INSTITUT DE HAUTES
ÉTUDES INTERNATIONALES
ET DU DÉVELOPPEMENT
GRADUATE INSTITUTE
OF INTERNATIONAL AND
DEVELOPMENT STUDIES

Graduate Institute of International and Development Studies
International Economics Department
Working Paper Series

Working Paper No. HEIDWP11-2016

Witch Trials: Discontent in Early Modern Europe

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Abstract

This paper examines the relationship between income and witch trials in early modern Europe. We start by using climate data to proxy for income levels. This builds on previous work by exploiting a far richer panel dataset covering 356 regions and 260 years, including both seasonal temperature and rainfall, as well as over 30,036 witch trials newly documented for this study. We find that a one degree temperature shock leads to a near quadrupling in witch trials in any given year. The second part looks at incomes more directly, and we find that different measures of income have different effects on witch trials. Furthermore, the impact may depend on the structure of the economy and how different stakeholder groups are affected. We also present evidence that the stage in the business cycle is important in predicting witch trials, with the bottom of the business cycle coinciding with a doubling of witch trials in England.

Keywords: witchcraft, persecution, plague, conflict, growth, climate change

JEL: I30, J14, J16, N43, N53, O12, Z12

1. Introduction

Witch trials, a series of hearings whereby courts would decide on whether the accused was in fact ‘a witch’ and should be punished, have had many explanations ascribed to them. From an economics standpoint, these focus on them being a response to falling incomes. Notably in Oster (2004) and Miguel (2005), they proxy income shocks through extreme weather behaviour. This implies a two stage impact, first weather on income and thence income on witch trials. However, we argue that there are other channels through which climate may effect witch trials. Rather than any implied hit to economic growth, it may also be that weathers’ linkages with disease or even the negative direct effects of bad weather were factors in causing the witch trials; a reasonable hypothesis to test given the historical linkages between witchcraft and weather.

We further postulate that it is not economic output per se which counts, but the real incomes of the individual villager. By using annual real wage data combined with food inflation, weather, GDP per capita, plague, war and population data we aim to more precisely identify the channels which affect the incidence of witch trials. In addition more than previous studies we focus on high resolution data, annual rather than longer period averages and differentiate between the different seasons in terms of weather impact. Another aim of this paper is to differentiate between short term cyclical fluctuations and actual absolute differences in living standards. That is to say, do people adjust their expectations over time to their present circumstances, or do they value gradual long term improvements to living standards.

While the European witch hunts of the early modern period and before may today seem fantastical to people in the West they are still practiced in many parts of the world; including Africa, Asia and the Middle East. The case of Fawza Falih Muhammad Ali in Saudi Arabia bears many striking similarities to those early European witch hunts. Poor and illiterate she was tortured by the Saudi religious police into confessing to crimes of witchcraft and sentenced to death in 2006. Even the iconography is similar, depicting witches flying on broom sticks, causing malady in animals and impotence in men (Arvin & Arvin, 2010 p.69; Jacobs, 2013).

The European witch trials occurred in a multitude of countries very different with respect to their legal institutions, cultures, religion, and economic development. They were supported by religious and state institutions, and were widely viewed as permissible by the society of the day. The impetus for individual witch trials came from within the general population. Regardless of the willingness of the state judicial apparatus to hear witchcraft cases, it was down to ordinary villagers to bring these accusations forward in the first place. So witch trials have two characteristics which make them an ideal phenomenon through which to measure discontent of the general population. Firstly, they are instigated at ground level and secondly, they are conducted through the court system and so are systematically recorded.

The geographical scope of the climate data means that we are able to build a large panel dataset of 30,036 witch trials categorised into 355 regions in Europe over the period 1500-1760. Using this dataset we analyse the effect climate variability has on witch trials and are able to infer some interesting conclusions about the underlying causes. Following this we forsake dataset size to directly examine the effect actual economic variables such as GDP per capita, grain prices, and real wages have on witch trials. In a section specifically devoted to the English experience we are able to analyse the incidence of witch trials at different points in the business cycle. We also go into greater depth in discussing the individual events and conditions affecting English society at the time.

GDP per capita is found to be significant in all specifications in reducing witch trials. In the case where Holland is excluded, GDP per capita is significant at the 1% level. In the case of Sweden, an increase in 1990 dollar prices from 900 to 1400 leads to an increase in witch trials from 2.12 to 5.79 per year. We do not find that real wages have a comparable effect, implying that the hourly earning power of labour was not a deciding factor in fostering discontent. War, defined as the presence of actual fighting in the region, strongly decreases the incidence of witch trials.

We generally do not find evidence that grain prices influence witch trials. This may at least partly be because grain prices have disparate effects on different stakeholders in society, and because farmers, who stand to lose from depressed prices, may be of varying importance across regions. We also find evidence that grain prices are only partially related to harvest quality. In Sweden, the harvest dummy variable is significant at the 1% or 5% level depending on how it is defined, while wheat price shocks are less significant. In the Swedish case we also find that the lowest witch trial years coincided with 'normal' harvests, i.e. neither too good nor too bad.

In the section using climate data, temperature seems to play a larger role in determining witch trials than rainfall. Greater temperature shocks and lower spring-summer temperatures significantly increase witch trials for up to four years ahead. We see this as consistent with an income based hypothesis, as the spring and summer months represent the main growing season. Cooler winter and autumn temperatures tend to decrease witch trials, which suggests temperature could also be linked to other channels than the income one. The results tend to be strongest in the environmental zones lying mainly in North West Europe – Germany, northern France, the Low Countries, and the UK.

One possible channel that we test for is Plague. The results show tentative evidence that where temperatures go outside the range which supports the plague virus, witch trials diminish. However, the evidence for plague is found to be weaker when we test for it explicitly in the GDP per capita and real wages sections.

Using English GDP data we show that in addition to absolute levels of income, short term income dynamics also play a role in determining mood. In years in which the economic cycle troughed, witch trials were significantly higher at the 5% level, while in the first year of recovery witch trials were significantly lower also at the 5% level.

The paper proceeds as follows. In the next two sections we review the literature on witchcraft and provide a discussion to the background to the witch hunts. We then discuss theoretical aspects before presenting the data and then the empirical results. Finally, we conclude the paper.

2. Literature Review

The economics literature pertaining to witch trials is still relatively modest. The literature is mainly limited to three papers listed in Table 1. Oster(2004) and Miguel(2005) both use weather variation as a proxy to examine the impact of income shocks on numbers of witch trials.

Oster (2004) focuses her analysis on the 16th-18th Century European witch trials. Using a multicountry panel dataset she shows a negative correlation between temperature and witch trials. Baten & Woitek (2003) look at the effect of grain prices on witch trials in Germany, England, and Scotland during the same early modern period as Oster. Looking at each region on a piecemeal basis they find evidence that wheat prices are positively correlated with witch trials. Miguel (2005) shifts the context to modern day Tanzania. Using variation in rainfall between villages he demonstrates there to be positive correlation between extreme rainfall and witch trials.

The witch trial research fits into the wider literature on persecution and scapegoating. The link between persecution of blacks and economic downturns in the American South, in the late 19th and early 20th century, is investigated in papers by Howland & Sears (1940), Hepworth & West (1988), and Green, Glaser & Rich (1998). Initially, Howland & Sears (1940) find that total lynchings, and lynchings of just blacks were negatively correlated with the value of land, of cotton, and of economic wellbeing (the Ayres index). The two later studies re-evaluate the evidence using improved econometric techniques and lengthening the data sample respectively. In the first instance, the size of the effect is diminished and in the latter disappears entirely.

Anderson et al. (2013) follow a similar approach to Oster (2004), in using temperature as a proxy for economic wellbeing. Instead of looking at witch trials however, they investigate the link with Jewish persecution. Their dependent variable, persecution, measures whether there was an expulsion from a city or major act of violence of the Jewish population in a given 5 year period. The results are quite striking; over the sample period 1100-1800 a one standard deviation decrease in temperature leading to an increase in the probability of a city's Jewish population being persecuted from a baseline of 2% to between 2.5% and 3%.

Table 1: Summary Table of Persecution Literature

Paper	Sample	Approach	Results
Hovland & Sears (1940)	14 states in the American South (1882-1930).	Association between economic downturns in Deep South of the US and lynchings.	Negative correlation between economic wellbeing (Ayres Index) and lynchings. Between -0.65 and -0.61.
Hepworth & West (1988)	14 states in the American South (1882-1930).	Same as Hovland & Sears (1940), but with improved econometric techniques.	Confirms the earlier results of Hovland & Sears (1940), although with diminished correlation (-0.21) between farm value and number of black lynchings.
Green et al. (1998)	14 states in the American South (1882-1940).	Builds on Hovland & Sears (1940) and Hepworth & West (1988), with an extended sample period.	Contradicts Howland & Sears (1940) and Hepworth & West (1988). No robust evidence of link between economic conditions and persecution of minorities.
Baten & Woitek (2003)	Germany, England, Scotland (1560-1760). Yearly data.	Impact of grain prices on witch trials looking at regions individually on piecemeal basis.	Witch trials highly responsive to changing grain prices, with a grain price elasticity of between 0.5 and 0.8.
Oster(2004)	11 European countries (1520-1770). Decadal data.	Proxies for economic output with temperature, and population density. Panel Data regression.	Strong relationship between economic growth and witch trials. 1 s.d. decrease in temperature leads to a 0.2 s.d. increase in witch trials.
Miguel(2005)	67 villages in Tanzania (1992-2002). Yearly data.	Proxies income shocks with rainfall variation. Panel Data regression.	Extreme rainfall (drought and flooding) has a strong impact on witch killings.
Anderson et al. (2013)	936 European Cities (1100-1800)	Impact of Temperature variation (proxying for income shocks) on Jewish persecution.	1 s.d. decrease in average growing season temperature increased the probability of a persecution 0.5-1 percentage points (relative to a baseline probability of 2 percent).

The psychology field has extensively examined the effects weather can have on people's moods, emotions, and behaviour. In a comprehensive study incorporating a wide range of weather variables Howarth & Hoffman (1984) show that the amount of sunshine, humidity, and temperature have the strongest effect on mood. They show that extreme cold temperature, between -8° C and -28° C, induced increased aggression in subjects. Meanwhile, a number of researchers including Baron & Ransberger (1978) and Howarth & Hoffman (1984) have found hot temperature inducive to aggression. On a similar tack Wyndham (1969) and Cunningham (1979) report findings of hysteria, apathy, and less willingness to help others under hot or cold temperatures. There has been little evidence produced to show a relationship between rain and mood. Huibers et al. (2010) find no statistically significant correlation between rainfall and depression. As with previous studies they do find a relationship between sunshine and depression however, and so rainfall may be indirectly related to mood through its correlation with cloud cover.

A number of works have examined the link between weather and witch trials[1]. Behringer (1995, 1999) shows that many trials made reference to 'weather magic'. He documented a number of such cases such as the remarks made by a contemporary chronicler on the eve of the great 1626-1630 witch hunt in South Western Germany (Behringer, 1995 p.15) :

"In the year 1626 on the 27th of May, the vineyards of the bishophrics of Bamberg and Wiirzburg in Franconia all froze over, as did the grain fields, which rotted in any case . . . Everything froze like never before remembered, causing a great inflation . . . There followed great lamentation and pleading among the common rabble, questioning why his princely Grace delayed so long in punishing the sorcerers and witches for spoiling crops since the beginning of the year." (Behringer, 1995 p.15)

He also argues that the spikes in witch trials evident in regions such as Scotland, Lorraine, Bar, Germany, and Switzerland were due to their agrarian dependent economies and high population densities. In contrast countries like Holland and England were trade centres and not so affected by weather, while countries in the South of Europe did not suffer the same deterioration in climate. Pfister (2007) argues that the 1570-1630 cold spell coincided with the wave of witch hunts in agreement with Oster (2004).

While papers have been done looking at the relationship between weather and witch trials, and between weather and grain prices the actual channels by which weather effects witch trials have not been examined in detail. People generally lived closer to nature, whether it be working in the field during the day or in relatively poorly constructed houses by night. According to (Scott, 2010 p.7) 'There were few windows to let in light, and those were small and unglazed. The rooms were unventilated, unsanitary, cold and damp'. Furthermore 'Cold weather forced people indoors to spend the long hours of darkness huddled around whatever sources of heat they could find'. There is little attention given to these psychological aspects of climate with respect to witch trials however.

In addition to causing considerable damage to property and livestock, the great floods affecting North Devon and Monmouth in January 1607 also led to considerable loss of life (Jones et al., 1997). Later, in the storm of 1703 approximately 9,000 people lost their lives in England and Wales (Dukes and Eden, 1997).

Climate may also impact on the appearance of pests such as locusts (Utterström, 1955), which are extremely harmful to grain production and as late as 1864 there was an invasion of locusts in England. The potential impact on the occurrence of disease, in particular the Plague has been slightly less studied in the literature, but there is some evidence linking it to climate. With the plague there are two factors to consider. Firstly, the impact on the rats who initially carried the plague and secondly, the bacteria. The disease results from infection with the plague Bacillus Yersinia pestis and is often transmitted by fleas. Most mammals can be infected by Yersinia pestis, but rodents are the most common hosts. The most common vector[2] of the plague is Xenopsylla cheopis, the common rat flea

[1] A picture depicting witches creating a hailstorm is shown in Appendix 4.
[2] In epidemiology, a vector is any agent (person, animal or microorganism) that carries and transmits an infectious pathogen into another living organism.

(Raoul et al, 2013; Velimirovic and Velimirovic, 1989) of bubonic plague. There is a clear link between the plague and temperature. The spread of the disease is checked by temperatures over 26° C, and cannot exist in epidemic form at temperatures over 27° C. Cold temperatures also limit the plague and a temperature range of 20-25° C has been judged the most suitable for facilitating the development of Xenopsylla cheopis (Duncan, 1992). Duncan also observes a link between the spread of the disease and rainfall, with both excessive and limited humidity being barriers to its spread. Thus the weather in year t will impact on the bacteria and hence the spread of the plague in the same year.

Oster (2004) uses population density to proxy for economic output, arguing that an economy required higher economic growth to support a higher population. She finds that higher populations are related to lower witch trials. Heinshohn & Steiger (2004) put a different interpretation on this relationship arguing that population stagnation drove accusers and prosecutors to stigmatize birth control[3], and thus to sideline witches.

It seems that there are a number of problems with using population to proxy for prosperity. Population growth may go together with increased food production and economic output, but it is arguably by the standard of living of the population which is important not the total output of the economy. Rather, appealing to Malthusian theory, higher population should lead to declining incomes and that is broadly what we see over the sample period. Indeed, the rapid population growth of the second half of the 16th century and beginning of the 17th century, coincided with the worst of the climate deterioration. Far more influential factors in the evolution of population were war, disease and migration. The thirty years war in 1618-48 killed as many as 8 million people (Sheikh, 2009). Just considering England, over half a million people emigrated between 1607-1700 (Foner, 2005).

Population measurement quality may also be an issue. The McEvedy & Jones (1978) data used by Oster (2004), measured at 50 year intervals may not be optimal to measure the effects of war and plague on witch trials. It may also be difficult to find population data for the specific region of interest. This is exemplified in a country like Hungary, where many Hungarians fled the Ottoman invasion to the Royal Hungary region in the West of the country (Turnbull, 2013). Population growth in the rural areas, where witch trials were prevalent, may be exaggerated given the increasing urbanization rates. Additionally, the year by year population changes may be misleading. Disease was a major cause of these yearly fluctuations in population, and occurring more in cities the effect on rural population may have been less noticeable. In fact, the effects on rural population may have shown up later as rural populations moved to the cities to replace the deceased[4].

3. Background to the Witch Trials

Notions of witchcraft and witches go back at least as far as Homer's odyssey in which the character Circe is called a witch by Odysseus' companion and later turns his men into pigs (Homer, 1945). The two books from the old testament, Exodus and Leviticus thought to be written in the 6th century BC

[3] Medicine women, often attacked as witches, provided birth control to pregnant women (Ehrenreich, 2010).

[4] Large city populations were usually fully repopulated within two years of a major plague outbreak (Yungblut, 2003).

(Johnstone, 2003 p.72; Grabbe, 1998 p.92), also make reference to witches: “thou shalt not suffer a witch to live” (Exodus 22:18, King James Version). The trial of Theoris of Lemmos in Athens circa 338 BC provides an example of an actual documented witch trial in Classical Greece in which the suspect was tried and burned for necromancy (Collins, 2000).

Witchcraft persecution continued to a greater or lesser extent over the next millennia. By the time of the early middle ages belief against witches was being actively discouraged. In 789 Charlemagne proclaimed (Hutton, 1993 p.257):

If anyone, deceived by the Devil, shall believe, as is customary among pagans, that any man or woman is a night-witch, and eats men, and on that account burn that person to death… he shall be executed.

This policy was not to last, and Charlemagne’s successor Louis the Pious decreed in 829 that anyone guilty of witchcraft would be executed. Similar laws followed in England and Scotland in the ninth and 10th centuries (Swenson, 2009 p.250).

It was not until the 14th century that witches began to be tried in significant numbers. In the preceding 200 years the Catholic Church had been actively persecuting heretical groups, such as the Cathars and Waldanesians. At some point though, the state went from persecuting ‘real’ heretics to imaginary witches (Tremp, 2008). Waldensian regions of central Europe were those to see the first mass trials of witches. Indeed, in the Savoyard Alps, Waldensian heretics confessed to acts of witchcraft under interrogation in the early 15th century, and subsequently the Waldensians became synonymous with sorcery (Herzig, 2010).

Over the next century however, witchcraft came to be seen as a distinct form of heresy. Whereas the early Swiss witches were predominantly male, as were tried heretics, witchcraft became increasingly associated with women. While both other heretical groups and witches were in league with the devil in a plot against Christendom, they remained distinct in that the former were purely doctrinal while the role of witchcraft was to inflict losses.

“… in the form of daily misfortunes on humans, domestic animals and the fruits of the earth through the permission of God and with the cooperation of demons.” (Herzig, 2010 p.60)

By the turn of the 16th century the authorities had become more focused on the actual social damage committed by witches than the aspect of diabolism which had predominated previously (Herzig, 2010).

Although the Church’s stance on witchcraft is mixed, the narrative surrounding witchcraft was undoubtedly a Christian one. Central to the mythology surrounding witchcraft was the link between witches and the devil. Christianity’s view of Satan underwent a dramatic change from the times of the early church to the central middle ages. With the response of the Catholic Church to the Cathars and Waldesians, and subsequent writings of Thomas Aquinas the devil had gone from mischievous troublemaker to a deeply sinister figure (Linder, 2005). Martin Luther, a prominent figure in the reformation, particularly emphasised the dangers of Satan to society (Kors & Peter, 2001 p.261). Indeed, both protestant and catholic lands persecuted witches with equal fervour.

The church sought to depict the devil similarly to the gods of non christian faiths. So for example, the goatee beard, the wrinkled skin, the cloven feet and the horns all bear resemblance to the Roman and

Greek God Pan and to the Celtic god Cernunnos. Similarly, the female breasts common in English 17th century depictions of Satan are likely to have derived from the goddess Diana (Levack, 2006 pp.32-37). It has thus been widely argued that the witches of the middle ages and early modern period were practicing an ancient fertility religion and in worshipping a horned beastlike god were not worshipping the devil as depicted in Christianity.

With the approval of Pope Innocent Vlll, the German clergyman Heinrich Kramer published Malleus Maleficarum ("Hammer of the Witches") in 1487 detailing the practice of witchcraft, and how best to catch and prosecute witches. This book was highly influential being reprinted 29 times by 1669 and translated into many languages. Though officially condemned by the Church in 1490 it was later taken up by both Protestant and Catholic civil and ecclesiastical judges. It's sales across Europe were only rivalled by the bible, until the publication of 'Pilgrim's Progress' in 1678 (Guiley, 2009 p.166).

The invention of the printing press by 1450 allowed Malleus Maleficarum as well as other witchcraft material to be spread quickly across Europe[5]. This furnished witches with a vast mythology and imagery to give pre-existing fears of the population added impetus. Witches were said to fly on broomsticks (pitchforks for the men) to gather in large congregations. These witch Sabbats would also usually include the presence of demons or even the devil himself, and the attendees would commit evil acts such as killing and eating babies and orgies with demons (Bryant, 2004)[6]. Witches were believed to have 'familiars' which would aid them in their witchcraft. These could be a number of different types of animals but were usually black dogs or black cats (Wilby, 2005). Another characteristic associated with witches was that they would have a marking on their body, usually resembling a wart, which was said to be made by the devil to seal their pact (Guiley, 2009).

The use of torture played a big part in witch trials. Reintroduced into Europe in the mid 13th century, it's use became more frequent after Pope Paul ll declared witchcraft crimen excepten[7], and allowed torture to be used without limit (Levack, 2006 p.81, Trevor-Roper, 1969). The frequent use of torture had the effect of increasing the numbers of victims caught up in the worst panics, as suspects would, under duress, name others from the region as witches. Under such circumstances suspects also found themselves confessing to whatever the inquisitor put to them, thus having the effect of confirming to onlookers the more colourful and lurid activities that witches supposedly got up to. In England where torture was not used, witch panics were more mild, and the beliefs in the diabolism aspects of witch trials less apparent (Gijswijt-Hofstra, 1999 p.53). In those cases where torture was routinely used 95% of defendants were found guilty, compared to less than 50% of cases in England (Levack, 2006 p.87).

The most common form of punishment was execution. On the European continent burning at the stake was preferred while in England and North America hanging was more common (Bryant, 2004). Other forms of execution used were breaking on the wheel, drowning, and beheading. Less severe forms of punishment include exile, imprisonment, and mutilation[8] (Pavlac, 2012). Estimates for the

[5] Images of the front covers of Malleus Maleficarum and a pamphlet describing a trial in England are shown in Appendix 4.
[6] A painting by Francesco Goya depicting the Witches' sabat is shown in Appendix 4.
[7] An exceptional crime of such seriousness that the required level of evidence be lower and normal rights of individuals may be infringed.
[8] Removal of an ear or hand.

total numbers executed in the 1450-1750 period varies from 35,000 to 100,000[9]. Given the 30,000 witch accusations collected for this paper and the missing years and regions (See Figure 4 and Table A1.1 in Appendix 1), as well as taking into account the lost records we would estimate the figure towards the higher end of this range.

Belief in witchcraft played a big part in people's everyday lives. Statistics from Macfarlane (1999, p.98), indicate that the crime of witchcraft was more common than murder, though less common than theft. During the peak of the witch hunts the impact would have been much greater of course. In Trier, in present day Germany, a total of 368 individuals were burned alive for witchcraft in 22 villages between 1587 and 1593. In 1585 two villages were left with only one woman remaining in each (Trevor-Roper, 1967 p.139).

The demographic of the accused varied somewhat depending on region. For instance, In Iceland over 90% of witches were men (Burns, 2003 p.140), while for Europe as a whole over 80% were women (Zika, 2003 p.238). Often unmarried or widowed most were over 50 years of age, and though poor were not necessarily the poorest of society. The wandering poor do not appear to have been targeted, other than in the case of the Hapsburg region. (Levack, 2006 pp. 149,156-157). In short the accused were targeted from among the most vulnerable in society.

Witch trials originated in earnest in the 15th century in the regions of eastern France, Switzerland, northern Italy, and Southern Germany (Levack, 2006). Over the ensuing years they spread to encompass almost the entire European continent. In England and the low countries they peaked around 1580-1610. It is generally the case that the peak of the witch trials came later the further east one moves. So, in Germany their were still mass witch hunts occurring in 1630 and in Austria, Hungary, and Russia on towards the end of the 17th and early 18th centuries. In the north in Scandinavia a great rash of witch trials also took place around the turn of the 18th century. The last witch trial in Europe is thought to have occurred in Posnan, Poland in 1793 in which two women were executed for bewitching their neighbours' cattle (Gijswijt-Hofstra, 1999 p.87)

4. Theory

We approach this from the point of view of the person making the complaint. We will assume a representative individual who will make a complaint if they believe they will be better off by doing so. Hence it encompasses the possibility of financial gain and the setting of old scores, but the primary focus is on the resolution of angst. Against this there are the costs of making a complaint. These include both the transaction costs, e.g. the time costs and the costs of preparing oneself for an appearance at the trial. There are also the potential social consequences. Even if the individual is convicted they may have friends, supporters and family with whom social relationships will deteriorate. But if the prosecution is not successful, if the individual is found innocent, the social stigma attached to the complainant may be considerable. Hence the i'th individual will be the subject of a complaint by the representative individual r over time t if:

[9] Monter – 35,000 (Monter, 2002 pp. 6-12); Gaskill – 40,000-50,000 Gaskill (2009, p.76); Levack – 60,000 (Levack, 2006 pp.24-25); Barstow – 100,000 (Barstow, 1995).

$p_{it}F_{it} + p_{it}A_{rt} - (1-p_{it})S_{irt} - T_{rt} > 0$ (1)

where p_i is the probability of individual i being found guilty, F_{ir} is the expected financial gain to the complainant. A_r is the benefit from relieving the angst which we assume is equal to the level of angst. S_{ir} the expected social stigma following an unsuccessful prosecution, which will be linked to the person being prosecuted and also includes associated monetary consequences, e.g. the loss of contracts. T_r is the transaction costs.

Rearranging we can derive a critical level of angst A* above which there will be a witch trial:

$A^*_{rt} = ((1-p_{it})/(p_{it}))\, S_{irt} + T_{rt}/p_{it} - F_{it}$ (2)

p_i is assumed to be a function of the institutional environment of the time (I_t). At times when witch trials and guilty verdicts are common people may perceive p_{it} to be relatively high. It will also be a function of 'the evidence' against the target witch. In part this will reflect their individual characteristics, which in an aggregate time series analysis we will ignore. But in part too they will depend upon unusual events (E_t) such as the Plague, or other epidemics and extreme weather events such as a violent storm which brings flooding and other damage. In this sense it will be correlated with angst. But because of the presence of this as part of the critical value which triggers a witch trial, it is implicit that angst alone is not enough, there has to be a chance of bringing a successful accusation and hence this is related to the plausibility of linking the underlying cause of the angst to a specific witch.

The financial gain to individual r, may vary with individual i. The gains may not be limited to the individual making the accusation, it could impact on much of the local community through, e.g., the removal of a beggar requiring charity. Its inclusion emphasises that then, as now, some prosecutions may be bought for reasons linked to financial gain rather than as a direct result of any harm perceived to have been suffered.

The transaction costs will be different in different locations due, once more, to differences in the institutional process of bringing a witch prosecution. These differences relate to the number of days the individual will have to be in the locality of the Court and the part they will play in the proceedings. In addition the opportunity costs of time are likely to vary. Thus in an emergency such as caused by war, or the flooding of property, these opportunity costs may be higher and the individual unlikely to bring a prosecution at this point in time, but at some later date. Hence the impact of extreme events may be diverse, a long term impact of building up resentment and anger and a short term one related more to the timing of the prosecution.

We model angst as a function of the extent to which utility, U, falls below expectations:

$A = f(U-U^e)$ if $U<U^e$ (3)
$= 0$ if $U \geq U^e$

Where U^e is the expected level of utility in the period and place we are studying. In times where we have consistent economic growth, linking expected utility to the average level of utility might not be a plausible assumption, but for the period we are studying it is. Utility in turn will be a function of living standards, proxied by GDP per capita (Y), disease (D), and other, non-climatic adverse events (X). Hence, (3) can be written as:

$A= f(Y-Y^e, D, X)$ if $U<U^e$ (4)

where:

$Y = Y(|C-C^e|, C, \text{productivity}, \text{population}, D, War, X)$

$D = D(C, Y, War)$ (5)

$X = X(C)$

Income shocks, $Y-Y^e$, can be viewed as either deviation from a fixed income level or from a moving average. The latter captures short term shocks such as fluctuations in the business cycle for example, and assumes that people's discontent is relative to that of their recent past. A fixed Y^e emphasises the importance of an absolute standard of living which dictates propensity towards persecution. At this time income shocks in the majority of locations was primarily linked to agricultural shocks. They would have been functions of both climate shocks ($|C-C^e|$), and climate, C, per se, but in particular we link income shocks to climate shocks.

We model shocks as the absolute deviation from the climate norm (C^e). However, there is the potential for asymmetry in the impact of the climate shock. So for example, a bout of cold weather may cause a greater increase in witch trials than if it was hotter than normal. In addition, in some cases we have data on income or agricultural shocks as well as climate shocks. In this case we will be including both types of shock in the regression.

Thus, combining (4) and (2), the probability of individual i being the subject of a witch trial prosecution (P_{wi}) is a function of extreme events and institutional factors:

$P_{wit} = \Phi(f(Y-Y^e, D,X)- ((1-p_{it})/p_{it}) S_{irt} – T_{rt}/p_{it}))$ if A>0 (6)

$P_{wit} = \Phi(-((1-p_{it})/p_{it}) S_{irt} – T_{rt}/p_{it})$ if A=0

Where Φ is the cumulative density function of the error terms related to the formulation of both angst and its critical value. Included in this error term is F_{it} the financial gain of bringing a witch trial. The total number of witch trials will then be this probability aggregated across individuals. In a community the size of N people, the probability of at least one witch trial equals[10]:

$P_{wt} = 1-\prod_{i=1}^{N}(1-p_{wit})$ (7)

and the expected number of witch trials, rather than people being tried, equals:

[10] This is the probability of a trial being brought by 'the representative agent', but we will equating this to witch trials for the whole population.

$$E(W_t) = \sum_{i=1}^{N} p_{wit} \quad (8)$$

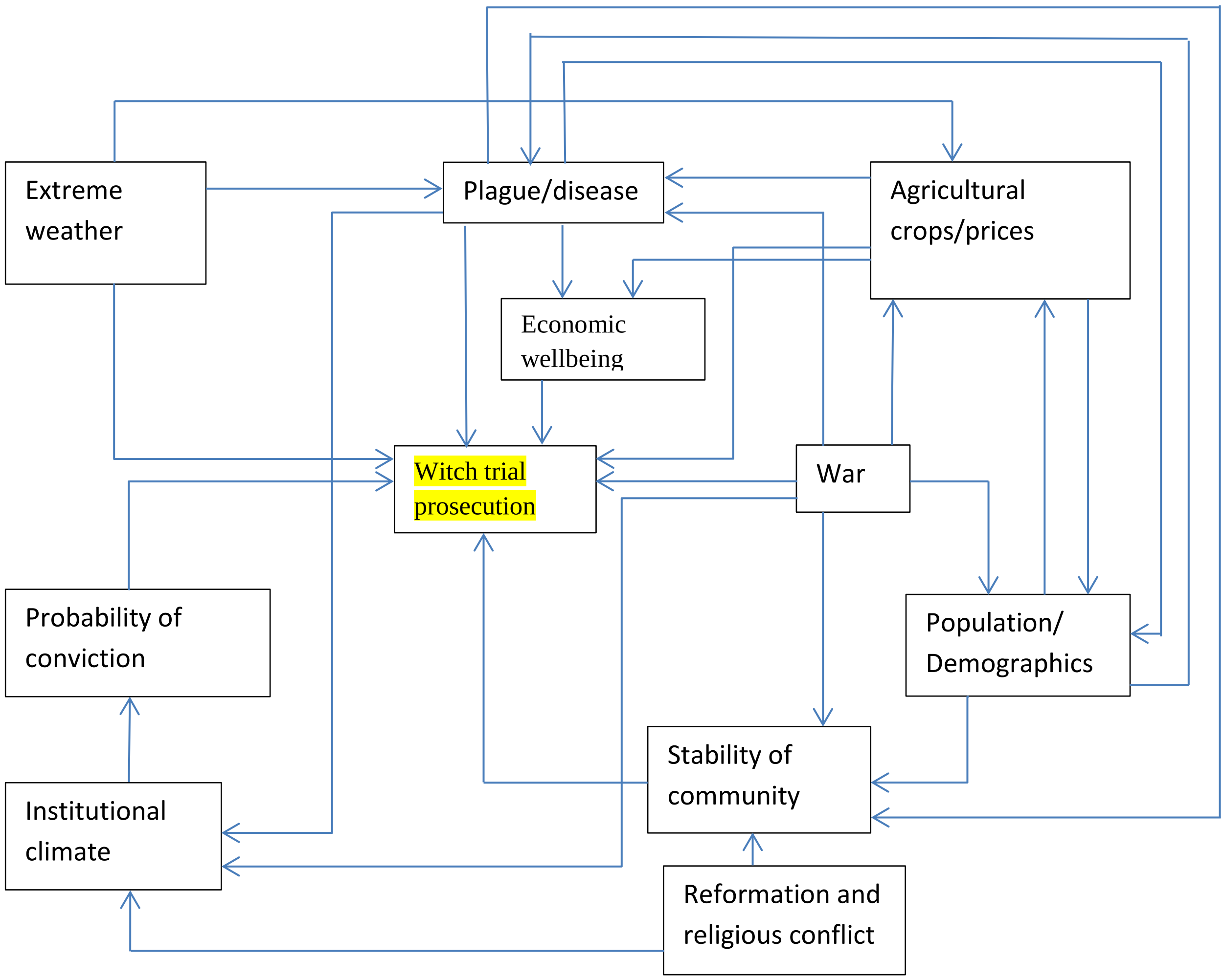
and hence also a function of the factors in (6). Witch trials will tend to start with the individual who maximises p_{wit}, then moving to the second most likely and so on. In (8) we order the population in this way. Thus the expected number of witch trials equals the probability of the most likely witch trial plus the probability of the second most likely one and so on. P_{wit} is not independent of the number of witch trials as it is a function of p_{it}, the probability of a successful witch trial, which because of judicial capacity constraints will decline with the number of trials occurring at the same time.

We abstract from a number of issues. In particular, a single witch trial may result in multiple prosecutions because more than one person may be accused. In this case the potential gains and costs will be more complex and in many cases the type of person bringing the witch trial is different, e.g. less likely to be a local. We are implicitly assuming, although it makes little difference to the empirical analysis, that each witch trial involves just one suspect.

We will proxy institutional affects through location and time specific dummy variables. Regardless of actual institutional factors a high number of recent witch trials will tend to increase perceptions of their acceptability, the extent of the witch problem and possibly the chances of a successful prosecution.

Lags are also likely to be important. According to Briggs' (2007) study on Witchcraft in the Duchy of Lorraine, the process of persecution of a witch took an average of 10 years, the culmination of which being the actual trial. It took time for the reputation of an individual to be formed and for critical mass among the enclosed community to be reached. It was not a costless enterprise for the accuser and thus they wanted to be sure of community wide support before bringing an official accusation. Lags could also occur due to time taken for angst to build. One bad harvest, one adverse spell of weather might not be sufficient for there to be a sufficient degree of angst to trigger a witch trial. But a sustained series of events might be. The probability of bringing a witch trial would also therefore be a function of stability of the community. Thus, when the demographic makeup of the community was affected then the likelihood of a witch trial would diminish. War and plague are both things which could have an effect, either through death or migration.

Figure 1: The Witch Trial/Plague/Harvest Nexus



5. Data

In this section we describe the data used in the empirical analysis. The data used for the different sections of the paper are described separately in 5.1, 5.2, and 5.3.

5.1 Data – For Section 6.1

These relate to the data in section 6.1. Seasonal temperatures and rainfall are for spring, summer, autumn and winter. Winter includes December from the previous year. For details on this data see Luterbacher et al (2004) and Xoplaki et al (2005). This provides data for the area: 25W - 40E and 30 - 70N for Winter 1500 - Autumn 2002. For each observation there are 9100 gridpoints covering different spatial locations. Each gridpoint corresponds to a region of approximately 50km by 50km and we extracted that pertaining to the location we were analysing. This data set has only recently become available and is, as far as we are aware, the first time that seasonal, as well as annual, variations in climate have been used to analyse witch trials or indeed any historical persecution. We feel this is important. Annual data can mask substantial seasonal variations, for example a very cold summer and a very warm winter can cancel each other out. But their impact on the population may not be the same as that of a normal summer and winter.

The witch trial data was grouped to correspond with the climate data. In total we have 30,066 witch trial accusations covering across 355 regions over the period 1500-1760. The location of these regions for which we have witch trial data is illustrated in Figure 4. The various sources for the witch trial data are listed in Table A1.1 in Appendix 1. The geographical coverage of the witch trials which took place in Europe is generally high, with those regions considered to be at the heart of the witch hunt craze, Germany, Switzerland and North East France (Behringer, 2004 pp.83-164) with very useful tables on pp 130, 150), particularly well represented.

5.2 Data – For Section 6.2

This relates to the data in the GDP per capita and real wages & grain prices parts of section 6.2. In the GDP per capita part five regions are considered: Spain, Italy, Holland, England, and Sweden[11]. For each country five variables are collated; witch trials, population, GDP per capita, and two binary variables; Plague epidemics and War. Sources for these variables are provided in Tables A2.1 – A2.5 in Appendix 2. Plague epidemics and war data[12] were constructed using the secondary historical sources given.

For the real wages and grain price part, six regions are used: Amsterdam, London, Madrid, Valencia, Munich and Stockholm. For each region six variables are collated; witch trials, population, real wages, wheat/rye price shocks, and the two binary variables; Plague epidemics and War. Sources for these variables are provided in Tables A3.1 – A3.5 in Appendix 3. The harvest quality data for Sweden comes from Edvinsson (2008).

5.3 Data – For Section 6.3

For this section only England is considered. Much of the data used is the same as for the previous section. Witch trials, plague, war, population and grain prices are as stated in section 5.2. For real wages we use two series (Clark, 2007 and Allen, 2001). The business cycle 'trough' data comes from Overton and Van Leeuwen (2012) and the dependency ratio from Wrigley & Schofield (1989, p.447, Table 10.6).

[11] The choice of regions used is dictated by the availability of data. Constructions of yearly GDP per capita data are a recent development with the first, for Holland, published only in 2009.

[12] The 80 years war engulfing the Netherlands ran from 1568-1648. It proved difficult to construct our variable for Holland, but we decided to include only the years 1568-1578 since this marked the period from the start of the dutch revolt up until the year 1578 in which the last of the major cities, Amsterdam and Middelburg, declared for the rebels and thus unifying the Holland region (Hart, 2014).

6. Empirical Analysis

6.1 Climate and witch trials

We start by using just the weather to explain the incidence of witch trials. This approach follows along the same lines as Oster (2004), which purports to exploit the relationship between weather and economic output to predict witch persecution. In addition our study provides a number of innovations. The high granularity and comprehensiveness of the weather data, both geographically and across time, allows us to use a much enlarged dataset. In addition for each year we have both rainfall and temperature observations for spring, summer, autumn and winter.

In Figures 2 and 3 we display a summary of the climate variables across our sample. Figure 2 shows the average temperature and rainfall. We note two troughs in temperature around 1600 and again around 1700. In Figure 3 we have displayed the average temperature and rainfall shocks. Of note is the general increase in rainfall variability post 1650 and the peak in temperature around 1600. Also evident in both charts is the 22 year Hale cycle which has previously been well documented (Newel et al., 1989).

To model the number of individuals accused of witchcraft a year, we use a Poisson count model for panel data[13]. This then gives:

$$\Pr(Y=y) = \frac{e^{-\mu}\mu^{y}}{y!} \qquad (9)$$

Where μ is as defined in (10). In the Poisson regression both the mean and variance of the distribution equal μ. The Poisson distribution assumes that:

$$\mu = e^{X_{it}'\beta} \qquad (10)$$

[13] The poisson fixed effects estimator is consistent and with use of cluster-robust standard errors is likely more robust in our case (Cameron and Trivedi, 2005 pp.667-677). The negative binomial model is designed to address over-dispersion as is present in our dataset. However, the fixed effects model proposed by Hausman et al. (1984), NB1 in Cameron and Traverdi (1986), has been shown to not be a true fixed effects method (Allison and Waterman, 2002). Both NB1 and NB2 give inconsistent results when the distribution is overdispersed but not negative binomial, although the level of bias is much greater in the NB1 case than for NB2. Moreover, Blackburn (2014) discourage the use of either NB1 or NB2 in panel data applications, even when the distribution is negative binomial. The results using the NB2 estimator are presented in appendix 5, and are similar to the poisson case.

Figure 2: Average Yearly Temperature and Rainfall

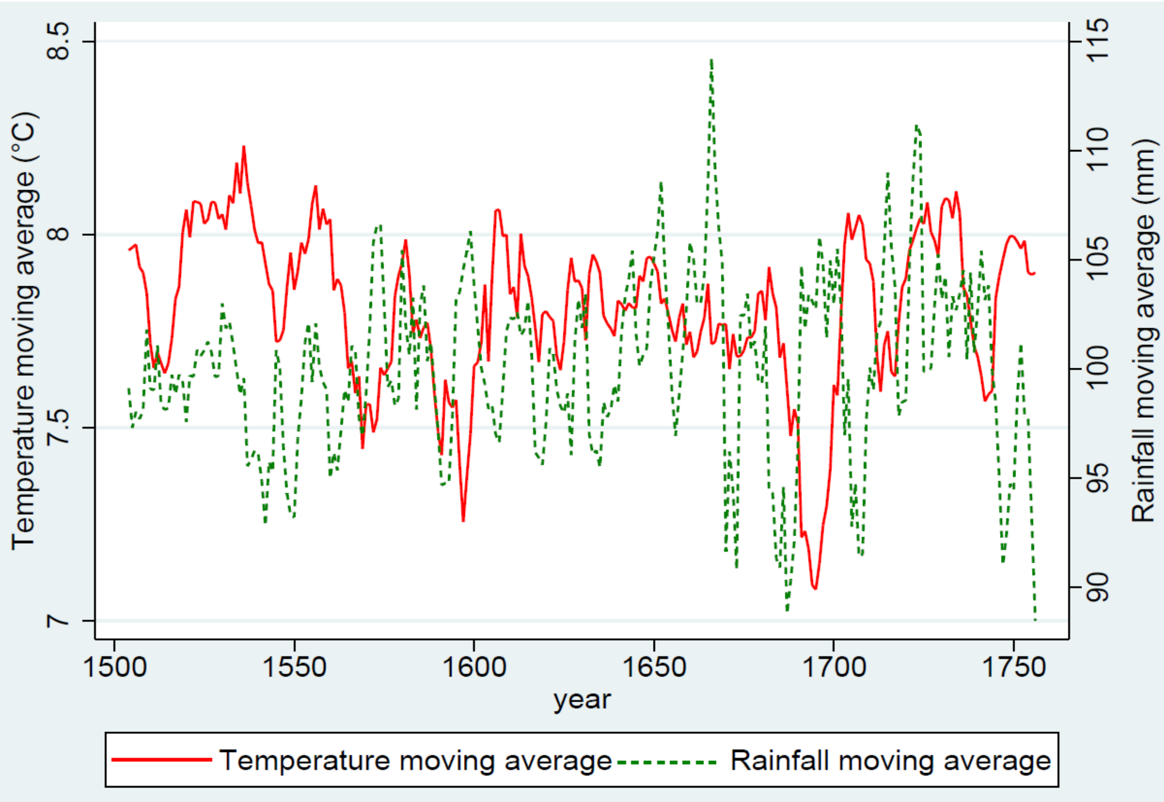
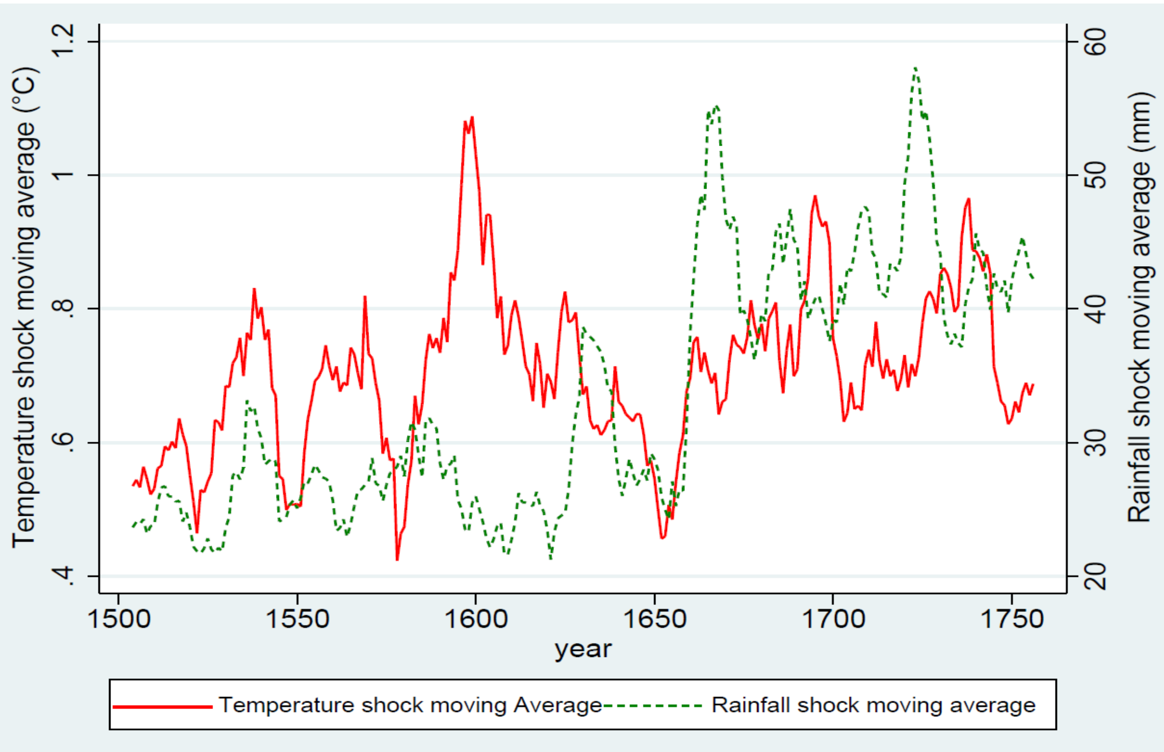


Figure 3: Average Yearly Temperature and Rainfall Shocks[14]



[14] The two shock variables, temperature shock and rainfall shock, are constructed by summing the absolute deviation from the mean for each of the four yearly seasons.

with the variables which specify X being those on the right hand side of (6). The maximum likelihood estimator of β is the solution to K nonlinear equations corresponding to the first order conditions:

$$\sum_{i=1}^{N}\{(y_i - \exp(x_i'\beta))\, x_i\} = 0 \qquad (11)$$

In addition, we will be using the fixed effects estimator, where the first order conditions amount to:

$$\sum_{t=1}^{1}\sum_{i=1}^{N}\{(y_{it} - \frac{\lambda_{it}}{\bar{\lambda}}\bar{y}_i)x_i\} = 0 \qquad (12)$$

where $\lambda_{it} = \exp(x_{it}'\beta)$. It is consistent as long as $E(y_{it}|\ \alpha_i\ , x_{i1}\ , \dots , x_{iT}\ ) = \alpha_i \exp(x_{it}'\beta)$. An alternative is to use OLS, or indeed random effects, with dummy variables for each region.

Climate cooling generally had a deleterious effect on farming during the early modern period. For Scotland it was calculated that a 1°C fall in temperature led to an increase in crop failure from 1 year in 20 to 1 year in 3. Worse still, the frequency of crop failure in successive years increased 70 fold. The lapse rate of temperature elevation was 0.68°C per 100m (Grove, 1988 pp.407-410). Elsewhere in Northern Europe, the effects were similarly damaging. There were many cases of glaciers overrunning farms in Scandinavia and Finland, with as many as half the medieval Norwegian farms becoming abandoned between 1300 and 1600. In Switzerland it was reported that snow cover remained for longer, sometimes until May. March and to some extent April were winter months. Grain crops were badly damaged by the parasite Fusarium nivale, which is present under snow cover in Northern Germany and Scandinavia, but is absent from Switzerland today (Lamb, 1995 p.216).

Aside from changes in mean climatic conditions, also of importance is climate variability. Farmers would have optimised farming practices to suit local conditions, and thus would have been ill-prepared for any increase in climate variability. Integral in the decision to abandon a farm is perception of risk. More important than the average yield is the likelihood of falling short of that required for subsistence and in the case of tenant farmers, as were prevalent in Scotland for example, subsistence plus rent. Harvest failure over two consecutive years leading to consumption of seed grain and any cash reserves was likely to be disastrous (Dodgshon, 2005).

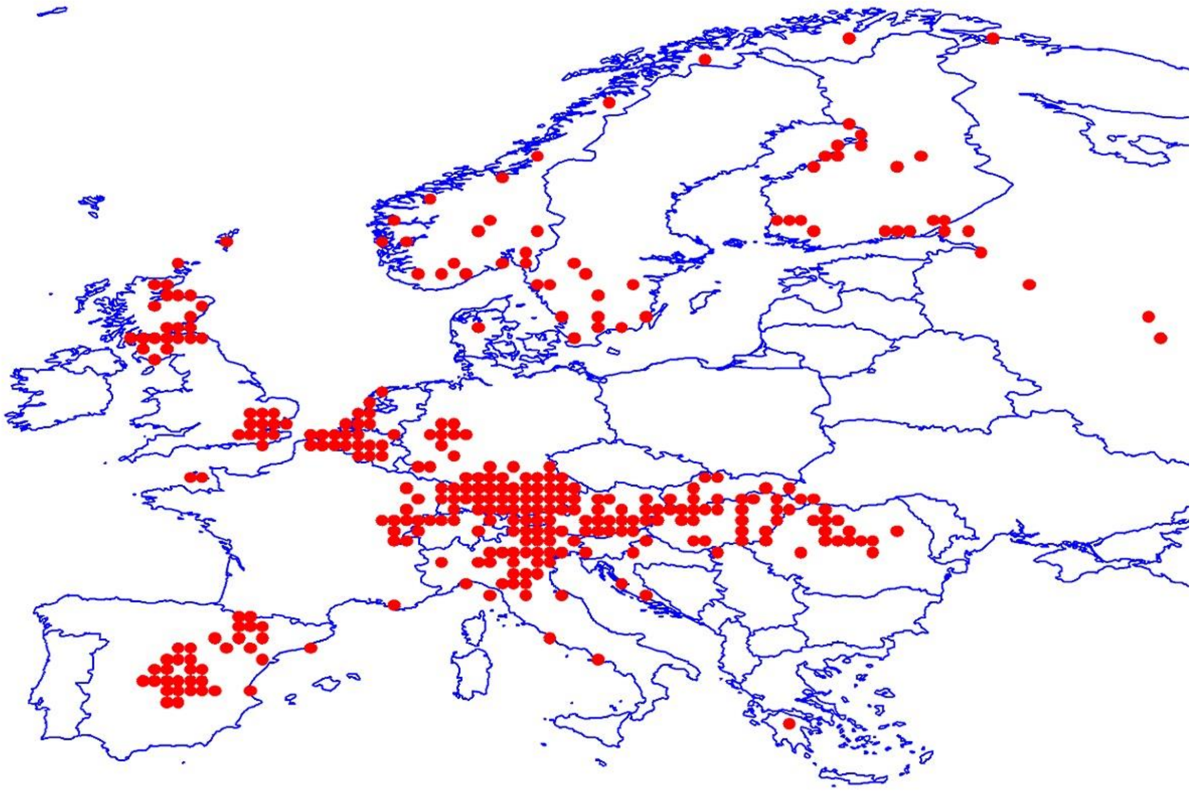
Climate variability also impacts fisheries. Cod, for example, thrive best in the range 4–7°C, and can't survive below 2°C. Cod fisheries in the Faeroe Islands began to fail around 1615 and increasingly so until there were no cod at all between 1675 and 1704. 1695 being the worst year, saw cod become scarce in Shetland and disappear entirely from the Norwegian coast (Lamb, 1995 p.219). However, cooler temperatures may not have been uniformly detrimental with respect to fisheries. Indeed, it may have benefitted England, France and the low countries as fish deserted the cooler Baltic waters in favour of the North Sea and the Atlantic.

We start by analysing the effect of rainfall shocks and temperature shocks on witch trials. The two shock variables, temperature shock and rainfall shock, are constructed by summing the absolute deviation from the mean for each of the four yearly seasons. The results are reported in Table 2 below. Temperature seems to play a more important role in determining witch trials than rainfall. The results imply that for a witch trial hotspot such as Geneva, a 1°C temperature shock in each of the previous 4 years leads to a predicted quadrupling of witch trials from 0.529 to just over 2 a year[15]. The strong

[15] 1 standard deviation temperature shock is equal to 0.367°C. We set rainfall shocks to be zero.

significance in all specifications of temperature shocks, in particular, for the four proceeding years to the witch trial casts light on the length of time the witch persecution took, indicating a witch hunt did not happen overnight, perhaps too the decision to commit an individual to trial was a culmination of a number of years of angst.

Figure 4. Locations of Witch Trials



The figure shows the locations for which we have witch trial data over the sample period.

Our finding regarding the extended duration of witch persecution is consistent with existing literature on this subject. Macfarlane (1999, pp.95,103,109), describes how persecutions against a witch lasted as long as 10 years and that the trial itself was often only the final stage in a process which may have also included threatening the witch and setting fire to the thatch of the suspect's house. Briggs (2007, pp.153-179) discusses the complicated process by which a community passed judgement on who was and was not a witch. It was a process whereby women, for it was they who concerned themselves with the business of reputational gossip, felt one another out regarding in which direction community opinion was moving. Immunity from being suspected often relied on support from others in the community and it may not always have been clear how much support a given individual could command. Therefore it paid to be cautious in helping to form public opinion, for fear of reprisals if a groundswell of support was not forthcoming.

In specification (2) we use the temperature and rainfall occurring in the years after the trials had concluded as a robustness check to ensure that the significance of the lagged terms is not attributable to a general correlation of these variables between years. The lack of significance indicates that this is not the case. In specifications (3) – (5) we control for common time trends[16]. These specifications show an increase in witch trials until around 1630 after which they moderated slightly. The results are generally robust to controlling for time trends. In specification (5) in which yearly fixed effects are included, rainfall shocks appear to play a more prominent role.

In specification (6) we adjust the response variable to restrict the influence of the outlier observations, by imposing a maximum value for witch trials[17]. These 'outlier' observations may indicate the presence of a different underlying process. The great witch hunt crazes saw suspects tortured to give up the names of other suspects who were in turn tortured to give up still more names, and so on and so forth. This is conceptually different to the cases where witch trials were brought forward in a more measured manner (Briggs, 2013 p.216). The results support this point of view, marginally strengthening the significance of the coefficients despite the reduction in heterogeneity.

Table 2: Witch Trials and Climate Shocks, 1500-1760

Explanatory Variable	Dependent Variable:					
	Witch Trials					Adjusted Witch Trials
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
	(1)	(2)	(3)	(4)	(5)	(6)
30 Year Fixed Effects	NO	NO	NO	YES	NO	NO
Year Fixed Effects	NO	NO	NO	NO	YES	NO
Year			0.0174*** (0.0032)			
Year squared			-0.00005*** (0.00001)			
Temperature Shock	0.1692*** (0.0629)	0.1713*** (0.0583)	0.1599*** (0.0572)	0.1742*** (0.0610)	0.1524 (0.1209)	0.1576*** (0.0411)
Temperature Shock (1 year lag)	0.2222*** (0.0538)	0.2179*** (0.0485)	0.1958*** (0.0470)	0.2101*** (0.0594)	0.2134** (0.0995)	0.2334*** (0.0401)
Temperature Shock (2 year lag)	0.2712*** (0.0642)	0.2797*** (0.0624)	0.2593*** (0.0607)	0.2633*** (0.0724)	0.1927* (0.1140)	0.2621*** (0.0427)
Temperature Shock (3 year lag)	0.3526*** (0.0547)	0.3481*** (0.0618)	0.3352*** (0.0588)	0.3298*** (0.0681)	0.3532*** (0.1105)	0.2377*** (0.0389)
Temperature Shock (4 year lag)	0.3239*** (0.0720)	0.3287*** (0.0687)	0.3100*** (0.0697)	0.2978*** (0.0718)	0.3603*** (0.1096)	0.2296*** (0.0445)
Temperature Shock (1 year Forward)		0.0652 (0.0534)				
Temperature Shock (2 year Forward)		-0.0914 (0.0656)				

[16] A specification including a lagged dependent variable with GMM was tried, although not included here. The climate shock effects largely remained intact while the other climate results largely did not.

[17] Maximum value set at 8 times the mean witch trials for each group. In addition only applied to cases where actual witch trials > 5.

Temperature Shock (3 year Forward)						
Rainfall Shock	0.2027	0.1764	0.0709	0.2046	0.4498***	0.1270*
	(0.1299)	(0.1215)	(0.1238)	(0.1252)	(0.1648)	(0.0748)
Rainfall Shock	0.0128	-0.0178	-0.1158	-0.0135	0.3127**	0.0956
(1 year lag)	(0.0957)	(0.0978)	(0.0994)	(0.0987)	(0.1485)	(0.0753)
Rainfall Shock	0.2078*	0.1798	0.0913	0.2158	0.2214	0.0879
(2 year lag)	(0.1107)	(0.1102)	(0.1152)	(0.1155)	(0.1625)	(0.0773)
Rainfall Shock	0.0658	0.0286	-0.0622	0.0403	0.3115*	0.0366
(3 year lag)	(0.1170)	(0.1178)	(0.1222)	(0.1240)	(0.1687)	(0.0972)
Rainfall Shock		0.0726				
(1 year Forward)		(0.1057)				
Rainfall Shock		0.1633				
(2 year Forward)		(0.1111)				
Number of Observations	42498	42451	42498	42498	42498	42498
Number of Regions	355	355	355	355	355	355

Notes: Robust standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels. In specification 2 Forward values or negative lagged values of the variables are used. 30 year fixed effects are dummy variables for each 30 year period.

Analysis at the seasonal level reveals a more complicated relationship. In Table 3 we split the yearly climate variables into seasonal climate variables. Where effects are similar across seasons we group those seasons together to make the specification as parsimonious as possible. We find that the temperature shock is strongest in summer but generally holds for all seasons. Spring-summer temperature is significantly negative for all lags in specifications (1)-(4) indicating that cooler temperatures during the growing season increase witch trials more than warmer temperatures. For winter-autumn temperatures the converse is true in that for lags 0, 1 and 2 years warmer temperature shocks have a larger impact on witch trials than cooler temperature shocks (Columns (1)-(3)). This finding is inconsistent with an agricultural explanation as rising winter temperatures would usually be expected to aid agricultural output. An alternative explanation could lie with plague and we return to this idea later in detail.

The rainfall shocks are largely driven by the autumn season giving significant results for the first three lags. Spring-summer rainfall gives a mixed story. The effect of rainfall is mixed depending on the season. Winter-spring rainfall significantly increases witch trials in lags 3 and 4 at the 1% level. The negative coefficient of autumn rainfall for lags 0 and 4, together with the autumn rainfall shock, provides evidence that drought had a more damaging effect than excess rainfall for this period of the year.

Specification (2) includes forward lags. However, in this case they are significant for a number of variables. One contributing factor for this is that the winter variables refer to three month period beginning in December of the previous, although one would not expect this to be a serious issue.

We further disaggregate the data into separate regions to see if the effects of climate variability were conditional on environment (See Table A1.2 in Appendix for details on the environmental zones used). Specifically, we look at three zone types: hot, cold and moderate. The results in Table 4 show that the overall results are largely driven by the moderate region. The significant coefficients for autumn rainfall shock are stronger than for the overall sample. Additionally, the variables spring-summer temperature and winter-autumn temperature are only significant in the moderate region. While strongest in the moderate region there is also evidence for a temperature shock effect in the remaining regions, with significant coefficients for lags 0 and 4 in the cold region and 1,3 and 4 in the hot region. The hot region also demonstrates a sensitivity to rainfall, with witch trials increasing with rainy winter-springs and dry autumns.

While noting the smaller standard errors in the moderate region's results, possibly owing to the greater sample size, there are also other reasons why this region may show a greater reliance on climate. The moderate region would have had both arable and pastoral activity whereas the colder region was mainly pastoral. Animals are homeostatic which means they can adapt within a range of temperatures and therefore the region should be less sensitive to climatic variation. The hot region would have also had arable farming, but cold was not such a limiting factor. It was far less likely that it would have caused land to be abandoned and may even have been a benefit in some areas. The lack of any clear effect assigned to increasing temperature in the warmer Mediterranean zones, aside from a lack of sample size, could be ascribed to the less severe implications of the little ice age. Whereas northern Europe was often at the margin of usability of the land, this is unlikely to have been the case further south. Indeed for the hottest parts a cooler climate may have been a benefit to agriculture.

Previously, we noted that plague may have a part to play in explaining the incidence of witch trials. The effect may move in either direction. On the one hand incidence of plague may disrupt normal life including the workings of the legal system (Behringer, 2003 p.209) as well as of society. In so much as people may interact less, this reduces the scope for slanderous gossip and interaction with potential witches. On the other hand, witches may be branded 'plague spreaders' (Monter, 1976 pp. 44-45) or more indirectly society may be so brutalized by the sudden loss of so many of the population that people may turn more violent. Indeed, arguments have been put forward that 'the mass mortality cheapened life and thus increased warfare, crime, popular revolt, waves of flagellants, and persecutions against the Jews' (Cohn, 2002). In Table 3 the positive coefficient of winter-autumn temperatures are consistent with plague acting to increase witch trials, as colder winters help to constrain the spread of the rat flea carrier Xenopsylla cheopis (Appleby, 1980).

We would also expect very high temperatures to restrict plague incidence, and indirectly test for this in Table 5. Xenopsylla cheopis is not sustainable above 25°C and therefore we test the effect of summer temperature above 22°C[18]. Summer temperature is significantly negative for lags 1-3 implying that higher temperatures decrease witch trials in all specifications. Specification (2) includes forward lags for summer temperature as a robustness check, and both coefficients are insignificant. In specification (4) we include spring temperatures as a further robustness check to distinguish agricultural effects from plague effects. Spring and summer both constitute the growing season in these warmer climes, and tend to have similar effects on farming. Since spring temperatures are too low, they should not have an effect through the plague channel. The results show spring temperature is indeed not significant. These results for plague are quite striking given the limited sample size for

[18] This is an average temperature so during the daytime temperatures would exceed 25°C.

these regressions, and given that climate was just one of a number of little understood causes of plague. It points at the great impact plague had on society during this period.

This section has provided some insights in terms of the relationships between climate and witch trials, and the possible channels which could be at work. However, it is not always possible to say with certainty which channels are really at work. Thus, availability of plague epidemic data and gdp data for example enable us to address these issues in the next section. An additional endogeneity issue arises as the abandonment of farmland causes population of the region to decline, which acts to bias down the impact on the persecution of witches. Using population data will help to address this concern.

Table 3: Witch Trials and Climate, 1500-1760

Explanatory Variable	Dependent Variable:					
			Witch Trials			Adjusted Witch Trials
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
	(1)	(2)	(3)	(4)	(5)	(6)
30 Year Fixed Effects				YES	NO	NO
Year Fixed Effects				NO	YES	NO
Year			0.0211*** (0.0032)			
Year squared			-0.00006*** (0.00001)			
Temperature Shock	0.2000*** (0.0559)	0.1800*** (0.0593)	0.1901*** (0.0571)	0.1887*** (0.0605)	0.0739 (0.1278)	0.1863*** (0.0501)
Temperature Shock (1 year lag)	0.1521*** (0.0553)	0.1269** (0.0526)	0.1031* (0.0559)	0.1179* (0.0618)	0.1221 (0.1024)	0.1859*** (0.0451)
Temperature Shock (2 year lag)	0.1441** (0.0591)	0.1564** (0.0626)	0.1116* (0.0628)	0.1044 (0.0676)	0.1990* (0.1157)	0.1655*** (0.0411)
Temperature Shock (3 year lag)	0.3009*** (0.0584)	0.3087*** (0.0620)	0.2726*** (0.0578)	0.2570*** (0.0626)	0.3114*** (0.1130)	0.2192*** (0.0453)
Temperature Shock (4 year lag)	0.3593*** (0.0723)	0.3578*** (0.0728)	0.3372*** (0.0726)	0.3072*** (0.0735)	0.3818*** (0.1151)	0.2669*** (0.0445)
Temperature Shock (1 year Forward)		0.0893 (0.0613)				
Temperature Shock (2 year Forward)		-0.0687 (0.0695)				
Autumn Rainfall Shock	0.1376** (0.0624)	0.1740*** (0.0621)	0.0699 (0.0643)	0.0921 (0.0631)	0.1809* (0.0980)	0.0999** (0.0400)
Autumn Rainfall Shock (1 year lag)	0.1976*** (0.6034)	0.1381** (0.0596)	0.1307** (0.0627)	0.1598*** (0.0736)	0.2117** (0.0937)	0.1620*** (0.0516)
Autumn Rainfall Shock (2 year lag)	0.1064 (0.0732)	0.0792 (0.0702)	0.0089 (0.0735)	0.0822 (0.0748)	0.0138 (0.0925)	0.1073* (0.0571)

Autumn Rainfall Shock (3 year lag)	0.1352* (0.0710)	0.0949 (0.0705)	0.0353 (0.0721)	0.0822 (0.0748)	-0.1177 (0.0915)	0.1081** (0.0474)
Autumn Rainfall Shock (4 year lag)	-0.0469 (0.0686)	-0.0399 (0.0702)	-0.1334* (0.0738)	-0.0915 (0.0714)	-0.0835 (0.0943)	-0.0200 (0.0463)
Autumn Rainfall Shock (1 year forward)		0.0727 (0.0672)				
Autumn Rainfall Shock (2 year forward)		0.1459** (0.0601)				
Spring-Summer Temperature	-0.0993** (0.0412)	-0.1033*** (0.0399)	-0.1031** (0.0423)	-0.0790** (0.0395)	-0.1700 (0.1122)	-0.0472 (0.0331)
Spring-Summer Temperature (1 year lag)	-0.1870*** (0.0406)	-0.2055*** (0.0435)	-0.1914*** (0.0409)	-0.1751*** (0.0385)	-0.3172*** (0.0714)	-0.1329*** (0.0273)
Spring-Summer Temperature (2 year lag)	-0.1746*** (0.0374)	-0.1641*** (0.0364)	-0.1761*** (0.0369)	-0.1640*** (0.0353)	-0.1755** (0.0758)	-0.1236*** (0.0267)
Spring-Summer Temperature (3 year lag)	-0.1244*** (0.0418)	-0.1198*** (0.0391)	-0.1284*** (0.0415)	-0.1186*** (0.0378)	-0.1092 (0.0783)	-0.0795*** (0.0299)
Spring-Summer Temperature (4 year lag)	-0.0951*** (0.0259)	-0.0954*** (0.0275)	-0.0951*** (0.0262)	-0.0762*** (0.0315)	-0.1833*** (0.0677)	-0.0753 (0.0233)
Spring-Summer Temperature (1 year forward)		-0.0414 (0.0326)				
Spring-Summer Temperature (2 year forward)		-0.0681* (0.0358)				
Winter-Autumn Temperature	0.1349*** (0.0338)	0.1397*** (0.0335)	0.1490*** (0.0344)	0.1425*** (0.0326)	0.1025* (0.0550)	0.0862*** (0.0195)
Winter-Autumn Temperature (1 year lag)	0.1039*** (0.0302)	0.1027*** (0.0292)	0.1147*** (0.0300)	0.1125*** (0.0277)	0.0778 (0.0574)	0.0718*** (0.0199)
Winter-Autumn Temperature (2 year lag)	0.1104*** (0.0299)	0.1060*** (0.0285)	0.1176*** (0.0295)	0.1159*** (0.0311)	0.2230*** (0.0541)	0.0566*** (0.0199)
Winter-Autumn Temperature (3 year lag)	0.0479 (0.0294)	0.0508* (0.0285)	0.0520* (0.0290)	0.0540* (0.0304)	0.0441 (0.0448)	0.0309* (0.0186)
Winter-Autumn Temperature (4 year lag)	0.0396* (0.0228)	0.0527** (0.0230)	0.0456** (0.0229)	0.0397 (0.0242)	0.0923** (0.0444)	0.0296* (0.0153)
Winter-Autumn Temperature (1 year forward)		0.1086*** (0.0295)				
Winter-Autumn Temperature (2 year forward)		0.0352 (0.0248)				
Winter-Spring Rainfall	0.0105 (0.0745)	0.0078 (0.0716)	0.0363 (0.0706)	0.0075 (0.0760)	-0.1336 (0.0986)	0.0518 (0.0566)

Winter-Spring Rainfall (1 year lag)	0.0588 (0.0710)	0.1208 (0.0842)	0.0860 (0.0780)	0.0452 (0.0821)	0.1395 (0.0995)	0.0874 (0.0584)
Winter-Spring Rainfall (2 year lag)	-0.0123 (0.0814)	-0.0076 (0.0766)	0.0159 (0.0778)	-0.0244 (0.0815)	0.0479 (0.0808)	0.0482 (0.0705)
Winter-Spring Rainfall (3 year lag)	0.2328*** (0.0682)	0.2515*** (0.0697)	0.2478*** (0.0671)	0.2204*** (0.0654)	0.2717*** (0.0731)	0.2129*** (0.0590)
Winter-Spring Rainfall (4 year lag)	0.2524*** (0.0682)	0.2487*** (0.0700)	0.2840*** (0.0666)	0.2550*** (0.0670)	0.2965*** (0.0856)	0.1818*** (0.0521)
Winter-Spring Rainfall (1 year Forward)		-0.0940 (0.0664)				
Winter-Spring Rainfall (2 year Forward)		-0.1539** (0.0754)				
Autumn Rainfall	-0.1401*** (0.0410)	-0.1459*** (0.0415)	-0.1387*** (0.0406)	-0.1207*** (0.0415)	-0.1212** (0.0579)	-0.0549* (0.0288)
Autumn Rainfall (1 year lag)	-0.0717 (0.0500)	-0.0929* (0.0503)	-0.0662 (0.0495)	0.0405 (0.0497)	0.0881* (0.0522)	-0.0229 (0.0313)
Autumn Rainfall (2 year lag)	0.0051 (0.0450)	0.0026 (0.0438)	0.0084 (0.0443)	0.0330 (0.0435)	0.0708 (0.0541)	-0.0367 (0.0354)
Autumn Rainfall (3 year lag)	-0.0474 (0.0455)	-0.0245 (0.0435)	-0.0474 (0.0437)	-0.0038 (0.0460)	0.0547 (0.0463)	-0.0743** (0.0313)
Autumn Rainfall (4 year lag)	-0.1740*** (0.0497)	-0.1542*** (0.0489)	-0.1593*** (0.0497)	-0.1272** (0.0515)	-0.1238** (0.0562)	-0.1170*** (0.0374)
Autumn Rainfall (1 year forward)		-0.0054 (0.0492)				
Autumn Rainfall (2 year forward)		0.0513 (0.0482)				
Number of Observations	42498	42451	42498	42498	42498	42498
Number of Regions	355	355	355	355	355	355

Notes: Robust standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels. In specification 2 Forward values or negative lagged values of the variables are used. In specification 2 Forward values or negative lagged values of the variables are used. 30 year fixed effects are dummy variables for each 30 year period.

Table 4: Witch Trials and Climate by Environmental Zone, 1500-1760

Explanatory Variable	Dependant Variable: Witch Trials & Adjusted Witch Trials					
	Moderate ATN, ATC, CON, PAN		Cold ALN, ALS, BOR, NEM		Hot MDS, MDN, MDM	
	Witch Trials	Adjusted Witch Trials	Witch Trials	Adjusted Witch Trials	Witch Trials	Adjusted Witch Trials
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature Shock	0.2155*** (0.0700)	0.1934*** (0.0641)	0.2017* (0.0878)	0.2122*** (0.0692)	0.0084 (0.1283)	0.0326 (0.1121)
Temperature Shock (1 year lag)	0.1487** (0.0691)	0.1937*** (0.0592)	0.0816 (0.1031)	0.0795 (0.0800)	0.2826** (0.1187)	0.2716** (0.1089)
Temperature Shock (2 year lag)	0.1606** (0.0698)	0.1955*** (0.0487)	0.1243 (0.1188)	0.0587 (0.0737)	0.0668 (0.1159)	0.0915 (0.1131)
Temperature Shock (3 year lag)	0.3494*** (0.0712)	0.2365*** (0.0556)	0.0274 (0.0789)	0.0726 (0.0578)	0.2798* (0.1508)	0.2639* (0.1399)
Temperature Shock (4 year lag)	0.4003*** (0.0924)	0.2825*** (0.0551)	0.1619* (0.0904)	0.1612*** (0.0575)	0.3232*** (0.1168)	0.3339*** (0.1082)
Autumn Rainfall Shock	0.1812*** (0.0698)	0.1501*** (0.0509)				
Autumn Rainfall Shock (1 year lag)	0.2615*** (0.0774)	0.2227*** (0.0709)				
Autumn Rainfall Shock (2 year lag)	0.1874** (0.0877)	0.1701** (0.0717)				
Autumn Rainfall Shock (3 year lag)	0.1778** (0.0835)	0.1360** (0.0559)				
Autumn Rainfall Shock (4 year lag)	0.0559 (0.0788)	0.0311 (0.0573)				
Spring-Summer Temperature	-0.1226** (0.0496)	-0.0692 (0.0426)				
Spring-Summer Temperature (1 year lag)	-0.2381*** (0.0484)	-0.1663*** (0.0345)				
Spring-Summer Temperature (2 year lag)	-0.2153*** (0.0439)	-0.1566*** (0.0327)				
Spring-Summer Temperature (3 year lag)	-0.1643*** (0.0492)	-0.0606*** (0.0296)				
Spring-Summer Temperature (4 year lag)	-0.0986*** (0.0300)	-0.0696*** (0.0253)				
Winter-Autumn Temperature	0.1404*** (0.0402)	0.0944*** (0.0248)				

Winter-Autumn Temperature (1 year lag)	0.1175***	0.0830***				
	(0.0344)	(0.0225)				
Winter-Autumn Temperature (2 year lag)	0.1403***	0.0728***				
	(0.0346)	(0.0236)				
Winter-Autumn Temperature (3 year lag)	0.0790**	0.0462**				
	(0.0344)	(0.0226)				
Winter-Autumn Temperature (4 year lag)	0.0533*	0.0362*				
	(0.0280)	(0.0206)				
Winter-Spring Rainfall	-0.0040	0.0311				
	(0.0839)	(0.0711)				
Winter-Spring Rainfall (1 year lag)	-0.0240	0.0597				
	(0.0913)	(0.0690)				
Winter-Spring Rainfall (2 year lag)	-0.0676	-0.0107				
	(0.1051)	(0.0901)				
Winter-Spring Rainfall (3 year lag)	0.2523***	0.2201***				
	(0.0862)	(0.0717)				
Winter-Spring Rainfall (4 year lag)	0.3222***	0.2007***				
	(0.0887)	(0.0632)				
Autumn Rainfall	-0.1189**	-0.0352			-0.2707**	-0.2598**
	(0.0485)	(0.0341)			(0.1064)	(0.1079)
Autumn Rainfall (1 year lag)	-0.0860	-0.0206			-0.2561***	-0.2552***
	(0.0574)	(0.0362)			(0.0818)	(0.0861)
Autumn Rainfall (2 year lag)	0.0073	-0.0307			-0.2066**	-0.2353***
	(0.0557)	(0.0406)			(0.0955)	(0.0886)
Autumn Rainfall (3 year lag)	-0.0630	-0.0752**			-0.2456***	-0.2452***
	(0.0545)	(0.0380)			(0.0952)	(0.0903)
Autumn Rainfall (4 year lag)	-0.1661***	-0.1021**			-0.1759*	-0.1530*
	(0.0621)	(0.0470)			(0.0902)	(0.0886)
Spring-Summer Rainfall					0.3281***	0.3363***
					(0.0889)	(0.0853)
Spring-Summer Rainfall (1 year lag)					0.1131	0.1326
					(0.1057)	(0.1013)
Spring-Summer Rainfall (2 year lag)					0.3801***	0.3673***
					(0.0643)	(0.0623)
Spring-Summer Rainfall (3 year lag)					0.6088***	0.5839***
					(0.1072)	(0.0973)
Spring-Summer Rainfall (4 year lag)					0.3972***	0.3700***
					(0.1248)	(0.1129)
Winter Rainfall					0.0422	0.0145
					(0.1410)	(0.1342)
Winter Rainfall (1 year lag)					0.2771***	0.2233***
					(0.1025)	(0.0856)

Winter Rainfall (2 year lag)					0.3309*** (0.0990)	0.3090*** (0.0896)
Winter Rainfall (3 year lag)					0.0635 (0.1249)	0.0131 (0.1166)
Winter Rainfall (4 year lag)					0.1479 (0.1720)	0.1582 (0.1734)
Number of Observations	23282	23282	8275	8275	8798	8798
Number of Regions	189	189	81	81	61	61

Notes: Robust standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels.
In specification 2 Forward values or negative lagged values of the variables are used.

Table 5: Witch Trials and Hot Summers (Where summer temperature >22°C), 1500-1760

Explanatory Variable	Dependent Variable: Witch Trials & Adjusted Witch Trials					
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
	Witch Trials	Witch Trials	Adjusted Witch Trials	Witch Trials	Witch Trials	Witch Trials
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature Shock				-0.0327 (0.1755)		
Temperature Shock (1 year lag)				0.2156*** (0.0839)		
Temperature Shock (2 year lag)				-0.1222 (0.1754)		
Temperature Shock (3 year lag)				0.1598 (0.1455)		
Temperature Shock (4 year lag)				0.2201 (0.2142)		
Summer Temperature	0.0261 (0.0611)	0.0045 (0.0587)	0.0425 (0.0699)	0.0461 (0.0589)	0.0176 (0.0607)	
Summer Temperature (1 year lag)	-0.1250*** (0.0459)	-0.1240*** (0.0479)	-0.1399*** (0.0431)	-0.1221*** (0.0398)	-0.1325*** (0.0496)	
Summer Temperature (2 year lag)	-0.1275*** (0.0489)	-0.1263*** (0.0542)	-0.1547*** (0.0351)	-0.1030** (0.0481)	-0.1536*** (0.0543)	
Summer Temperature (3 year lag)	-0.1986*** (0.0473)	-0.2004*** (0.0242)	-0.1970*** (0.0469)	-0.1628*** (0.0428)	-0.2170*** (0.0400)	
Summer Temperature (1 year Forward)		0.1120 (0.1062)				
Summer Temperature (2 year Forward)		-0.1152 (0.0718)				
Spring Temperature					0.0435 (0.0573)	

Spring Temperature (1 year lag)				0.0055 (0.0390)	
Spring Temperature (2 year lag)				0.0480 (0.0514)	
Spring Temperature (3 year lag)				0.0463 (0.0574)	
Summer Temperature-Rainfall					-0.5826** (0.2980)
Summer Temperature-Rainfall (1 year lag)					-0.4978 (0.3119)
Sumer Temperature-Rainfall (2 year lag)					-1.2343*** (0.2463)
Summer Temperature-Rainfall (3 year lag)					-1.6340*** (0.4887)
Number of Observations	3755	3755	3753	3755	3734
Number of Regions	33	33	33	33	33

Notes: The sample includes only observations in which summer temperature exceeds 22°C. Robust standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels. In specification 2 Forward values or negative lagged values of the variables are used.

6.2 Real wages, GDP per capita, and grain prices

While climate variability allows us to draw some interesting observations, it may deviate in a number of important respects from actual living standards which are also importantly influenced by population growth and productivity growth as well as plague and war. Using real wages and GDP per capita allows us to track actual living standards over the sample period. Having said this we are restricted to using less data given the limited availability of the economic variables.

We start by considering GDP per capita. We have five regions; Spain, Italy, Holland, England and Sweden. Applying a poisson fixed effects model for witch trials per capita the results are shown in Table 6. War and plague are both significant at the 1% level in all specifications. War lowers witch trials disrupting the normal functioning of society. The effect of plague is theoretically ambiguous as we discussed in section 5.1. In our sample, plague epidemics tend to increase witch trials. GDP per capita is significant at the 5% level over the full sample in specification (3).

Omitting the Holland region from the sample strongly increases the significance of GDP per capita in specification (4). Indeed, Holland is the only region to not show any relationship between GDP per capita and witch trials. We can present two possible reasons for this. Firstly, GDP per capita was considerably higher than the other countries meaning that even in the worst years incomes were still high enough on which to get by. Secondly, in Dutch cities witch trials largely alternated with anababtist trials with respect to the years in which they occurred (Waite, 2007 p.82). GDP per capita data for

Spain is nonstationary[19], although omitting Spain in addition to Holland from the sample does not notably alter the results (specification (5)).

Table 6: GDP per capita and witch trials: 1502-1760

Explanatory Variable	Dependent Variable: Witch Trials per capita					
				w/o Holland	w/o Spain & Holland	
	Poisson	Poisson	Poisson	Poisson	Poisson	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
GDP per capita	-0.00082*	-0.00095*	-0.00097**	-0.0020***	-0.00193***	-0.00535
	(0.00048)	(0.00047)	(0.00045)	(0.00024)	(0.00025)	(0.0038)
War		-1.0344***	-1.0259***	-1.2259***	-1.1859***	-3.8546***
		(0.2439)	(0.2318)	(0.1775)	(0.1726)	(0.7031)
Plague			0.2594***	0.2584***	0.2701***	2.24629
			(0.0637)	(0.0577)	(0.0590)	(1.7545)
Number of Observations	903	903	903	729	481	903
Number of Groups	5	5	5	4	3	5

Notes: Robust standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels.

We calculate the marginal effects for Sweden, the country in our sample displaying the strongest relationship between gdp per capita and witch trials. The results are that for non plague and non war years, witch trials decrease from 5.7885 to 2.12 per year in response to an increase in GDP per capita from 900 to 1400 in 1990 dollar prices.

For the real wages and grain prices analysis we have six regions in our sample; Madrid, Valencia, Stockholm, Munich, London, and Amsterdam. Again applying a fixed effects poisson model we present the results in Table 7. Real wages are not significant. We note here the apparent disparity between the effects of GDP per capita and real wages on witch trials, and discuss this at greater length in Section 6.3. War is significant at the 1% level, while plague is not significant in this case.

[19] Since it is a 10 year moving average.

Table 7: Real wages, grain prices and witch trials: 1504-1754

Explanatory Variable	Dependent Variable: Witch Trials per capita					
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
	(1)	(2)	(3)	(4)	(5)	(6)
Real wages	0.0396 (0.070)	0.0064 (0.0708)	0.0138 (0.0660)			
Wheat price deviation				-0.5330 (0.4045)		
Wheat price spike dummy 1[20]					-0.2316 (0.2274)	
Wheat Price spike dummy 2[21]						-0.5257*** (0.1898)
War		-1.2455** (0.5667)	-1.2491** (0.5857)	-1.1962** (0.6063)	-1.2093** (0.6002)	-1.1684** (0.5636)
Plague			-0.0232 (0.1391)	0.0111 (0.1096)	-0.0011 (0.1119)	0.0014 (0.1223)
Number of Observations	924	924	924	903	903	903
Number of Groups	6	6	6	6	6	6

Notes: The six regions used are Valencia, Madrid, Stockholm, Amsterdam, Munich, and London. Robust standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels.

Grain price variation has been used to identify income shocks on witch trials ((Baten & Woitek, 2001), (Baten & Woitek, 2003), (Behringer, 1995, 1999)), with higher grain prices representing diminished purchasing power, and frequently subsistence crises. The inundation of new silver from South America during this time makes it problematic to have directly comparable grain prices over the entire sample period. Instead, we use a Hodrick Prescott filter to derive the short run deviations. Despite this, it may not be possible to completely eradicate the silver supply component from wheat price. Nevertheless, the high short term variation in wheat prices suggest that it retains a high degree of information about the true cost of grains. Another implication of taking deviations from the trend is that increases from a low level are treated equally to increases from an already high level.

High grain prices are not necessarily bad in and of themselves. What is more important is the agricultural output of the region. Increased prices on their own merely represents a redistribution of benefits within society towards farmers. If the region is a grain exporter then higher prices may even benefit the region overall. As Berg (2003) argues, in those cases where grain is imported, prices should be determined by the imported grain which is the marginal supply of grain. Edvinsson (2008)

[20] Dummy variable = 1 if wheat price shock > 0.15 (161 observations), 0 otherwise.

[21] Dummy variable = 1 if wheat price shock > 0.3 (72 observations), 0 otherwise.

shows that for Sweden, where detailed information on harvest quality is available, 57% of the variance of domestic prices is explained by harvest quality and 33% by the foreign price[22].

In Table 8 we show the improved results from using a harvest variable on witch trials rather than wheat prices. Harvest pc dummy 1 takes the value of 1 for the 21 worst harvests and 0 otherwise. Specification (1) shows a 'bad' harvest significantly increases the number of witch trials at the 5% level. Modifying the harvest dummy variable to include exceptionally good harvests somewhat improves the results (specification (2)-(4)). The implication being that any sizable deviation from ordinary agricultural output, good or bad, causes witch trials to increase. A surplus of supply could act to drive prices below cost, thus negatively impacting farmers. Wheat price shock dummy 1 and 2 are analogous except with conditions represented by deviations from trend price rather than harvest quality.

While prices may not provide a very good fit for local farming conditions we can look at some anecdotal cases of severe subsistence crises in Europe and their impact on witch trial cases. One example is that of the 1696-97 famine in Finland in which a third of the population died (Jutikkala, 1955). There was no discernible effect on witch trials however. After six steady years of trials remaining above ten a year in 1696 there were eight and in 1697 just three. Similarly, during the 1590-93 subsistence crisis in Modena in Italy only one trial was held in these four years. During this episode in Modena the rural areas in particular became very unsafe. Stories abound of bandits attacking rural houses and torturing villagers in hope of finding food (Alfani, 2011). Thus, given these warlike conditions, extreme subsistence crises may somewhat counteract the income effects of poorer harvests. There is some evidence of this in the Sweden harvest data. The worst harvest years, though giving higher than average witch trials, were not the highest. Those harvests which were merely 'bad' resulted in higher witch trials. Furthermore, in Table 7 the wheat price dummy using only extreme price spikes is negatively significant implying that subsistence crises decrease witch trials (Specification (6)). Using the milder wheat price spike dummy in (5) produces no apparent relation. Similarly, in Table 8 using only the more extreme wheat price spikes in (7) leads to a downward shift in the coefficient on witch trials per capita.

[22] Sweden imported large quantities of grain from the Baltic states, especially during periods of poor harvests (Kirby, 2014 pp.241-42)

Table 8: Witch Trials, Harvest Quality and Wheat prices in Sweden, 1665-1754

Explanatory Variable	Dependent Variable: Witch Trials per capita						
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Harvest pc index Dummy 1	0.4069** (0.1643)						
Harvest pc index Dummy 2		0.4483*** (0.1545)	0.4586*** (0.1526)	0.4452*** (0.1509)			
Wheat price shock Dummy 1					0.3463** (0.1726)		
Wheat price shock Dummy 2						0.2925* (0.1599)	
Wheat price shock Dummy 3							0.0699 (0.1822)
War			-0.6322* (0.3365)	-0.6497* (0.3367)	-0.6565** (0.3241)	-0.5924* (0.3234)	-0.6374* (0.3604)
Plague				-0.5436* (0.3253)	-0.5372 (0.2871)	-0.6519** (0.2836)	-0.6235* (0.3251)
Number of Observations	90	90	90	90	90	90	90

Notes: Robust standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels. 'Harvest pc index Dummy 1' takes a value of 1 for the 21 worst harvests, and 0 otherwise. 'Harvest pc index Dummy 2' takes the value of 1 for the 17 best harvests, the 21 worst harvests, and 0 otherwise. Analogously, 'Wheat price shock Dummy 1' takes a value of 1 for the 21 biggest positive wheat price deviations from trend, and 0 otherwise. 'Wheat price shock Dummy 2' takes the value of 1 for the 17 biggest positive wheat price deviations, the 21 biggest negative wheat price deviations from trend, and 0 otherwise. 'Wheat price shock Dummy 3' for the 5 biggest positive wheat price deviations (>0.3).

6.3 England

We devote a section looking at the English case in particular owing to the quality of the data. In addition to the variables considered already we also have the dependency ratio (nonworking age-working age population ratio), business cycle troughs, real wages for various occupations, and a highly detailed population series. We also have available GDP data disaggregated by sector.

We present the results in Table 9. GDP per capita significantly affects witch trials per capita in all specifications. Business cycle troughs represent short term downturns in the economy and its significance at the 5% level in specification (2) indicates that short run economy dynamics are important in determining witch trials. Cycle troughs lagged one year are significantly negative indicating that witch trials are lower in the first year of the upswing phase of the cycle. Combining GDP per capita and business cycle troughs in the same specification in (4) leads to a weakening in significance of both variables due to multicolinearity, and lack of sample size. However, evidence remains that both the long run level of GDP per capita and short run downturns affect persecution. The results imply that witch trials in trough years were almost double those in non-trough years[23].

Plague lagged one year is significantly negatively related to witch trials. This differs to results in the previous section, suggesting that the belief of whether plague was thought to be caused by witches may have differed across countries. We have noted previously how witches were accused of 'plague spreading' in Switzerland. In England, on the other hand, witches were not thought to be responsible for plague which is consistent with our results (Macfarlane, 1999 pp.179-180). Plague may be indirectly acting to reduce witch trials if it reduces the number of dependents and surplus labour. Real wages and GDP per capita substantially increased following the Black Death in 1348-1349 (Broadberry et al., 2010). Localised plague outbreaks in Essex may have impacted regional economic conditions not picked up in national GDP per capita figures. While 'War' is significant it should be noted that there was only one year, 1648, in which conflict occurred in Essex.

Of interest is the different effect of the variables GDP per capita and real wages on witch trials. While they are both ostensibly measures of economic wellbeing, GDP per capita seems to display a strong relationship with witch trials while real wages do not. Figure 5 compares the evolution of different series of real wages with GDP per capita over 1500-1700. It is clear that GDP per capita grew more rapidly than any of the measures of real wages. Indeed, for farm workers real wages were by 1675, at the end of our sample and by which point witch trials were dying out, still below their level of the 1580's when the witch trials were at their peak.

Angeles (2008) finds that the divergence between real wages and GDP per capita can largely be explained by an increase in per capita labour hours worked. This reflects not only the increase in days worked per year by existing workers but is also consistent with the entry into the labour market of women. Muldrew (2012) documents the importance of advancements in the spinning industry during the 17th century. Overall, employment from spinning increased from 225,083 in 1580 to 481,564 in 1700. Furthermore, spinning was largely done by single women and women and children of poorer

[23] Using the specification in (6) and assuming the year to be without plague, predicted witch trials in non-trough years are 16.5 per million population, increasing to 29.35 in trough years.

families. This source of income would have been significant – a 42% increase in the case of married women- and could well have been the difference keeping these women from having to beg from their neighbours. The evolution of the spinning industry could be particularly pertinent for our sample given that many of the towns and villages in which the witch trials occurred were dependent on it (Macfarlane, 1999 p.149).

The increase in per capita labour supply makes it problematic to use the Williamson Index[24] as a measure of inequality. Nevertheless it does seem that inequality did increase during this period (Hoffman et al., 2002). One factor which may have ameliorated the effects of low wages was the development of the poor laws in the 17th century.

The population had grown strongly, as in much of Europe, doubling over the 16th Century. The rapid expansion was greater than the economy could absorb, and during the latter part of the century in particular reports of unemployment were frequent. The dissolution of the monasteries, from 1536-1541, with the reformation, 'left a huge vacuum' in aid for the poor according to Slack (1990a). As an example, at Westminster Abbey the monks distributed £400 per annum, or 10% of the Abbey's gross income, to the poor of Westminster and London (Harvey, 1993).

The actions of government to deal with the increasing strain from overpopulation were initially inclined towards severity. Poor law acts were passed in 1552, 1563, 1572, and 1576 with the 1572 act, coinciding with the first year of elevated witch trials, calling for offenders to be bored through the ear for a first offence. The poor law of 1597 was more compassionate in nature, and established overseers for the poor. Funding for the poor relief after 1597 came from landowners, and thus represents a form of redistribution of wealth between different strata's of society and thus effectively supplementing the incomes of the poor.

Early poor rates and workhouses were less comprehensive than in later years. It was not until 1660 that the coverage of the poor laws really took off with poor rates reaching 1% of national income in 1750 enabling 8% of the population to take relief (Slack, 1990a p.45). Nevertheless, these early efforts must have helped to some degree in shifting the responsibility of care for the poor from individuals to the state.

Another factor related to economic hardship is the dependency ratio. Those families close to the subsistence level could well be pushed beyond their means by increased dependants (Norberg, 1985 pp.104-107). A graphical representation, in Figure 6, would indeed seem to indicate a relationship between the dependency ratio and witch trials.

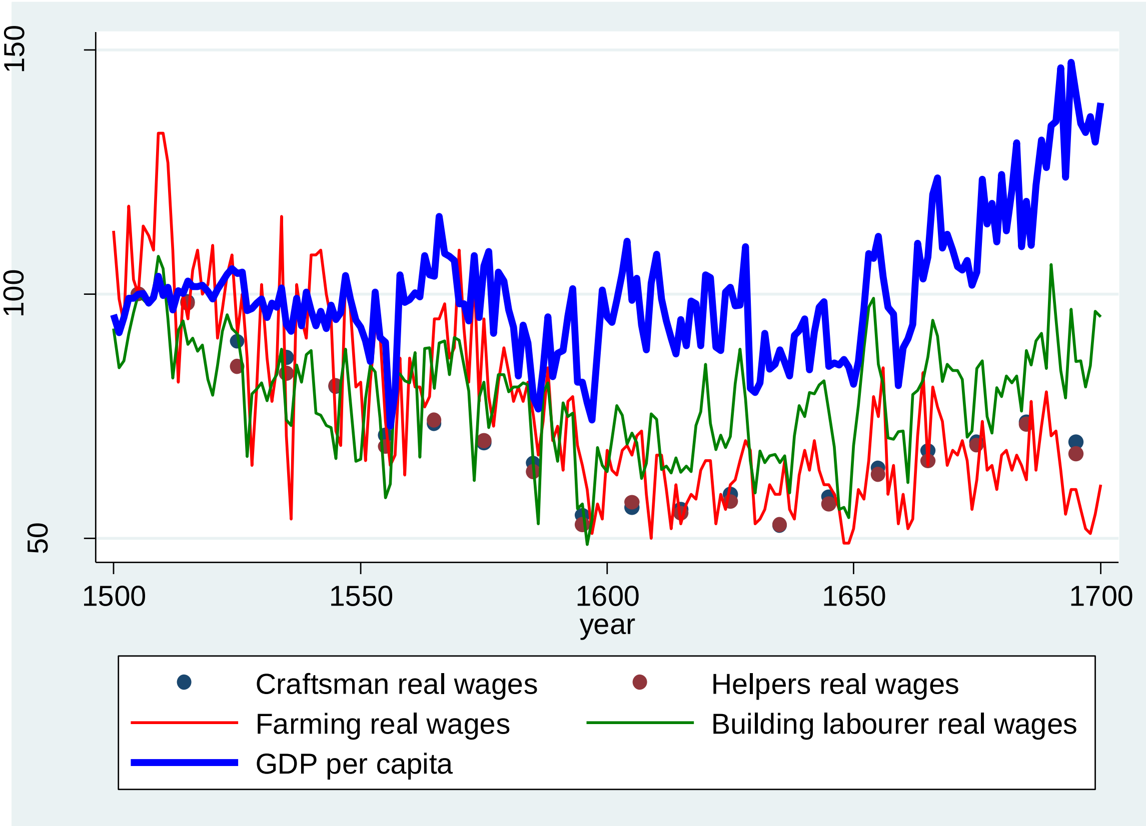
[24] Proposed by Williamson (1997), the Williamson Index is an inequality index defined as a ratio between the GDP per capita or per worker and the unskilled wage.

Table 9: Witch Trials in England, 1560-1675

Explanatory Variable	Dependent Variable: Witch Trials per capita							
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GDP per capita	-0.0360** (0.0178)				-0.0271* (0.0157)	-0.0272* (0.0156)	-0.0286* (0.0155)	-0.5471* (0.3165)
Business Cycle Trough		0.5602** (0.2840)			0.4428* (0.2626)	0.4552* (0.2671)	0.4334 (0.2666)	9.5864 (6.9079)
Business Cycle Trough 1 year lag			-0.4786* (0.2470)					
Real Wages				0.1303 (0.1155)				
Plague (1 year lag)						-0.6641** (0.3202)	-0.6742** (0.3214)	-10.23** (4.2298)
War							-22.776*** (1.0188)	-21.4*** (3.7220)
Number of Observations	116	116	116	116	116	115	115	115

Notes: Robust standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels.

Figure 5: Real Wages vs GDP per capita in England, 1500-1750



Notes: Craftsman real wages and Helpers real wages are paired data (craftsman with helper); All series normalised to 100 in 1505; Sources: GDP pc (Broadberry, 2010), Craftsman & Helpers real wages (Clark, 2005), Farming real wages (Clark, 2007), Building labourer real wages (Allen, 2001).

Broadberry et al's. (2010) detailed breakdown of English GDP into sectors of the economy affords us the possibility to look at the relationship between climate variation and agricultural output and GDP in general for the case of England. We apply a Hodrick-Prescott filter to obtain the cyclical component of Agricultural output[25]. Given the limited sample size, we are not able to look in as much detail as in the climate section of this paper, but applying a parsimonious specification suggests some evidence for a negative impact of weather shocks on agriculture in Table 10. Yearly temperature shock[26] from the prior year and spring rainfall shock are both significant at the 10% and 5% level respectively.

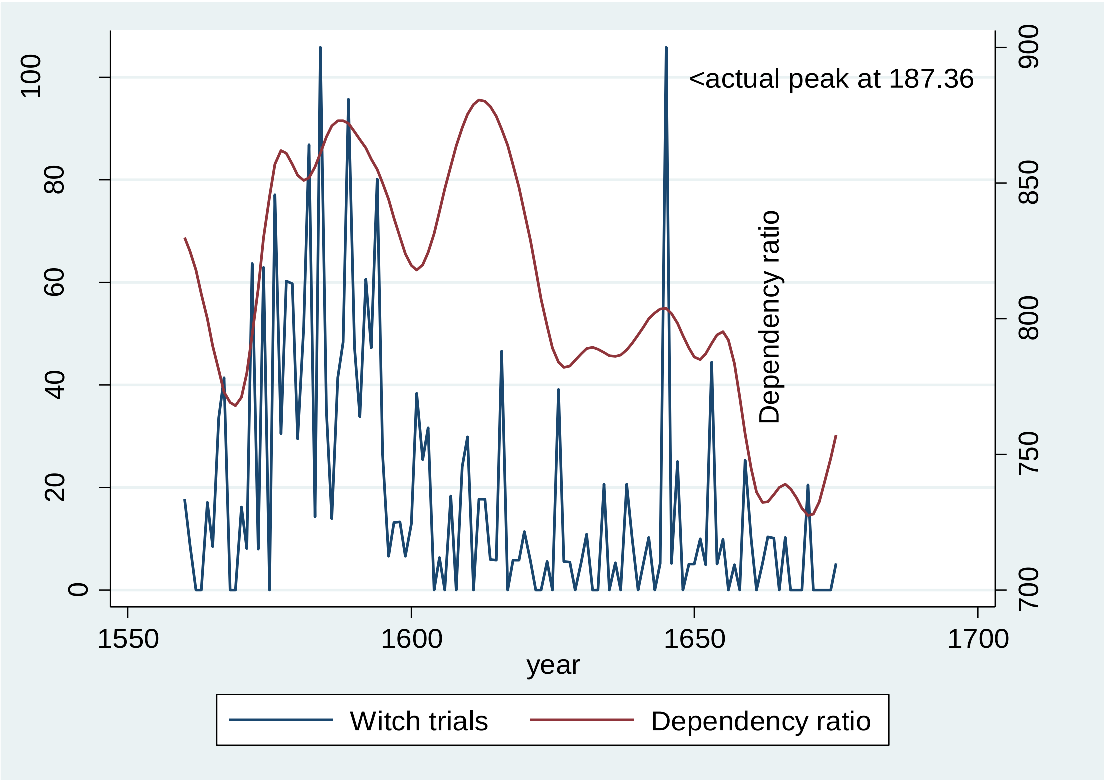
Using only the cyclical component of agricultural output means that we only consider the short term fluctuations to GDP. Given that the volatility of the agricultural sector is so much greater than the remainder of the economy, as can be seen from Figure 7, these shocks do represent well the short run dynamics of the economy overall. However, over the medium and long term it was productivity growth and population growth which had a far greater influence on GDP per capita. GDP per capita was able to increase from 1560 onwards in England, due to the rapid increase in the services and

[25] Using a lambda of 1600.

[26] Calculated as in section 5.1.

industry sectors even as the agricultural sector was hit by deteriorating climate on into the little ice age.

Figure 6: Witch trials vs Dependency Ratio

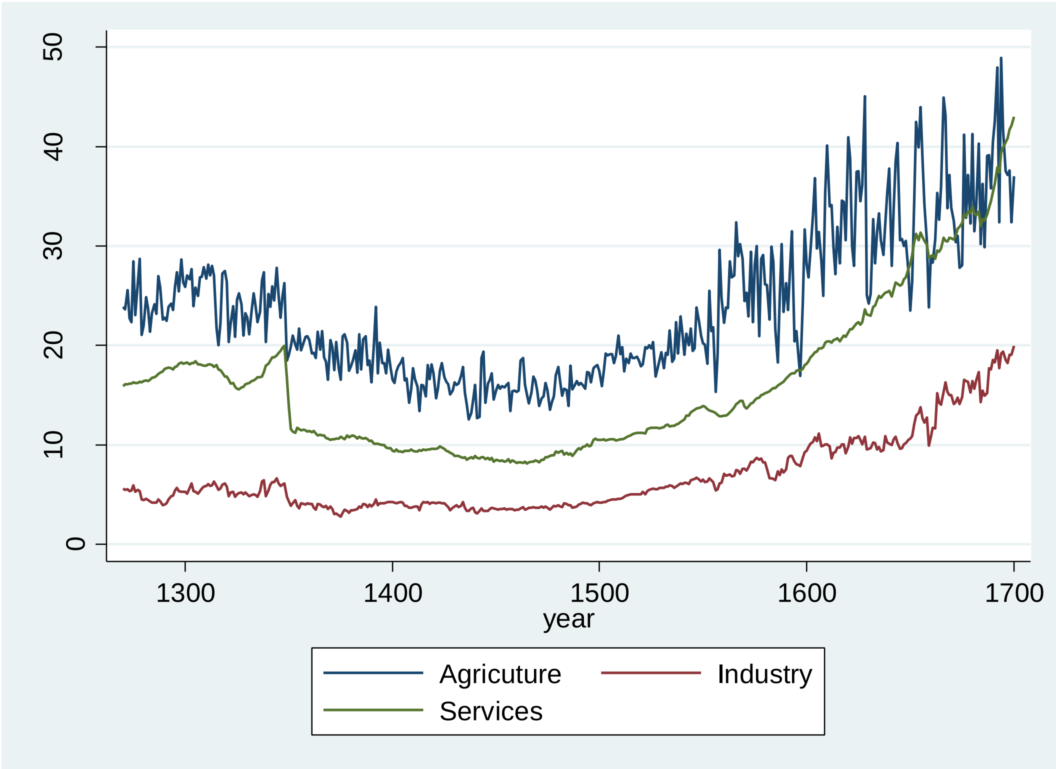


Notes: The dependency ratio is defined as the number of non working age population (less than 15 years and greater than 59 years of age) per 1000 working age population (aged 15-59 years). Source: (Wrigley & Schofield (1989), p.447 - Table 10.6)

It is clear from Figure 7 that agricultural output volatility does increase markedly from around 1560 onwards, in line with the start of the little ice age and the onset of witchcraft trials in earnest. Two developments can be noted which would have ameliorated the fallout from this. Firstly, as England moved away from being an agrarian economy – from 53% agricultural share of total output in 1560 to 37% in 1700 (Broadberry et al., 2010; Crafts, 1985 p.16) – agricultural shocks had less of an effect overall. Secondly, strong agricultural productivity growth in the century following 1550 allowed England to go from being a grain net importer to an exporter by 1650 allowed the country to remain self sufficient, often even in bad years[27] (Goldstone, 1991 p.79; Hoskins, 1968).

[27] The county of Essex itself was a grain exporter for the whole period (Band, 2011 p.3).

Figure 7: Output by sector in England, 1270-1700



Notes: All sectors combined indexed to equal 100 in 1700. Source: Broadberry et al. (2010), Crafts (1985, p.16)

Table 10. Agricultural Output and climate, 1500-1700

Explanatory Variable	Dependent Variable: Cyclical component of agricultural output			
	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)
Temperature Shock (1 year lag)	-1.4942* (0.8571)		-1.5207* (0.8433)	-1.6068* (0.8467)
Spring Rainfall Shock		-0.0402** (0.0185)	-0.0407** (0.0185)	-0.0398** (0.0186)
War				-1.6095 (0.0186)
Number of Observations	200	201	200	200

Notes: Robust standard errors given in parenthesis.   ***/**/* denotes significance at the 1%/5%/10% levels.

7. Conclusion

While this paper has produced a number of new results it has also brought into focus the difficulty of identifying specific underlying causes of witch trials when war, plague, population growth, agricultural output, and economic wellbeing are so interconnected. Furthermore, we have highlighted the difficulty in using climate variation to proxy for other related phenomena.

The evidence presented indicates that it is climates' variation with respect to factors such as agriculture and disease, rather than directly in and of itself that causes witch trials. It is the deviation around the regional mean, which relates to farming, which is most significant in determining witch trials. Perhaps the most obvious place to observe any such comfort effect of climate on witch trials is in winter temperatures. Colder temperatures should increase witch trials through both the comfort and agricultural channels. However, this is not observed in the data as colder temperatures actually lead to less witch trials.

Our findings also have relevance for modern day persecution. Particularly in areas heavily dependent upon agriculture or prone to disease epidemics. This is particularly the case when the disease is new or unknown and there is evidence that the ebola outbreak in West Africa in 2014 has been linked with witchcraft (Zaimov, 2014). Given that the weather may become increasingly erratic, and disasters such as hurricanes and flooding may be more common, there is also the potential for an increase in witchcraft for this reason.

The results from the GDP per capita analysis again indicate that economic wellbeing is an important driver of witch trial accusations, and not necessarily directly related to agriculture. The lack of predictive power of real wages on witch trials indicates that it was total earnings rather than earnings power which determined the propensity to target witches. Precursory evidence from England points to both absolute living standards as well as shorter run cyclical economic conditions as factors dictating persecution.

It is quite clear in the England analysis that the effect of the economic downturn on witch trials is felt in the lowest point of the cycle, after which the number of trials recedes. This is somewhat at odds with the results from the climate section and anecdotal evidence which suggest that it often took a number of years between the perceived infraction and the trial being brought. This incongruity could be due to the richer dataset in the climate section allowing more complex relationships to be identified. It is also the case that climate and the business cycle trough may not be directly comparable variables.

Our analysis shows a strong diminishing effect of war on witch trials. The evidence regarding plague is mixed. In the climate section and GDP per capita section plague is seen to increase witch trials while elsewhere it does not. This is consistent with the anecdotal evidence which suggests that witches were only seen as spreaders of plague in some areas and not in others.

A recurring theme throughout the analysis has been the importance of a certain modicum of stability for witch trials to flourish. Witch trials represent a state approved outlet for communities' discontent whereby the wider community singles out certain individuals for persecution. This relies on a certain cohesion in society in order for the unfortunate suspects to be weeded out and the effective working of the courts for them to be tried; both of which can be found lacking in times of war, famine or pestilence. At such times other non state approved outlets, such as food riots or general lawlessness, may prevail.

In further work, it would be of interest to investigate how witch trials relates to persecution of immigrants, of those from other religious beliefs, and other types of persecution. The inquisition in Spain and Italy in the early modern period included the witch trials as just one of a number of offences, and it's rich documentation make it a useful place to start.

Appendix

Data and Sources

Appendix 1.

Table A1.1 Witch trial data for Section 6.1.

Region	Number of Accusations	Period	Source
Germany	**9320**		
South West Germany	4205	1504-1700	Midelfort (1972)
South East Germany	3331	1505-1755	Behringer (1997)
Westphalia	1141	1562-1732	Decker (1981)
Trier	643	1516-1660	Dillinger (2009)
Scotland	**3074**	1549-1727	Goodare et al.(2003)
Italy	**2975**		
Italy (Other)	2708	1506-1760	Seitz (2014), Prodi & Spaggiari (2003)
Italian Tirol	267	1503-1753	Rabanser (2006)
Switzerland	**2484**		
Pays de Vaud	974	1580-1620	Kamber (1982), Kamber (1998)
Lucerne	589	1500-1686	Jäggi (2014)
Geneva	317	1527-1681	Monter (1976)
Neuchatel	314	1568-1677	Monter (1976)
Solothurn	153	1531-1715	Kocher (1943)
Surselva	137	1619-1718	Giger (2001)
Hungary	**2004**	1502-1760	Tóth (2000)
Austria	**1435**		
East Austria	1124	1513-1759	Schleich (1999)
Vorarlberg	156	1528-1656	Waite (2007)
Austrian Tirol	155	1509-1759	Rabanser (2006)
France	**1407**		
Franche-Comte	198	1599-1667	Monter (1976)
Lorraine	1209	1571-1630	Briggs (2003)
Spain	**1164**		

Castilla	362	1518-1760	Estopañán (1942)
Aragon	180	1500-1662	Tausiet (2004)
Barcelona	287	1552-1690	Knutsen (2009)
Valencia	335	1554-1692	Knutsen (2009)
Romania	**1111**	1562-1760	Tóth (2000)
Norway	**910**	1539-1732	University of Oslo (2013)
Belgium	**712**		
Flanders	352	1502-1692	Monbalyu (2002a), Monbalyu (2002b), Monbalyu (1996)
Namur	360	1509-1646	Brouette (1954)
England	**544**		
South East England	544	1560-1701	Macfarlane (1999), Ewen (2003)
Finland	**533**	1620-1700	Nenonen (1992)
Denmark	**494**	1609-1687	Ankarloo & Henningsen (1990)
Slovakia	**493**	1548-1759	Tóth (2000)
Sweden	**350**	1634-1754	Sörlin (1999)
Netherlands	**339**		
Holland	286	1502-1726	Waardt (1991)
Roermond	53	1522-1613	Dresen-Coenders (1983)
Russia	**258**	1589-1705	Muravyeva (2014)
Croatia	**193**	1565-1751	Tóth (2000), Seitz (2014)
Channel Islands	**146**		
Jersey	66	1558-1661	Bellows (2011)
Guernsey	80	1563-1634	Bellows (2011)
Ukraine	**58**	1638-1750	Tóth (2000)
Greece	**26**	1584-1691	Seitz (2014)
Serbia	**6**	1728-1732	Tóth (2000)
Total	**30036**	**1500-1760**	

Table A1.2: Environmental Zones in Europe

Zone	Countries Included	No. of Regions	No. of witch trials	Climactic conditions	Growing Season	Average Temperature	Average Rainfall
Alpine North (ALN)	Norway	11	460	Grasslands	Short (130 days)	1.92°C	345mm

Boreal (BOR)	Finland Russia Norway	31	1815		Short (157 days)	2.94°C	142mm
Alpine South (ALS)	Switzerland, Austria, Hungary, Spain	19	799		Intermediate-Short (220 days)	3.42°C	337mm
Nemoral (NEM)	Sweden, Norway	11	335		Intermediate-Short (196 days)	5.93°C	165mm
Continental (CON)	Sweden, Switzerland, Germany, Hungary, Norway	66	9936	Most of the land is fertile and employed in crop production.	Intermediate-Short (227 days)	7.52°C	217mm
Atlantic North (ATN)	Scotland Norway Denmark Germany	27	3761		Intermediate (255 days)	7.62°C	268mm
Pannonian (PAN)	Hungary, Romania	30	2519		Intermediate (250 days)	9.24°C	169mm
Atlanntic Central (ATC)	England Belgium Netherlands France Germany	56	4711		Intermediate-long (296 days)	9.37°C	189mm
Mediterranean Mountains (MDM)	Hungary, Croatia, Italy, Spain	36	570	transhumance flocks & small scale agricultures on terraces.	Intermediate-Long (298 days)	9.65°C	207mm

Mediterranean North (MDN)	Italy, Croatia, Spain	36	2431		Long (335 days)	11.45°C	221mm
Mediterranean South (MDS)	Spain	13	814		Long (363 days)	13.62°C	114mm

Appendix 2

Table A2.1: Population data for GDP pc section.

Country	Source
England	Broadberry et al. (2011), Broadberry et al. (2010)
Italy	Malanima (2011)
Spain	Reher (2014)
Holland	Van Zanden & Van Leeuwen (2012)
Sweden	Schön & Krantz (2012), Palm (2000)

Table A2.2: GDP per capita.

Country	Source
Spain	Alvarez-Negal & Escosura (2013)
Italy	Malanima (2011)
Holland	Van Leeuwen & Van Zanden (2009)
England	Broadberry et al. (2011)
Sweden	Schön & Krantz (2012)

Table A2.3: Witch Trials for GDP pc section

Country	Period	No. of Trials	Source
Spain	1513-1760	458	Estopañán (1942)
Italy	1517-1760	1588	Prodi & Spaggiari (2003)
Holland	1528-1726	436	Waardt (1991)
England	1560-1675	348	Macfarlane (1999)
Sweden	1634-1754	349	Sörlin (1999)
TOTAL	**1513-1760**	**3179**	

Table A2.4: Plague Epidemics for GDP pc section

City	Source
Holland	Noordegraaf & Valk (1996), Goldgar (2008), de Blécourt (1993)
Germany	Behringer (2003), Fries (1964), Eckert (1996), Eckert (2000), Watteck (1983)
Spain	Casey (2002), Thompson & Casalilla (1994), Payne (1973), Scott & Duncan (2001), Gelabert & González (2001)
England	Slack (1990b), Shrewsbury (2005), Totaro (2012), Creighton (1894), Kohn (2007)
Sweden	Frandsen (2010)

Table A2.5: War for GDP pc section

City	Source
Holland[28]	Hart (2014)
Germany	Parker (1997)
Spain	Barton (2009), Kamen (1969), Glete (2002)
England	Worden (2009)
Sweden	Frost (2014)

Appendix 3

Table A3.1: Population data for real wages & grain price shock section.

Region	Source
Amsterdam (Holland)	Van Zanden & Van Leeuwen (2012)
Munich (Germany)	Pfister & Fertig (2010)
Essex (England)	Broadberry et al. (2011), Broadberry et al. (2010)
Valencia (Spain)	Moreda (1988), Reher (2014)
Madrid (Spain)	Reher (2014)
Stockhom (Sweden)	Palm (2000), Schön & Krantz (2012)

[28] It is difficult to decide how to classify 'war'. Here we classify war if a major conflict occurred for that region in that year. Holland is particularly problematic, because the sample period coincided with the 'eighty years war'. We specified war for the years 1568-1579 after which point Holland was largely secure from Spanish attack. Nevertheless, the rural areas were still subject to marauding soldiers, and the occasional foray from Spanish forces which still held much of the Southern Netherlands (Hart, 2014 p.103).

Table A3.2: Real wages and & grain prices

City	Source
Amsterdam (Holland)	Allen (2001)
Munich (Germany)	Allen (2001)
Madrid (Spain)	Allen (2001)
Valencia (Spain)	Allen (2001)
London (England)	Allen (2001)
Stockholm/Ostergotland (Sweden)	Söderberg (2010), Hansson (2006)

Table A3.3: Witch trials for real wages & grain price shock section.

Region	Period	No. of Trials	Source
Amsterdam	1529-1700	179	Waardt (1991)
Munich	1578-1755	570	Behringer (1997)
London	1560-1675	348	Macfarlane (1999)
Valencia	1566-1692	332	Knutsen (2009)
Madrid	1551-1760	196	Estopañán (1942)
Stockholm	1634-1754	349	Sörlin (1999)
Total	**1529-1760**	**1974**	

Table A3.4: Plague Epidemics for real wages & grain price shock section.

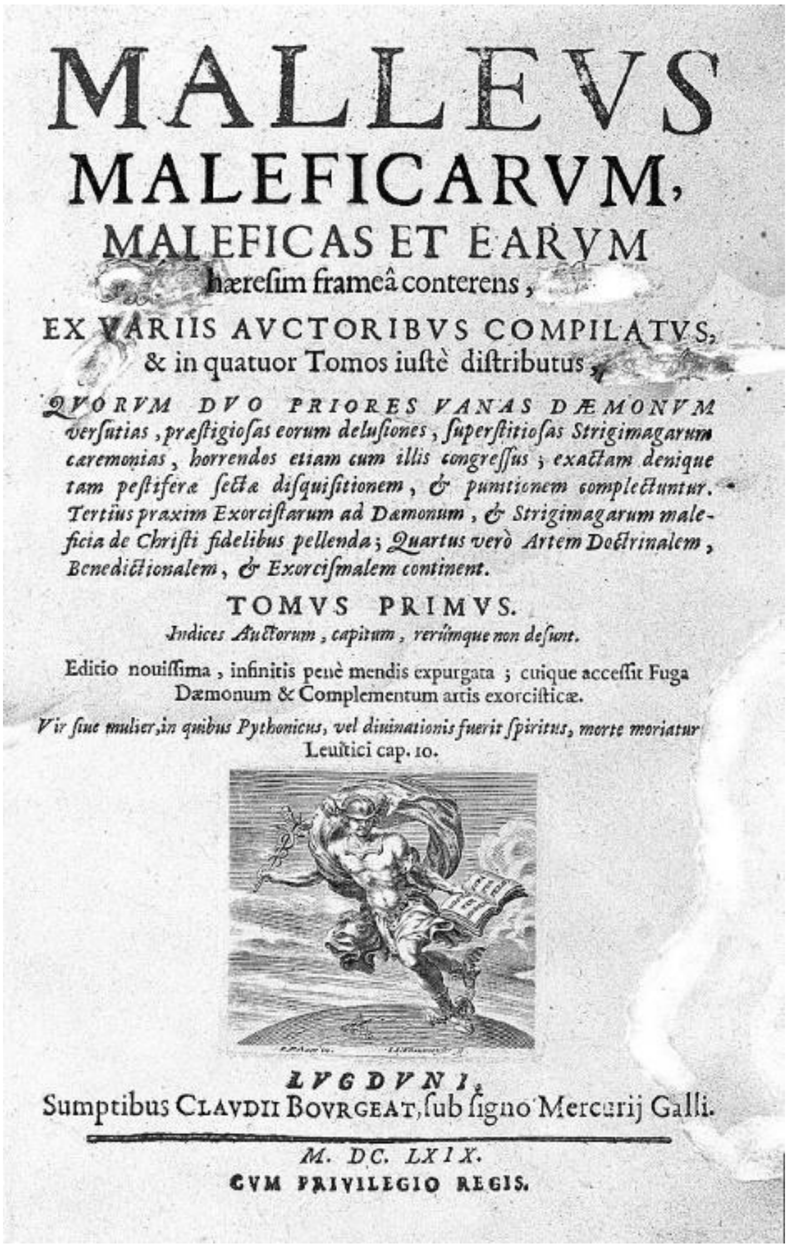
City	Source
Amsterdam (Holland)	Noordegraaf & Valk (1996), Goldgar (2008), de Blécourt (1993)
Munich (Germany)	Behringer (2003), Fries (1964), Eckert (1996), Eckert (2000), Watteck (1983)
Madrid (Spain)	Casey (2002), Thompson & Casalilla (1994), Payne (1973), Scott & Duncan (2001), Gelabert & González (2001)
Valencia (Spain)	Casey (2002), Casey (2008), Thompson & Casalilla (1994), Scott & Duncan (2001)
London (England)	Slack (1990b), Shrewsbury (2005), Totaro (2012), Creighton (1894), Kohn (2007)
Stockholm (Sweden)	Frandsen (2010)

Table A3.5: War for real wages & grain price shock section.

City	Source
Amsterdam (Holland)	Hart (2014)
Munich (Germany)	Parker (1997)
Madrid (Spain)	Barton (2009), Kamen (1969), Glete (2002)
Valencia (Spain)	Barton (2009), Kamen (1969), Glete (2002)
London (England)	Worden (2009)
Stockholm (Sweden)	Frost (2014)

Appendix 4

Figure A4.1


MALLEVS
MALEFICARVM,
MALEFICAS ET EARVM
hæresim frameâ conterens,
EX VARIIS AVCTORIBVS COMPILATVS,
& in quatuor Tomos iustè distributus,

QVORVM DVO PRIORES VANAS DÆMONVM versutias, præstigiosas eorum delusiones, superstitiosas Strigimagarum cæremonias, horrendos etiam cum illis congressus; exactam denique tam pestiferæ sectæ disquisitionem, & punitionem complectuntur. Tertius praxim Exorcistarum ad Dæmonum, & Strigimagarum maleficia de Christi fidelibus pellenda; Quartus verò Artem Doctrinalem, Benedictionalem, & Exorcismalem continent.

TOMVS PRIMVS.
Indices Auctorum, capitum, rerúmque non desunt.

Editio nouissima, infinitis penè mendis expurgata; cuique accessit Fuga Dæmonum & Complementum artis exorcisticæ.

Vir siue mulier, in quibus Pythonicus, vel diuinationis fuerit spiritus, morte moriatur. Leuitici cap. 10.

LVGDVNI,
Sumptibus CLAVDII BOVRGEAT, sub signo Mercurij Galli.

M. DC. LXIX.
CVM PRIVILEGIO REGIS.

Title page of an edition of Malleus Maleficarum (“Hammer of the Witches”) dated 1669.

Figure A4.2

Witches' Sabbath, 1797-98. Francisco Goya. Museo Lázaro Galdiano, Madrid

Figure A4.3

A True
RELATION
Of the
ARAIGNMENT
Of eighteene
VVITCHES.
That were tried, convicted, and condemned, at a Seſſions holden at St. *Edmunds-bury* in *Suffolke*, and there by the Iudge and Iuſtices of the ſaid Seſſions condemned to die, and ſo were executed the 27. day of *Auguſt* 1645.
As alſo a Liſt of the names of thoſe that were executed, and their ſeverall Confeſſions before their executions.
VVith a true relation of the manner how they find them out.

The names of thoſe that were executed.

Mr. *Lewes* parſon of *Branſon*.
Thomas Evered a Cooper with *Mary* his wife.
Mary Bacon.
Anne Alderman.
Rebecca Morris.
Mary Fuller.
Mary Clowes.
Margery Sparham
Katherine Tooley.
Sarah Spinlow.
Iane Limſtead.
Anne Wright.
Mary Smith.
Iane Rivers.
Suſan Manners.
Mary Skipper.
Anne Leech.

Printed at *London* by *I. H.* 1645.

Front page of a pamphlet published in 1645, describing the witch trial in Bury St. Edmunds, Suffolk which took place in August 1645.

Figure A4.4

Witches cause a hailstorm, illustration from the “De Laniss et phitonicis mullieribus” [Concerning Witches and Sorceresses], by the scholar Ulrich Molitoris, published in 1489.

Appendix 5

Table A5.2: Witch Trials and Climate Shocks

Explanatory Variable	Dependent Variable:					
	Witch Trials					Adjusted Witch Trials
	NB	NB	NB	NB	NB	NB
	(1)	(2)	(3)	(4)	(5)	(6)
30 Year Fixed Effects	NO	NO	NO	YES	NO	NO
Year Fixed Effects	NO	NO	NO	NO	YES	NO
Year			0.0086*** (0.0028)			
Year squared			-0.00015*** (0.00001)			
Temperature Shock	0.1435*** (0.0449)	0.1462** (0.0573)	0.1308*** (0.0443)	0.1262 * (0.0441)	0.1833** (0.0856)	0.1273*** (0.0379)
Temperature Shock (1 year lag)	0.1747*** (0.0541)	0.1794*** (0.0692)	0.1610*** (0.0546)	0.1491** (0.0570)	0.2615*** (0.0765)	0.1728*** (0.0420)
Temperature Shock (2 year lag)	0.1806*** (0.0569)	0.1806** (0.0725)	0.1662*** (0.0590)	0.1412*** (0.0527)	0.0741 (0.0876)	0.1906*** (0.0378)
Temperature Shock (3 year lag)	0.2954*** (0.0698)	0.2922*** (0.0851)	0.3055*** (0.0685)	0.2726*** (0.0680)	0.2005** (0.0991)	0.2212*** (0.0420)
Temperature Shock (4 year lag)	0.2831*** (0.0495)	0.2777*** (0.0540)	0.2705*** (0.0493)	0.2506*** (0.0520)	0.3037*** (0.0663)	0.2191*** (0.0416)
Temperature Shock (1 year Forward)		0.0283 (0.0471)				
Temperature Shock (2 year Forward)		-0.0478 (0.0726)				
Temperature Shock (3 year Forward)						
Rainfall Shock	0.2225* (0.1328)	0.2174 (0.1490)	0.0978 (0.1402)	0.1876 (0.1380)	0.2549* (0.1364)	0.0634 (0.0593)
Rainfall Shock (1 year lag)	0.1288 (0.1095)	0.1216 (0.1165)	-0.0051 (0.1046)	0.0701 (0.1086)	0.2391* (0.1368)	0.1996** (0.0811)
Rainfall Shock (2 year lag)	0.1945* (0.1005)	0.1906* (0.1120)	0.0222 (0.1006)	0.1133 (0.1066)	0.1587 (0.1314)	0.1156* (0.0657)
Rainfall Shock (3 year lag)	0.1222 (0.1483)	0.1193 (0.1391)	-0.0523 (0.1486)	0.0048 (0.1445)	0.2135 (0.1431)	0.1374 (0.0937)
Rainfall Shock (1 year Forward)		-0.0048 (0.1068)				
Rainfall Shock (2 year Forward)		0.0778 (0.1042)				

Number of Observations	42498	42451	42498	42498	42498	42498
Number of Regions	355	355	355	355	35551	355

Notes: Bootstrapped standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels. In specification 2 Forward values or negative lagged values of the variables are used.

Table A5.3: Witch Trials and Climate

Explanatory Variable	Dependent Variable:					
			Witch Trials			Adjusted Witch Trials
	NB	NB	NB	NB	NB	NB
	(1)	(2)	(3)	(4)	(5)	(6)
30 Year Fixed Effects				YES	NO	NO
Year Fixed Effects				NO	YES	NO
Year			0.0107*** (0.0036)			
Year squared			-0.00002** (0.00001)			
Temperature Shock	0.1344** (0.0578)	0.1214** (0.0572)	0.1250** (0.0547)	0.1123* (0.0599)	0.1222 (0.0805)	0.1241*** (0.0422)
Temperature Shock (1 year lag)	0.1069* (0.0631)	0.0967* (0.0538)	0.0883* (0.0484)	0.0813 (0.0625)	0.2013** (0.0736)	0.1251** (0.0509)
Temperature Shock (2 year lag)	0.0798 (0.0678)	0.0794 (0.0748)	0.0573 (0.0712)	0.0433 (0.0641)	0.0840 (0.0889)	0.0984** (0.0466)
Temperature Shock (3 year lag)	0.2290*** (0.0579)	0.2415*** (0.0595)	0.2276*** (0.0593)	0.2077*** (0.0603)	0.2149** (0.1019)	0.1820*** (0.0453)
Temperature Shock (4 year lag)	0.2607*** (0.0571)	0.2678*** (0.0676)	0.2494*** (0.0592)	0.2182*** (0.0588)	0.3239*** (0.0719)	0.2161*** (0.0461)
Temperature Shock (1 year Forward)		0.0326 (0.0758)				
Temperature Shock (2 year Forward)		-0.0435 (0.0992)				
Autumn Rainfall Shock	0.1876** (0.0796)	0.1869*** (0.0683)	0.1093 (0.0681)	0.1334* (0.0789)	0.1516 (0.0813)	0.1063*** (0.0388)
Autumn Rainfall Shock (1 year lag)	0.1973*** (0.0551)	0.1531*** (0.0566)	0.1227** (0.0521)	0.1399*** (0.0498)	0.1802*** (0.0725)	0.1922*** (0.0451)
Autumn Rainfall Shock (2 year lag)	0.1431* (0.0799)	0.1412 (0.0911)	0.0479 (0.0823)	0.0739 (0.0826)	0.0868 (0.1105)	0.1188*** (0.0478)

Autumn Rainfall Shock (3 year lag)	0.0711 (0.0766)	0.0529 (0.0579)	-0.0222 (0.0650)	-0.0046 (0.0780)	-0.0108 (0.0987)	0.0883* (0.0511)
Autumn Rainfall Shock (4 year lag)	-0.0669 (0.0541)	-0.0805 (0.0691)	-0.1467** (0.0653)	-0.1240** (0.0534)	-0.1422** (0.0696)	-0.0484 (0.0384)
Autumn Rainfall Shock (1 year forward)		0.0746 (0.0651)				
Autumn Rainfall Shock (2 year forward)		0.1608*** (0.0661)				
Spring-Summer Temperature	-0.1059*** (0.0358)	-0.1122*** (0.0329)	-0.1119*** (0.0343)	-0.0981*** (0.0349)	-0.1563** (0.0715)	-0.0707** (0.0298)
Spring-Summer Temperature (1 year lag)	-0.1179*** (0.0338)	-0.1436*** (0.0511)	-0.1247*** (0.0288)	-0.1078*** (0.0345)	-0.2295*** (0.0543)	-0.0946*** (0.0213)
Spring-Summer Temperature (2 year lag)	-0.1477*** (0.0312)	-0.1577*** (0.0383)	-0.1502*** (0.0330)	-0.1438*** (0.0300)	-0.1334** (0.0550)	-0.1219*** (0.0223)
Spring-Summer Temperature (3 year lag)	-0.1050** (0.0424)	-0.1052** (0.0477)	-0.1104*** (0.0454)	-0.1124*** (0.0403)	-0.1817** (0.0771)	-0.0847*** (0.0307)
Spring-Summer Temperature (4 year lag)	-0.0914*** (0.0246)	-0.0919*** (0.0276)	-0.0851*** (0.0233)	-0.0679*** (0.0255)	-0.1098* (0.0654)	-0.0667*** (0.0201)
Spring-Summer Temperature (1 year forward)		-0.0129 (0.0290)				
Spring-Summer Temperature (2 year forward)		-0.0744** (0.0386)				
Winter-Autumn Temperature	0.0854** (0.0346)	0.0911*** (0.0344)	0.0992*** (0.0276)	0.0930*** (0.0332)	0.0026 (0.0403)	0.0673*** (0.0235)
Winter-Autumn Temperature (1 year lag)	0.0986*** (0.0293)	0.1060*** (0.0227)	0.1089*** (0.0249)	0.1071*** (0.0283)	0.0789* (0.0505)	0.0734*** (0.0164)
Winter-Autumn Temperature (2 year lag)	0.0466 (0.0289)	0.0596 (0.0392)	0.0516* (0.0273)	0.0499* (0.0269)	0.1628*** (0.0386)	0.0222 (0.0211)
Winter-Autumn Temperature (3 year lag)	0.0261 (0.0269)	0.0295 (0.0257)	0.0261 (0.0249)	0.0268 (0.0276)	0.0436 (0.0414)	0.0243 (0.0170)
Winter-Autumn Temperature (4 year lag)	-0.0047 (0.0268)	0.0141 (0.0284)	-0.0059 (0.0192)	-0.0115 (0.0276)	0.0765 (0.0492)	0.0005 (0.0186)

Winter-Autumn Temperature (1 year forward)		0.0543** (0.0256)				
Winter-Autumn Temperature (2 year forward)		-0.0005 (0.0360)				
Winter-Spring Rainfall	-0.0459 (0.0770)	-0.0372 (0.0828)	-0.0453 (0.0805)	-0.0680 (0.0769)	-0.0742 (0.0786)	-0.0026 (0.0623)
Winter-Spring Rainfall (1 year lag)	0.0537 (0.0872)	0.0714 (0.0730)	0.0212 (0.0710)	0.0135 (0.0858)	0.0354 (0.0951)	0.0156 (0.0619)
Winter-Spring Rainfall (2 year lag)	0.0211 (0.0774)	0.0157*** (0.0874)	0.0452 (0.0729)	0.0314 (0.0744)	0.0203 (0.0770)	0.0778* (0.0453)
Winter-Spring Rainfall (3 year lag)	0.0486*** (0.0791)	0.2336*** (0.0679)	0.2248*** (0.0519)	0.2068*** (0.0759)	0.2617*** (0.0921)	0.2134*** (0.0641)
Winter-Spring Rainfall (4 year lag)	0.2312*** (0.0455)	0.1788*** (0.0560)	0.1503*** (0.0539)	0.1330*** (0.0480)	0.3070*** (0.0576)	0.1345*** (0.0412)
Winter-Spring Rainfall (1 year Forward)		0.0156 (0.0769)				
Winter-Spring Rainfall (2 year Forward)		-0.1451** (0.0764)				
Autumn Rainfall	-0.1191** (0.0560)	-0.1282*** (0.0482)	-0.1301** (0.0524)	-0.1081** (0.0551)	-0.0972* (0.0584)	-0.0511 (0.0396)
Autumn Rainfall (1 year lag)	-0.0579 (0.0302)	-0.0732 (0.0572)	-0.0741* (0.0485)	-0.0447 (0.0310)	0.0506 (0.0425)	-0.0248 (0.0290)
Autumn Rainfall (2 year lag)	-0.0407 (0.0397)	-0.0455 (0.0508)	-0.0478 (0.0466)	-0.0207 (0.0400)	0.0010 (0.0475)	-0.0659** (0.0310)
Autumn Rainfall (3 year lag)	-0.0075 (0.0360)	-0.0060 (0.0455)	-0.0193 (0.0403)	0.0088 (0.0353)	0.0701 (0.0502)	-0.0563* (0.0297)
Autumn Rainfall (4 year lag)	-0.1131** (0.0438)	-0.1024** (0.0438)	-0.1199*** (0.0379)	-0.0860** (0.0426)	-0.0639 (0.0515)	-0.0864*** (0.0318)
Autumn Rainfall (1 year forward)		-0.0120 (0.0338)				
Autumn Rainfall (2 year forward)		0.0805* (0.0463)				
Number of Observations	42498	42451	42498	42498	42498	42498
Number of Regions	355	355	355	355	355	355

Notes: Bootstrapped standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels. In specification 2 Forward values or negative lagged values of the variables are used.

Table A5.4: Witch Trials and Climate by Environmental Zone

Explanatory Variable	Dependant Variable: Witch Trials & Adjusted Witch Trials					
	Moderate ATN, ATC, CON, PAN		Cold ALN, ALS, BOR, NEM		Hot MDS, MDN, MDM	
	Witch Trials	Adjusted Witch Trials	Witch Trials	Adjusted Witch Trials	Witch Trials	Adjusted Witch Trials
	NB	NB	NB	NB	NB	NB
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature Shock	0.1750** (0.0753)	0.1334** (0.0611)	0.1351* (0.0711)	0.1684*** (0.0605)	-0.1725 (0.1555)	-0.1302 (0.1268)
Temperature Shock (1 year lag)	0.1049 (0.0890)	0.1450** (0.0702)	0.0794 (0.0848)	0.0632 (0.0825)	0.1446 (0.1157)	0.1198 (0.1054)
Temperature Shock (2 year lag)	0.1509** (0.0761)	0.1642*** (0.0462)	0.0084 (0.1244)	-0.0228 (0.0718)	0.0559 (0.1105)	0.1129 (0.1129)
Temperature Shock (3 year lag)	0.2808*** (0.0683)	0.2183*** (0.0595)	0.0685 (0.1060)	0.0772 (0.0604)	0.1476 (0.1230)	0.1579 (0.1104)
Temperature Shock (4 year lag)	0.3055*** (0.0946)	0.2495*** (0.0718)	0.1796 (0.1292)	0.1689** (0.0684)	0.3074*** (0.1196)	0.3044*** (0.0943)
Autumn Rainfall Shock	0.2896*** (0.0741)	0.1908*** (0.0447)				
Autumn Rainfall Shock (1 year lag)	0.3560*** (0.0744)	0.3123*** (0.0407)				
Autumn Rainfall Shock (2 year lag)	0.2409** (0.0952)	0.2072*** (0.0559)				
Autumn Rainfall Shock (3 year lag)	0.1259 (0.0981)	0.1445*** (0.0438)				
Autumn Rainfall Shock (4 year lag)	0.0558 (0.0726)	0.0203 (0.0719)				
Spring-Summer Temperature	-0.1989*** (0.0440)	-0.1426*** (0.0472)				
Spring-Summer Temperature (1 year lag)	-0.1829*** (0.0478)	-0.1347*** (0.0377)				
Spring-Summer Temperature (2 year lag)	-0.1821*** (0.0483)	-0.1424*** (0.0307)				
Spring-Summer Temperature (3 year lag)	-0.1510*** (0.0560)	-0.1183*** (0.0324)				

Spring-Summer Temperature (4 year lag)	-0.1087***	-0.0725*				
	(0.0297)	(0.0428)				
Winter-Autumn Temperature	0.0985**	0.0776***				
	(0.0430)	(0.0254)				
Winter-Autumn Temperature (1 year lag)	0.1223***	0.0817***				
	(0.0416)	(0.0296)				
Winter-Autumn Temperature (2 year lag)	0.0676**	0.0283				
	(0.0356)	(0.0214)				
Winter-Autumn Temperature (3 year lag)	0.0504*	0.0296				
	(0.0369)	(0.0261)				
Winter-Autumn Temperature (4 year lag)	0.0110	0.0075				
	(0.0342)	(0.0230)				
Winter-Spring Rainfall	-0.0454	-0.0335				
	(0.1033)	(0.0970)				
Winter-Spring Rainfall (1 year lag)	0.0000	0.0348				
	(0.1283)	(0.0784)				
Winter-Spring Rainfall (2 year lag)	0.0176	0.0565				
	(0.1082)	(0.0687)				
Winter-Spring Rainfall (3 year lag)	0.2461***	0.2673***				
	(0.0902)	(0.0700)				
Winter-Spring Rainfall (4 year lag)	0.2124**	0.1728**				
	(0.0774)	(0.0626)				
Autumn Rainfall	-0.1296**	-0.0606			-0.1632	-0.1497
	(0.0534)	(0.0418)			(0.1183)	(0.1257)
Autumn Rainfall (1 year lag)	-0.0778	-0.0341			-0.1641	-0.1778*
	(0.0514)	(0.0432)			(0.1123)	(0.1054)
Autumn Rainfall (2 year lag)	-0.0384	-0.0588			-0.0457	-0.1229*
	(0.0513)	(0.0391)			(0.1005)	(0.0687)
Autumn Rainfall (3 year lag)	-0.0176	-0.0673			-0.1545	-0.1403
	(0.0510)	(0.0409)			(0.1098)	(0.1095)
Autumn Rainfall (4 year lag)	-0.1123**	-0.0673*			-0.1489	-0.1362
	(0.0547)	(0.0385)			(0.1090)	(0.1072)
Spring-Summer Rainfall					0.2065**	0.2180**
					(0.1090)	(0.0925)
Spring-Summer Rainfall (1 year lag)					-0.1131	-0.0539
					(0.1823)	(0.1515)
Spring-Summer Rainfall					0.3021***	0.2693**
					(0.1188)	(0.1148)

(2 year lag)						
Spring-Summer Rainfall (3 year lag)					0.5046*** (0.1338)	0.4970*** (0.1132)
Spring-Summer Rainfall (4 year lag)					0.3482** (0.1350)	0.3381*** (0.1058)
Winter Rainfall					-0.0343 (0.1149)	-0.0111 (0.0948)
Winter Rainfall (1 year lag)					0.2882** (0.1242)	0.2261* (0.1214)
Winter Rainfall (2 year lag)					0.2817*** (0.1251)	0.2459** (0.1118)
Winter Rainfall (3 year lag)					0.0997 (0.1495)	0.0175 (0.1196)
Winter Rainfall (4 year lag)					0.2270* (0.1428)	0.2059 (0.1413)
Number of Observations	23282	23282	8275	8275	8798	8798
Number of Regions	189	189	81	81	61	61

Notes: Bootstrapped standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels. In specification 2 Forward values or negative lagged values of the variables are used.

Table A5.5. Witch Trials and Hot Summers (Where summer temperature >22°C)

Explanatory Variable	Dependent Variable: Witch Trials & Adjusted Witch Trials					
	NB	NB	NB	NB	NB	NB
	Witch Trials	Witch Trials	Adjusted Witch Trials	Witch Trials	Witch Trials	Witch Trials
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature Shock				-0.2563 (0.2139)		
Temperature Shock (1 year lag)				0.2111 (0.1227)		
Temperature Shock (2 year lag)				0.0582 (0.1852)		
Temperature Shock (3 year lag)				0.0930 (0.2091)		
Temperature Shock (4 year lag)				0.1721* (0.1952)		
Summer Temperature	0.0257 (0.0591)	0.0013 (0.0776)	0.0596 (0.0687)	0.0672 (0.0673)	-0.0012 (0.0611)	

Summer Temperature	-0.1019	-0.1057	-0.1327**	-0.0975	-0.1218*	
(1 year lag)	(0.0731)	(0.0716)	(0.0604)	(0.0661)	(0.0632)	
Summer Temperature	-0.1086*	-0.0985	-0.1402**	-0.0830	-0.1205*	
(2 year lag)	(0.0640)	(0.0711)	(0.0609)	(0.0670)	(0.0756)	
Summer Temperature	-02326***	-0.2404***	-0.2241***	-0.2222***	-0.2220***	
(3 year lag)	(0.0524)	(0.0518)	(0.0515)	(0.0577)	(0.0485)	
Summer Temperature		0.0512				
(1 year Forward)		(0.0823)				
Summer Temperature		-0.0538				
(2 year Forward)		(0.1247)				
Spring Temperature					0.0489	
					(0.0415)	
Spring Temperature					0.0252	
(1 year lag)					(0.0459)	
Spring Temperature					-0.0012	
(2 year lag)					(0.0717)	
Spring Temperature					-0.0149	
(3 year lag)					(0.0808)	
Summer						-0.8498**
Temperature-Rainfall						(0.4205)
Summer						-0.5225
Temperature-Rainfall						(0.3201)
(1 year lag)						
Sumer						-1.1704***
Temperature-Rainfall						(0.2743)
(2 year lag)						
Summer						-0.9453**
Temperature-Rainfall						(0.4967)
(3 year lag)						
Number of Observations	3838	3824	3838	3836	3836	3814
Number of Regions	33	33	33	33	33	33

Notes: The sample includes only observations in which summer temperature exceeds 22°C. Bootstrapped standard errors given in parenthesis. ***/**/* denotes significance at the 1%/5%/10% levels. In specification 2 Forward values or negative lagged values of the variables are used.

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