The Little Ice Age was a period of climate cooling and changes in rainfall from the 16th to 19th century. Climate change during this period caused famine and agricultural failure that civilizations were not prepared for. This shortage in food stock was a factor in the civil unrest, warfare, and economic wellbeing of nation states during this period. The focus of this section will be on the impact of economic growth due to climate change during the Little Ice Age. Since there were no reliable measurements of growth during the 16th and 17th century, economic historians that study this period focus on urbanization as the primary variable of growth in lieu of modern growth measurements.[14] The theory behind the use for urbanization assumes that the population of cities can provide a representation of economic wellbeing. If a city has continuous population growth that would theoretically indicate higher economic growth. The opposite can be said for steadily decreasing populations.[15] During the LIA urban centers had difficulty maintaining stability due to the changes in the climate. This paper will contribute to the literature on how the changes in climate during the Little Ice Age impacted urban regions in Europe during the 16th and 17th century by exploring a new dataset on the topic.

The remainder of this paper will be organized as follows: Section 2.1 will provide a literature review covering the LIA and economic growth, Section 2.2 will define the source of the data and the method used, Section 2.3 will provide results and an interpretation of the results, and Section 2.4 provides future research and concludes.

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[14] Acemoglu (2016) introduced this method of measuring historical population data.

[15] During the LIA urban populations may have grown or remained steady in some regions despite harsh climate conditions. One explanation is the forced migration of famers and rural populations to cities to find work. This will be further explored in the data/methods section of this paper.

2.1. Literature Review

The field of economic history commonly utilizes urbanization as a proxy for economic growth. Two approaches to urbanization will be used as a proxy for economic growth. The first will be the number of cities in the modern interpretation of a country with a population over 10,000 citizens. Delong and Shliefer (1993) has used this method as a measure for growth from data that was taken from de Vries (1984). The second will be the modern interpretation of a country population density. This data was originally recorded from McEvedy and Jones (1978) and has been used by Acemoglu, Johnson, and Robinson (2002). The theory behind utilizing urbanization as a proxy for economic growth is that the continuous population growth or density of a city, the higher the economic prosperity and vice versa.

Oster (2003) and Leeson and Russ (2018) followed the proxies of economic growth outlined in the prior paragraph when studying the effects of witch trials on urbanization during 16^{th} to 18^{th} centuries. From these studies it was concluded that witch trials influenced urbanization rates and density at a statistically significant level. Waldinger (2000) found that weather during the little ice age negatively affected agriculture and urban populations. The decrease in temperature led to shortened harvest seasons and increase in the price of wheat. The study also revealed that the decrease in temperature negatively affected urban populations growth. Cities that were in cold regions had a higher negative impact to their urban population than cities that were in warmer regions. Waldinger (2015) added that weather during the little ice age did not impact cities that had good access to trade. Nunn (2011) found that during a similar period, the introduction of the potato positively affected urbanizations rates in the Old World to the Americas.

The potato is unique due to its resilience to colder temperatures. A modern interpretation of weather's effect on economic growth can be found from Dell, Jones, and Olken (2012). They found that higher temperature negatively impacts economic growth in poor African countries by reducing output and political stability. This paper will use a new dataset to add to the literature on the LIA and economic growth.

2.2. Data

The full dataset utilized for this analysis primarily stem from raw temperature and population data. This data set includes a total of 10 European countries between 1520 and 1690. The European countries where the data was available are Austria, Belgium, Czech Republic, Denmark, England, France, Germany, Hungary, Scotland, and Switzerland. The time interval of 1520 to 1690 was the most severe period of the LIA and where the urbanization data was available to analyze. The temperature and population are recorded on a decadal level. Due to data limitations decadal level of observations yield the most accurate results possible. The temperature data will be recorded as the decadal average in Celsius.

The primary source of temperature data comes from Leeson & Russel (2018). This dataset includes the countries mentioned in the prior paragraph (Austria, Belgium, Czech Republic, Denmark, England, France, Germany, Hungary, Scotland, and Switzerland). A "winter severity" index similar to Oster (2004) is included in this dataset. Full temperature data is also recorded and observed relative to a country's mean.[16]

Population data will exclusively come from Leeson & Russel (2018). All the European countries that have temperature data have population and urbanization data to match on a decadal level. Population data will be observed as the log value of a country's population.[17] The other form of population data that will be analyzed is urbanization. Urbanization measurements was used as a proxy for economic growth by Acemoglu, Johnson, and Robinson (2002). In this paper they argue that the aggregate changes in

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[16] Both these temperature datasets will be used for additional confirmation of results in the next section.
[17] Country level population data originates from McEvedy and Jones (1978).

urban population density parallels the success or failure of a country. Urbanization in this paper is the function of each country's urban centers with population of at least 5000 inhabitants divided by the total country population. Appendix B provides a table of the temperature data that is being utilized and Appendix C provides the population data.

2.3. Multi-country Analysis

Initial observations of both the temperature and population variables will show that there is a clear positive relationship. Over the period of 1520 to 1690 there is decrease in the temperature variable and the rate of change in the population variable. Appendix D provides an illustration of Denmark's temperatures and change in population. Both variables are moving in a way that is consistent with what this paper claims. As time progressed during the LIA, the temperature decreases felt by early European civilizations negatively affected population growth. The Denmark case is a typical illustration of the countries provided in the dataset.

Table 1
Temperature and Economic Growth

	Dependent variable:			
	lnpopulation	urbanization	lnpopulation	urbanization
	(1)	(2)	(3)	(4)
temperature	0.123***	1.173***	0.119	1.146***
	(0.016)	(0.222)	(0.222)	(0.222)
Decade Fixed Effects	Yes	Yes	No	No
Observations	180	180	180	180
R2	0.225	0.116	0.207	0.110
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 1 shows the results of four logistical regressions that confirm initial observations. In each regression temperature is the independent variable and the dependent variables are two population variables. The first dependent variable is the logistic value of population and the second is urbanization. With the inclusion of decadal fixed effects, there is a highly significant relationship between temperature and population. If there were a decrease by one unit in the temperature variable that would correspond to a 12 percent change in population. When urbanization is the dependent variable the relationship with temperature is highly significant with and without decadal fixed effects. A unit decrease in temperature decreases urbanization by 1.173 with decadal fixed effects and by 1.146 without. The R-squared value is low due to the noisy quality of the data. Further summary statistics on the variables used in regressions of Table 1 can be found in Appendix E.

When interpreting the results of these logistical regressions, there are a few factors to consider. There are a variety of control variables that would influence the values of these results. Due to the nature of analyzing this period, the availability of data is sparse and majority of what is available has questionable legitimacy. There can also be omitted variable bias due to the lack of control for significant historical events. Warfare (Thirty Year War) and disease (bubonic plague) were frequent during 1520-1690. To control for these factors, the decadal fixed effects were added. The decadal dummies marginally changed the value of the coefficients and changed the significance level of the logical population variable. Columns 1 and 2 show the regressions with decadal fixed effects and columns 3 and 4 show the results without decadal fixed effects.[18]

[18] Oster (2004) had similar econometric concerns and justification for using decadal dummy fixed effects.

2.4. Conclusion

This paper explored climate changes impact on economic growth in Early Modern Europe from 1520-1690. It was argued that due to the agriculture shocks, spread of disease, and other peripheral factors of climate cooling there would be a negative effect on population variables. The empirical results show that the most intense period of temperature cooling during the LIA had a measurable effect on population and aggregate urbanization in Europe. Population and urbanization variables served as a proxy for economic growth.

This paper shows that more research should be focused on the topic of climate change and economic growth. Future research would benefit from the availability of more historical data. This would provide stronger results by clarifying specific factors affecting the economic growth from climate change. In addition, future research can explore how lagged time periods affect economic growth as well. Years of cooler climate can arguably have negative effects that are felt in future years and not in the year that temperature is currently being experienced. Another dimension of climate change that can be analyzed with economic growth is rainfall. During the LIA there was historical confirmation of an increased frequency in drought and floods that could have an impact on economic growth.

In the modern context, climate change research should be discussed more to prevent the negative economic affects that will be experienced in the future. This is particularly true in the case of developing countries, because they will feel the effects of climate the most and they may not have the resources for research available.[19]

[19] Miguel (2004) explores global warming and modern developing countries.

3.0. Conflict and Climate Change during the Little Ice Age

Long term climate change during the Little Ice Age caused change in environments across the world. The environmental change affected the agricultural output of regions that have susceptible soil quality. This change in output caused economic hardship for farmers and put pressure on the populations that were dependent on annual agricultural products. This pressure that was put upon early civilization has been shown to affect economic growth from 1520 to 1690. The focus of this section will explore to what degree the most extreme climatic period of the LIA played a role in violent conflict.

In the context of this thesis, conflict is defined as a violent conflict between two countries that is equal to or exceeds 1.5 on the Ricardson's magnitude (Brecke 1999). This can also be interpreted as a conflict that resulted in 32 or more deaths. This interpretation of conflict is consistent with the literature on conflict and climate change (Iyigun, Nunn, Qian 2017). More specifics on data and interpretation of this data will be further explained in section 3.2.

As mentioned in the beginning paragraph, the period of this Little Ice Age that will be studied is from 1520 to 1690. Students of medieval warfare know that there was no shortage of interstate conflict during this time duration. Notable conflicts during this time include the Long War, Thirty Years' War, and Franco-Spanish War. Plenty of historical analysis has been devoted to these topics. However, there is a lack of focus given to how climate played a role in these conflicts and to what extent. This section of the thesis will empirically measure the role of climate change in European conflict during 1520 to 1690. The subsections of this topic will be providing a literature review, an explanation of the data being utilized in the paper, the model and results of climate change during the LIA and conflict, and a conclusion.

3.1. Literature Review

The literature on climate change during the Little Ice Age and conflict is relatively new but is growing. The topic is found primarily in the climate change, economic history, and political science literature. Majority of the literature that will be referenced is from the humanities because references from the climate change literature focus on the scientific elements that are beyond the scope of this thesis. The topic of the LIA and conflict largely falls under two categories, by region and by type of conflict.

China is one of the regions that is observed in conflict and climatic change studies. Zhang et al. (2006) was the first to publish on the topic where they analyzed the frequency of war and climate change during the past millennium in China. In this piece they found strong a strong correlation between climatic changes and war occurrence. Specifically, the results found that China experienced frequent wars and population loss during cold periods of climate change. The explanation for these findings were partially explained by the stress of limited food supplies from crop failure during periods of colder temperatures. This argument was backed back up by multiple geographical regions (North, Central, and South China) which have different agricultural endowments.

Bai and Kung (2011) were the next to write on the topic of climate change and conflict in China. In this paper they studied climate shocks impact on conflict by utilizing proxies on rainfall. The goal of the piece was to see if there was a statistical relationship between rainfall total and military conflict. Ultimately, they concluded that in periods of drought there was a higher occurrence of military conflict due to the implied economic shock.[20]

[20] The implied economic shock for prolonged periods of shocks in rainfall relate to agriculture.

Similarly, periods of prolonged flooding related to higher military conflict for similar economic reasons.

Jia (2014) discussed how weather shocks and the introduction of the sweet potato impacted peasant revolts in China. Utilizing an extensive dataset covering 267 prefectures, Jia researched to what extent weather shocks caused civil conflict and did the introduction the sweet potato mitigate these effects. Prior to the introduction of the sweet potato, weather shocks doubled the probability of peasant revolts in comparison to periods of regular temperature. Once the sweet potato was introduced, the probability was reduced significantly.

Fenske and Kala (2015) wrote on the effect of the climate on the slave trade in Africa. This study provides additional support of climate's impact on societal and economic changes during a similar time series that is being considered for this thesis. The results presented statistical evidence to support the claim that colder temperatures of African ports reduced the mortality of slaves and increased agricultural output. Fenske and Kala (2015) also showed the opposite, that warmer temperatures led to an increase in mortality and negative agricultural yields.

Tol and Wagner (2010) focused on how the climate influenced violent conflict in Europe over a thousand year period. They found similar results to Zhang et al. (2006) case in China over the same period. However, they found that the correlation between violent conflict and the climate began to weaken as the time series advanced to the industrial age. This suggests that society better adapted to climate shocks as technology advanced.

Lee et al. (2013) share similar results to Tol and Wagner (2010) when analyzing climate change and conflict in Europe from 1400-1995. The results of this study concluded that there was a similar correlation with climate change and conflict that has been highlighted in the prior papers of this review. They added that the areas of Europe most affected by climate change over this time series were southern Europe and the Mediterranean. They also share evidence that the correlation between climate change and conflict weakens as time progressed to the industrial age.

Iyigun et al. (2015) observe the long-run effects of climate change and conflict from 1400-1900. This study constructed a geo-referenced and digitized database for conflict and temperature in Europe, North Africa, and Near East. The first stage of their analysis concludes that colder temperature did increase the probability of violent conflict. The second stage utilizes time lags in their analysis to conclude that areas affected by cold temperatures from a preceding fifty-year period are more likely to experience future conflict. Ultimately, this supports the claim that the negative effects of climate change are managed for a long duration.

Anderson et al. (2015) and Oster (2004) respectively showed that climate change had an influence on the persecution of Jews and Women accused of witchcraft during the medieval period. Both concluded that periods of colder temperature led to increased persecutions of each sub-group of society. The rationale given for this conclusion was that society would scapegoat minorities in times of economic hardship. This was supported by statistical evidence using historical data and proxies for temperature in medieval Europe.

The literature relating to historical conflict and climate change shared the underlying goal of utilizing history as a tool to understand what could occur for future global warming. The historical analysis provides an insight of societal issues, like violent conflict and scapegoating, that can occur in susceptible areas of the world.[21] This analysis will add to the existing literature to observe the relationship between the harshest duration of climate cooling during the LIA and violent conflict in medieval Europe.

[21] Regions of Africa have been referenced as areas that could be susceptible to violent conflict (Lee et al. 2013).

3.2. Data

3.2.1. Violent Conflict

The primary source for conflict data comes from Peter Brecke's *Conflict Catalogue*. This source annually lists all violent engagements beginning at 1400 CE. The details given for these violent engagements include the participants in the conflict, the given name for the engagement, and the date of the battle. A subset of the recorded battles in the catalog provide the duration and exact number of casualties.[22] Violent conflict is defined by a battle between two states resulting in a Richardson's magnitude of 1.5 or at least 32 deaths. Brecke's source is the standard in conflict studies and is used by Zhang (2007), Iyigun et al. (2015), and Lee et al. (2013). The digitized version of Brecke's catalog is available on an open public domain.

The dataset used for this section is organized by decade from 1520 to 1690. This time interval includes the harshest degree of climate change during the LIA, which is the primary area of focus. The time measurement for the dataset will be organized at a decadal level and each individual entry for a state's decade will be recorded as a dummy variable. A value of one will indicate a conflict occurred during that decade and zero if there was no conflict. This measurement of time and classification of the conflict variable is consistent with the conflict studies literature. For example, Miguel et al. (2004) cataloged their conflict variable as a one if at least one conflict occurred during the decade for the state of observation and a zero if there was not conflict. The benefit of

[22] Approximately less than half of the listed battles have these details.

utilizing the same measurement as previous studies allows for easier comparison for results. Appendix F provides a detailed list of the conflict data utilized.

3.2.2. Temperature

The temperature data used in the dataset was from Leeson and Russel (2018). They utilized this temperature data to test the scapegoat theory of medieval witch persecution. The origin of this temperature data came from Luterbacher et al (2004) where they applied paleoclimatic methods to extract surface temperature data from medieval Europe to present. A detailed explanation of the methods used in this paper are highly specialized and beyond the scope of this paper.

The temperature data spans from 1520-1690 to capture the harshest period of the LIA cooling. The annual temperature is measured in Celsius and is listed at the decadal level to align with the conflict data. Decadal level of temperature data was created by averaging the ten annual temperatures from a given decade. The temperature data is then matched with countries historical borders from the 16th and 17th century. A list of the data utilized can be found in Appendix B.

3.3. Multicounty Analysis

Conflict and Temperature data was collected for the following European Countries: Austria, Belgium, Czech Republic, Denmark, England, France, Germany, Hungary, and Scotland. The temperature data is the same as the section 2 except for Switzerland. Switzerland is omitted from the analysis because they did not participate in conflict, as defined by this thesis, during the time series of observation. The inclusion of Switzerland would add bias to the regression results associated with conflict and temperature.

Appendix G highlights summary statistics for conflict and temperature for medieval Europe. Preliminary observations show that conflict has an overall mean of 0.716. This is consistent with historical records indicating that conflict was frequent during the 1520-1690 period of medieval Europe. Further summary statistics show that 162 observations for conflict and temperature with standard deviations of 0.45 for conflict and 1.42 for temperature.

Analyzing a simple model from this dataset will provide more clarity on the relationship between conflict and temperature during the harshest conditions of the LIA. The dependent variable will be the occurrence of conflict during a decade and the independent variable will be temperature. Table 2 shows the results of a linear probability model with decadal fixed effects. The temperature coefficient is consistent with the hypothesis that a decrease in temperature increases the likelihood of conflict. Indeed, if there were a negative change of one unit in the temperature variable that would increase the likelihood of conflict by 1.4 percent with decadal fixed effects and 0.2 percent without. The results

Table 2

Temperature and Conflict

	Dependent variable: conflict_decade (1)	(2)
temperature	-0.014	-0.002
	(0.024)	(0.024)
Decade Fixed Effects	Yes	No
Observations	162	162
R2	0.132	0.0001
Note:	*p<0.1; **p<0.05; ***p<0.01	

Table 2- Linear Probability Model.

Table 3

Temperature and Conflict

	Dependent variable: conflict_decade (1)	(2)
temperature	-0.078	-0.012
	(0.135)	(0.117)
Decade Fixed Effects	Yes	No
Observations	162	162
Log Likelihood	-83.721	-96.652
Akaike Inf. Crit.	205.443	197.303
Note:	*p<0.1; **p<0.05; ***p<0.01	

Table 3- Logit Model.

Table 4

Temperature and Conflict

```
Conditional marginal effects                    Number of obs     =        162
Model VCE    : OIM

Expression   : Pr(conflict_decade), predict()
dy/dx w.r.t. : temperature
at           : temperature     =    8.066556 (mean)
```

	dy/dx	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
temperature	-.0024886	.0250515	-0.10	0.921	-.0515886	.0466114

Table 4 Logit Model Marginal Effects.

came without any confirmation of statistical significance. This is likely the case because of omitted variable bias in the model. Due to the lack of available historical data it is difficult to definitively argue exact coefficients. Since the relationship between temperature and conflict show the correct sign, the results should not be completely discounted.

The second model that was applied to the dataset was a logit model with marginal effects. As with the linear probability model, this logit model had conflict as the dependent variable and temperature as the independent variable. The results are shown on Table 3 with the first column results applying decadal fixed effects and the latter column displaying the results without. Table 4 shows the marginal effects of the logit model without decadal fixed effects. The logit model shows a similar negative relationship between conflict and temperature. A change in negative one unit of temperature shows an increased probability of conflict in a decade by 0.2 percent without decadal fixed effects. Similar levels of significance were found for the output of the logit model coefficients. The increase in the coefficients indicate a negative relationship between conflict and temperature, however, more historical data would be needed to legitimize the relationship with statistical significance.

3.4. Conclusion

This section explored the impact of climate cooling during the Little Ice Age on violent conflict from 1520-1690 in medieval Europe. The following European nations' conflict and temperature data were studied: Austria, Belgium, Czech Republic, Denmark, England, France, Germany, Hungary, and Scotland. After applying a linear probability model and Logit model, it was found that there is a negative relationship between conflict and temperature. These results are consistent with the historical accounts that colder temperatures were more likely to influence conflict during the LIA, but the results were not at a significant level. Future research should be dedicated to collecting additional historical data to legitimize the relationship between climate change and conflict during the LIA.

4. Discussion

This thesis was written with the intent of providing a foundation for future research exploring the effects of climate cooling during the Little Ice Age on medieval society. A variety of different dimensions can be explored when analyzing this topic. The following is a list of some of these dimensions.

The addition of Asian or African countries could provide more robust results to economic growth and conflict. The implementation of control variables to the quantitative analysis can provide richer results for economic growth and conflict. The addition of basic control variables such as income, employment, and government supply of specie would greatly benefit the statistical significance of the economic growth and conflict models. At least a subset of this data exists for medieval countries, but this would require extraction of data from historical texts. A comparative study of multiple identical models with independent variable time lags would provide an interesting insight to both economic growth and conflict. This analysis with time lags would provide further context to the behavior of economic growth and conflict with temperature. For example, there could have been a cold snap that resulted in poor crop cultivation during the growing season in France. Did this cold snap immediately effect the population growth and/or conflict of France or was the effect of this cold snap felt during future years? Annual studies of economic growth cannot provide an explanation to this question.

Appendix A Parliamentary Activity Data Summary

The original summary of data may be found from the Appendix of Van Zanden et al. (2012).

	12th	*13th*	*14th*	*15th*	*16th*	*17th*	*18th*
Castile and Leon	2	30	59	52	66	48	7
Catalonia	3	29	41	61	16	14	4
Aragon	2	25	38	41	19	11	1
Valencia	0	7	28	29	12	4	0
Navarre	2	7	17	33	62	30	20
France*	0	4	8	19	12	2	1
Portugal	0	9	27	47	12	14	0
England	0	6	78	67	59	73	100
Scotland	0	0	10	61	96	59	93
Ireland	0	0	30	50	45	40	50
Germany, Reichstag	0	0	0	8	18	43	90
Württemberg	0	0	0	20	58	40	10
Hesse	0	0	2	5	45	45	45
Saxony	0	0	0	10	30	20	20
Palatinate	0	0	0	11	25	51	21
Bavaria	0	0	5	10	26	3	0
Brandenburg	0	0	0	5	5	4	0
Bohemia	0	0	9	9	13	4	0
Hungary	0	3	5	10	10	19	17
Austria	0	0	0	0	5	3	2

Belgium	0	0	0	20	80	10	10
Netherlands	0	0	0	20	80	100	100
Poland	0	0	20	90	5	0	0
Switzerland	0	0	0	50	100	100	98
Sweden	0	0	0	0	19	35	33
Denmark	0	0	0	5	10	10	0
Sicily	0	50	80	80	52	80	7
Sardinia	0	0	0	12	21	12	3
Southern Italy	0	0	0	10	40	21	0
Papal states	0	0	37	19	60	45	40
Piedmont	0	0	50	50	50	0	0
Russia	0	0	0	0	2	30	0
Standard deviation	0,8	12	23	25	28	28	34
Average	0,3	5	17	28	36	30	24
Coefficient of variation	2,74	2,19	1,38	0,89	0,78	0,94	1,43

Appendix B – Temperature Data

Original source of data is from Leeson and Russle (2018). Data is organized at a decadal level from 1520-1690.

country	temperature	avg.temp	sd.temp	zscore.temp
Austria	6.002	5.76365	0.223935	1.06437038
Austria	6.211	5.76365	0.223935	1.997676063
Austria	5.937	5.76365	0.223935	0.774107847
Austria	6.016	5.76365	0.223935	1.126888464
Austria	5.634	5.76365	0.223935	-0.578962114
Austria	5.567	5.76365	0.223935	-0.878155802
Austria	5.731	5.76365	0.223935	-0.145801103
Austria	5.542	5.76365	0.223935	-0.989795237
Austria	5.722	5.76365	0.223935	-0.1859913
Austria	5.904	5.76365	0.223935	0.626743792
Austria	5.77	5.76365	0.223935	0.028356417
Austria	5.858	5.76365	0.223935	0.421327231
Austria	5.672	5.76365	0.223935	-0.409270171
Austria	5.741	5.76365	0.223935	-0.101145329
Austria	5.856	5.76365	0.223935	0.412396076
Austria	5.722	5.76365	0.223935	-0.1859913
Austria	5.678	5.76365	0.223935	-0.382476707
Austria	5.133	5.76365	0.223935	-2.816216406
Belgium	9.367	9.0797	0.282205	1.018052697
Belgium	9.588	9.0797	0.282205	1.801170156
Belgium	9.165	9.0797	0.282205	0.302262078
Belgium	9.379	9.0797	0.282205	1.060574912
Belgium	8.96	9.0797	0.282205	-0.424159094
Belgium	8.865	9.0797	0.282205	-0.760793296
Belgium	8.979	9.0797	0.282205	-0.356832254
Belgium	8.889	9.0797	0.282205	-0.675748866
Belgium	9.029	9.0797	0.282205	-0.179656358
Belgium	9.227	9.0797	0.282205	0.521960189
Belgium	8.963	9.0797	0.282205	-0.413528541
Belgium	9.341	9.0797	0.282205	0.925921231
Belgium	9.066	9.0797	0.282205	-0.048546195
Belgium	9.098	9.0797	0.282205	0.064846378
Belgium	9.11	9.0797	0.282205	0.107368593
Belgium	8.893	9.0797	0.282205	-0.661574795
Belgium	9.152	9.0797	0.282205	0.256196345
Belgium	8.236	9.0797	0.282205	-2.989666064

Czech Republic	7.284	6.9665	0.25417	1.249164143
Czech Republic	7.462	6.9665	0.25417	1.949482939
Czech Republic	7.124	6.9665	0.25417	0.619664103
Czech Republic	7.241	6.9665	0.25417	1.079986007
Czech Republic	6.81	6.9665	0.25417	-0.615729727
Czech Republic	6.814	6.9665	0.25417	-0.599992226
Czech Republic	6.955	6.9665	0.25417	-0.045245315
Czech Republic	6.747	6.9665	0.25417	-0.863595368
Czech Republic	6.899	6.9665	0.25417	-0.26557033
Czech Republic	7.129	6.9665	0.25417	0.639335979
Czech Republic	6.947	6.9665	0.25417	-0.076720317
Czech Republic	7.093	6.9665	0.25417	0.49769847
Czech Republic	6.909	6.9665	0.25417	-0.226226577
Czech Republic	6.936	6.9665	0.25417	-0.119998445
Czech Republic	7.01	6.9665	0.25417	0.171145324
Czech Republic	6.836	6.9665	0.25417	-0.513435971
Czech Republic	6.906	6.9665	0.25417	-0.238029703
Czech Republic	6.222	6.9665	0.25417	-2.929142377
Denmark	7.716	7.3462	0.294863	1.25414266
Denmark	7.813	7.3462	0.294863	1.583109231
Denmark	7.369	7.3462	0.294863	0.077324101
Denmark	7.624	7.3462	0.294863	0.942133129
Denmark	7.212	7.3462	0.294863	-0.455126947
Denmark	7.296	7.3462	0.294863	-0.170248679
Denmark	7.349	7.3462	0.294863	0.009495942
Denmark	7.232	7.3462	0.294863	-0.387298788
Denmark	7.245	7.3462	0.294863	-0.343210485
Denmark	7.482	7.3462	0.294863	0.4605532

Denmark	7.172	7.3462	0.294863	-0.590783265
Denmark	7.629	7.3462	0.294863	0.959090168
Denmark	7.404	7.3462	0.294863	0.19602338
Denmark	7.347	7.3462	0.294863	0.002713126
Denmark	7.252	7.3462	0.294863	-0.319470629
Denmark	6.979	7.3462	0.294863	-1.245324999
Denmark	7.507	7.3462	0.294863	0.545338398
Denmark	6.455	7.3462	0.294863	-3.022422765
England	9.07	8.86625	0.234425	0.869149073
England	9.251	8.86625	0.234425	1.641252053
England	8.889	8.86625	0.234425	0.097046093
England	9.097	8.86625	0.234425	0.984324656
England	8.799	8.86625	0.234425	-0.286872516
England	8.708	8.86625	0.234425	-0.675056887
England	8.766	8.86625	0.234425	-0.427642673
England	8.753	8.86625	0.234425	-0.483097583
England	8.83	8.86625	0.234425	-0.154633884
England	8.964	8.86625	0.234425	0.416978267
England	8.718	8.86625	0.234425	-0.632399264
England	9.143	8.86625	0.234425	1.180549722
England	8.899	8.86625	0.234425	0.139703716
England	8.903	8.86625	0.234425	0.156766765
England	8.855	8.86625	0.234425	-0.047989826
England	8.636	8.86625	0.234425	-0.982191774
England	9.015	8.86625	0.234425	0.634532145
England	8.169	8.86625	0.234425	-2.974302778
France	10.342	10.17725	0.233294	0.706189778
France	10.622	10.17725	0.233294	1.906390919
France	10.27	10.17725	0.233294	0.397566628
France	10.442	10.17725	0.233294	1.134833043
France	10.091	10.17725	0.233294	-0.369704816
France	9.897	10.17725	0.233294	-1.201272749
France	10.037	10.17725	0.233294	-0.601172179
France	9.979	10.17725	0.233294	-0.849785272
France	10.159	10.17725	0.233294	-0.078227396
France	10.291	10.17725	0.233294	0.487581713
France	10.092	10.17725	0.233294	-0.365418383
France	10.392	10.17725	0.233294	0.920511411
France	10.124	10.17725	0.233294	-0.228252538
France	10.211	10.17725	0.233294	0.144667102
France	10.286	10.17725	0.233294	0.46614955

France	10.129	10.17725	0.233294	-0.206820375
France	10.191	10.17725	0.233294	0.058938449
France	9.534	10.17725	0.233294	-2.757247799
Germany	8.349	8.02825	0.280431	1.143773441
Germany	8.552	8.02825	0.280431	1.867658113
Germany	8.138	8.02825	0.280431	0.391361294
Germany	8.326	8.02825	0.280431	1.061756951
Germany	7.883	8.02825	0.280431	-0.517951964
Germany	7.843	8.02825	0.280431	-0.660589337
Germany	7.967	8.02825	0.280431	-0.218413479
Germany	7.818	8.02825	0.280431	-0.749737696
Germany	7.96	8.02825	0.280431	-0.243375019
Germany	8.183	8.02825	0.280431	0.55182834
Germany	7.931	8.02825	0.280431	-0.346787115
Germany	8.256	8.02825	0.280431	0.812141547
Germany	8.001	8.02825	0.280431	-0.097171711
Germany	8.025	8.02825	0.280431	-0.011589287
Germany	8.056	8.02825	0.280431	0.098954678
Germany	7.844	8.02825	0.280431	-0.657023403
Germany	8.071	8.02825	0.280431	0.152443693
Germany	7.195	8.02825	0.280431	-2.971314793
Hungary	9.903	9.67205	0.198288	1.164718084
Hungary	10.052	9.67205	0.198288	1.916149106
Hungary	9.873	9.67205	0.198288	1.013423247
Hungary	9.886	9.67205	0.198288	1.078984343
Hungary	9.542	9.67205	0.198288	-0.655863117
Hungary	9.55	9.67205	0.198288	-0.615517827
Hungary	9.696	9.67205	0.198288	0.120783711
Hungary	9.466	9.67205	0.198288	-1.03914337
Hungary	9.624	9.67205	0.198288	-0.242323897
Hungary	9.819	9.67205	0.198288	0.741092541
Hungary	9.76	9.67205	0.198288	0.443546029
Hungary	9.654	9.67205	0.198288	-0.09102906
Hungary	9.576	9.67205	0.198288	-0.484395635
Hungary	9.627	9.67205	0.198288	-0.227194413
Hungary	9.746	9.67205	0.198288	0.372941772
Hungary	9.705	9.67205	0.198288	0.166172162
Hungary	9.403	9.67205	0.198288	-1.356862526
Hungary	9.178	9.67205	0.198288	-2.491573801
Scotland	6.898	6.74825	0.194219	0.771038771
Scotland	7.022	6.74825	0.194219	1.409494916

Scotland	6.734	6.74825	0.194219	-0.073370968
Scotland	6.924	6.74825	0.194219	0.904908608
Scotland	6.71	6.74825	0.194219	-0.196943125
Scotland	6.644	6.74825	0.194219	-0.536766557
Scotland	6.678	6.74825	0.194219	-0.361706001
Scotland	6.687	6.74825	0.194219	-0.315366442
Scotland	6.713	6.74825	0.194219	-0.181496606
Scotland	6.809	6.74825	0.194219	0.312792022
Scotland	6.585	6.74825	0.194219	-0.84054811
Scotland	7.005	6.74825	0.194219	1.321964638
Scotland	6.797	6.74825	0.194219	0.251005944
Scotland	6.785	6.74825	0.194219	0.189219865
Scotland	6.716	6.74825	0.194219	-0.166050086
Scotland	6.499	6.74825	0.194219	-1.283348339
Scotland	6.966	6.74825	0.194219	1.121159883
Scotland	6.188	6.74825	0.194219	-2.884637541
Switzerland	4.4	4.2289	0.233991	0.731224063
Switzerland	4.673	4.2289	0.233991	1.897934579
Switzerland	4.379	4.2289	0.233991	0.641477101
Switzerland	4.518	4.2289	0.233991	1.235516521
Switzerland	4.131	4.2289	0.233991	-0.418391793
Switzerland	3.931	4.2289	0.233991	-1.273124772
Switzerland	4.127	4.2289	0.233991	-0.435486453
Switzerland	4.009	4.2289	0.233991	-0.93977891
Switzerland	4.2	4.2289	0.233991	-0.123508915
Switzerland	4.352	4.2289	0.233991	0.526088148
Switzerland	4.174	4.2289	0.233991	-0.234624203
Switzerland	4.391	4.2289	0.233991	0.692761079
Switzerland	4.128	4.2289	0.233991	-0.431212788
Switzerland	4.238	4.2289	0.233991	0.038890351
Switzerland	4.375	4.2289	0.233991	0.624382441
Switzerland	4.2	4.2289	0.233991	-0.123508915
Switzerland	4.253	4.2289	0.233991	0.102995324
Switzerland	3.586	4.2289	0.233991	-2.74753916

Appendix C – Population Data

Originial Source of the data is from Leeson and Russel (2018). Data is organized at a decadal level from 1520-1690.

country	urbanization	lnpopulation
Austria	2.5	6.322219
Austria	2.5	6.332438
Austria	2.5	6.342423
Austria	2.5	6.352183
Austria	2.5	6.361728
Austria	2.5	6.371068
Austria	2.5	6.380211
Austria	2.5	6.389166
Austria	3.64	6.39794
Austria	3.64	6.39794
Austria	3.64	6.39794
Austria	3.64	6.39794
Austria	3.64	6.39794
Austria	3.64	6.39794
Austria	3.64	6.39794
Austria	3.64	6.39794
Austria	3.64	6.39794
Austria	3.64	6.39794
Belgium	27.679	6.078674
Belgium	27.679	6.086947
Belgium	27.679	6.095065
Belgium	27.679	6.103034
Belgium	27.679	6.110859
Belgium	27.679	6.118546
Belgium	27.679	6.126099
Belgium	27.679	6.133523
Belgium	20.68	6.140822
Belgium	20.68	6.148001
Belgium	20.68	6.155063
Belgium	20.68	6.162011
Belgium	20.68	6.168851
Belgium	20.68	6.175584
Belgium	20.68	6.182215
Belgium	20.68	6.188746
Belgium	20.68	6.19518

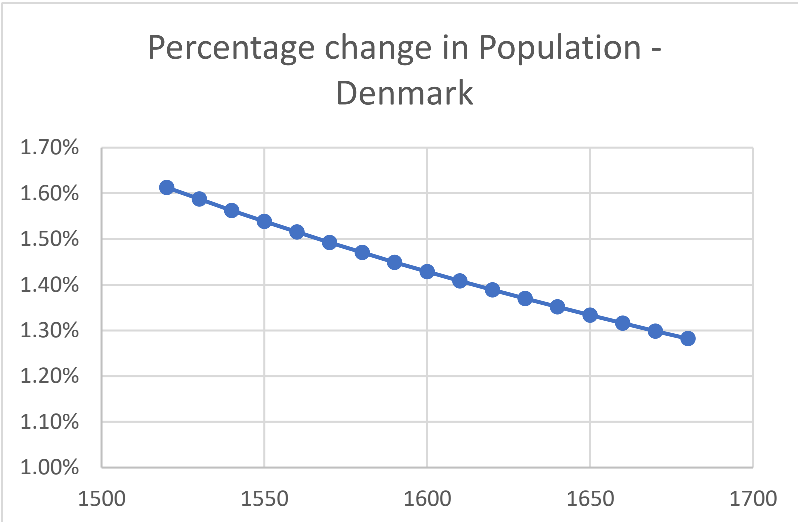
Belgium	20.68	6.20152
Czech Republic	5.889	6.308799
Czech Republic	5.889	6.328104
Czech Republic	5.889	6.346588
Czech Republic	5.889	6.364316
Czech Republic	5.889	6.38135
Czech Republic	5.889	6.39774
Czech Republic	5.889	6.413534
Czech Republic	5.889	6.428774
Czech Republic	4.142	6.443498
Czech Republic	4.142	6.443498
Czech Republic	4.142	6.443498
Czech Republic	4.142	6.443498
Czech Republic	4.142	6.443498
Czech Republic	4.142	6.443498
Czech Republic	4.142	6.443498
Czech Republic	4.142	6.443498
Czech Republic	4.142	6.443498
Czech Republic	4.142	6.443498
Denmark	1.667	5.792392
Denmark	1.667	5.799341
Denmark	1.667	5.80618
Denmark	1.667	5.812913
Denmark	1.667	5.819544
Denmark	1.667	5.826075
Denmark	1.667	5.832509
Denmark	1.667	5.838849
Denmark	7.714	5.845098
Denmark	7.714	5.851258
Denmark	7.714	5.857332
Denmark	7.714	5.863323
Denmark	7.714	5.869232
Denmark	7.714	5.875061
Denmark	7.714	5.880814
Denmark	7.714	5.886491
Denmark	7.714	5.892095
Denmark	7.714	5.897627
England	3.028	6.521472
England	3.028	6.527075
England	3.028	6.532608
England	3.028	6.538071

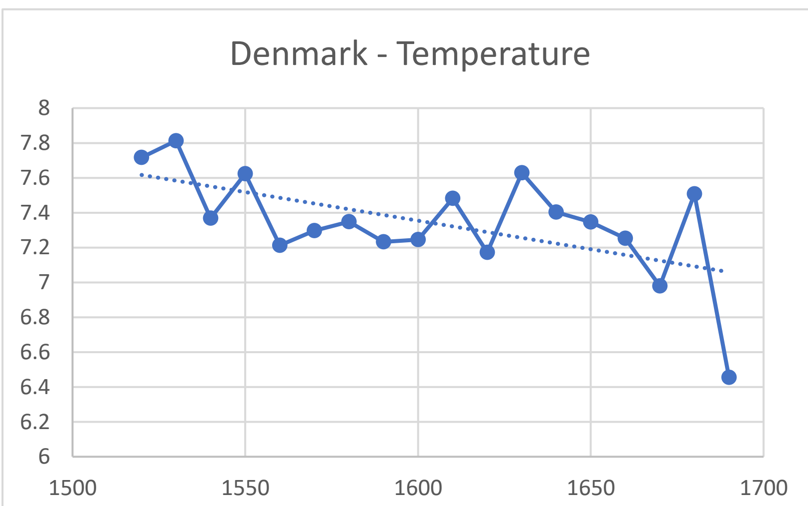
England	3.028	6.543466
England	3.028	6.548795
England	3.028	6.554059
England	3.028	6.55926
England	9.106	6.5644
England	9.106	6.579463
England	9.106	6.594022
England	9.106	6.608109
England	9.106	6.621753
England	9.106	6.634981
England	9.106	6.647818
England	9.106	6.660287
England	9.106	6.672407
England	9.106	6.684199
France	7.207	7.1959
France	7.207	7.205475
France	7.207	7.214844
France	7.207	7.224015
France	7.207	7.232996
France	7.207	7.241795
France	7.207	7.25042
France	7.207	7.258877
France	7.541	7.267172
France	7.541	7.275311
France	7.541	7.283301
France	7.541	7.291147
France	7.541	7.298853
France	7.541	7.306425
France	7.541	7.313867
France	7.541	7.321184
France	7.541	7.32838
France	7.541	7.335458
Germany	6.344	6.982271
Germany	6.344	6.995635
Germany	6.344	7.0086
Germany	6.344	7.021189
Germany	6.344	7.033424
Germany	6.344	7.045323
Germany	6.344	7.056905
Germany	6.344	7.068186
Germany	6.742	7.079181

Germany	6.742	7.082785
Germany	6.742	7.08636
Germany	6.742	7.089905
Germany	6.742	7.093422
Germany	6.742	7.09691
Germany	6.742	7.100371
Germany	6.742	7.103804
Germany	6.742	7.10721
Germany	6.742	7.11059
Hungary	3.04	6.09691
Hungary	3.04	6.09691
Hungary	3.04	6.09691
Hungary	3.04	6.09691
Hungary	3.04	6.09691
Hungary	3.04	6.09691
Hungary	3.04	6.09691
Hungary	3.04	6.09691
Hungary	1.44	6.09691
Hungary	1.44	6.10551
Hungary	1.44	6.113943
Hungary	1.44	6.122216
Hungary	1.44	6.130334
Hungary	1.44	6.138303
Hungary	1.44	6.146128
Hungary	1.44	6.153815
Hungary	1.44	6.161368
Hungary	1.44	6.168792
Scotland	5.4	5.732394
Scotland	5.4	5.748188
Scotland	5.4	5.763428
Scotland	5.4	5.778151
Scotland	5.4	5.792392
Scotland	5.4	5.80618
Scotland	5.4	5.819544
Scotland	5.4	5.832509
Scotland	7.143	5.845098
Scotland	7.143	5.863323
Scotland	7.143	5.880814
Scotland	7.143	5.897627
Scotland	7.143	5.913814
Scotland	7.143	5.929419

Scotland	7.143	5.944483
Scotland	7.143	5.959041
Scotland	7.143	5.973128
Scotland	7.143	5.986772
Switzerland	2.75	5.924279
Switzerland	2.75	5.934498
Switzerland	2.75	5.944483
Switzerland	2.75	5.954243
Switzerland	2.75	5.963788
Switzerland	2.75	5.973128
Switzerland	2.75	5.982271
Switzerland	2.75	5.991226
Switzerland	4.1	6
Switzerland	4.1	6.010724
Switzerland	4.1	6.021189
Switzerland	4.1	6.031408
Switzerland	4.1	6.041393
Switzerland	4.1	6.051153
Switzerland	4.1	6.060698
Switzerland	4.1	6.070038
Switzerland	4.1	6.079181
Switzerland	4.1	6.088136

Appendix D – Temperature and Population Time Series





Appendix E – Temperature and Population Summary Statistics

```
     decade        country           temperature        avg.temp     
 Min.   :1520   Length:180         Min.   : 3.586   Min.   : 4.229  
 1st Qu.:1560   Class :character   1st Qu.: 6.712   1st Qu.: 6.748  
 Median :1605   Mode  :character   Median : 7.764   Median : 7.687  
 Mean   :1605                      Mean   : 7.682   Mean   : 7.688  
 3rd Qu.:1650                      3rd Qu.: 9.118   3rd Qu.: 9.080  
 Max.   :1690                      Max.   :10.622   Max.   :10.177  
    sd.temp         zscore.temp        urbanization      avg.urban     
 Min.   :0.1942   Min.   :-3.02242   Min.   : 1.440   Min.   : 2.151  
 1st Qu.:0.2239   1st Qu.:-0.43228   1st Qu.: 3.040   1st Qu.: 3.500  
 Median :0.2342   Median :-0.06096   Median : 5.889   Median : 5.697  
 Mean   :0.2430   Mean   :-0.02122   Mean   : 6.925   Mean   : 6.925  
 3rd Qu.:0.2804   3rd Qu.: 0.62497   3rd Qu.: 7.541   3rd Qu.: 6.565  
 Max.   :0.2949   Max.   : 1.99768   Max.   :27.679   Max.   :23.791  
    sd.urban        zscore.urban        population        lnpopulation  
 Min.   :0.1708   Min.   :-1.0865   Min.   :  540000   Min.   :5.732  
 1st Qu.:0.5829   1st Qu.:-1.0865   1st Qu.: 1018750   1st Qu.:6.008  
 Median :0.8547   Median : 0.8692   Median : 1813275   Median :6.255  
 Mean   :1.4028   Mean   : 0.0000   Mean   : 4439100   Mean   :6.369  
 3rd Qu.:3.0919   3rd Qu.: 0.8692   3rd Qu.: 3700112   3rd Qu.:6.568  
 Max.   :3.5787   Max.   : 1.0865   Max.   :21650000   Max.   :7.335  
```

Appendix F – Conflict Data

Original Source of the conflict data was from Brecke (1999). Data is organized at a decadal level from 1520-1690.

country	Conflict by decade
Austria	1
Austria	1
Austria	1
Austria	1
Austria	1
Austria	1
Austria	1
Austria	1
Austria	1
Austria	1
Austria	1
Austria	0
Austria	0
Austria	1
Austria	1
Austria	0
Austria	1
Austria	1
Belgium	1
Belgium	1
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0
Belgium	0

Belgium	0
Czech Republic	1
Czech Republic	1
Czech Republic	1
Czech Republic	0
Czech Republic	0
Czech Republic	0
Czech Republic	0
Czech Republic	0
Czech Republic	0
Czech Republic	1
Czech Republic	1
Czech Republic	0
Czech Republic	0
Czech Republic	0
Czech Republic	0
Czech Republic	0
Czech Republic	0
Czech Republic	0
Denmark	1
Denmark	1
Denmark	1
Denmark	1
Denmark	1
Denmark	1
Denmark	0
Denmark	0
Denmark	0
Denmark	1
Denmark	1
Denmark	1
Denmark	1
Denmark	1
Denmark	1
Denmark	1
Denmark	1
Denmark	0
England	1
England	1
England	1
England	1

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France	1
France	1
France	1
France	1
France	1
Germany	1
Germany	1
Germany	1
Germany	1
Germany	1
Germany	1
Germany	0
Germany	0
Germany	1

Germany	1
Germany	1
Germany	1
Germany	1
Germany	1
Germany	1
Germany	1
Germany	1
Germany	1
Hungary	1
Hungary	1
Hungary	1
Hungary	1
Hungary	1
Hungary	1
Hungary	0
Hungary	1
Hungary	0
Hungary	1
Hungary	0
Hungary	0
Hungary	0
Hungary	0
Hungary	1
Hungary	0
Hungary	1
Hungary	0
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1
Scotland	1

Scotland	1
Scotland	1
Scotland	1
Scotland	1

Appendix G – Conflict Summary Statistics

The following is summary statistics for the data listed in Appendix F. Temperature is the same as Appendix E, except Switzerland is omitted from the summary.

```
     decade          country          conflict_decade   temperature
 Min.   :1520   Length:162         Min.   :0.000   Min.   : 5.133
 1st Qu.:1560   Class :character   1st Qu.:0.000   1st Qu.: 6.913
 Median :1605   Mode  :character   Median :1.000   Median : 8.013
 Mean   :1605                      Mean   :0.716   Mean   : 8.067
 3rd Qu.:1650                      3rd Qu.:1.000   3rd Qu.: 9.215
 Max.   :1690                      Max.   :1.000   Max.   :10.622
```

```
                vars   n mean   sd median trimmed  mad  min   max range  skew kurtosis   se
conflict_decade    3 162 0.72 0.45   1.00    0.77 0.00 0.00  1.00  1.00 -0.95    -1.11 0.04
temperature        4 162 8.07 1.42   8.01    8.09 1.68 5.13 10.62  5.49 -0.06    -1.18 0.11
```

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