European
Historical
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EHES Working Papers in Economic History | No. 24

Epidemic Trade

Lars Boerner,
FU Berlin and Stanford University

Battista Severgnini
Copenhagen Business School

September 2012

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Lars Boerner
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Abstract

This paper studies the spread of the Black Death as a proxy for the intensity of medieval trade flows between 1346 and 1351. The Black Death struck most areas of Europe and the wider Mediterranean. Based on a modified version of the gravity model, we estimate the speed (in kilometers per day) of transmission of the disease between the transmitting and the receiving cities. We find that the speed depends on distance, political borders, and on the political importance of a city. Furthermore, variables related to the means of transportation like rivers and the sea, religious seasons such as Advent, and geographical position are of substantial significance. These results are the first to enable us to identify and quantify key variables of medieval trade flows based on an empirical trade model. These results shed new light on many qualitative debates on the importance and causes of medieval trade.

JEL codes: F10, F15, N13

Keywords: Trade, Middle Ages, Black Death, Gravity model, Poisson regression

Acknowledgements:
We would like to thank Benjamin Arbel, Ole J. Benedictow, Georg Christ, Giovanni Ciappelli, Lorenzo Del Panta, Dave Donaldson, Paolo Epifani, Yadira Gonzáles de Lara, Regina Grafe, Avner Greif, Nicolai Kaarsen, Lars Lund, Jakob Madsen, Peter Mllgaard, Giovanni Peri, Karl Gunnar Persson, Moritz Schularick, Nathan Sussman, Andrea Vaona, Hans-Joachim Voth and Jacob Weisdorf as well as seminar participants at London School of Economics, at University of Copenhagen, at Bocconi University, at Humboldt University in Berlin, at Copenhagen Business School, at University of Mannheim, at CEU-Cardinal Herrera University in Valencia, at Verona University, at the Conference Union in Separation in Heidelberg, at the European Historical Economics Society Conference in Dublin and at the European Economic Association Congress in Malaga. Battista Severgnini gratefully acknowledges the financial support of the Danish Social Science Research Council-Ministry of Science, Technology and Innovation.

1 Introduction

If we want to understand the long-run economic growth and success of Europe we need to study the economic development of the Middle Ages. The foundation of many leading cities of the last millennium and the first urbanization of Europe can be traced to the Late Middle Ages. The driving force of urbanization and early city growth was the intensification of regional and long-distance trade among different regions of Europe and the wider Mediterranean area (Lopez (1952 and 1976), North and Thomas (1973), Postan (1975), Bairoch (1988), Cipolla (1993) and Epstein (2000a)). Furthermore, complementary institutional innovations related to trade, known as the Commercial Revolution (Lopez (1976)), with impact on the institutional structure nowadays such as early financial instruments like the bill of exchange (De Roover (1953)) or business partnerships in form of early firm structures originated in the Late Middle Ages (Sapori (1955), Hunt and Murray (1999), Greif (2006a and 2006b) and Boerner and Ritschl (2009)).

Complementary to this strand of literature, a debate over *the Great Divergence* (Pomeranz (2001)) emerged, comparing the success of Europe to that of China and other parts of the world. This debate over the "rise of Europe" goes back to discussions by Weber (1921), Braudel (1949), Wallerstein (1974), North and Thomas (1973), Landes (1998), Epstein (2000a), more recently Acemoglu, Johnson, and Robinson (2005), Greif (2006b), Clark (2007) and many other prominent social scientists, who have studied the economic and political rise and decline of regions, empires and civilization. Despite the divergence of economic growth rates that manifested during the 19^{th} century, some of these scholars trace the roots of this divergence back to economic and political institutional changes during the late medieval process of urbanization (for example, Weber (1921) and Epstein (2000b)).

Although trade flows among different cities and regions of Europe are key to understanding the initial growth and urbanization, only a few quantitative statements can be made about the determinants of trade flows among places and regions in Europe during this important epoch. The lack of appropriate data permit economic historians to mainly make qualitative assertions about what determined commerce. For instance they have identified transportation routes and the related means of transportation. In addition, political fragmentation and the absence of bigger territorial states which restricted the trade flows due to limited safety and the existence of a variety tolls and taxes imposed by local rulers along the trading routes have been identified as constraints on European commerce (van Werveke (1952), North and Thomas (1973) and Postan (1975)). However measuring such effects quantitatively and comprehensively all over Europe and in the wider Mediterranean area and making a comparative analysis based on different trade determining variables has not been possible due to the lack of appropriate trade flow data. This strand of research has brought in some cases of clear, other cases of tentative, and in many cases inconclusive results: while economic historians agree that water trade was more intense than land trade, most economic historians conjecture that political borders mattered, but disagree as to how much this influenced medieval trade. Finally, it is an open question as to how much market integration this epoch really brought to Europe and the Mediterranean or if mainly long-distance trade effects for single cities importing and exporting luxury goods can be identified.

One way to overcome these qualitative restrictions has been taken up by scholars of integration in pre-industrial Europe based on the law of one price. In these mostly regional studies grain price data (Persson (1998), Jacks (2004), Bateman (2007) and Ozmucur and Pamuk (2007)) and prices of gold-silver ratios (Volckart and Wolf (2006), Boerner and Volckart (2011) and Chilosi and Volckart (2011)) are used to measure differences in prices in different cities as a proxy for market integration. Most of these studies go back to the 16^{th} century and a few to the late 14^{th} and 15^{th} centuries (Chilosi and Volckart (2011) and Boerner and Volckart (2011)). This is due to a lack of price series available for

earlier periods. These approaches assume that observed price convergence is driven by the underlying trade flows that lead to market integration.

In contrast empirical trade economists and economic historians who mainly studied 20^{th} century data can rely on import and export data among countries to measure trade flows (Maddison (1991 and 1995), O'Rourke and Williamson (1999 and 2002)). Their empirical analysis centers on the gravity model (Tinbergen (1962), Helpman and Krugman (1987) and Deardorff (1998)) which takes country size, physical distance, and institutional and cultural variables such as political borderlines and geographical characteristics to explain trade flows among countries. The empirical findings in the baseline models are that economic size of the two comparing countries and similar sociopolitical characteristics raise the intensity of trade, while distance and borderlines can explain trade resistance on an international level.

This paper takes a different approach from that of previous studies on medieval trade. Due to the lack of data for the Late Middle Ages, we use the spread of the Black Death from 1346-1351 as a proxy to study trade flows among cities. Cipolla (1974) identified traveling merchants and population density as the main transmitters of the disease among cities. This statement has been confirmed by several studies in history, economic history, demography and epidemiology (Biraben (1975), Del Panta (1980), McCormick (2003) and Benedictow (2004)). Other forms of social interaction, which could have triggered the transmission, such as war, pilgrimage, or other economic mobility can be excluded from the period under investigation. Furthermore, medieval historians who studied the Black Death were able to date the start of the infection in many cities and track the spread of the disease from one city to the next. In this way we are able to identify city-pairs in which we can measure the speed of the spread of the disease along different trade routes and use this as a proxy to measure trade flows. Thus the more trade takes place between two cities the more likely and the faster the disease is transmitted. Furthermore, there was no way for the inhabitants of a town to stop or postpone the outbreak of the Black Death. In addition, the spread of the infection within a town followed a general pattern and was no biased process. This way the time of transmission between two cities is a good proxy for our study and the data are not systematically biased. We use the speed (kilometers per day) as the dependent variable in a modified gravity model. We run the model along a set of explanatory and control variables which can be derived from historical investigations or have been identified as important by empirical trade economists.

Our main findings are that the intensity of trade depends on the means of transportation, the political borders, the distance, religious holidays, and the institutional function of a city. We show that transportation on rivers and seas was more intense than along land trade routes. This is in line with findings of qualitative studies by medieval economic historians. Political borders slowed down the speed of transmission. This confirms the findings by empirical trade economists (McCallum (1995)). This supports the argument by North and Thomas (1973) that political borders were a major obstacle to medieval trade and growth. Furthermore we find that distance has a positive impact of the speed of transmission. This contrasts with the findings of the recent empirical trade literature but is in line with the argument that long-distance trade was the critical factor in medieval trade (Braudel (1949), Lopez (1952 and 1976), Cipolla (1993)). Furthermore we show that the religious season of Advent slowed down trade and that political residential cities, in particular bishop cities had a significantly slower outflow. We explain this slower outflow in terms of the weaker production of residential cities. Neither the religious holidays nor political function have, to the best of our knowledge, been used to explain trade flows in the literature. City size (used as a medieval proxy for economic size) plays no significant role in determining the speed of transmission. These results are not in line with the standard results in gravity models based on country level data, but confirm several insights from studies in urban economics and economic geography (Von Thunen (1826), Krugman (1991), Ades

and Glaeser (1995) and Combes, Mayer, and Thisse (2008)). Finally, we show that the speed of inflows and outflows depend on the geographical location of a place. We find high speeds in particular in Northwest Europe and the North Mediterranean area. We detect fast contagion in the North Mediterranean and in North Western Europe: we find fast in- and outflows. In contrast we detect only fast inflows in the Eastern Mediterranean and no significant effects in the African Mediterranean. Furthermore we can track distance effects geographically: we find strong effects in Northwest Europe, Northern Italy and Southern France. These results confirm general studies in late Medieval Economic history, which conclude a relative rise of Northwest Europe driven by long-distance trade.

In addition, to motivate and frame our empirical results we introduce a trade model which best represents the medieval trade environment. We create a model inspired by Armington (1969), in which we add specific taste parameters to non locally produced goods. This modelling assumption is based on the historical observation that product differentiation can be explained mainly by geographic origin and trading networks were created by the exchange of different types of goods. Furthermore, we consider cities (instead of countries) as unit of observations.

The findings of this paper contribute in three ways. First, the results offer insights to many open debates in economic history related to what determined trade in late medieval Europe. Furthermore, it is worthwhile to note that we consider the Black Death not as a cause of ensuing (economic) historical events (Bridbury (1962), Domar (1970), Munro (2005) and Voigtlaender and Voth (2012)), but use the Black Death to explain what happened before the spread of the plague. Second, the economic development of late medieval Europe has been recognized as the origin of the successful economic divergence of Western Europe from many other regions of the world (Epstein (2000a)). In this way we might gain insights on what shapes a successful developing economy in terms of trade. Finally, this methodology offers a new way to measure trade flows where we lack other data. This approach can be extended to many other applications. Interestingly, epidemiologists now use channels of communications to predict the spread of flus and other diseases. Thus they exploit the data in reverse order.[1] Furthermore, recent studies on unified theory on the cities found that urban life (Bettencourt, Lobo, Strumsky, and West (2007) and Bettencourt and West (2010)) is strongly related to epidemics and economic transition: in cities diseases spread and firms are born and die at very similar rates.

The remainder of the paper is structured as follows: Section 2 gives a short introduction to the late medieval economic history of Europe and the spread of the Black Death. In addition, the main candidates for explaining medieval trade are identified. Section 3 introduces our theoretical foundation for the gravity equation model and specifies the empirical model applied to measure the speed of the spread of the Black Death. Section 4 presents the data and the descriptive statistics. Section 5 discusses the estimation results. Section 6 introduces a wide range of robustness checks. Section 7 displays geographical effects: beside the aggregate geographical effects we show the marginal effects of the variable distance with respect to the geographical positions of the cities. Section 8 concludes.

[1] A recent medical article (Pepperell and al. (2011)) shows how French Canadian fur merchants spread tuberculosis among indigenous people in western Canada from 1710 until 1870. For an economic study of the relation between disease and economic activity, see Carlos and Lewis (2012) and Oster (forthcoming). For the use of gravity models and epidemics, see Viboud and al. (2006).

2 The Missing Link: Medieval Trade and the Black Death

2.1 Determinants of Medieval Trade Flows

The second half of the Middle Ages is a turning point in the history of Western Europe. After the decline of the Roman Empire and an economic disintegration of Europe, a new phase of city growth and intensification of trade appeared in Western Europe, starting in the late 10^{th} and 11^{th} centuries (Bairoch (1988)). The period from the 11^{th} until the middle of the 14^{th} century has been characterized by Lopez (1976) as the "commercial revolution". Small cities grew and many new cities were founded. This urbanization was triggered by regional trade and long-distance trade among cities across Europe and the wider Mediterranean area (Lopez (1952 and 1976), North and Thomas (1973), Postan (1975), Bairoch (1988), Cipolla (1993) and Bosker, Buringh, and van Zanden (2008)).

The revitalization of trade was based on the reestablishment and increase of trade connections between different European cities. Trade routes on land, rivers, and the sea were used to exchange a large variety of goods. However, although there is evidence of inter-regional trade of bulk goods such as basic foodstuff , for example grain (which could not been produced sufficiently in the surrounding areas of bigger cities), transportation costs were still high and preferable high-value-per-weight goods for example textiles, spices, or jewelry were transported along these routes (Pegolotti (1340; eds. 1936), Postan (1975), Lopez (1976) and Freedman (2008)). Cities started to develop a demand for luxury products, which also contained low-end products which also modestly wealthy citizens could consume (Stuard (2006)). For example Genoa or Venice had to import grain from various Mediterranean areas since they could not produce sufficient amounts themselves from their own hinterlands. However they also imported spices and other luxury products from Asia via the Mediterranean, which they could not grow or produce themselves. In turn they manufactured high-quality textile products based on imported silk from Asia and wool from England and exported these finished textiles again to the Mediterranean area or North of Europe (Abulafia (2011)). Furthermore these merchant cities acted as intermediary hubs for trade flows between different regions of Europe. This way along the medieval urbanization process a demand for a variety of trade goods arose in these cities.

According to this line of argumentation, Lopez sees the commercial revolution rather as an increase in the number of trade connections among cities and less as a dramatic change in the quantities traded. Furthermore, the increase in connections was uneven. Trade between sometimes distant merchant cities was more intense than the connection of such merchant cities with local surrounding cities.[2] In this way late medieval trade and related city growth is driven by an increase in long-distance trade. However there is also a line of research enclosed by scholars like Weber (1921), Braudel (1949) and Wallerstein (1974) who argue that the economic integration of Europe that had started by the late Middle Ages turned into roots of globalization by the early modern time. On contrary, O'Rourke and Williamson (1999 and 2002) argue that quantitatively measurable market integration resulting in globalization cannot be observed before the 19^{th} century.

The two channels of transportation on land and on waterways (rivers and on the sea) can be differently characterized. Land trade was based on the use of old Roman roads. How these streets were preserved and maintained during this period remains a matter of scholarly debate. However it stands to reason that streets were the slowest and most costly way to transport goods. Horses and mules with carts could transport only limited amounts of goods. A cheaper and faster option to transport larger quantities of goods was on rivers, especially on sea ships. However shippers on

[2]For a regional study of the 15^{th} century Germany, see Chilosi and Volckart (2011).

the sea had to deal with unpredictable weather. For this reason shipping on the sea was comparably slower than on rivers (Lopez (1952 and 1976) and Postan (1975)).

Furthermore, whereas transportation on the river as on land was rather safe since land routes were under the control of dukes, as soon ships left the coast and were on the open sea, they were vulnerable to pirates. However the safety of trade routes on land and rivers depended on the political structure of a region. Western Europe was only partially characterized by territorial states such as England; small territorial or city states as in Italy or Germany were the rule. Passing thorough many political territories along a trade route implied not only reliance on rulers who guaranteed safety and property rights, but on more frequent payments of taxes and tolls. The extent to which this political fragmentation hindered trade and growth of Europe is an open question. For example traders during the 14^{th} century who shipped their goods along the Rhine had to pass through more than three dozen toll stations, most of which were mainly run by local ecclesiastical princes and states (Postan (1975), pp.182ff.). Nevertheless, the Rhine was one of Germany's largest and safest transport routes. In contrast, in territorial England tolls were rather rare and the legislation centrally enforced. Does this imply that trade flows in England were faster than in Germany? Postan claims that on many trade axes a sufficiently large number of routes existed which made the toll setting competitive enough not to harm long-distance trade too much. This statement is confirmed by our data on the Black Death: the speed of the dispersion of the Black Death along rivers in England is about 3 kilometers per day, while along the Rhine and other important rivers in Germany the disease propagated almost three times faster. North and Thomas (1973), pp. 69ff., claim that the territorial fragmentation restricted law enforcement to small local territories. The missing central enforcement on bigger territorial states explains why Europe was not able to escape the Malthusian trap and to reach sustained growth path by the end of the 13^{th} century. However, Planitz (1919) and later in a formal institutional analysis Greif (2002 and 2006b) and Boerner and Ritschl (2002 and 2009) showed that the institution of community responsibility maintained cross-border legislation also in politically very fragmented parts of Europe.

Furthermore, trade was conductive to city growth. Indeed most of the growing cities during the Late Middle Ages can be identified as merchant cities which produced manufacturing products for export and imported all kinds of input and consumption goods (van Werveke (1952) and Hibbert (1963)). However, many of these cities can also be identified by other functional meanings (van Werveke (1952), pp.22ff). Some cities were residences of bishops and dukes and served political and administrative purposes. Some cities already hosted universities. All these cities could also be merchant cities, but could rely on external income streams, for example in form of fiscal incomes. This way these cities were very likely consuming more than producing.[3]. The follow up question we can raise is if these cities with different institutional functions influenced trade flows differently from sole merchant cities. In addition and more generally we need to ask if the size of the cities influenced the intensity of trade flows.

Finally we like to bring in an aspect of medieval life, which has to the best of our knowledge not been discussed in medieval trade literature: the effect of religious holidays on trade activities. Although there is a consensus on the importance of the church in daily (and economic) life (Le Goff (1988)), no researcher has asked whether or not Advent and Lent had an impact on the intensity of trade.

The phase of commercialization came to an end with the outbreak of the Black Death. Medieval scholars have seen the period between the end of the 10^{th} century until the 14^{th} century as one of

[3]For instance in the city of Mainz approximately one third of the population under the administration of the bishop (Heinig (1983)).

ongoing economic progress. Lopez (1952), pp. 360ff., identifies the last hundred years before the Black Death as the heyday of medieval trade. Thus taking the moment of the outbreak of the Black Death as a benchmark for the achievements of the Commercial Revolution in terms of trade can be justified.[4]

2.2 Nature and Transmission of the Virus

According to McNeill (1980) and Findlay and Lundahl (2002), the virus originated in Mongolia during the 11^{th} century and was transmitted by merchants from Asia to Western Europe during the 14^{th} century. The unification and pacification of big parts of the Asian continent based on the *Pax Mongolica* enabled inter-continental trade and made the spread of the disease from Asia to Europe possible. The 14^{th} century Italian notary and historian Gabriele de' Mussi, in his book *Istoria de Morbo sive Mortalitate que fuit de 1348*, stated that the Plague was transmitted to Europe from Kaffa (now the Ukrainian city of Feodosiya), one of the most important commercial trade hubs of the Republic of Genoa on the Black Sea. The plague was easily introduced to Italy by the Genoese boats into the Sicilian harbor of Messina and from there into the most important commercial harbors in Europe in 1347. Considering the Middle East Asia and the Northern African, the main hubs of propagations were Constantinople and Alexandria.

Figure 1 provides a general view of the main spread routes of the Black Death in Europe and the wider Mediterranean area based on our dataset:[5] the yellow, red, blue, green, orange and black lines represent the main propagation of the disease during 1346, 1347, 1348, 1349, 1350, and 1351 respectively. The second city to be struck was Constantinople, from which the Black Death moved towards the Egyptian city of Alexandria, the Balkans and the internal part of Anatolia. From Alexandria, the disease spread towards to the South (Cairo) and the North (along the Silk Road, involving the cities of Damascus and Aleppo in 1348 and Baghdad in 1349). Looking at Continental Europe, from Messina the disease emanated to the western part of Northern Africa (Tunis and Fez) and the main ports in the Mediterranean sea (Pisa, Genoa, Marseilles, Barcelona, Valencia, Ragusa and Venice) between December, 1347 and the first months of 1348. Italy, with Pisa and Venice as the two main centers of contagion, and large areas of France and Spain were contaminated until June 1348. From Spain the virus moved to the main ports on the Atlantic Ocean (Lisbon and Bordeaux) and to the North and Baltic Sea. Infected cities included London, Amsterdam, Bergen, Oslo, and Copenhagen. Germany was infected directly from the South via the trading routes coming from Italy/Austria and France/Switzerland. In addition, the plague was transmitted via sea trade from the North and Baltic Sea. In 1351 the disease reached the maximum expansion. Cipolla (1963) estimated a mortality rate of about 30 percent of the total European population, making it the worst catastrophe in human history.[6]

[Figure 1 about here]

Despite several studies in the past claiming that the propagation of the Black Death was driven by "psychological facts" (Bloch (1953)) or, following a Malthusian mechanism, by malnutrition (Bridbury (1973) and Romano (1972)), historians and epidemiologists now concur that there is a solid and strict connection between the Black Death and trade. Cipolla (1974) was the first scholar stating that only

[4] However during the early 14^{th} century several famines led to regional economic stagnation (Bridbury (1962)).

[5] The sources are listed in Appendix A. Unfortunately, we do not have precise data for the cities after 1351 and located in Central and Eastern Europe (Benedictow (2004).

[6] As a matter of comparison, during World War II the mortality rate in Europe was between 6 and 16 percent.

two factors, population size and trade, drove the pandemic. His thesis was confirmed by demographers Livi-Bacci (1983 and 1997) and was later accepted by medieval historians (Bridbury (1977), Herlihy (1985) and Cipolla (1993)). Moreover, epidemiologists also agreed upon the causal link between trade and the spread of the disease: the typology of virus which spread across Europe during the 14^{th} century is a typical case of a bubonic plague (*yersinia pestis*), which is usually transmitted to humans by rats and fleas which traveled on the goods along the trade routes.[7] The spread must have been supported by the social interaction of people. Rats were not able to spread the disease themselves in such a wide area (Indian Plague Research Commission (1907) and McCormick (2003)). This argument can be further tested. We show that the spread followed an S-shape curve (shown in the next paragraph), which indicates a systematic spread along conscious social interactions (Pyle (1979)). If the spread had been only based the interaction of rats we should find a random pattern in the spread.

Economic activities (and this means for the period of investigation trade activities) were the main form of social interaction between cities. Thus traders where the main carriers of the virus. Two other types of travelers which could have an impact are solders or pilgrims. However there is in general no major movement of solders caused by war during the time and in the area of investigation. We found just two city pairs in which the disease could also be propagated by war activities. Their exclusion, however, does not affect our results. Furthermore, pilgrimages routes do not indicate that pilgrims initiated the spread of the Black Death (Benedictow (2004)).[8] Other forms of social mobility can be documented only for the time after the Black Death (Domar (1970)).

The time from the incubation to the appearance of the illness took only 3-5 days. This way it was very difficult for the inhabitants to take any preventive measures. Furthermore, medieval sources do not reveal any information that the medieval inhabitants were aware of any way to protect themselves against the plague (Cipolla (1981)). Thus the arrival, outbreak, or spread could not been endogenously influenced by the citizens.[9]

Furthermore, the spread of the Black Death within a city took place systematically. Merchants and other locals who had to deal with trade (e.g. lawyers and notaries) were infected, first, well protected people like rulers or noble class who participated less in the "outside world" were infected later on (Livi-Bacci (1978) and Gelting (1991)). This way the process from the arrival to the outbreak until the highpoint was no random process, but followed a systematic path of diffusion. In addition, the information of the death of different kinds of people reveals information on the stage of the course of the plague through each town. This way medieval historians have been able to pinpoint the periods of the outbreak of the plague in different cities. Based on different types of sources the dates can be aligned and assigned to single days of a month: for example, in the Italian city of Orvieto the appearance of the disease and the mortality rate was compared using parochial registers, chronicles of the writers and from the mortality rate of the upper classes (e.g., lawyers and notaries) (Carpentier (1993)). This allows us to identify city-pairs with different speeds of transmission (measured in kilometers per day). The speed of the spread of the Black Death can be taken as a proxy to study

[7]According to Pollitzer (1954) the bearers of the virus were the fur fleas of the black rats. The virus only survives if the flea is able within half a day (or a day) either to bite human beings, move on grain seeds (their preferred food) or if it is in humid environments like on ship cargos Estrade (1935). Scott and Duncan (2004) and Bossak and Welford (2010) have recently suggested that the Black Death was transmitted only by humans. This hypothesis would strengthen the link between economic relation and the pandemic.

[8]In addition, we made an empirical test on this where we control for the pilgrims routes. But we could not find any significance.

[9] Even if inhabitants had been informed about the approaching disease and been able to flee, then they would have needed a transportation infrastructure, which strongly correlated with the quality of the trade infrastructure (which in turn was based on the trade intensity) Thus the infection/ trade causality still holds.

medieval trade flows between different cities. The speed indicates the direction and the intensity of trade. The more people with more goods travelling between two cities the more likely and faster the infection takes place.[10] Figure 2 provides additional information on the nature of the transmission of the disease exploiting the dataset we are going to describe in the following section: the horizontal axes represents the number of months that elapsed after the appearance of the Black Death in the city of Kaffa, while the vertical ones contain the cumulative number of cities affected. We can observe that the contagion evolved according to a S-shape spread. According to several studies in medical geography (e.g., Pyle (1979)), the logistic spread is an indicator of the importance of human networks in the diffusion process, excluding the role of other animal or natural agents. Furthermore, recent empirical evidence (Benedictow (2011) and Oster (forthcoming)) and biological studies (e.g.,Indian Plague Research Commission (1907)) show the strong and constant relationship between diseases and trade also for other cases in history. Making this assumption implies that we should find sufficient variation of speed of spreads along different trade routes.

An interesting case which documents the unequal speed of the spread is related to the transmission of the infection from Florence, one of the largest important cities in Italy with about 100,000 inhabitants. After the outbreak of the plague in the Tuscan city at the beginning of March 1348 (Corradi (1865) and Del Panta (1980)) the Black Death moved during the same months to Bologna and Modena, about 110 and 160 kilometers away. In contrast, the virus took almost two months to reach Siena, just 70 kilometers from Florence. Even at first glance it is difficult to identify the causes of this different timing. Benedictow (2004) claims that "*the Black Death showed its ability to perform middle-range metastatic leaps along important commercial roads between large commercial and production centers in areas with great population density*". Thus the speed of the transmission might be explained by the different trade intensities between cities.

2.3 Explanatory Variables: Candidates

Next we need to identify explanatory variables, which are potential candidates to determine trade flows and we are able to derive from the medieval source material. A first set of variables is related to the classical approach in gravity models: the population size of the two cities in a city-pair, the distance between the cities, and the existence of shared or different borders between the two cities. Following the gravity model (which we discuss in the coming section) we should expect a stronger trade flow between bigger cities, cities which are closer and city-pairs which have a common border. Larger cities are expected to import and export more goods. Thus a bigger flow increases the likelihood of the spread since more merchants travel between the two cities. Following the argument by Lopez, this does not need to be the case during the commercial revolution, since the period can be characterized by a qualitative improvement of trade flows and less by a quantitative enhancement and a general market integration (O'Rourke and Williamson (2002)). Thus the prediction for the medieval trade environment is not unambiguous. A complementary motivation for a reverse prediction of the

[10]To strengthen this assumption we use another hypothesis in the medieval trade literature. Spufford (1988) and Le Goff (2012) claim that trade intensity between two cities can be measured by the value of foreign coins used in the local city. Thus foreign coins with a high value (e.g. a strong gold content or big dimension) indicate strong trade with this foreign city. We use the information in the merchant handbook by Pegolotti (Pegolotti (1340; eds. 1936) and Grierson (1957)) to make a case study in the Mediterranean. We analyze if in cities with high value coins we can also find fast transmission of the plague. This is indeed the case. Figure 7 shows the relationship between the speed of the disease among different French, Italian, Spanish and Byzantine cities and the value of the foreign coins, which we measure as exchange rate in terms of Genoese coin *Soldo*. The red line in the figure shows the predicted values obtained by the OLS regression displaying a strict positive relation between the two factors. Data and output of the regression are available upon request.

coefficient of population can be found in the urban studies by Von Thunen (1826), Krugman (1991) and Fujita and Mori (1996) where trade costs are positively related to city size. This argument is also supported by empirical evidence provided by Ades and Glaeser (1995) and Bosker, Buringh, and van Zanden (2008): during the last millennium, especially in big cities outside Europe such a pattern can be documented. With respect to distance, trade economists have predicted and also found empirical confirmation that nearby cities trade more since keeping up with a transportation and communication channel is easier over short distances. Again, this might be different in the historical context since geographical proximity in the period of investigation does not necessarily mean a better connection. In addition, as described in the previous section a large fraction of trade was long distance trade. Thus to find confirmation for the long-distance trade hypothesis we should find a positive coefficient. Finally, common borders reduce transaction costs related to a higher number of institutional barriers. This is what trade economists predict and also found in their empirical studies. For example, McCallum (1995) predicts higher intra-national Canadian trade than international trade with the US. In addition, a border can be considered as a valid proxy for tariffs on imported goods. As discussed in the previous section medieval economic historians arrived at different conclusions as to what extent political borders hindered trade.

A second set of variables consists of the geographic variables which might influence the intensity of trade. We identify trade routes along lakes and rivers, and city connections via the sea. Following the historical literature, we expect more intensive trade on waterways in general and stronger trade on rivers or lakes than on the sea. A range of trade intensities can be measured on different seas. The Mediterranean should be the most intense, the Baltic Sea comparably less and the Atlantic Ocean from north of Spain, France to England up to Belgium on an upswing, but still somewhere in between. In addition, we check for more geographical control variables: the elevation, longitude and latitude of a city, and the remoteness of a city from the next harbor. In another quasi geographical variable we make a distinction between European and non-European cities. Following the literature on the rise of the West and the relative decline of the superior non European Mediterranean area we expect a slower trade outside Europe, *ceteris paribus*. However such a differentiation has more of a cultural than a geographical explanatory content. Therefore we grouped this among the social and political variables that will discuss later.

Another important set of variables is represented by religious periods, more precisely, Lent and Advent. Following the Catholic liturgical year, which was observed during the Middle Ages, Lent was the forty days preceding Easter. Lent is not observed during the same date of the calendar, but it is fixed between March 22 and April 25 just after the first full moon.[11] Advent, in contrast, is a fixed period of the calendar, consisting of the four weeks before Christmas. Those two liturgical seasons are characterized by fasting and abstinence from certain types of food and from sexual intercourse. A general rule for all the cities is the abstinence from all of kind of meat. Thus we can expect trade to slow down during these religious periods. In addition, we control if trade slows down in general or only between regions and not locally within the same political borders.

In a last set of variables we look into the functional nature of the city. We analyze if the city is the residence of a bishop, a prince, or if the city hosts a university. Cities with these extra characteristics have additional income streams. Thus they might consume more than they produce. This way we expect that they had fewer outgoing but more incoming trade streams. Consequently such a city is less likely to be a transmitter of the disease and more likely to be a receiver. As with the presence of a university, a bishop or a prince. Alternatively, Blum and Dudley (2003) assume that a bishop

[11]Lent has the five Sundays: *Invocabit*, *Reminiscere*, *Oculi*, *Laetare*, and *dominica in passione Domini*. The only exception to this timing of Lent is in Milan, where the period is slightly different.

is a good indicator of human capital. The same could be assumed for university cities. A higher level of human capital could be an indicator for more trade activities and thus a higher transmission and receiving of the plague. Such an indicator assume De Long and Shleifer (1993) also for Southern European prince cities. They argue that prince cities were less autocratic and thus more open to trade.

Finally, we control for seasonal and time effects. Even if the epidemiological literature agrees that the Black Death was not affected by different types of season since the virus could be transmitted by rats and fleas (Pollitzer (1954)), several epidemiologists have claimed that the speed of the Black Death could be indeed affected by the temperature.[12] We add to all the regressions a set of climate variables related to the period of the epidemic's diffusion.[13] In addition, we consider different year dummies, which could be related to any other unobservable time effect we do not control for.

A concluding remark must be made about the products traded on these different routes. Intuitively we would expect on trade routes where large amounts of food were transported more rats and thus a faster transmission of the disease. However, on most trade routes mixed bundles of goods were traded. For instance Mediterranean ships transported both grain and luxury goods. This way it is hard to disentangle such effects. Some product effects might be already captured by the variables which control for the mean of transportation. On water routes we might expect more trade in basic food stuffs than over land.

3 The Gravity Model

In this section we introduce a theoretical framework for highlighting the relationships between the intensity of trade (and the speed of the dispersion of the disease) and different factors. We start our analysis considering the gravity model, which in international trade is one of the most considered theoretical (Helpman and Krugman (1987) and Deardorff (1998)) and empirical (Eaton and Kortum (2002) and Anderson and van Wincoop (2003)) framework for predicting the determinants of trade between two geographical areas. Inspired by Isaac Newton's law of gravity (1687), which states that in the universe each particle can attract any other element with a force which is directly proportional to the product of their masses and inversely related to the square of the distance between them, the gravity model states that bilateral trade flows are correlated to the economic sizes of the trading entities and inversely proportional to some resistances, which can be assumed as the geographical distance or also other type of factors like trade or sociopolitical and cultural barriers.

Starting from this framework, we have to take into consideration three important issues of our model which are going to be different from the standard gravity model. First, in our dataset we have cities, which are small units of observations compared to macroareas, such as countries or regions. Second, we do not directly observe trade: so we have to link the relationship between commercial flows and the speed of the dispersion of the Black Death. Third, we have to take into consideration the different role played by long-distance trade as explained in the previous chapter on medieval trade.

We start our model in the spirit of Armington (1969), where the productions and the trade flows of differentiated products are explained by their geographical origin. This choice can be motivated by the medieval trade environment previously discussed. We consider the existence of two cities i and j. Both cities dispose the same type of technology and cost of production, while their utility is based

[12] For a discussion see Benedictow(2004 and 2011).

[13] We are going to describe in more detail the climate data in Section 5.

on the two-tier utility function introduced by Head and Ries (2001). For the economic intuition we focus on the lower-tier utility function u,[14] The form of these utility functions assumed to be a CES which can be approximated by the homothetic and identical preferences and is taken by a version of the standard monopolistic-competition model of Armington (1969) and Feenstra, Markusen, and Rose (2001):

$$u_i = \left[\sum_{k=1}^{n} \left(\beta_i^i C_k\right)^{\left(\frac{\sigma-1}{\sigma}\right)} + \sum_{k=n+1}^{N} \left(\beta_i^j C_k\right)^{\left(\frac{\sigma-1}{\sigma}\right)} \right]^{\left(\frac{\sigma}{\sigma-1}\right)} \quad (1)$$

$$u_j = \left[\sum_{k=1}^{n} \left(\beta_j^i C_k\right)^{\left(\frac{\sigma-1}{\sigma}\right)} + \sum_{k=n+1}^{N} \left(\beta_j^j C_k\right)^{\left(\frac{\sigma-1}{\sigma}\right)} \right]^{\left(\frac{\sigma}{\sigma-1}\right)} \quad (2)$$

where the additionally introduced βs are positive distribution parameters which can also be assumed to be indicator of taste modifiers since they weight the variety of goods attributed by consumers, while σ is the elasticity of substitution between all goods, expressing that each cities have a "love of variety". In addition, we define $\sum_{k=1}^{n} C_k$ and $\sum_{k=n+1}^{N} C_k$ as the amount of good consumed in i produced in i and j, respectively. Similarly, in (2) we concentrate our attention on $\sum_{k=1}^{n} C_k$, which represents the amount traded from city i to city j. We assume that this type of utility function fits particularly well with our historical context for two reasons. First, we would like to stress the product differentiation (or even specialization) of medieval cities. Second, according to the theory of Krugman (1991) and Ades and Glaeser (1995) and unlike the "home-market effects"' models (Krugman (1980) and Feenstra, Markusen, and Rose (2001)), we would like a model which can predict a larger export elasticity with respect to the receiving city than to the sending one, which is also expressed by β_j^i.

Furthermore, we can define the production functions Y expressed both by population and wage and budget constraints, respectively:

$$Y_i = w_i POP_i = \sum_{k=1}^{n} p_i C_k + \sum_{k=n+1}^{N} p_j \tau C_k \quad (3)$$

$$Y_j = w_j POP_j = \sum_{k=n+1}^{N} p_j C_k + \sum_{k=1}^{n} p_i \tau C_k \quad (4)$$

where w is wage, POP population, C the amount of consumption, goods $k \in [1, n]$ are varieties produced by city i, while $k \in [n+1, N = n + n^*]$ are varieties produced by city j, p is the price for the goods produced locally, while $p\tau$ with $\tau \geq 1$ is the transportation cost.[15]

[14] The assumption of an upper tier utility is only a technicality since the presence of the numeraire Z is necessary for ruling out the zero trade cost assumption (Davis (1998)). More precisely, U is a natural logarithm Cobb-Douglas function:

$$U_i = \alpha^i \ln u_i + \left(1 - \alpha^i\right) \ln Z_i$$

$$U_j = \alpha^j \ln u_j + \left(1 - \alpha^j\right) \ln Z_j$$

where α is the parameter of the Cobb-Douglas function, while Z is the consumption level of the numeraire good in each city.

[15] The share of city i demand of its own produced good Sh_i can be written as

$$Sh_i = \frac{Y_i}{Y_i + Y_j} = \frac{1}{1 + \left(\frac{w_i}{w_j}\right)\left(\frac{POP_i}{POP_j}\right)}$$

Maximizing (1) subject to (3) with the operator L and the Lagrangean operator λ, we obtain the following three first order conditions:

$$\frac{\partial L}{\partial \sum_{k=1}^{n} C_k} = 0 \Rightarrow \left[\sum_{k=1}^{n} \left(\beta_i^i C_k\right)^{\left(\frac{\sigma-1}{\sigma}\right)} + \sum_{k=n+1}^{N} \left(\beta_i^j C_k\right)^{\left(\frac{\sigma-1}{\sigma}\right)} \right]^{\left(\frac{1}{\sigma-1}\right)} \left(\beta_i^i\right)^{\left(\frac{\sigma-1}{\sigma}\right)} \sum_{k=1}^{n} \left(C_k\right)^{\left(-\frac{1}{\sigma}\right)} - \lambda p_i = 0 \quad (5)$$

$$\frac{\partial L}{\partial \sum_{k=N}^{n+1} C_k} = 0 \Rightarrow \left[\sum_{k=1}^{n} \left(\beta_i^i C_k\right)^{\left(\frac{\sigma-1}{\sigma}\right)} + \sum_{k=n+1}^{N} \left(\beta_i^j C_k\right)^{\left(\frac{\sigma-1}{\sigma}\right)} \right]^{\left(\frac{1}{\sigma-1}\right)} \left(\beta_i^j\right)^{\left(\frac{\sigma-1}{\sigma}\right)} \sum_{k=n+1}^{N} \left(C_k\right)^{\left(-\frac{1}{\sigma}\right)} - \lambda p_j \tau = 0 \quad (6)$$

and the budget constraint (3). Combining (5) and (6), we can derive the share of expenditure of local goods both for city i and j:

$$\frac{\sum_{k=1}^{n} p_i C_k}{Y_i} = \frac{n\left(\frac{p_i}{\beta_i^i}\right)^{1-\sigma}}{n\left(\frac{p_i}{\beta_i^i}\right)^{1-\sigma} + n^*\left(\frac{p_i}{\beta_i^j}\right)^{1-\sigma}} \quad (7)$$

$$\frac{\sum_{k=n+1}^{N} p_j C_k}{Y_j} = \frac{n^*\left(\frac{p_j}{\beta_j^j}\right)^{1-\sigma}}{n\left(\frac{\tau p_i}{\beta_j^i}\right)^{1-\sigma} + n^*\left(\frac{p_j}{\beta_j^j}\right)^{1-\sigma}} \quad (8)$$

In addition, combining (7) and (8), we obtain:

$$\frac{\sum_{k=n+1}^{N} p_j C_k}{\sum_{k=1}^{n} p_j \tau C_k} = \frac{T_{ij}}{\sum_{k=1}^{n} p_j \tau C_k} = \frac{n^*\left(\beta_j^i\right)^{(1-\sigma)}}{n\left(\tau\beta_j^j\right)^{(1-\sigma)}} \quad (9)$$

where T_{ij} is the value of trade between city i and city j. In (9) we can observe that the higher is the level of β_j^i and $\frac{n^*}{n}$, i.e. the taste indicator of city j towards the the products of city i and the ratio of the varieties of goods, and the lower is τ, the trade costs, the higher is going to be the intensity of trade.

3.1 Cost, Distance and Taste

We include the additional assumption that τ is modelled following Samuelson (1948)'s iceberg trade costs, which implies that the total amount of goods shipped between the two cities, must be discounted by trade costs which represent a share of the total value of goods.[16]

$$p_j = p_i \tau_{ij} \quad (10)$$

and taking logs of (9) and substituting (10),

$$\ln T_{ij} = 2\ln\left(n^* - n - w_j\right) + 2\left(1-\sigma\right)\ln\beta_i^i - 2\left(1-\sigma\right)\ln\left(\frac{\tau_{ij}}{\beta_j^i}\right) + \ln POP_j \quad (11)$$

[16]As a matter of example, the method of preserving fish under salt was introduced only in the 14^{th} century (Michell (1977)).

which is similar to the Dixit-Stiglitz-Krugman version proposed by Combes, Mayer, and Thisse (2008). Given the elasticity of substitution $\sigma < 1$, equation (11) suggests that trade between city i and j is positively driven by the variety of goods from i with respect to the good produced in i, $(n^* - n)$, by the taste indicators β_i^i and β_j^i, i.e. the level of the preference on the goods imported, and by the population size in j. On the other hand, the cost τ is supposed to reduce the intensity of trade between the two cities. Particularly relevant is the interaction between trade cost and the bias in preference. The higher is the bias of taste towards external products β_j^i, the more positive the intensity of trade between the two cities is expected to be.[17]

4 Speed of Disease and Trade

As an additional step in our analysis we consider the relationship between speed ($SPEED$) and trade (T_{ij}) between the first infector city i and the second infected city j as

$$\ln T_{ij} = \theta_0 + \theta_1 \ln SPEED_{ij} + \epsilon_{ij} \tag{12}$$

This relationship has been motivated in Section 2 and by Figure 7 where we explained the connection between medieval trade and spread of the Black Death. This comes into the previous section. Substituting (12) into (11), we obtain a functional form which can be estimated as:

$$\ln SPEED_{ij} = \alpha_0 + \gamma_1 \ln \beta_i^i + \gamma_2 \ln \left(\frac{\tau_{ij}}{\beta_j^i} \right) + \gamma_3 \ln POP_j + \xi_{ij} \tag{13}$$

with $\alpha_0 = \frac{2\ln(n^* - n - w_j) - \theta}{\theta_1}$, $\gamma_1 = \frac{2\ln(n^* - n - w_j) - \theta}{\theta_1}$, $\gamma_2 = \frac{-2\ln(1-\sigma) - \theta}{\theta_1}$, $\gamma_3 = \frac{1}{\theta_1}$ and $\xi_{ij} = \frac{\epsilon_{ij}}{\theta_1}$. Assuming $\theta_1 > 0$ we are expecting the same relations between the explanatory variables of trade and the speed of the disease. In addition, τ_{ij} can be expressed adopting the technique proposed by McCallum (1995), who model the bilateral transactions as a function of observable social and political variables:

$$\ln \tau_{ij} = \delta_0 + \delta_1 \ln DIST_{ij} + \delta_2 X_{ij} + \delta_3 Z_i + \delta_4 Z_j + \xi_{ij} \tag{14}$$

where X_{ij} are bilateral trade variables, and Z_i and Z_j are variables related to city i and j respectively. This structure of (13) is similar to the traditional framework of the gravity equation, introduced into economics by Tinbergen (1962), which represents bilateral trade between the two areas as a function of Gross Domestic Product (GDP), geographical distance and a stochastic error term.[18]

Comparing our specification (13) and the traditional gravity equation, we can observe some differences. First of all, in our analysis we cannot estimate the standard gravity equation since data on bilateral trade and GDP are not available for the 14^{th} century. In addition, political and social variables can be considered proxies for the taste indicators β. Moreover, the assumption that the geographical distance is the only term of resistance could be reductive since other social and political variables can play an important role in stimulating or reducing trade. Furthermore, our choice of POP_j could be considered an accurate approximation of GDP for the second city, since, following De Long and Shleifer (1993) and Acemoglu, Johnson, and Robinson (2005) show the strong positive

[17] Recent empirical evidence on the commerce of French wine (Crozet, Head, and Mayer (2012)) confirms the effects of quality and tastes on long distance trade.

[18] More formally, the log-linearization form of the gravity equation between two areas i and j can be represented as

$$\ln T_{ij} = \ln B_0 + \delta_1 \ln Y_i + \delta_2 \ln Y_j + \gamma_1 \ln DIST_{ij} + \ln \epsilon_{ij}$$

where Y is the GDP and ϵ_{ij} is a stochastic error term, assumed to be independent by the other regressors.

link between income and population growth. In order to get a better comparison with the standard gravity model, we consider as measure of economic size for the trade pair ij the number of inhabitants of the two cities in the year 1300 (POP_i and POP_j).

The following sections analyze different estimation techniques and several robustness checks.

5 Data and Descriptive Statistics

The dependent variable is the speed of transmission of the plague between two towns expressed in kilometers per day. We take the arrival of the disease in each town as the mark. The data is based on the research of a cohort of medieval historians who worked on the topic for the last century intensively. The sources are listed in Appendix A. We take these data and fit them into a roster of four quarters per month. We cover the period from 1346-1351. We restrict our set of observations to this time interval to avoid any feedback loops of the plague to already infected cities or areas which would bias our data set. As explanatory variables we consider several types of data whose sources are also described in Appendix A. Tables 1 and 2 display the names and brief descriptions of the variables chosen for the estimation. The motivation for the choice of the variables has been given in the previous chapter. Along this motivation we split the table into five groups of regressors: the ones typically used in standard gravity model, geographical variables, social and political variables, religious variables and time variables which describe the environment during the period of the spread of the Black Death from 1346 to 1351. A complete list of the political regions and the number of cities taken into consideration can be found in Appendix B.

[Tables 1 and 2 about here]

Table 3 depicts the descriptive statistics of the variables related to both the bilateral and singular characteristics of the cities. We were able to collect data from 205 pairs of cities. Similar to the results obtained by Benedictow (2004), the speed of the disease is very heterogeneous: in our dataset we can find values from about 110 meters to about 54 km per day. The average speed of transmission is about 5.4 km per day. If we split up the observations by land, sea, and river trade we arrive at different speeds of transmission. The transmission by land is the slowest, at roughly 3.5 km per day, sea trade takes 10 km per day and river trade 7.2 km per day. If we compare these velocities with the actual traveling time of a merchant, we observe that the average spread of the disease is much slower than the potential maximum speed the infection could take just based on the physical restriction by the mean of transportation. Merchants traveled 15-30 km per day on land. On boats, merchants could make around 30 km per day and on sea 100-130 km per day (Pryor (1992) and McCormick (2001)). This supports our argumentation that the spread of the disease is a measure for trade intensity between two cities. The mean of transportation is a partial function of this trade intensity as elaborated earlier in the text. More results related to the speed will be discussed when we analyze and interpret the estimation coefficients in the next chapter.

[Table 3 about here]

Let us characterize the sample further: The city size in the sample ($pop1$, $pop2$) is also rather heterogeneous: the sample contains small towns with 1,000 inhabitants in Sicily to 400,000 inhabitants in Cairo (and 150,000 in Europe with Paris). The distance ($dist$) between city-pairs covers distances as short distances as 6 kilometers to more than 3,335 kilometers. About 37 percent of the city-pairs have a common border. About 20 percent of the sample considers cities which are involved in trade

with cities located by the sea. Finally, the maximum elevation considered is about 1,800 meters with an average of about 160 meters. The other variables related to geography and sociopolitical factors have heterogeneous distributions.

A final special note must be given to the climate data we use. Unfortunately, we do not have detailed climate measures for all of Europe during the 14^{th} century. For those reason, we consider the data absolute surface air temperatures provided by Jones (1999). Those data collect the average of monthly land air temperature on a 5% by 5% grid-box basis depurated by temperature anomalies of the last of the global warming. We assume that those data can be considered a good approximation. Our assumption is confirmed by other local or more aggregated studies in climatology and economics (e.g., Mann, Bradley, and Hughes (1999), Chuine (2004) and Kelly and O Grada (2012)). Furthermore, in a previous version (Boerner and Severgnini (2011)) we obtained very similar results considering three different dummies if the Black Death appeared in autumn, spring, or summer and from 1347 to 1351.

6 Estimation Results

Tables 4 and 5 display the main results of our modified gravity estimation represented by (13) with Ordinary Least Square (OLS) following different types of specifications. In all columns we control for time, climate effects and longitude and latitude.[19]

[Tables 4 and 5 about here]

Columns (1) and (2) consider the standard model of (13) assuming that all effects of resistance and/or positive adjustments to trade can be explained by the geographical distance or by a political border: the first column studies the effect on population size and distance on the speed of propagation; in the second column the model is extended to the presence of a political border. The coefficient for distance is the only significantly positive one. Thus, the coefficients suggest that the longer the distance, the greater the intensity of trade. This supports the conclusion by medieval economic historians that long-distance trade plays a crucial role in medieval trade, but is different from what international trade empiricists find when they measure trade flows between countries based on GDP of imports and exports. Next, column (3) reports the coefficients of the basic model extended by additional geographical variables, and more precisely the dummies controlling whether the two cities are connected by a river (*river*) or they trade along a sea route in the North Atlantic Ocean (*ocean*), in the Mediterranean (*mediterranean*), or in the North and Baltic Sea (*northbaltic*). The estimator for *river* connections is positively significant. Hence, this suggests that the trade on a water channel is much more intense than on land or on sea. This confirms the studies by medieval historians. Furthermore, we find a positive and significative sign for the North Atlantic Ocean. However we cannot find any significant effects for the other sea connections. This supports the argument by historians emphasize the upswing of North West Europe.

Column (4) extends the analysis considering remoteness for both cities ($remoteness1$ and $remoteness2$). We define remoteness as the (log of) ratio of distance with respect to population with respect to the nearest seaport.[20]

[19] In Section 8 we investigate the geographical effects on trade in a more detailed way.

[20] In modern trade theory remoteness is calculated as the natural logarithm of the distance of a country with respect to all the others weighted by the GDP (Wei (1996)). Remoteness is significant and negative for the first city, and positive for the second city, respectively.

Furthermore, column (5) displays the previous specification enhanced with the religious periods *lent* and *advent*. We can observe that, even if sometimes not always significant, the dispersion of the disease during advent (*advent*) decelerates in comparison with to the other periods of the year. Column (5) also introduces the social and political variables *bishop*, *prince*, and *university* and a dummy which is equal to 1 if one of the two cities involved in trade is situated in an extra European territory and if the two cities are connected by a waterway (*noeurope*). The coefficients for the receiving residential cities *bishop*2 are positive and significant. Incorporating the results from columns (6) and (7) we also find a negative sign for transmitting residential cities *bishop*1 and *prince*1. This slightly confirms our hypothesis that consuming cities receive the plague faster and transmit the disease more slowly. The signs for university cities are all negative and only in one case weakly significant. Hence, lines of argument along human capital or autocratic rulers discussed in the previous sections cannot be confirmed. Finally, we do not find any significant effect for *language*: this confirms the historical evidence that difference in language did not obstacle commercial flow since merchants adopted either special language for trade or Latin, which was the universal language for nobility and religious elites (Pirenne (1969) and Lopez (1979)).

Finally, columns (6) and (7) display results refining the religious period variables and keeping all the other variables unchanged. The variable *lent* and *advent* is tested with all kinds of interaction terms. We find for the population size of the city a negative significant coefficient for the sending and a positive significant coefficient for the receiving city. These results are different from the ones provided by the standard gravity model using international trade data. However the outcome is consistent with the theoretical and empirical evidence on urban studies. The sign of the variable *border* is negatively significant and very similar to the one showed by McCallum (1995) Thus, political borders constitute barriers to medieval trade. This is consistent with the empirical insights by trade economists and confirms the findings by medieval historians who argued that political fragmentation confined trade. In general, the results suggest that trade slows down during religious seasons, in particularly and significantly during the Advent.

7 Robustness Checks

As remarked by Silva and Tenreyro (2006), the traditional estimates of the OLS estimation techniques can be affected by several biases once the dependent variable consists of the logarithm of the positive values of T_{ij} and excludes the observations equal to zero. In the first instance, this procedure could violate the Jensen inequality biasing the estimation results. Secondly, the exclusion of the observations $T_{ij} = 0$ can raise problems related to truncation. Thirdly, the choice of different sets of explanatory variables could be not completely specified. Furthermore, the presence of heteroskedasticity can worsen those biases once a log-linearization of the specification is chosen. In our study, we should control especially for those problems since we have several pairs of cities, sometimes, located in close proximity to each other, in which we do not observe a direct transmission of the disease and which could play an important role in our estimation results.

We start the robustness checks with controlling whether our gravity equation could be affected by nonlinearities in some regressors. In order to test for that, we perform a heteroskedasticity robust RESET test.[21] The *p*-values of this test (with values between 0.81 and 0.96 shown in the last part of Table 5) reject such misspecifications for all the models proposed and estimated with an OLS. However we find that the specifications are affected by heteroskedasticity. The last line of Table 5

[21] This test, introduced by Ramsey (1969), consists in adding the square of the fitted value of the model to the original specification and in testing whether this extra regressor is significant.

reports the p-values of a White (1980)'s information test (Cameron and Trivedi (1992) and Wooldridge (2010)). With values between 0.15 and 0.47, we reject the hypothesis that errors obtained by the OLS regressions are not homoskedastic, suggesting that the OLS could provide some biases in our specification. Thus another type of estimation in particular considering also the "zero" observations could be more appropriate.

For these reasons we take into account also observations of city-pairs. We do not directly observe any transmission between them. Beside the 206 observations already in the OLS specification, we incorporate all the possible land-trade contacts which are less than or equal to the maximum distance observed in the first cities of 206 city-pairs and all the connections of cities on waterways at a distance less or equal than 700 kilometers.[22] In this way we obtain a new set based on 377 observations.

We test our specifications in the following way:[23] First, we consider whether different distances used for the threshold can imply different types of potential geographical clustering due to several externality effects: we compare the White standard errors obtained by the OLS regression with the ones obtained by spatial correlation following the approach suggested by Conley (1999). Figure 8 in Appendix C shows the difference of the two measures for the standard errors related to population size (the variables $lnpop1$ and $lnpop2$) and the distance ($lndist$). We can observe that the changes in the Conley standard errors increases over the distance considered, measured in degrees, especially after 3 degrees, which is about 350 kilometers. This confirms that our results are not affected by geographical externalities effects.[24] Finally, we consider different types of water distance between cities: if we restrict the distance on waterways between 0 and 1,100 km we get the same results in terms of sign, size and significance and the RESET test always rejects the hypothesis that the model is not specified completely. If we consider a distance higher than 1,200 km, the RESET test does not accept the hypothesis that the model is fully specified.

In Tables 6 and 7 we compare the most complete OLS regression illustrated in the previous section (column (1)) with the other estimation techniques which allow us to consider the 377 observations. The regression in column (2) transforms the dependent variable $\ln Speed_{ij}$ (used in column (1)) into $\ln(1 + Speed_{ij})$ and provides the estimation results with an OLS. Column (3) reestimates the same regression using a Tobit technique. Furthermore, column (4) displays the estimates following the method proposed by Eaton and Tamura (1994), which differs from the standard Tobit model in the construction of the dependent variable. In this type of estimation, we consider as measure of trade intensity $\ln(a + Speed_{ij})$, where the additional estimated parameter a is assumed a sort of iceberg costs such that we obtain some bilateral activities if and only if trade is higher than this value. Finally, columns (5) and (6) show the technique introduced by Silva and Tenreyro (2006) which is based on a Pseudo Poisson Maximum Likelihood (PPML) (Gourieroux, Monfort, and Trognon (1984)) both for the 206 pairs of cities with positive dependent variable and for the entire sample. This methodology is considered to be particularly versatile in dealing with measurement errors and sample selections.

[Tables 6 and 7 about here]

The RESET tests reported at the end of Table 7 reject in all the cases the hypothesis of any misspecification of the model. In all the cases, we can observe that all results in terms of sign and significance are almost always confirmed by the different types of specification-even if the distance,

[22]We also tried other distances obtaining similar results.

[23]A different approach considering the matches between the first "infector"' city with the second "infectee"' city is often used in epidemiology (Eggo and Ferguson (2011)).

[24]Similar results are obtained for all the other variables on our specification.

geographical and political variables are more significant and bigger in terms of size-suggesting the robustness of the results. First, the coefficient obtained by the Poisson estimation are just slightly different once both the sub-sample with positive value at the dependent variable and the entire sample are taken into consideration. This suggests that the truncation of the observations with zero values has a limited impact on the estimation results. Furthermore, the geographical coordinates also turn out to be significant indicating greater intensity from East to West and from North to South. In addition, the similar results displayed by columns (5) and (6) suggest that truncation is not a relevant problem for our regression. The final hypothesis to test is the one related to heteroskedasticity: if we increase the number of observations, another serious bias related to the estimation of the log-linearized form of the basic gravity equation can appear: when zero values on the dependent variables are added, the error term ξ_{ijt} of (13) can depend on the other regressors. For those reasons, assuming that our best specification is the one obtained by column (6), we consider the Gauss-Newton regression (GNR) test (Davidson and MacKinnon (1994)), and the Park-type test introduced by Manning and Mullahy (2001).[25] All the tests reported in Table 8 reject the hypothesis of heteroskedasticity.

[Table 8 about here]

8 Geographical Effect on Trade

In this section we study trade effects determined by the geographical coordinates of longitude and latitude in more detail. So far we could disentangle many factors, which drive medieval trade. A specific emphasis in historical studies has been put on the economic developments of different regions in Europe and the Mediterranean area. As pointed out earlier, the Late Middle Ages were a period of catching up with (or even overtaking) Western Europe compared to the African and Eastern Mediterranean area. This brings us to the question if we can identify different trade intensities based on variations in-, and outflows across Europe and the Mediterranean area for the period of investigation. Furthermore, we have found that marginal effects of distance are crucial in determining the speed of transmission. Thus, we need to check if this ”far distance trade effect” varies by region.

The Mediterranean area and especially the Genoese and Venetian trading areas have been recognized as central to trade activities (Lopez (1976), Epstein (2000b) and Abulafia (2011)). In comparison, the East Mediterranean was found to have entered a phase of economic decline (Lewis (2002) and Kuran (2003)). Egypt and the Byzantine empire were rich, but started to become politically backwards and less technology-friendly (Runciman (1952)). For example, the area was swamped by textile products from Northwest Europe, especially from Flanders whose own textile production was in decline. Spices and silk were still traded to the West. Furthermore, with the Muslim decline in Europe and new dominance of Venice and Genoa the Mediterranean East West trade had moved from along the African to the Northern European coast lines (Pryor (1992)). England profited from the uprise of the Italian city states also the trade axis Italy- France/Belgium - England.(Postan (1952) Favier (1980)) In addition Western and Southern Germany and neighbouring Bohemia and Silesia had an economic upswing related to the Italian/ Mediterranean trade. (Kellenbenz (1980); Malowist (1952)) Furthermore a lively trade in the Bay of Biscay between the French/Basque/Spanish coast took place (O'Callagan (1975)). Complementary to this North Western rise the Baltic area also developed. Dollinger (cite) claims that the first rise of the Hanseatic area came to an end when the Plague broke out in Northern Europe.

[25] Those tests are based on a robust covariance matrix estimator of the equation $\frac{(T_i - \hat{T}_i)^2}{\sqrt{\hat{T}_i}} = \delta_0 \sqrt{\hat{T}_i} + \delta_0 (\delta_1 - 1)(\ln T_i)\sqrt{\hat{T}_i} + \epsilon_i$ where $\hat{T}_i$ is the estimated value of the level of speed.

In order to create geographical predictions for trade flows we follow the estimation strategy suggested by Dell (2010) considering the following regression form:

$$SPEED_{ij} = g\left(f\left(geographic\ coordinates_{ij}\right), \Theta_{ij}\right) + \mu_{ij} \tag{15}$$

where $f\left(geographic\ coordinates_{ij}\right)$ controls for smooth functions of geographic locations and Θ_{ij} are the variables we considered in the previous sections for our estimates. We define the geographical function as a polynomial of longitude and latitude coordinates

$$f\left(geographic\ coordinates_{ij}\right) = \lambda_1 longitude1 + \lambda_2 latitude1 + \lambda_3 longitude1^2 + \lambda_4 latitude1^2 \tag{16}$$

$$+\lambda_5 longitude1 * latitude1 + \lambda_6 longitude1^3 + \lambda_7 latitude1^3 + \lambda_8 longitude1^2 * latitude1 + \lambda_9 longitude1 * latitude1^2$$

$$+\lambda_{10} longitude2 + \lambda_{11} latitude2 + longitude2^2 + \lambda_{12} latitude2^2 + longitude2 * latitude2$$

$$+\lambda_{13} longitude2^3 + \lambda_{14} latitude2^3 + \lambda_{15} longitude2^2 * latitude2 + \lambda_{16} longitude2 * latitude2^2$$

We proceed in four steps. First, since we want to concentrate on the geographical effect and some of the covariates considered in our regression can be highly correlated with the polynomial (16), we consider as explanatory variables for Θ_{ij} the variables *sea* and *river*.[26] Second, we estimate a PPML of the (15) for the 377 observations. Third, given the results of the estimation, we compute the nonlinear predictions for a spaced grid of longitude-latitude coordinates. Finally, we repeat our estimation exercise including as additional estimator the variable *lndist* and we compute the marginal fixed effect of distance on the speed of the disease. Figures 3, 4 and 5 consider the regressions constrained to sea, land, and river routes, respectively. The upper part of these figures show the predictions of the speed of the disease for the infector and the infectee, which we use as proxy for inflows and outflows. The lower part shows instead the marginal fixed effects of distance on the speed of the speed along the range of the different coordinates, i.e. how much the speed of dispersion can increase or decrease once the value of *lndist* is increased by one unit. The colors follows a rainbow spectrum, while the color white covers non significant areas. Furthermore, those predictions are measured on a scale of 10 meters in order to make the graphs clearer.[27]

[Figures 3, 4 and 5 about here]

These figures depict the following results. With respect to sea trade we find fast outflows in the North West of Europe, inclusive strong effects around Venice. Similar results can be found for the distance effects. However here we find the strongest estimates around the cost of Northern Italy and Southern France. Inflow effects can be measured in the North and Eastern Mediterranean and into the neighboring Black Sea and in the Atlantic and Baltic Sea. Stronger effects can be found in the East Mediterranean, the North Sea, and the Bay of Biscay. Distance effects look similar. Land trade effects fit neatly into the sea trade effects. Effects can be found in the North West. However with a stronger emphasis on Southern Germany/ Switzerland, distance effects are again strongest in Northern Italy, Southern France, and the Basque area. Significant inflows can be measured in most Continental Europe and Byzantine Empire. Distance effects can be found mainly in Central/ Eastern Europe and the Byzantine empire. In general these inflow effects are weaker than the corresponding outflow effects. The river trade effects look similar. The exception are outflow distance effects where almost none effects are measured except in Russia.

[26] Also including the cubic polynomial, the results of the estimations are robust. Results are available upon request.

[27] For some software problems in the MATLAB packages is not possible to represent the effects for the Black Sea. We provide the effect in Figure 8 in Appendix C.

Thus, although these results rely on simulated estimators, and we have to be careful not to over interpret these findings, as they confirm the thesis by medieval historians: rising economic areas like the North West of Europe have a stronger trade outflow than inflow-intensity. Conversely, stagnating areas with high consumption, like the Eastern Mediterranean areas have faster incoming than outgoing trade streams. Furthermore, the distance effects confirm the trade axis from the Northern Mediterranean to the North West of Europe. (Strong outgoing distance effects can be documented in Italy and Southern France). Corresponding inflow effects can be identified in Northern and Western Europe. In addition, on the aggregate level trade was more intense in North West Europe.

9 Conclusion

This paper studied medieval trade flows based on the spread of the Black Death from 1346-1351 in Europe. We used the speed of the transmission of the plague from one city to the next as a proxy to identify the intensity of trade between these two cities. We created a set of approximately 206 city-pairs from Europe and the Mediterranean area to identify these trade flows. Our main findings are that the intensity of trade depends on the means of transportation, the distance, the political borders, religious holidays, and the institutional function of a city.

To arrive at these conclusions, we introduced a modified gravity model where the speed of transmission (in kilometers per day) is the dependent variable. We identified a set of dependent variables which are based on the findings of medieval economic historians, who used qualitative observations of what determined trade and on the insights of empirical trade economists who estimated significant variables which influence trade flows. We run several variations of this modified gravity equation and made several robustness checks: we started with a simple OLS-regression and corrected for the standard error by the robustness methodology by White (1980) and by Conley (1999). Next we introduced several types of Tobit estimation techniques to control for unobservable data sets. This way we expanded the data set to more than 377 observations. Beside the standard Tobit technique we also used the methods by Eaton and Tamura (1994) and Silva and Tenreyro (2006).

Based on these estimation techniques, we showed that water trade on rivers and seas was more intense than overland trade. Political borders slowed trade. Furthermore, we found that distance had a positive impact on the speed of transmission. In addition we showed that the religious holidays of Advent slowed down trade and concluded that political residential cities, especially bishop cities had a significantly faster inflow. City size (used as a medieval proxy for economic size) played a negative role for outflows and a positive role for inflows. However the results are non-significant role in determining the speed of transmission. Finally, we showed that the speed of in- and outflow depended on the geographical location of a place. We found high speeds and thus strong trade intensity in the Northern Mediterranean area and in Northwest Europe. We detected strong in- and outflows in North West Europe. Strong inflows could also be identified in the Eastern Mediterranean area. We found similar geographical effects and distance effects between two cities. Regions with fast receiving and transmitting rates had strong positive distance effects.

These results allow us for the first time to quantify medieval trade flows on an aggregate level. We can confirm findings by medieval economic historians that trade on water transport routes was more intensive (Postan (1952)), and that political borders were a major impediment to medieval trade. North and Thomas (1973) We can back up the argument that long-distance trade was the critical factor in medieval trade (Braudel (1949), Lopez (1952 and 1976), Cipolla (1993)). Thus this period of trade can be characterized by a qualitative improvement of trade connections than by a general market integration (O'Rourke and Williamson (2002)). Furthermore, the results of the impact of city

size and positive impact on distance also confirm insights by urban economists (Von Thunen (1826), Krugman (1991) and Ades and Glaeser (1995)) In addition, we can identify religious holidays and political functionality as determinant for late medieval trade flows, neither of which have been taken into consideration to explain trade flows in the literature.

Furthermore, even the results are only a snap-shot of late medieval trade, the geographical effects confirm the thesis that the Late Middle Age was the crucial period for the rise of (North) Western Europe. The results document strong trade intensity, in terms of import and export flows in this area. In contrast, only significant inflows can be measured for the Eastern Mediterranean area and no effects in the African Mediterranean area. This indicates a stronger consumption and in general comparably less trade activities for this area, which can be interpreted as a slowly incipient economic decline. In this way our findings contribute to knowledge of the early triggers of the Great Divergence of Western Europe from other parts of the world (Weber (1921), Epstein (2000b) and Pomeranz (2001)).

Finally, with the application of the gravity model to data in epidemics we contribute to a small but growing literature which studies the channels of communication and economic activities in the context of or in relation to epidemics (Bettencourt, Lobo, Strumsky, and West (2007), Bettencourt and West (2010), Viboud and al. (2006) and Oster (forthcoming)). Such a link can be useful when quantitative data are missing or can be used as a complementary approach to study trade flows and other social interaction effects.

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Tables and Figures

Tables

Table 1: Variable names and descriptions (first part)

Variable	Description
	Standard gravity model
speed	speed of the disease in km/day
lnspeed	ln(speed)
pop1	population size in 1300 for the 1^{st} city (in in thousands)
lnpop1	ln(pop1)
pop2	population size in 1300 for the 2^{nd} city (in thousands, second city)
lnpop2	ln(pop2)
dist	bilateral geographical distance (in km)
lndist	ln(dist)
border	equals 1 if the two cities are in different regions, and 0 otherwise
	Geographical variables
sea	equals 1 if the two cities traded along a sea route, and 0 otherwise
river	equals 1 if the two cities traded along a sea route, and 0 otherwise
ocean	equals 1 if the two cities are along sea routes in North Atlantic Ocean, and 0 otherwise
mediterranean	equals 1 if the two cities are along a sea route in the Mediterranean, and 0 otherwise
northbaltic	equals 1 if the two cities are along a sea route in the North and Baltic Sea, and 0 otherwise
elevation1	elevation of the first city (in natural logarithm, in m)
lnelevation1	ln(elevation1)
elevation2	elevation of the second city (in natural logarithm, in m)
lnelevation2	ln(elevation2)
latitude1	latitude of the first city
latitude2	latitude of the second city
longitude1	longitude of the first city
longitude2	longitude of the second city
noeurope	equals 1 if at least one of the two cities are not in the European continent, and 0 otherwise
remoteness1	remoteness from the hub for the 1^{st} city
remoteness2	remoteness from the hub for the 2^{nd} city

Table 2: Variable names and descriptions (second part)

Variable	Description
	Social and political variables
bishop1	equals 1 if the first city has a bishop, and 0 otherwise
bishop2	equals 1 if the second city has a bishop, and 0 otherwise
prince1	equals 1 if the region of the first city has a prince, and 0 otherwise
prince2	equals 1 if the region of the second city has a prince, and 0 otherwise
university1	equals 1 if the first city has a university, and 0 otherwise
university2	equals 1 if the second city has a university, and 0 otherwise
language	equals 1 if the the two cities share a common language, and 0 otherwise
	Religious variables
lent	equals 1 if the first city is contaminated during lent, and 0 otherwise
advent	equals 1 if the first city contaminated during advent, and 0 otherwise
lentborder	lent*border
adventborder	advent*border
	Climate and time variables
temperature1	estimate of the temperature (in Celsius degrees*100) of the first city
temperature2	estimate of the temperature (in Celsius degrees*100) of the second city and 0 otherwise
year1347	equals 1 if the contamination happened during 1347 and 0 otherwise
year1348	equals 1 if the contamination happened during 1347 and 0 otherwise
year1349	equals 1 if the first city is contaminated during 1349, and 0 otherwise
year1350	equals 1 if the contamination happened during 1350 and 0 otherwise
year1351	equals 1 if the contamination happened during 1351 and 0 otherwise

Table 3: Descriptive statistics

Variable	**Mean**	**Standard deviation**	**Min**	**Max**
Standard gravity model				
speed	5.25	7.90	0.11	54.08
*pop*1	24,668.87	30,511.86	200.00	16,6553.00
*pop*2	18,306.05	36,761.11	100.00	400,000.00
dist	280.07	461.71	6.37	3,355.00
border	0.49	0.50	0.00	1.00
Geographical variables				
sea	0.34	0.44	0.00	1.00
river	0.15	0.36	0.00	1.00
ocean	0.06	0.24	0.00	1.00
mediterranean	0.20	0.40	0.00	1.00
baltic	0.08	0.27	0.00	1.00
*elevation*1	114.44	202.41	1.00	1,350.00
*elevation*2	166.76	247.21	1.00	1,815.00
*latitude*1	44.62	5.88	31.21	60.38
*latitude*2	44.76	6.30	30.05	60.38
*longitude*1	9.80	9.46	-8.55	46.28
*longitude*2	9.50	9.70	-8.64	44.39
noeurope	0.03	0.18	0.00	1.00
*remoteness*1	1.03	7.30	0.00	52.75
*remoteness*2	0.23	1.71	0.00	17.61
Social and political variables				
*bishop*1	0.45	0.50	0.00	1.00
*bishop*2	0.39	0.49	0.00	1.00
*prince*1	0.51	0.50	0.00	1.00
*prince*2	0.51	0.50	0.00	1.00
*university*1	0.06	0.24	0.00	1.00
*university*2	0.07	0.25	0.00	1.00
language	0.65	0.48	0.00	1.00
Religious variables				
lent	0.26	0.44	0.00	1.00
advent	0.04	0.20	0.00	1.00
$advent * border$	0.02	0.15	0.00	1.00
$lent * border$	0.15	0.35	0.00	1.00
Climate and time variables				
*temp*1	13555.57	6326.33	-2400.00	25600.00
*temp*2	12748.10	5821.59	-8900.00	25600.00
*year*1347	0.29	0.46	0.00	1.00
*year*1348	0.50	0.50	0.00	1.00
*year*1349	0.19	0.40	0.00	1.00
*year*1350	0.01	0.10	0.00	1.00
*year*1351	0.00	0.07	0.00	1.00
Number of observations: 206				

Table 4: Determinants of Trade: OLS Regressions (first part)

Dep. Variable:	$\ln Speed_{ij}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Standard gravity model							
*lnpop*1	0.00	0.00	-0.01	-0.05	-0.04	-0.07	-0.06
	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.07)	(0.07)
*lnpop*2	0.07	0.08	0.08	0.09	0.08	0.09	0.08
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
lndist	0.51***	0.54***	0.44***	0.41***	0.51***	0.53***	0.54***
	(0.07)	(0.08)	(0.10)	(0.10)	(0.10)	(0.09)	(0.09)
border		-0.21	-0.22	-0.25	-0.34*	-0.37**	-0.49***
		(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.18)
Geographical variables							
river			0.56*	0.60**	0.72***	0.70***	0.68***
			(0.24)	(0.23)	(0.24)	(0.23)	(0.24)
ocean			1.11**	0.92**	1.25***	1.17***	1.13***
			(0.41)	(0.43)	(0.40)	(0.38)	(0.41)
northbaltic			0.15	0.40	0.54	0.52	0.55
			(0.35)	(0.38)	(0.39)	(0.38)	(0.39)
mediterranean			0.31	0.28	0.08	0.09	0.12
			(0.26)	(0.25)	(0.25)	(0.25)	(0.26)
*lnelevation*1				0.07	0.05	0.03	0.04
				(0.06)	(0.06)	(0.06)	(0.06)
*lnelevation*2				-0.14***	-0.12**	-0.12**	-0.11**
				(0.05)	(0.05)	(0.05)	(0.05)
*longitude*1	0.01	0.01	0.02	0.02	0.03*	0.03*	0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
*latitude*1	-0.04	-0.03	-0.02	-0.06	-0.06	-0.06	-0.06
	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)
*longitude*2	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
*latitude*2	-0.01	-0.00	-0.03	-0.01	-0.03	-0.01	-0.01
	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)
*remoteness*1				-0.20***	-0.15**	-0.16**	-0.19***
				(0.06)	(0.06)	(0.07)	(0.07)
*remoteness*2				0.51	0.56*	0.58**	0.58**
				(0.39)	(0.27)	(0.27)	(0.28)
Religious variables							
advent						-1.26***	-1.49**
						(0.48)	(0.73)
lent						0.10	-0.04
						(0.20)	(0.28)
adventborder							0.48
							(0.87)
lentborder							0.28
							(0.34)

Table 5: Determinants of Trade: OLS Regressions (second part)

Dep. Variable:	$\ln Speed_{ij}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Social and political variables							
language					0.24	0.22	0.20
					(0.19)	(0.18)	(0.18)
*bishop*1					-0.36*	-0.45**	-0.45**
					(0.19)	(0.18)	(0.18)
*bishop*2					0.21	0.24	0.23
					(0.18)	(0.17)	(0.17)
*prince*1					-0.03	-0.13	-0.12
					(0.21)	(0.21)	(0.21)
*prince*2					-0.34	-0.32	-0.33
					(0.24)	(0.23)	(0.23)
*university*1					0.07	-0.03	-0.04
					(0.32)	(0.32)	(0.33)
*university*2					-0.29	-0.30	-0.28
					(0.24)	(0.24)	(0.24)
noeurope					-1.48***	-1.21**	-1.23**
					(0.54)	(0.55)	(0.56)
Climate and time variables							
*temp*1	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
*temp*2	0.00**	0.00**	0.00	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
*year*1347	0.92**	1.07***	1.04*	1.06**	1.98***	1.83***	1.93***
	(0.36)	(0.39)	(0.42)	(0.53)	(0.56)	(0.56)	(0.57)
*year*1348	1.61***	1.74***	1.85***	1.96***	3.09***	2.51***	2.63***
	(0.44)	(0.45)	(0.45)	(0.51)	(0.63)	(0.66)	(0.68)
*year*1349	2.22***	2.37***	2.51***	2.59***	3.73***	3.03***	3.19***
	(0.50)	(0.51)	(0.51)	(0.58)	(0.69)	(0.73)	(0.75)
*year*1350	0.88*	0.98*	1.40*	1.13*	2.00**	0.97	1.05
	(0.57)	(0.56)	(0.54)	(0.67)	(0.83)	(0.90)	(0.91)
*year*1351	2.13***	2.11***	2.36***	1.92***	2.64***	1.94***	1.96***
	(0.46)	(0.46)	(0.45)	(0.47)	(0.62)	(0.66)	(0.66)
Constant	-2.40*	-2.73*	-2.05	-0.42	-1.86	-1.36	-1.62
	(1.43)	(1.44)	(1.62)	(1.93)	(1.99)	(1.83)	(1.86)
R^2	0.31	0.31	0.34	0.37	0.41	0.43	0.43
RESET test (p-value)	0.03	0.02	0.02	0.05	0.96	0.81	0.96
White test (p-value)	0.27	0.08	0.15	0.21	0.47	0.47	0.47
Number of observations: 206							

*; **; *** indicate significance at 10, 5 and 1% respectively.
All estimates with robust standard error clustered by the first city
White test computed on regressions without clustered standard errors.

Table 6: Determinants of trade: Robustness check (first part)

	(1)	(2)	(3)	(4)	(5)
Dep. Variable	$\ln(1+Speed_{ij})$	$(1+Speed_{ij})$	$(a+Speed_{ij})$	$Speed_{ij}$	$Speed_{ij}$
Estimator	OLS	TOBIT	TOBIT	PPML	PPML
Standard gravity equation model					
*lnpop*1	-0.00	-0.01	-0.03	-0.09	-0.07
	(0.03)	(0.05)	(0.04)	(0.08)	(0.07)
*lnpop*2	-0.00	-0.02	0.04	0.03	0.01
	(0.03)	(0.06)	(0.04)	(0.07)	(0.07)
lndist	0.36***	0.46***	0.32***	0.43***	0.62***
	(0.07)	(0.10)	(0.05)	(0.08)	(0.10)
border	-0.15	-0.22	-0.24**	-0.52***	-0.46
	(0.14)	(0.23)	(0.10)	(0.20)	(0.30)
Geographical variables					
river	1.08***	1.57***	0.50***	0.92***	1.45***
	(0.19)	(0.25)	(0.15)	(0.21)	(0.28)
ocean	0.08	-0.12	0.98***	1.55***	0.80*
	(0.38)	(0.61)	(0.25)	(0.26)	(0.49)
northbaltic	-0.37	-0.81*	0.35	0.17	-0.96
	(0.29)	(0.47)	(0.22)	(0.35)	(0.62)
mediterranean	-0.06	0.00	0.08	0.54**	0.10
	(0.20)	(0.30)	(0.15)	(0.25)	(0.33)
*longitude*1	0.04**	0.05**	0.01	0.02	0.05**
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)
*latitude*1	-0.04	-0.06	-0.03	-0.04	-0.11*
	(0.04)	(0.06)	(0.02)	(0.04)	(0.06)
*longitude*2	-0.02	-0.04	0.00	0.00	-0.01
	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)
*latitude*2	-0.02	-0.01	-0.02	-0.01	0.02
	(0.04)	(0.06)	(0.02)	(0.03)	(0.06)
*lnelevation*1	-0.02	-0.05	0.03	0.04	-0.05
	(0.03)	(0.05)	(0.03)	(0.05)	(0.07)
*lnelevation*2	-0.02	-0.01	-0.07***	-0.08	-0.05
	(0.03)	(0.05)	(0.03)	(0.06)	(0.09)
*remoteness*1	0.06	0.16*	-0.09**	-0.03	0.15*
	(0.05)	(0.09)	(0.04)	(0.05)	(0.09)
*remoteness*2	0.30	0.41	0.46**	0.87***	0.96**
	(0.36)	(0.48)	(0.23)	(0.19)	(0.46)
Religious variables					
advent	0.02	0.29	-0.63*	-2.42**	-2.25*
	(0.33)	(0.49)	(0.35)	(1.23)	(1.27)
lent	-0.01	0.00	-0.04	-0.29	-0.27
	(0.17)	(0.24)	(0.17)	(0.25)	(0.33)
lentborder	0.00	-0.00	0.17	0.25	0.29
	(0.24)	(0.36)	(0.20)	(0.27)	(0.40)
adventborder	-0.02	-0.05	-0.01	1.00	1.42
	(0.40)	(0.77)	(0.32)	(1.19)	(1.39)

Table 7: Determinants of trade: Robustness check (second part)

Dep. Variable	(1) $\ln(1+Speed_{ij})$	(2) $(1+Speed_{ij})$	(3) $(a+Speed_{ij})$	(4) $Speed_{ij}$	(5) $Speed_{ij}$
Estimator	OLS	TOBIT	TOBIT	PPML	PPML
		Social and political variables			
language	-0.02	-0.00	0.09	0.08	-0.11
	(0.11)	(0.20)	(0.10)	(0.22)	(0.25)
*bishop*1	-0.10	-0.14	-0.26**	-0.39**	-0.31
	(0.11)	(0.16)	(0.10)	(0.18)	(0.21)
*bishop*2	0.14	0.19	0.15	0.36**	0.33**
	(0.10)	(0.18)	(0.10)	(0.17)	(0.16)
*prince*1	0.04	0.04	-0.04	0.13	0.16
	(0.16)	(0.23)	(0.13)	(0.17)	(0.24)
*prince*2	-0.13	-0.09	-0.24	-0.42***	-0.31
	(0.15)	(0.22)	(0.15)	(0.13)	(0.20)
*university*1	0.14	0.24	0.01	-0.11	-0.14
	(0.17)	(0.26)	(0.18)	(0.37)	(0.40)
*university*2	-0.16	-0.27	-0.20	-0.59***	-0.60***
	(0.12)	(0.23)	(0.14)	(0.19)	(0.20)
noeurope	-0.71	-0.90	-0.83**	-0.69	-1.42**
	(0.45)	(0.54)	(0.36)	(0.50)	(0.55)
		Temporal and climate variables			
*temp*1	0.00***	0.00***	-0.00	0.00	0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
*temp*2	0.00	0.00	0.00	0.00	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
*year*1347	0.69	0.34	1.44***	1.93***	1.68***
	(0.46)	(0.67)	(0.33)	(0.47)	(0.54)
*year*1348	1.64***	1.94**	1.84***	2.84***	3.40***
	(0.56)	(0.76)	(0.38)	(0.66)	(0.74)
*year*1349	1.82***	2.02**	2.24***	3.35***	3.79***
	(0.60)	(0.82)	(0.42)	(0.71)	(0.82)
*year*1350	1.97***	2.98***	1.00*	1.05	2.97**
	(0.70)	(0.92)	(0.53)	(1.04)	(1.14)
*year*1351	2.82***	3.92***	1.53***	2.27***	4.60***
	(0.56)	(0.77)	(0.39)	(0.63)	(0.76)
Constant	-0.28	-1.20	0.20	-1.54	-2.51
	(1.18)	(1.70)	(1.10)	(2.11)	(1.95)
R^2	0.28	0.12	0.28	0.33	0.45
RESET test (p-value)	0.00	0.01	0.01	0.20	0.15
N. of observations	377	377	377	206	377

*; **; *** indicate significance at 10, 5 and 1% respectively.
All estimates with robust standard error clustered by the first city

Table 8: GNR and Park test for heteroskedasticity

Test	206 obs.	377 obs.
GNR $(V\left[T_{ij}\|x\right]\alpha\mu\left(x\beta\right)$	0.00	0.31
Park	0.05	0.00

Figure 1: Spread of the Black Death and Trade Routes in Europe

Figure 2: Diffusion of the Black Death

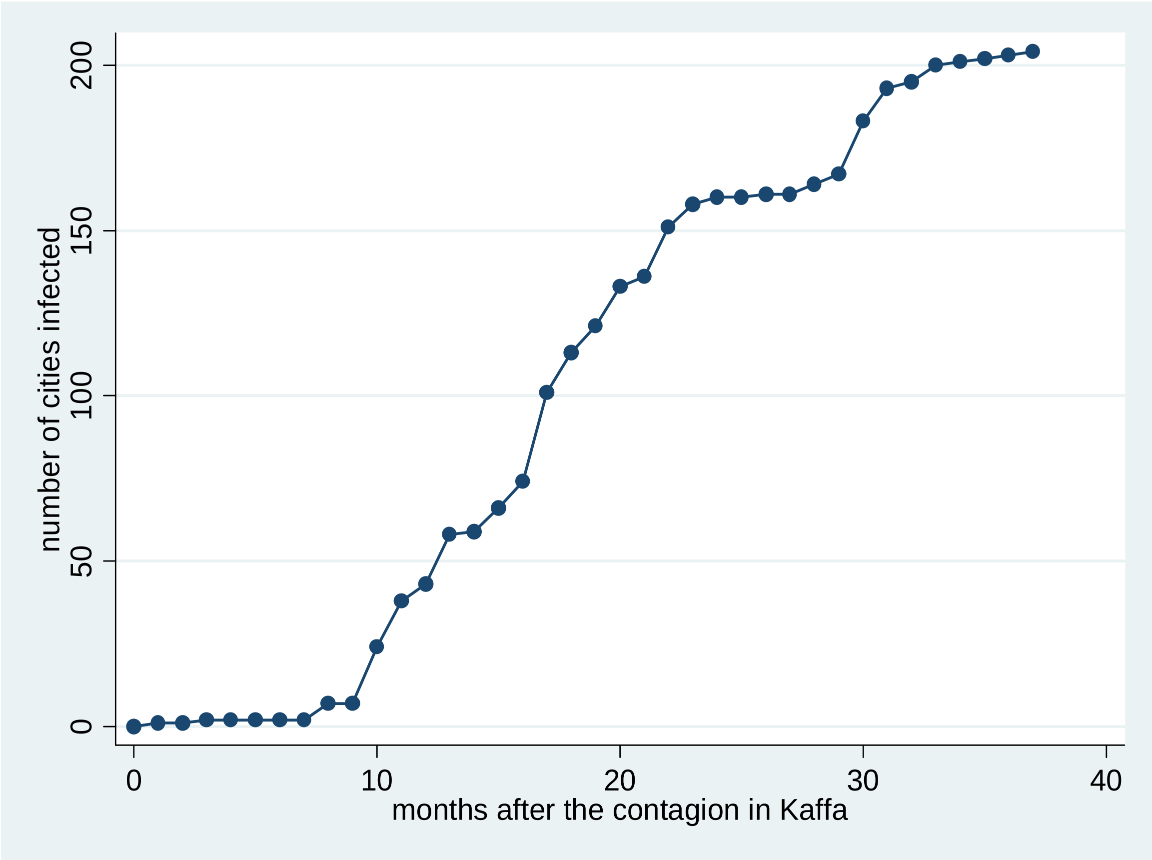


Figure 3: Trade along sea routes: Predictions of outflows and inflows (upper part) and marginal fixed effect with respect to distance (lower part)

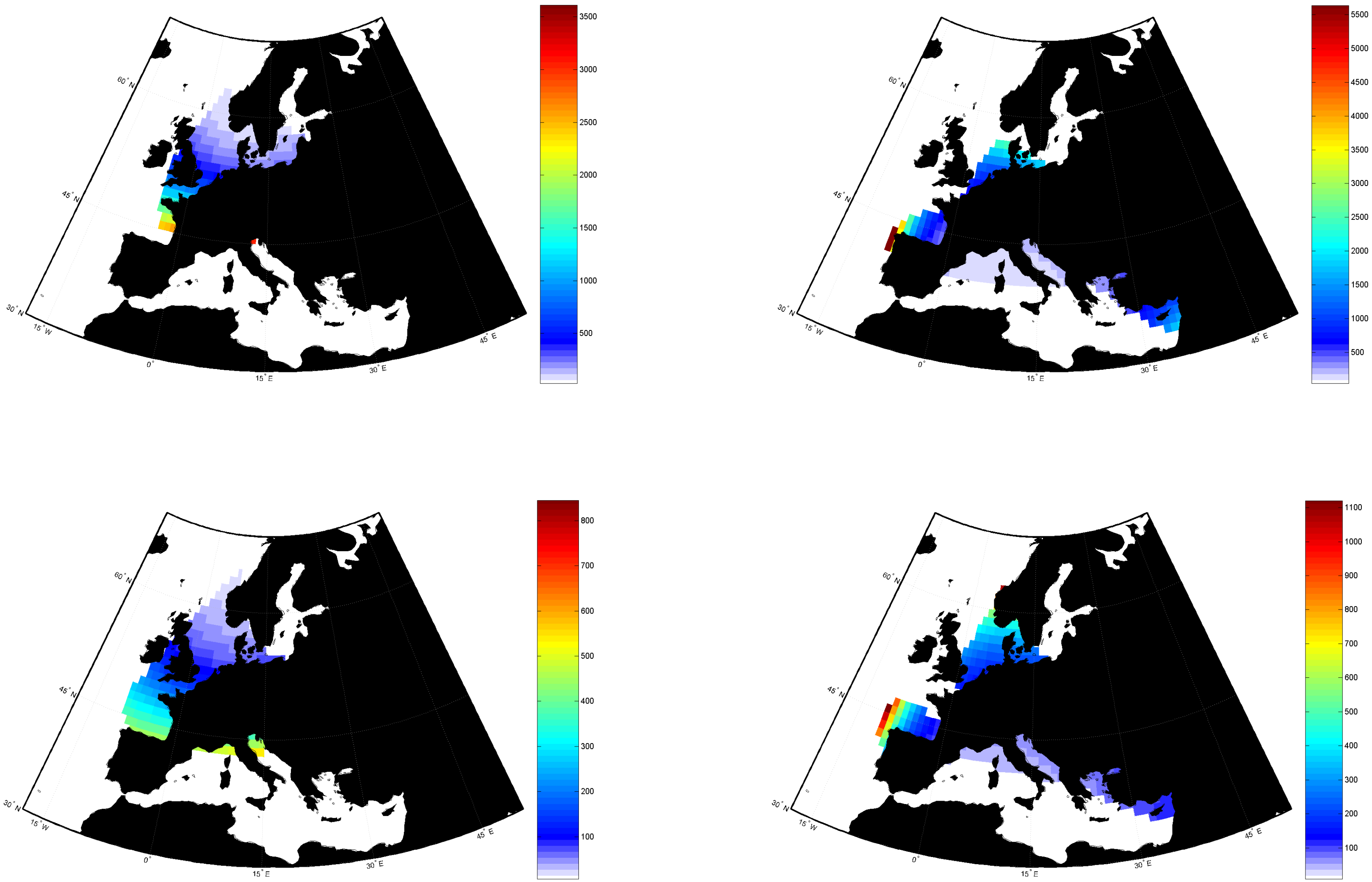


Figure 4: Trade along land: Outflows and inflows of predictions (upper part) and marginal fixed effect with respect to distance (lower part)

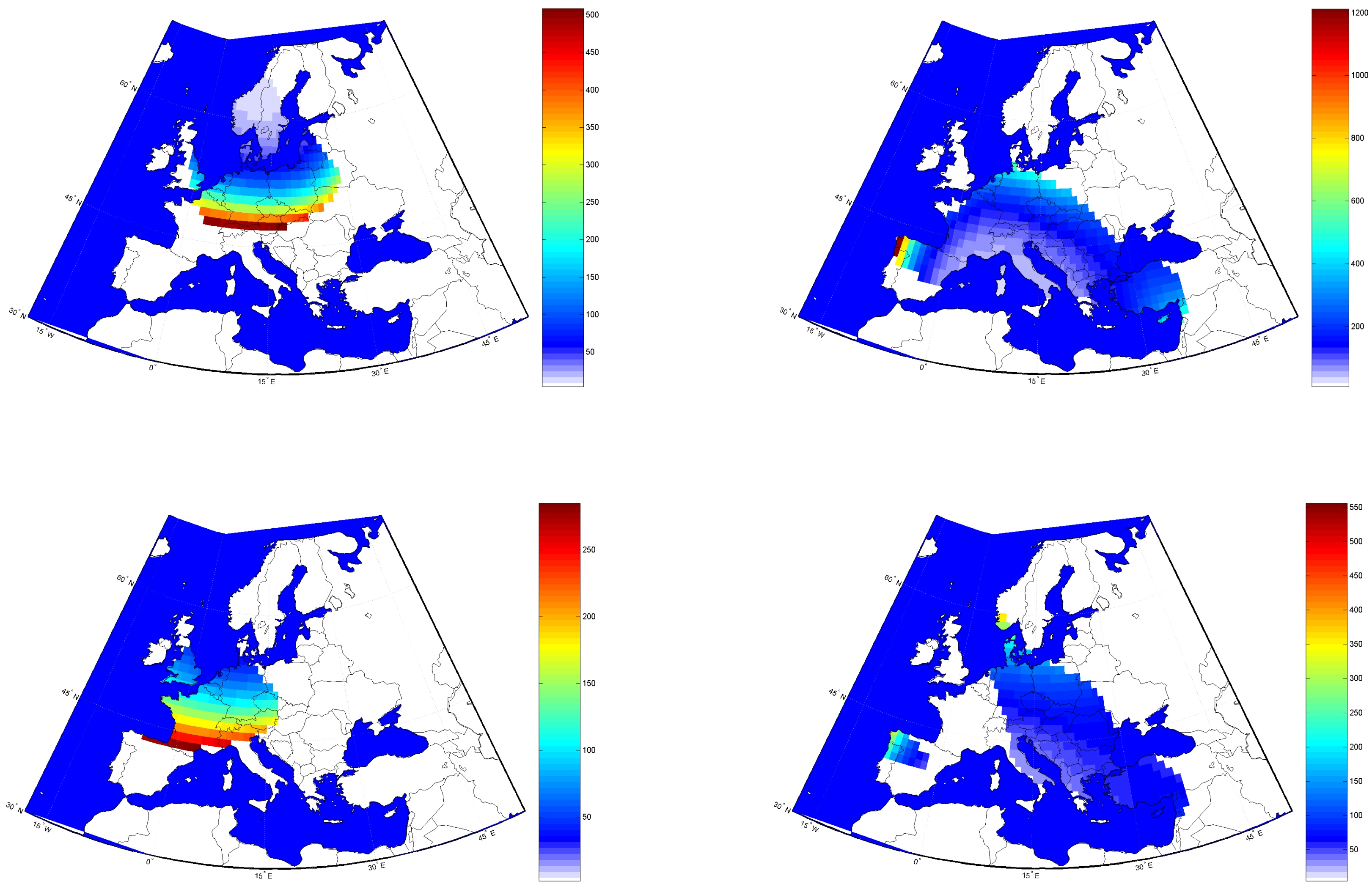
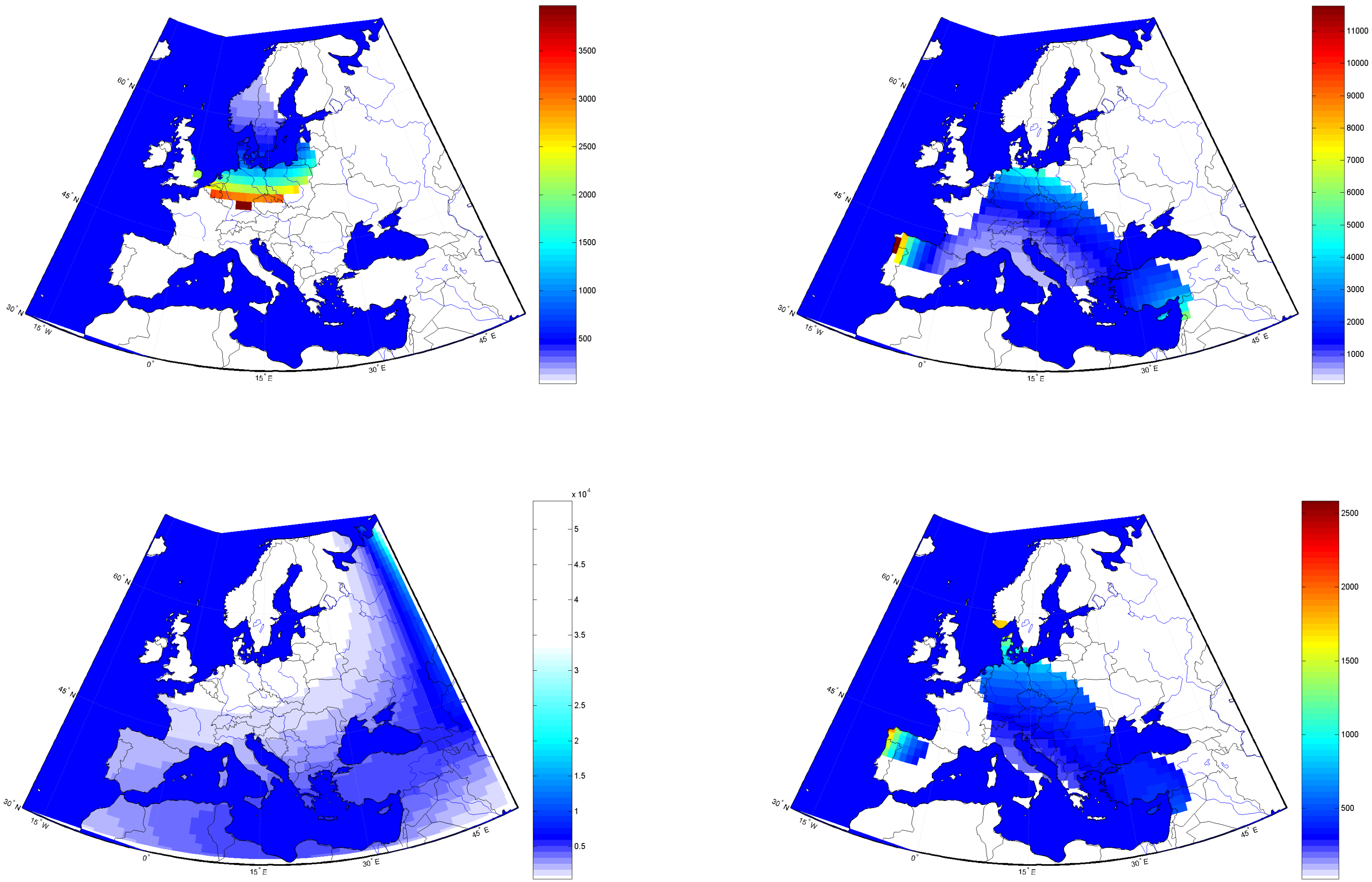


Figure 5: Trade along river: Outflows and inflows of predictions (upper part) and marginal fixed effect with respect to distance (lower part)



Appendix A: Data Sources

Geographical Transmission of the Black Death

We collect and elaborate the geographical transmission and the timing of the Black Death in Europe from different sources: the data are mainly constructed following the information contained in Biraben (1975) and Benedictow (2004). Data on dispersion on non European countries are collected from Dols (1977) and Borsch (2005). Additional observations for England, Germany, Italy and Spain are obtained by Corradi (1865), Hoeniger (1881), Gasquet (1908), Ubieto Arteta (1975), Del Panta (1980) and Fössel (1987).

Standard Gravity Model and Geographical Variables

Data of urban population during 1300 are taken by Bairoch, Batou, and Chévre (1992), Chandler (1987) and Malanima (1998). We also collect data on geographical location (i.e., longitude and latitude) and on altitude from Nunn and Puga (2011) and from geographical atlas. The variables *lndist* on land are computed as geodesic distances between a pair of coordinated on the surface of the Earth assuming no elevation. Distances on the sea routes are calculated according to the traditional trade ways (McCormick (2001)). We define that trade across a border if the pair of cities belongs to different areas. Table 9 displays the list of regions. Definitions on political regions, rivers and water ports are mainly obtained by McEvedy and Woodrofe (1992) and by Nuessli (2011).

Social and Political Variables

We consider data on the presence of a bishop before the Black Death from Jedin, Latourette, and Martin (1970) and Magosci (1993) and integrated by Wikipedia (`www.wikipedia.org`). The different classifications of Western European Régimes is derived from De Long and Shleifer (1993) at 1330. Finally, pieces of information on university sites are taken from Sheperd (1911) and Darby (1970). Language location is taken by Macleod (1997) and integrated with Der Grosse Historische Atlas (1953).

Climate Data

Climate data are obtained by the dataset *abstem* provided by Jones (1999) (`http://www.cru.uea.ac.uk/cru/data/temperature/#datdow`).

Appendix B: Regions considered

Table 9: List of regions

Region	N. of Obs.	Region	N. of Obs.	Region	N. of Obs.
Austria	5	*Este*	4	*Kingdom of Granada*	5
Hausburg Dominion	5	*Florence*	6	**Sweden**	4
Belgium	1	*Republic of Genoa*	2	*Kingdom of Denmark*	2
Hainaut-Holland	1	*Hausburg Dominion*	1	*Sweden*	2
Denmark	2	*Milan*	10	**Switzerland**	9
Kingdom of Denmark	2	*Kingdom of Sicily in Naples*	26	*Basel*	1
England	8	*Padoa*	1	*Bern*	1
England	8	*Papal State*	2	*Geneva*	1
France	30	*Perugia*	1	*Hausburg Dominion*	1
Bordeaux	1	*Romagna*	1	*Saint Gallen*	1
Lordship of House of Burgundy	1	*County of Savoy*	1	*Vaud*	2
Kingdom of France	21	*Venice*	6	*Zurich*	2
Hainaut-Holland	1	**Morocco**	1	**Syria**	4
Holy Empire	3	*Kingdom of Maghreb*	1	*Egypt*	4
County of Provence	4	**The Netherlands**	3	**Tunis**	1
Germany	20	*Friesland*	2	*Hafsid Caliphate*	1
Cologne	1	*Hainaut-Holland*	1	**Turkey**	2
Holy Empire	15	**Norway**	2	*Roman Empire*	2
Lower Baviera	2	*Norway*	2	**Ukraine**	1
Mainz	1	**Poland**	3	*Republic of Genoa*	1
Mecklenburg	1	*Wolgast*	1	**Non Europe**	
Hungary	1	*Welgast*	2	**Ilkhanate**	2
Hungary	1	**Russia**	2	*Egypt*	2
Ireland	4	*Welgast*	2	**Iran**	1
England	3	**Serbia**	1	*Ilkhanate*	1
Ormond	1	*Raška*	1	**Iraq**	1
Italy	67	**Spain**	26	*Ilkhanate*	1
Ancona	3	*Crown of Aragon*	14	**Israel**	3
Giudicato di Arborea	3	*Castilla*	7	*Egypt*	3

Appendix C

Figure 6: White and Conley standard errors for population size and distance

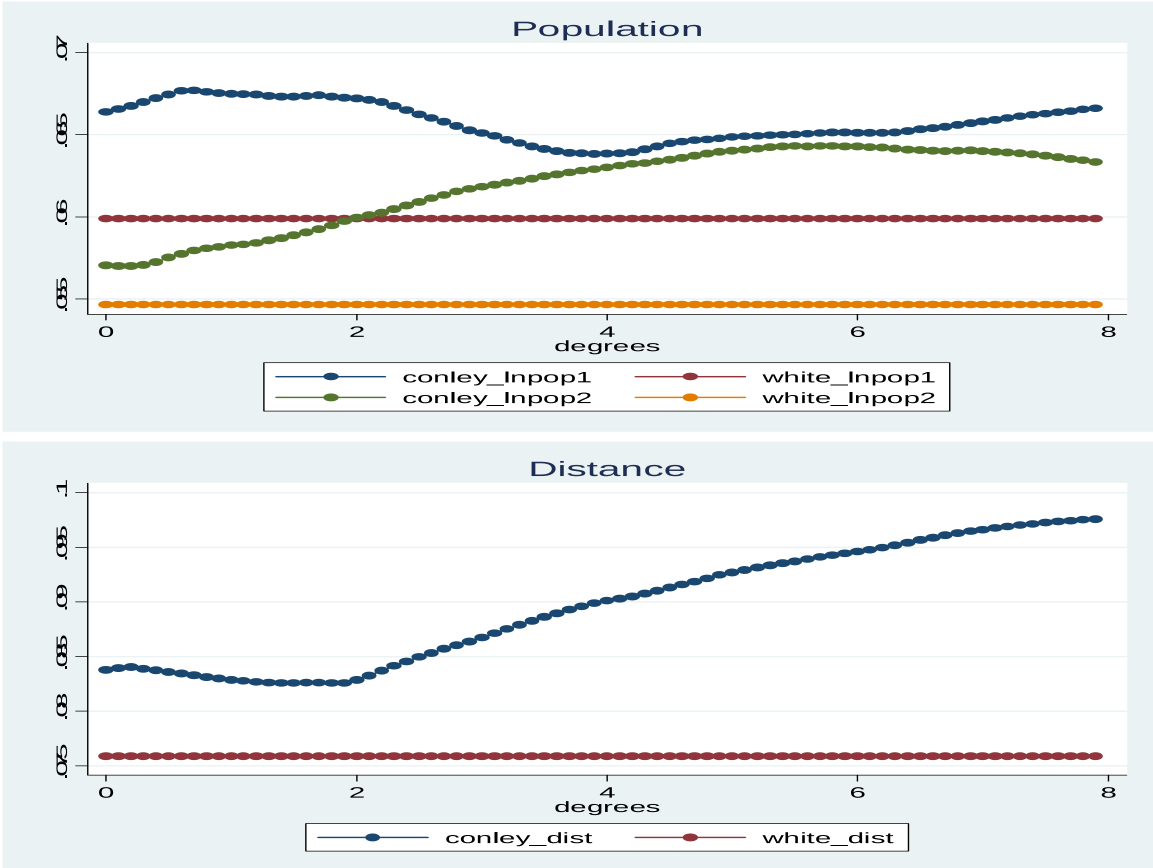


Figure 7: The relationship between coin values and speed of the disease

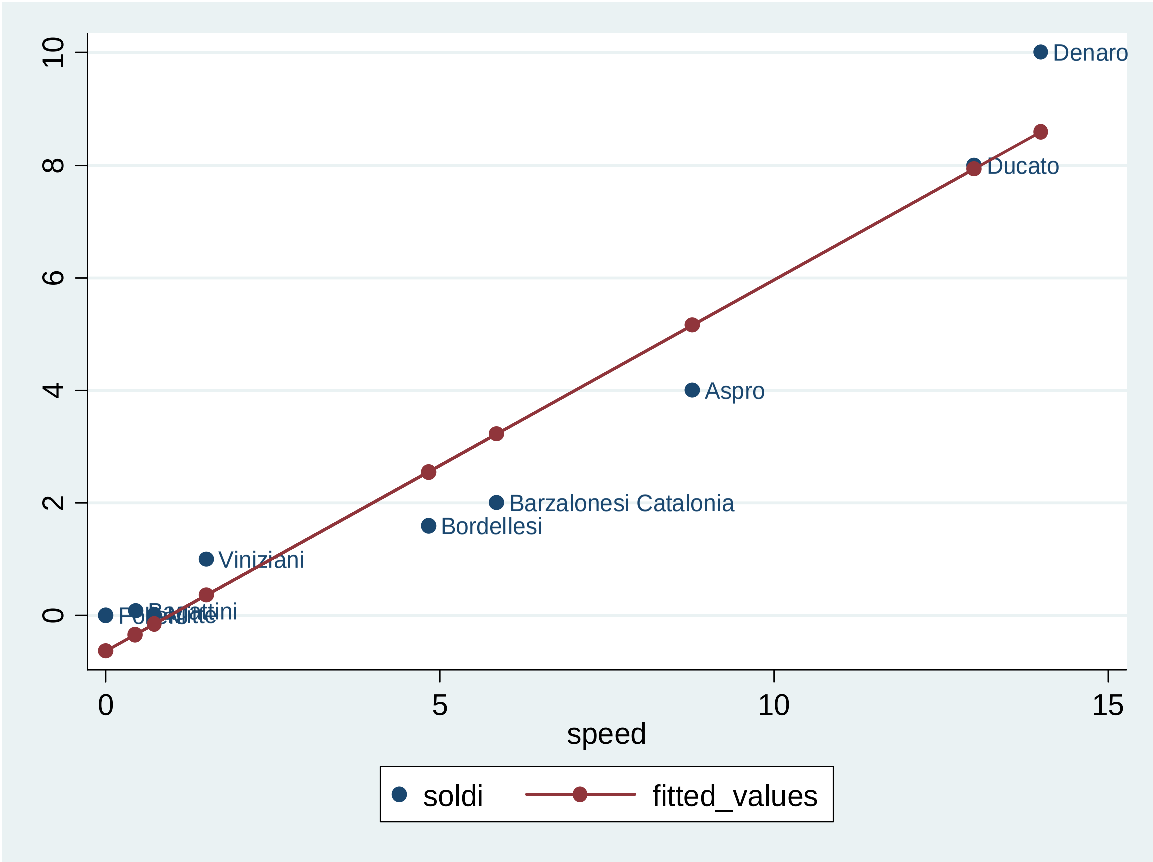
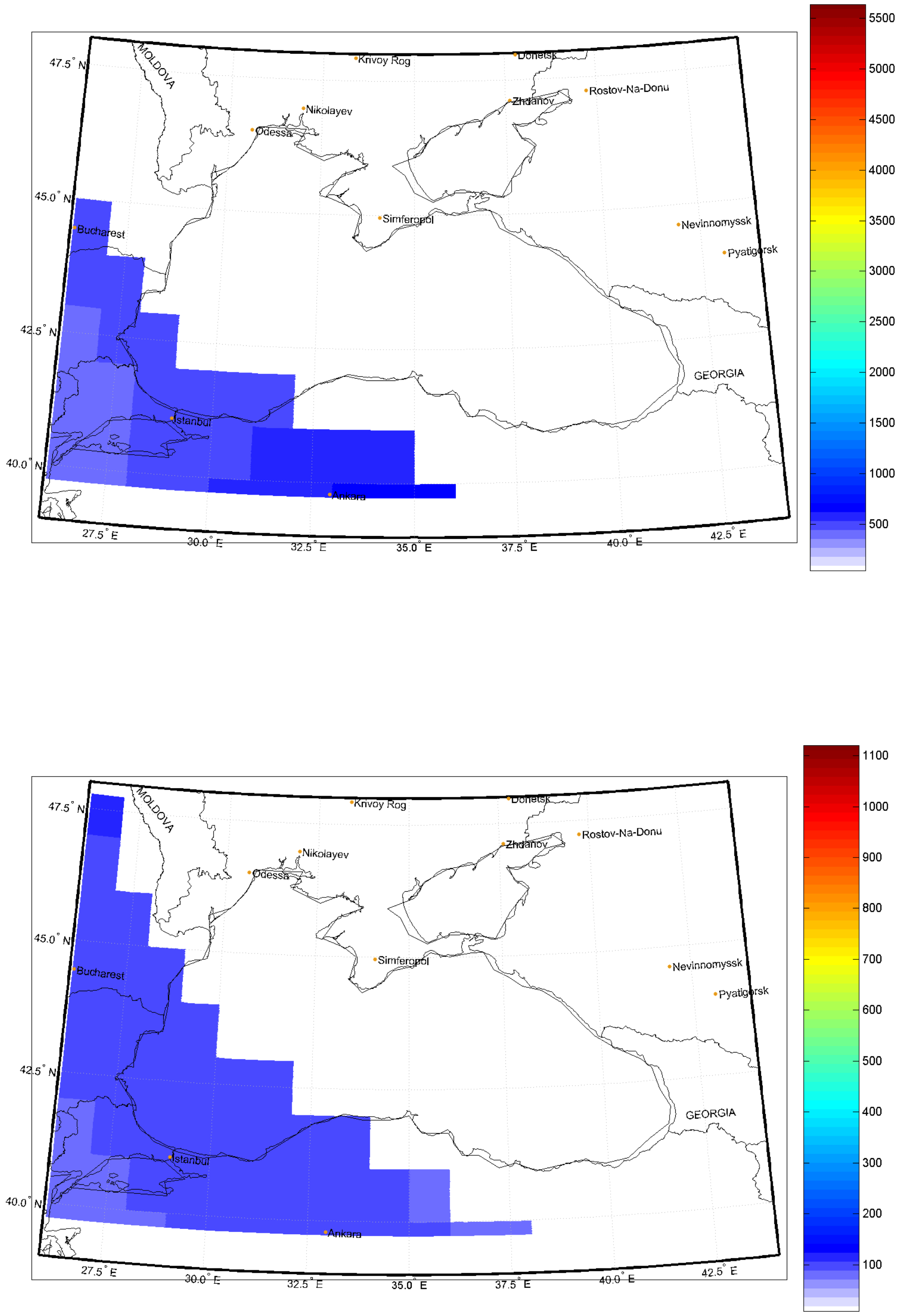


Figure 8: Trade in the Black Sea: Predictions of outflows and inflows (left) and marginal fixed effect with respect to distance (right)



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