The Voyage of Homo-œconomicus: some economic measures of distance*

Preliminary Version

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Abstract

In this paper I construct new measures of distance and transportation costs for the pre-industrial era. I generate the measures by finding the cost-minimizing paths between regions, where the cost of travel is determined by geographical, technological, and biological conditions. More specifically, I calculate for every square kilometer on land the walking time required to cross it, taking into account topographic, climatic, and terrain conditions, as well as human biological abilities. Additionally, I generate similar measures for each square kilometer on seas in the Old World. Based on these travel times, I construct measures of the total travel time along the optimal path among various cities, and compare them with historical data on trade and pilgrimage routes, the speed of news diffusion to Venice during the 16^{th}-18^{th} century, and genetic, linguistic, and religious distances among countries. Performing various tests I find a high explanatory power of these measures for the studied phenomena. In particular, the measures perform better than commonly used great circle distances. These results show that these measures, and the indices on which they are based, capture well the levels of interaction and the technology of movement in the pre-industrial era, allowing for a wide range of possible applications.

Key Words: Geographical distance, trade routes, travel time, information diffusion, trade, historical paths, transportation costs, human mobility index, ruggedness index, sea travel, land travel, HMI, HMISea, RIX
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Contents

1 Introduction

The distance among villages, cities, regions, countries, and other socio-economic and political entities has long been considered an important aspect in the explanation of their comparative political and economic development. For example, Smith (1776, ch.3) argues that the wealth of any nation increases with the division of labor, which in turn benefits from it being close to other economic agents, "[a]s it is the power of exchanging that gives occasion to the division of labour, so the extent of this division must always be limited by the extent of that power, or, in other words, by the extent of the market". In the same vein, modern trade theory's use of gravity equations (Feenstra, Markusen, and Rose, 2001; Frankel and Romer, 1999; Rose, 2004) centers around the idea that economic units trade more with units that are located at smaller distances, implying that less isolated countries trade more. Additionally, geographical distances determine genetic and cultural distances among different populations (Giuliano, Spilimbergo, and Tonon, 2006; Liu, Prugnolle, Manica, and Balloux, 2006; Prugnolle, Manica, and Balloux, 2005; Ramachandran, Deshpande, Roseman, Rosenberg, Feldman, and Cavalli-Sforza, 2005), which have been found to explain cross-country differences in income per capita.

Traditionally, the distance between two populations, A and B, on Earth has been calculated by the length of the shortest segment of the circumference that goes through both locations, which is called the great circle distance between A and B. From the previous examples one can see that this measure cannot be universally applicable as a measure of distance between A and B, especially in historical contexts, since it might not be correctly measuring the element of interest and might also be capturing many elements at the same time. Furthermore, if geographical distance is used as a proxy for costs of transportation or interaction among social groups, the use of great circle distances can only be meaningful if the great circle route is a good approximation to the geographic route that humans take when going from A to B or vice versa. This requires in particular, that the cost of movement per geographical unit *must be independent* of the particular locations of A and B. Clearly, a sufficient condition would be for Earth to be a perfect sphere, without any hydrographic, topographic, or climatic effects on the cost of movement. If either population has aerospace technology this condition is *almost* verified, although even in this case winds play a crucial role in the determination of paths and costs of movement between A and B, e.g. by jet streams. Additionally, historically determined communication and transportation networks might still hinder the use of the great circle routes and thus make the use of great circle distances troublesome.

In the absence of technology (especially aerospace and maritime) the ability of humans to move across large distances is determined by such factors as temperature, relative humidity, terrain type and ruggedness, resource abundance, etc.. It seems reasonable to assume that the cost associated with such movements is a function of these factors. Arguably, humans use paths that allow them to move from one location to another incurring the least amount of time, energy or some other cost measure. So, in order to have a good measure of "actual" distances among locations one has to determine the cost of movement as determined by geography, technology, and human abilities. In order to do so, this paper constructs three cost surfaces for the movement on the surface of Earth and applies these measures in order to construct the cost-minimizing path between locations.

The first proposed cost surface is based only on the effect of ruggedness on the cost of movement. Clearly, the ruggedness of a location increases the cost (be in terms of time, energy, money, etc.) of moving in that location. Furthermore, ruggedness is one of the principal impediments to possible paths and can only partially be avoided by circumvention or investment. As will become clear below, by construction, this measure cannot be used to estimate travel across large bodies of water, so movement is limited to locations on the same landmass.

The second cost surface captures the effects of temperature, relative humidity, and ruggedness on the time required to travel between locations. Following in the spirit of the analysis based on the first cost surface, and given that the second cost surface is constructed from measures on the capacity for human mobility under different conditions, movement is again restricted to locations on the same landmass.

The third cost surface complements the second one by using historical data on the travel time in certain seas, which allows for the estimation of movement across certain large bodies of water. Clearly, the first and second cost surfaces can be considered as zero-transportation-technology estimates, while the third surface includes the seafaring technology before the year 1500 CE.

Using these three cost surfaces I compute the optimal paths that would be used when traveling between various locations. These paths measure the "actual" distance between any two locations under different technological conditions. Furthermore, given their historical nature, they can help understand the effects of past interaction between societies on their modern economic outcomes, as well as the historical formation of information, transportation, trade, travel, and other types of networks and their change due to technological advances. Additionally, these networks can help explain the location and prosperity (or lack of it) of cities, ports, etc. as emergent from the requirements of communication among other locations (see Durante and Özak, 2010).

One difficulty in the analysis of distance among locations is the lack of data against which to compare estimates. This is especially true for historical distances, since the surviving historical record is very incomplete and excludes most ancient societies that were not in contact with advanced civilizations. In order to evaluate how well the computed paths measure "actual" distances, I contrast my results with some historical evidence on trade routes and news diffusion. The emphasis being on the ability of the generated distances and paths to closely replicate the historical record. I find that the measures seem reasonable and conform well to the record. This might prove extremely useful in the application of this method to other historical problems where no record has survived. For example, the discovery of a handful of cloves in the Syrian dessert within an archeological site dated around the year 1,721 BCE is evidence for the existence of a trade route that allowed cloves to reach Syria from the Indonesian archipelago (Turner, 2004). Given the lack of other evidence on how that trade was realized, the methods of this paper can be used to construct possible routes and estimates of transportation costs.

In order to show some potential uses of these measures, I use my measures in order to reexamine the effect of geographical distance on genetic, linguistic, and religious distance, which are measures of cultural distance and capture the levels of historical interaction between societies. Other papers have already used the proposed measures with interesting results. In Ashraf, Galor, and Özak (2010) we use my second measure in order to construct a measure of historical isolation and show that it is positively correlated with economic development. In Özak (2010) I employ my third measure in order to estimate the geographical distance to the technological leader and show that it has a U-shaped relation with measures of economic development.

The rest of the paper is structured as follows: section 2 introduces the three indices on which the new measures will be based, explains their construction, and the calculation of the optimal paths. Section 3 compares my measures with the historical record. Section 4 notes some problems caused by the use of geodesic distances and in the construction of the Import-Wizzard freight data (Giuliano, Spilimbergo, and Tonon, 2006; Guiso, Sapienza, and Zingales, 2009; Spolaore and Wacziarg, 2009). Section 5 concludes.

2 New Distance Measures

This section presents three new indices that will be employed in the construction of cost surfaces, which will allow for the estimation of distance measures among locations on Earth. The starting point for the construction of these cost surfaces is the assumption that transportation, travel, and communication in early history is determined by the cost of human movement between regions. The cost and the possibility of such movement depends mostly on topographic, climatic, hydrographic, and technological conditions. Each cost surface constructed tries to capture these different conditions.

The first measure considers *only* ruggedness as a factor in costs to mobility. One reason for this is that the costs imposed by temperature, relative humidity and resource abundance can be circumvented, at least partially, by changing the timing of travel, by traveling at times with better climatic or meteorological conditions and by carrying provisions, thus lowering the cost imposed by these factors. One problem that can come up with the ruggedness index (RIX) measure is that cost-minimizing paths on the ruggedness surface might just require too long travel times to be believable. Furthermore, there is no clear way of expanding the measure over large bodies of water. For these reasons, the other two measures concentrate directly on travel times.

The second measure considers the effect of temperature, relative humidity, and terrain slope on the sustained walking speeds biologically attainable by humans. This allows for the estimation of the required time to move on any region in the world and allows for the construction of a cost surface of human mobility in the absence of maritime or aerospace technologies. Unlike the previous measure, this human mobility index (HMI) considers average conditions of topography, temperature, and relative humidity in each region in order to determine the cost of movement. Although the data from which the estimation is built could allow for different types of terrain to be incorporated, using terrain type in any calculation of the cost of movement is problematic since it can be modified easily and relatively fast through the use of technology (e.g. setting fire, cutting trees, drying out of lakes), or simply by the repeated use of the terrain (think of a lot of people walking on the same path, cutting trees in the same forest, overexplotation of resources), which makes it difficult to incorporate this variable in a meaningful and reliable way in the calculation, since any available data might not reflect conditions for the time of interest.

The third measure complements the human mobility index by incorporating travel times over large bodies of water. Using primary and secondary historical sources on travel times between certain ports in the world, I estimated the required travel time in different seas.

All cost surfaces are constructed by splitting the world with a latitude-longitude grid of cells each of 30 arc-seconds (approximately 924 meters), with a coverage from 180° West to 180° East longitude and 90° North to 90° South latitude, resulting in a matrix of dimensions of 21,600 rows and 43,200 columns. To each element of this cost matrix I assign the cost of crossing the particular geographic location it represents.

In order to simplify computations, I assume the only ways in which a cell i can be entered or left from is at an angle that is a multiple of 45° and movement goes from the center of the cell to the center of one of its neighbors, as shown in figure 1.

Having determined for each cell i the cost of moving on it, $C(i)$, and the possible moving directions, I can determine the total cost of moving to any other cell j using a path T_{ij} by

$$C(T_{ij}) = \sum_{k \in T_{ij}} C(k).$$

The optimal path to move between i and j, T^*_{ij}, is defined as

$$T^*_{ij} = \arg\min_{T_{ij}} C(T_{ij}),$$

which will determine the measures of geographical distance that I will introduce below. I consider two types of possible measures, the length of the path $\|T^*_{ij}\|$ and the optimal cost $C(T^*_{ij})$. Clearly, the latter is more fundamental then the former, and as such I will use it whenever the cost measure is well defined and is interpretable.

2.1 Ruggedness Index (RIX)

For the construction of the first cost surface I assume that the cost of mobility across a cell i is *uniquely* determined by the ruggedness of that cell, which is given by some measure of ruggedness $RIX(i)$, and that such a cost is given by

$$C(i) = \alpha RIX(i)^2.$$

For simplicity, and since it is not clear (nor required) in which units costs are given, I additionally normalize $\alpha = 1$.[1] This implies that the total cost of moving on a path T_{ij} that goes from cell i to cell j is simply

$$C(T_{ij}) = \sum_{k \in T_{ij}} C(k) = \sum_{k \in T_{ij}} RIX(k)^2.$$

Following Riley, DeGloria, and Elliot (1999), the ruggedness of cell i is defined as

$$RIX(i) = \sqrt{\sum_{k=1}^{8} (h_i - h_{j_k})^2}$$

[1] Although ruggedness has an effect on energy expenditure, travel time, etc. and even if it is the only variable affecting those costs in the way specified above, the value of α is dependent on the exact measure one assumes.

where h_l is the elevation, in meters, above sea level of cell $l = i, j_1, j_2, \ldots, j_8$. Given that the cost measure is not easily interpretable, I will use the length of the optimal path generated by RIX, $\left\|T^*_{ij}\right\|_{RIX}$, as the new distance measure.

In order to construct the RIX cost surface, I employ the topographical data of the *Global Land One-Kilometer Base Elevation (GLOBE)* digital elevation model (GLOBE Task Team and others, 1999). GLOBE was developed by the GLOBE Task Force, an international consortium of governmental agencies and educational organizations around the world (see appendix A in Hastings and Dunbar (1999) for a complete list). GLOBE is a global data set of elevation measures that is similar to ETOPO5 and GTOPO30, which had previously been used in economics (see e.g. Nunn and Puga, 2009). Although similar in its construction and sources, it supersedes these other two data sets in accuracy and includes new sources for its construction.[2] Figure 3 presents the GLOBE data set and figure 4 shows the constructed RIX cost surface.

2.2 Human Mobility Index (HMI)

As a second approach, I assume that the cost of mobility is measured by the time required to cross any region. Hayes (1994) estimates the maximal sustainable speeds of dismounted infantry movement under different temperature, relative humidity, slope, and terrain conditions. First he determined the maximum sustainable metabolic rates for soldiers of weight 70 kilograms, 23 years of age, and 1.7 meters height, each carrying a load of 20 kilograms, which he then used to estimate the maximum sustainable speed for each terrain characteristic. Hayes focused on the levels of metabolic rates and speeds that can be sustained for long periods of time without causing the soldier to become a victim of heat-exhaustion. The different meteorological, terrain, and risk conditions considered by him are:

- temperature: 5°-35°C in 5° increments

[2]There are two new data sets which have come out since the moment I started this project. The Shuttle Radar Topography Mission (SRTM) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM), both of which have resolutions of at least 1 degree. Lack of time has impeded the comparison of results with these new data sets, but researchers interested in performing similar exercises and estimations to the ones I perform here can easily adapt the present method to these databases. Furthermore, there exist digital elevation models with a lower resolution than the currently used and which might prove useful for more localized research.

- relative humidity: 5, 25, 50, 75 and 95%

- cloud cover: night, cloudy, partially cloudy, clear sky

- slope: -50% to 50% in 10% steps, except in the range -20% to 20% where 5% steps were used

- terrain: black top, dirt road, and loose sand

- heat exhaustion risk: high, medium, and low

Figure 2 shows for a fixed set of climatic conditions the maximum sustainable speed under different conditions of heat exhaustion risk, terrain types and slopes. As can be seen there, the relation between slope and speed is highly non-linear. Although Hayes presents estimates for more sky cover conditions and heat exhaustions risk levels, I use the clear sky and high risk conditions, since the high risk of heat stress condition generates *ceteris paribus* the highest sustainable speeds among any configuration of meteorological and terrain conditions. On the other hand, the clear sky condition generates the slowest speeds sustainable under high risk of heat exhaustion.[3] Tables 1-3 present the estimation of the effect of slope, temperature, and relative humidity on the maximum sustainable speeds with a high risk of heat stress for different types of terrains under a clear sky. As expected, the effect of temperature on speed is negative irrespective of the type of terrain. Similarly, relative humidity is also inversely related to speed. On the other hand, and as is clear from figure 2, slope is inversely related to speed as long as the slope is positive and positively related to speed if the slope is negative. In other words, one can say that it the absolute value of slope is inversely related with speed. Although I do not present them here, the normalized coefficients show that slope is the variable that has the largest effect on speed in all regressions.

Clearly, one can use equations (1) and (3) (or (2) and (4)) from any of the tables 1-3 in order to generate cost surfaces. As mentioned before, it is difficult to determine the type of terrain present at a location in a historical context, given that it is easily affected in a short period of

[3] Clearly, one could use the other conditions in order to see the effect of these different configurations. Although this would be a desirable sensitivity analysis, the required investment in time and resources exceeds at this point the resources I have.

time. Given the types of terrains Hayes analyzes, I take loose sand as closer to the types one would expect humans to have encountered earlier in history. Thus, using equations (1) and (3) (and (2) and (4)) I calculate the maximum sustainable speed on each cell, which determines the (minimum) time required to cross it according to the average slope in the cell, its average yearly temperature, and its average yearly relative humidity.

One important point one has to consider is the determination of the slope to use for the construction of the cost of movement. Clearly, the speed of movement depends on the slope, but the slope that is relevant to each cell cannot determined a priori, since it should be determined by the direction of movement. Yet the direction of movement cannot be determined in this case without knowledge of the relevant slope. In order to overcome this problem I use the average slope on each cell as the one relevant for the determination of the maximum sustainable speed on it.[4]

In order to construct the time required to cross each cell, what I shall call the Human Mobility Index (HMI), I construct the average slope using the GLOBE data set and calculating the ratio

$$slope = \frac{1}{\bar{l}}\left(\frac{1}{8}\sum_{k=1}^{8}(h_i - h_{j_k})\right)$$

where the term in parenthesis is the average change in altitude when moving out of the cell i and $\bar{l}$ is the distance between the centers of the cells. I take the average temperature of cell i from Hijmans, Cameron, Parra, Jones, and Jarvis (2005) and the average relative humidity from New, Lister, Hulme, and Makin (2002). Given that New, Lister, Hulme, and Makin (2002) estimate these values for a latitude-longitude grid of 10 arc-minutes, I assign to each cell i on my cost surface, of latitude-longitude 30 arc-seconds, the value that is implied directly from their data set without any transformation. Figures 5 and 6 present these data sets. The HMI cost surface implied by equations (1) and (3) is presented in figure 7 and the one implied by equations (2) and (4) in figure 8.

[4]Another possibility would be to use the minimum or maximum slopes. Or if enough computational resources are available, to do the calculations and determine jointly costs and direction of movement. Additionally, an agent based model could be used to determine the dynamics on this surface.

2.3 Human Mobility Index with Seafaring (HMISea)

The two previous cost surfaces can be used to calculate distances between any two points on the same continental mass for periods before the advent of seafaring technology or for distances among places in which seafaring is either unfeasible or regarded as inferior to mobility by land. Although this might be useful for helping to answer certain types of questions, the lack of the possibility to cross major bodies of water might limit the usefulness of these exercises and the types of questions that can be answered. For this reason, in this section I present an extension of the HMI cost surface in order to incorporate the possibility of travel across larger bodies of water.

The introduction of seafaring raises many issues, since the time required to travel by sea is extremely dependent on climatic conditions and the technological level of the seafaring technology. Climatic conditions affect both the possibility of travel, but also the route that can be used. For example, the Monsoon in the Indian Ocean determined the East/West direction of travel, allowing for months at a time travel in only one direction. A similar problem arises in the Mediterranean Sea, where travel from Europe to Africa was generally done by crossing directly, once technology and mariners' bravery allowed for it, while the travel from Africa to Europe had to be done by coastal routes. Although direct routes were employed, the importance of coastal routes, which make seafaring routes similar to land routes seem not to have decreased even up to the XVII century as can be seen in figures 9 and 10.

Additionally, the lack of surviving information on the routes used, the conditions under which it occurred and the time it took is pervasive. For example, Turner (2004) argues that the *The Periplus maris Erythraei* (Casson, 1989) is one of the only primary sources that has survived from antiquity. Marine archaeology can help determine the possible routes, but only in so far as remains have survived and are found.[5] These problems restrict the available sources that can be used for the construction of indices for the estimation of the time required to traverse

[5] Recent deep sea archaeological discoveries have shed light into the goods that were being traded and other types of information. Still, for a shipwreck's location to be informative as to the routes used, requires that many ships ought to be found in a similar location, but from different periods. Otherwise, this might just be the remains of a trade fleet that got lost or which failed when trying to establish a new route.

any cell i.

The history of ancient seafaring is characterized by three major events: (i) the introduction of boats with paddles (ca. 11000-5,000 BCE), (ii) the invention of the sail (ca. 3,500 BCE), and (iii) the invention of navigational devices (ca. 100 CE). Table 4 shows some of the major developments in history of seafaring from 11000 BCE to 1,200 CE. Although many improvements and innovations were accumulated during this period, the data suggests that the gains that these permitted in terms of speed and wider applicability were limited. Table 5 presents estimations by historians and from primary sources on the speed of ships between the years 500 BCE and 1000 CE. As can be seen there the average speed remained relatively stable during this period. The main differences in speed seem to stem, unsurprisingly, not from the period in which the voyage took place, but its purpose and location.

Using the information in table 5, I set the speed required to cross a cell i in each sea by averaging the speeds of the voyages that passed through it. If there is no information available, although the historical record showed that sea travel was common in that sea, I assigned to it the value of the closest sea for which information is available. Table 6 shows the assigned speeds and implied crossing times and figures 11 and 12 show the new cost surfaces.

2.4 Optimal Paths between Capitals

As a first application I compute the optimal paths from current capitals to any square kilometer on the continent using all three cost surfaces. Clearly, for RIX and HMI only the distances to locations on the same continental mass can be computed, so that *all* islands have to be excluded from the analysis (unless one is willing to assume certain crossing points). Even though only America (by itself) and Africa, Asia and Europe satisfy this connectivity requirement, for some of the exercises I further assumed humans were able to cross the Bering Strait at the closest point in our data set between the Asian and American continents, enabling the computation of the optimal paths between all the national capitals and locations on those four continents.[6] Using this data I calculated the distances on the optimal routes among

[6]Although HMISea allows for the inclusion of islands in the Old World, lack of data prevents the inclusion of islands in the New World. Furthermore, the connectivity between the Old and New Worlds is again assumed

capitals, which table 7 and figures 13-15 present. Clearly, these optimal routes define optimal communication/transportation/interaction networks among the capitals. Having constructed the optimal paths to move from each cell j to each of the capitals, I also constructed an isolation index for each capital, where the isolation of each capital is determined by the unweighted average time required to move to it from any cell i on the same continental mass. Ashraf, Galor, and Özak (2010) used this isolation index in order to examine the relationship between this level of *historical isolation* on historical and contemporary economic development finding a positive effect of isolation.

3 Comparison with Historical Data

As in the case of modern measures of transportation costs or interaction, the data on historical costs of transportation, the time required for travel between regions or the level of interaction between societies is incomplete and not always generalizable. This is especially so for societies that did not develop modes of keeping records, or which disappeared without leaving definite clues as to their culture. Still, the comparison of the constructed measures with historical data allows one to have a better understanding of how well these measures capture transportation costs, levels of interaction among humans, etc. in the past. In order to do so, in this section I compare my results with historical data on trade routes, with the speed with which news traveled to Venice between the sixteenth and eighteenth centuries, and use them in order to explain linguistic and genetic distances. As will be seen below, the measures constructed in this paper fit the historical record rather well.

3.1 Historical Trade Routes

Historical data on trade and pilgrimage routes compiled by Ciolek (2004) serves as a first measure of the quality of the computed paths. Ciolek (2004) compiles and georeferences around 4,500 stopping places of networks that allow for the movement of goods, people and information

to occur *only* through the Bering Strait. Although research about the Clovis culture has pointed to another European route (Jablonski, 2002), in this first application I keep with the more traditional approach (Goebel, Waters, and O'Rourke, 2008).

from the year 10,000 BCE to 1,820 CE in the Old World Trade Route (OWTRAD) data set.[7] In order to verify the quality of the paths generated, I measure how close the constructed paths among capitals are from the locations identified by Ciolek (2004). Since not all capitals are starting points of a trade or pilgrimage route studied by him, the fit between the optimal networks and the routes identified by Ciolek can be interpreted as positive evidence for the quality of the generated measures and data. Figure 16 shows the locations compiled by Ciolek (2004).

Figures 17-19 overlay the optimal paths (OPRIX) on the OWTRAD nodes, figures 20-22 do the same for the optimal paths calculated for HMI (OPHMI), and figures 23-25 do it for the optimal paths for HMISea (OPHMISea). The figures show that there is a non-depreciable set of nodes, which are not capitals, that are very close to the optimal paths. At the same time, the optimal paths are far away from pilgrimage routes in Europe, and of trade routes within continental China and coastline locations for OPRIX and HMI. In order to have a better measure as to how these locations are geographically distributed with respect to the optimal paths, I computed the minimum distance from each location to the optimal networks OPRIX, OPHMI, and OPHMISea. Table 8 and 9 present some statistics of the distribution of these distances. As a basis for comparison I created 5,000 random linear networks (RLN) between the same capitals I used to create the optimal networks, imposing the condition that none of the edges should cross any major body of water.[8] For each set of 5,000 RLN's I imposed a different number of edges that each capital could have. As can be seen in table 8 all the constructed optimal networks perform rather well compared to the RLN's. In particular OPHMISea has all 9 lowest deciles below *any* of the networks that do not cross over water, included OPRIX, with half the nodes in OWTRAD being at a distance of 28 kilometers or less from a path in OPHMISea. Finally, I included the linear network that connected all capitals in the Old World with each other, allowing for sea crossing. Although this last network has the lowest distances to the OWTRAD nodes, it only does so by a large increase in the number of edges.

[7]The data is available at `http://www.ciolek.com/owtrad.html`.

[8]This makes the comparison with OPHMISea less transparent, since this one allows for travel across major bodies of water. Still, I think the exercise helps to have an idea as to the quality of the measures. Additional tests below will, I hope, put the reader's mind at rest.

Additionally, even in this case the maximum distance under OPHMISea is almost half of the one in this linear network.

One interpretation of the edges is that they represent the different routes that have to be created in order to connect a certain capital or region. With this interpretation, it seems that the optimal paths calculated are very economical in the sense that they can explain the location of more nodes with fewer additional edges. One could try to determine the number of edges a RLN requires in order to have a similar explanatory power as each of the optimal routes. Since I do not think much can be learnt from this exercise at this moment, I leave it for further research.

3.2 Diffusion of News from Venice

In his *magnum opus*, Braudel (1972) analyzes the connections between history and geographical space using the Mediterranean as his example. One aspect analyzed by him is the effect of geography on communication and transportation costs. Using data by Sardella (1948) on the record of arrival of letters and news to the Signoria of Venice between 1497 and 1532 and on evidence of the Venetian *avvisi* available at the Public Record Office in London, he constructs some measures of the speed with which news travelled to and from Venice. He summarized this information about the speed of the transmission of news in 1500, 1686-1700 and 1733-1765 by means of iso-chronic lines in three graphs that are reproduced in Figure 26. As can be seen there, and as Braudel (1972) himself argues, the maps are roughly equivalent, showing the persistence of the effect of technological limitations on the speed of communication.[9] These maps are not perfect, in the sense that they are only approximations since, as Braudel shows, the speed with which news traveled in the period was very volatile and depended both on climatic conditions and on the price paid to the courier. Furthermore, the iso-chronic lines can only be imperfectly asserted at places with which there is communication. Still, they serve as a another source for comparison of the proposed cost surfaces and the travel times generated

[9]In particular, Braudel (1972) argues that "[t]he differences from one map to another may seem very marked in certain directions. They are the result of the varying frequency of communications, depending on the urgency of the circumstances. Generally speaking, communication seems to be as slow on the third map as on the first, while the second shows noticeable shorter delays. But it cannot be regarded as definite proof." (p.367)

by them.

Using both HMI and HMISea I calculated the optimal paths to get from any cell i on the Old World to Venice.[10] Using georeferencing methods, figures 27(a)-27(c) overlay the graphs generated by Braudel on the surface of optimal accumulated times of travel to Venice and the iso-chronic lines generated by HMI. Each red iso-chronic line represents half a week time of travel, which, under the assumption that news was transported in twelve-hour working days, can be interpreted as representing a one week accumulated travel time. Figures 28(a)-28(c) repeat this same exercise using the HMISea data. Although the iso-chronic lines look similar in certain regions, it is difficult to ascertain the adequacy of the measures compared to the estimates visually. For this reason, table 10 reproduces the data on the number of days required to travel from Venice to various cities as presented by Braudel (1972) and on my calculations using HMI and HMISea. For example, Braudel found that news from Antwerp to Venice took a minimum of 8 days, normally 16 days and on average 20 days, while both my HMI and HMISea measures require 7 days of continuous travel, or 15 twelve-hour working days or 22 eight-hour working days. Looking at the average travel times over all the cases presented by Braudel, one can infer that on average, the HMI is similar to the "normal" time estimate of Braudel, while the transformation of HMI into 8 hour days makes it similar to Braudel's maximum time estimate and the 12 hour days makes it similar to the average time measured by him. On the other hand, HMISea is similar to the minimum times reported by Braudel, while the 12 and 8 hour conversions of HMISea are similar to the normal and average times found by him. Table 11 compares again the different measures with Braudel's estimates confirming the similarity between HMI and the "normal" time estimates, and between HMISea and the minimum travel time of news under the 24-hour continuous travel interpretation. If a 12 or 8-hour interpretation is taken, then HMISea is similar to Braudel's "normal" and average time estimates, making it a better measure of "normal" or average travel/transportation times for historical purposes for the period.

[10] I omit RIX since I cannot convert the cost value into a time measure that would allow a comparison with Braudel's data.

3.3 Genetic and Linguistic Distances

Cultural differences among societies are determined historically by their level of interaction, which are determined, at least partially, by the initial differences in culture among those societies and their technological possibilities of interaction. Three measures that have been frequently used in order to measure cultural differences are genetic, religious and linguistic distances between populations (see e.g. Alesina, Devleeschauwer, Easterly, Kurlat, and Wacziarg, 2003; Cavalli-Sforza, 1973; Cavalli-Sforza and Bodmer, 1971; Cavalli-Sforza, Menozzi, and Piazza, 1994; Fearon, 2003; Giuliano, Spilimbergo, and Tonon, 2006; Liu, Prugnolle, Manica, and Balloux, 2006; Prugnolle, Manica, and Balloux, 2005; Ramachandran, Deshpande, Roseman, Rosenberg, Feldman, and Cavalli-Sforza, 2005). Although some of these studies have shown that geographical distances explain the cultural differences between populations as measured by genetic, religious or linguistic distances, the analysis has been based on geodesic distances and not on more sophisticated measures, like the ones introduced in this paper.

Using data on genetic distances from Cavalli-Sforza, Menozzi, and Piazza (1994), Spolaore and Wacziarg (2009) construct genetic distance measures for most pairs of modern countries in the world for the year 1500 and the modern period. I use these measures in order to analyze the effect of geographical distance as measured by RIX, HMI, HMISea and great circle distances on genetic distances. Tables 13-18 show the results of the regression of various measures of genetic distance on these measures of mobility costs. As can be seen there, the measures introduced in this paper have a good explanatory power, which is in general higher than the one of geodesic distances. In particular, the HMI measure seems to be the best among all the analyzed measures in order to explain genetic distances, both in the modern era as well as in 1500. As can be expected the explanatory power is higher for the 1500 genetic distances than for modern ones, independent of the measure used, given the changes in genetic composition caused by the modern waves of colonization and population exchange.

Tables 19-22 analyze the effect of geographic distance conditioning on genetic distances in 1500. This captures the idea that both geographic distances and initial genetic distances play a role in the determination of modern genetic distances. The results for the whole world sample, summarized in tables 19 and 20, show a positive effect of genetic distance in 1500 and a negative effect of geographical distance and its interaction with initial genetic distance. Although this result might seem strange at first, it clearly comes from the inclusion of the New World in the analysis, as location that are far away geographically, e.g. the U.S. and the U.K. or Latin America and Spain, have small genetic distances in the modern period caused by colonization. Tables 19-22 restrict the sample to the Old World, where colonization did not completely replace aboriginal populations. These tables show that for this subsample the genetic distance in 1500 is again well explained by the new measures. Additionally, they show that initial genetic distance, geographic distance, and their interaction have positive effects on current genetic distances. These results confirm the idea that mobility costs and initial cultural distances, as measured by genetic distance in 1500, determine the cultural distances in modern times. These findings support the idea that genetic distances measure cultural distances and Spolaore and Wacziarg's (2009) interpretation of genetic distances as a measure of the level of past interaction between populations.

Using data from Fearon (2003) on linguistic distance and from Mecham, Fearon, and Laitin (2006) on religious distance, I further investigate the effect of mobility costs on current cultural distances.[11] The results are similar to the ones found for genetic distances: there is a positive and statistically significant correlation between mobility costs and cultural differences as can be seen in tables 23-26.

3.4 Discussion

The previous subsections presented various tests to validate the different measures constructed in this paper. They also compared the new measures with simpler ones generated by great circle distances. The results are quite encouraging and show the usefulness and validity of the new measures. Although it was shown that the new measures were adequate and useful in understanding phenomena in the pre-industrial age, before the widespread use of steam as a

[11] Given that these measures are constructed for the modern composition of the countries, I cannot do a similar exercise as with genetic distances in order to determine the effect of initial cultural differences and mobility costs. One possible route would be to construct similar measures for 1500 using the matrix created by Putterman, Weil, and Box (2008).

source of power, the period of relevance of each measure has to be considered carefully if no additional data is available.

An important aspect that should be highlighted is that not all measures faired equally well for the explanation of the different phenomena studied. Notice, e.g., that the explanatory power of the different geographical distance measures is much lower for linguistic than for genetic distances, and even lower for religious ones. Also, the measure with the highest explanatory power for each measure of cultural distance varied depending on the aspect of culture being measured. For example, in the regressions for genetic and linguistic distances, HMI had a quite higher explanatory power than any of the other measures, while RIX had a better explanatory power for religious distance. On the other hand, as the previous subsections showed, HMISea seemed to explain better the diffusion of news and the trade. Thus it seems that the different measures capture different dynamics and temporalities of the object of study, e.g. the fact that genetic and linguistic distances have an older origin than religious distances, or that the dynamics of expansion of a language are different from the ones of a religion. Understanding these issues is important as it might help in determining the best use for the new measures as well as to the cultural variables, all of which is part of an ongoing research agenda.

4 Some Problems of Commonly Used Distance Measures

4.1 Great Circle Distances

As mentioned in the introduction, the use of great circle distances in economics (and other sciences) is pervasive in many areas. Table 27 presents the great circle distances, taken from the distance database generated by CEPII, among the capitals of a selected sample of countries. Although the great circle distances between each pair in each subgroup are very similar, the conditions for mobility between different pairs are too dissimilar for great circle distances to convey any real information about the proximity of each pair of countries. So, unless great circle distances are accompanied by *additional information* that affects the mobility between regions, the information provided by these distances might be capturing elements unrelated to distance and transportation costs, or most probably biased.

An additional problem of great-circle distances is the fact that they do not capture the effect of technology on distances. Clearly, the invention of seafaring, aerospace, and information technologies has made the world a smaller place for those societies that have adopted them. An effect of such new technologies is that in the modern era the "[i]ntercourse between nations spans the whole globe to such an extent, that one may almost say all the world is but a single city, in which a permanent fair comprising all commodities is held, so that by means of money all the things produced by the land, the animals and human industry can be acquired and enjoyed by any person in his own home." (Montanari (1683, p.40) cited in Marx (1859; 1973))

Although this is the most used and the most easily computed measure, it is not always clear that the topology generated by such a measure is of interest to every problem. Consider for example the spatial economy in figure 29. Panel (a) represents the topology implied by the geographical locations of the core and four peripheries, assuming a direct relationship between the great circle distance and the length of the connecting edge. Panel (b) represents the topology implied by transportation costs, assuming that the available transportation technology has constant returns to scale and is such that it implies that optimal transportation between the peripheries can *only* occur through the core, and that such a cost is equal for all. Clearly, in such a world, the topology implied by great circle distances, panel (a), is of little interest for economic phenomena that use the transportation technology, since these are based on the topology implied by the transportation costs summarized in panel (b).

Consider now the case of a trade study on this economy. Since the transportation costs between any two peripheries or between a periphery and the core are equal, if one observes a higher volume of trade between, say, periphery 1 and 3 than between periphery 1 and 4, this clearly *cannot* be a consequence of transportation costs. But, given that periphery 1 is closer to periphery 3 than to 4 in panel (a), one could mistakenly infer that the difference in trade patterns is caused by differing transportation costs. Furthermore, by the nature of the core in any world system, in this economy, one should expect to see more trade between the peripheries and the core than among the peripheries themselves. If periphery 1 does not trade with any of the other peripheries because of non-economic reasons, then again it will look as if transportation costs are behind the lack of trade.

Although this is a very artificial example, one can see that if the transportation costs are not correctly measured, one can easily impute to them effects that are not caused by them and thus bias any estimation of the effect of transportation or interaction costs. Furthermore, given that for certain pairs of locations great circle distances are correlated with other differences among those locations, *unless all* such differences are included, one will get inconsistent estimates of the effect of transportation costs on the problem at hand. For example, the number of different languages, the number of different cultures, number of waterways, mountains, etc. between any two locations are positively correlated with great circle distances. Clearly, all of these measures also have an effect on trade flows, so that a regression of trade volumes on great circle distances, without the inclusion of *all* these other measures, generates inconsistent estimates of the regression coefficients. Furthermore, the coefficient on distance will capture not only the effects of transportation costs, but of all these other variables.

4.2 Import-Wizzard (Modern) Freight Costs Data

This section presents the estimation results for the relationship between geodesic distance and the measure of air and surface transportation costs employed by Giuliano, Spilimbergo, and Tonon (2006), Spolaore and Wacziarg (2009) and Guiso, Sapienza, and Zingales (2009), among others.[12] A close examination of this data shows certain features that make it suspect of an artificial construction: First, the transportation cost between any pair of countries is a linear function of the weight of the package being sent. In particular, sending X kilograms of unspecified freight transported over sea or land, with no special handling, costs X times as much as sending one kilogram of the same type of freight using the same means. Second, there exists a *perfect* linear relationship between the cost of transporting X kilograms of unspecified

[12] The data can be freely accessed at `http://www.importexportwizzard.com`.

freight, with no special handling, over sea or land and the cost of transporting X kilograms of unspecified freight by air, with no special handling. Figure 30 shows this relationship for the case of 1,000 kg, which is given by the equation

$$aircost = \underset{(0.0346)}{-655.85} + \underset{(0.0001)}{5.2}\ surfacecost,$$

which has $R^2 = 1$! Third, the cost of transportation of 1,000 kilograms of unspecified freight, with no special handling, within the same country is $156 *independent of the mode of transportation and of the country.*

Given these "anomalies" in the data, a closer inspection of it seems prudent. Figures 31-41 show the relationship between air transportation costs and geodesic distance from each country to the rest of the countries for the whole sample of countries. As can be seen there, for most countries there exists a suspiciously good linear fit between those two measures. The exceptions being Bhutan (BTN), Georgia (GEO), Greenland (GRL), Latvia (LVA), Swaziland (SWZ), and Ukraine (UKR), for which the relation does not hold as tightly, and which are also the outliers in other countries' regressions. Additionally, in the case of Bhutan (BTN) transportations costs are negatively related to distance, contrary to most priors. Similarly, for the case of Swaziland there exists a region where distance and costs are negatively related, while on the complement the relation is positive.

In addition to the graphical analysis, I estimated the relation for each country using OLS, obtaining an average adjusted R^2 of 0.95 if all countries are included and of 0.99 if the anomalies are omitted. Table 28 shows the results of the joint estimation of the relation for all countries using both OLS and SUR. Clearly the results are very similar and favor SUR, which is equivalent to the country by country regressions.

Although the underlying relation might really be linear, the existence of these anomalies and the results from the regressions should make one wonder about the way in which this data was constructed. Import-Wizzard.com gives this data for free and offers to put users in contact with freight companies in order to get actual price quotes. Thus, the free data might just be an approximation to real freight costs based on some algorithm that they do not publish and might be wrong. So, results based on this data set should be taken with caution, since it is not clear what type of measurement errors or other types of noise one is including in the analysis when using it. I would suggest not using it altogether and rather use other measures, even if it is geodesic distances, where it is clearer what kind of problems the measure has.

5 Conclusion

In this paper I have proposed new methods for estimating the transportation costs between regions during the pre-industrial era. I have shown that the estimates generated by these methods have high explanatory power for trade, information diffusion, and cultural distances, which is higher than other more widely used methods, like great circle distances.

Already some papers have used these methods to generate estimates of measures of interaction in the past and have shown their correlation with measures of economic development. Ashraf, Galor, and Özak (2010) used the average optimal time required to travel to each capital in the Old World from any location in the Old World, according to OPHMI, as a measure of historical isolation and showed that this measure if positively correlated with economic development. Özak (2010) uses the OPHMISea travel time as a measure of the geographical distance to the technological frontier and shows that this measure has a U-shaped relation with economic development. Both papers have shown that the relations uncovered by them hold both in pre-industrial and modern eras, presenting evidence on the long shadow of the past for economic development.

A Tables

Table 1: Maximum Sustainable Speed under Clear Sky, High Risk of Heat Exhaustion, and Black Top Terrain.

	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	OLS
	Dependent Variable is Maximum Sustainable Speed (km/h) under Clear Sky, High Risk, and Black Top Terrain			
	Slope≥ 0		Slope≤ 0	
Observations	263	263	264	264
Adjusted R^2	0.88	0.94	0.80	0.91

Notes: Data taken from Hayes (1994), estimations by author.

Heteroskedasticity robust standard error estimates are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 2: Maximum Sustainable Speed under Clear Sky, High Risk of Heat Exhaustion, and Dirt Road Terrain.

	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	OLS
	Dependent Variable is Maximum Sustainable Speed (km/h) under Clear Sky, High Risk, and Dirt Road Terrain			
	Slope≥ 0		Slope≤ 0	
Observations	263	263	264	264
Adjusted R^2	0.89	0.94	0.80	0.91

Notes: Data taken from Hayes (1994), estimations by author.

Heteroskedasticity robust standard error estimates are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 3: Maximum Sustainable Speed under Clear Sky, High Risk of Heat Exhaustion, and Loose Sand Terrain.

	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	OLS
	Dependent Variable is Maximum Sustainable Speed (km/h) under Clear Sky, High Risk, and Loose Sand Terrain			
	Slope≥ 0		Slope≤ 0	
Observations	258	258	264	264
Adjusted R^2	0.92	0.95	0.82	0.92

Notes: Data taken from Hayes (1994), estimations by author.

Heteroskedasticity robust standard error estimates are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 4: A timeline of seafaring.

Year	Event	Civilization	Note
11000 BCE	Evidence of trade		Obsidian imported into Greece from the island of Melos
6000 BCE	People settle the island of Crete		
5000 BCE	Dugout boats and wodden paddle in China		Neolithic dugout boats and wooden paddles have been excavated at Hemudu and Xiaoshan in China’s Zhejiang province
4500 BCE	Oak canoes are used on the Seine		The oldest wooden boats ever found in Europe. The largest of the canoes is nearly 5 meters (16 ft)
4000 BCE	Boats in Egypt	Egyptian	“Egyptians build boats made from planks joined together; previuosly, boats were dogout canoes and possible rafts of reeds bound together or skins stretched over a framework”
3500 BCE	Invention of sails	Sumerians Egyptians	
3000 BCE	Evidence of sailing activities		“Boats built in Egypt or Mesopotamia are paddled or sailed with a simple square sail; rowing has not yet been discovered; egyptians boats are essentially papyrus rafts at this time, although shaped with upturned ends”
2900 BCE	Earliest contacts between Egypt and Crete	Egyptian	“Bowls found on crete appear to have been made in Egypt, suggesting seagoing trade between the two; it is likely that the Minoan ships were even more venturous, trading all over the mediterranean by this period”
2650 BCE	Import of timber from Lebanon	Egyptian	“A command from the Egyptian pharao Snefru to bring ””40 ships filled with cedar logs”” to Egypt from Lebannon is the first written record of the existence of boats and shipping”
2500 BCE	Wooden Boats and invention of oars	Egyptian	“Boats in Egypt are now made of wood, instead of being papyrus rafts with unturned ends; oars have probably been invented by this time”
2500 BCE	Shipping		“Clay tablets record imports of stone to southern Mesopotamia form either Magan or Makran (both ports on the Persian Gulf); Magan developed a reputation as a port, and the stone was probably transported by boat to the mouth of the Euphrates at the head of the gulf and then up the Tigris-Euphrates river system”

Table 4: A timeline of seafaring (continued).

Year	Event	Civilization	Note
2400 BCE	Fleet of transports to ferry troops to some Asiatic coast	Egyptian	Pharaoh Sahure orders for his pyramid a representation of the levant coast; this is the earliest known depiction of seagoing ships that has been preserved and the earliest recorde use of ships for military purposes (they were undoubtely used in war earlier)
2000 BCE	Multi-planked boats in China	Xia Dynasty	
2000 BCE	Mentuhotep sends a ship to the Red Sea	Egyptian	
2000-1500 BCE	Heyday of Minoan maritime activity	Minoan	
1500 BCE	Expedition to Punt	Egyptian	
1400 BCE	Seagoing ships in the Mediterraean		Seagoing ships in the Mediterraean are built by first joining planks together to make a hull
1100 BCE	Wenamon's voyage	Egyptian	To bring wood from Lebanon
1100 BCE	Voyage of the Argo	Greek	To go to Colchis (Georgia today)
970 BCE	Trade with India	Phoenician	
1000-700 BCE	Phoenician colonize the west	Phoenician	From Tyre (where a port was built) to Utica to Cadiz
800 BCE	Invention of the Penteconter	Greek	"Penteconters are believed to have been between 28 and 33 meters long, approximately 4 meters wide and capable of reaching a top speed of 9 knots (18km/h)"
700 BCE	Invention of the two-banked galleys (Bireme)	Phoenician	
550 BCE	Invention of the trireme	Greek	"This type was employed by ancient Greece, Rome, and other Mediterranean maritime nations. The Athenian trireme had 54 oarsmen in the lowest or thalamite bank, 54 in the second or zygite bank, and 62 in the uppermost or thranite bank. Such a galley would have a length of about 39 m (about 128 ft) and a maximum width of perhaps 4.6 m (15 ft) at the waterline. The boat would sink about 1.2 m (about 4 ft) into the water."
500 BCE	Canal linking the Mediterranean with the Indian Ocean	Persian	This canal was 145km (90 miles) long and 45m (150ft) wide
425 BCE	Trade by sea with China	Chinesse Babylonian Greek	"Babylonians sailed to the South China Sea. Meanwhile, Chinese silk was sent to Greece by sea."

Table 4: A timeline of seafaring (continued).

Year	Event	Civilization	Note
398 BCE	Invention of the quinquereme	Greek	
350 BCE	Peryplus of Niarchus	Greek	"The Periplus (pilot book) of Niarchus, an officer of Alexander the Great, describes the Persian coast. Niarchus commissioned thirty oared galleys to transport the troops of Alexander the Great from northwest India back to Mesopotamia, via the Persian Gulf and the Tigris, an established commercial route."
200 BCE	Construction of Magic Canal in China	Chinese	That enables a ship to sail from Canton (or anywhere else on the China Sea) to the latitude of present day Beijing
200 BCE	Construction of the largest naval vessel in the classical age	Egyptian	"Built by Ptolemy IV of Egypt. It had 4000 rowers in 40 banks, and carried as many as 3250 others as a crew and fighting marines (was a catamaran over 120 m-400 ft- long)"
200 BCE	Invention of the dry dock	Egyptian	"Ptolemy's ship was built in a channel that was connected to the sea; when the ship was completed, the channel was filled with water and launched it "
200 BCE	Introduction of three-masted vessels	Greek	"A foremast called an artemon, the main, and a mizzenmast at the rear"
120 BCE	Eudoxus sails to India	Greek	
12 BCE	Construction of Canal in Netherlands	Roman	Nero Claudius Drusus joins the Flevo Lacus (the largest lake in Netherlands) to the Rhine with a canal that also uses the Yssl River for part of the passage
0	Use of a small triangular topsail above the mainsail	Roman	
0	Earliest known despiction of a ship's rudder	Chinesse	
45 CE	Construction of Canal in Germany	Roman	Gnaesus Domitius Corbulo digs a ship's canal joining the Rhine with the Meuse River
62 CE	St. Paul's voyage to Rome	Roman	
70 CE	The Grand Canal of China is started	Chinesse	965 Km (600 mi) long
100 CE	Use of grid for location	Chinesse	Zhang Heng develops the method of using a grid to locate points on a map
130 CE	Creation of device for orientation	Chinesse	Zhang Heng combines a water clock with an armallary to produce a device that keeps track of where stars are expected to be in the sky

Table 4: A timeline of seafaring (continued).

Year	Event	Civilization	Note
270 CE	First form of compass	Chinesse	"The first form of compass is probably used for finding south, earlier applications of magnetic lodestones were more magical than practical"
520 CE	Paddle wheel boats	Roman	"The first paddle wheel boats are designed, to be powered by oxen walking in circles, as in a mill; it is unlikely that these were built"
1020 CE	Earliest known evidence that seagoing wooden ships are bieng built in the modern way		"A vessel wrecked off Serce Limani (Turkey), the construction started with a keel and framework to which planked is added"
1080 CE	First known reference to use of magnetic compass for navigation	Chinesse	Chinese scientist Shen Kua's Dream pool essays contains the first reference
1170 CE	Regulations and navigation for navigation in China	Chinesse	"Were described by Zhu Yu, son of a former high port official and then governor of Guangzhou. Large ships carried several hundred men, the smaller ones more than a hundred. They navigated by the coasts, the stars, the compass, and seabed sampling."
1180 CE	Sternpost rudder		"The sternpost rudder, possibly borrowed from the chinese, replaces the steering oars that have been used in Europe and the near East since antiquity"
1190 CE	First known western reference to the magnetic compass		in De naturis rerum by Alexander Neckam)

Sources:

Table 5: Historical shipping speeds.

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Abdera	Mouth of the Danube	500 BCE	4	500	5.2	14.5	1	Thucydides	Greek - Classical-	
Carthage	Gibraltar	500 BCE	7	820	4.9	13.6	1	Scylax of Caryanda	Greek - Classical-	

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Syrtes	Heraclea Minoa	350 BCE	4.5	475	4.4	12.2	1	Plutarch	Greek - Hellenistic-	Fleet
Zacynthus	Cape Pachynus	350 BCE	12.5	340	1.1	3.1	1	Plutarch	Greek - Hellenistic-	"Zacynthus = Zakynthos, Cape Pachynus = Capo Passero. Very light winds. Fleet"
Dunnet Head	Thule	300 BCE	6	500	3.5	9.6	NA	Plythea	Greek - Hellenistic-	"Ancient European descriptions and maps locate Thule in the far north, often Iceland, possibly the Orkney Islands or Shetland Islands. The more realistic guesswork is Iceland"
Cadiz	Cape St Vicent	300 BCE	5	150	1.3	3.5	NA	Plythea		
Cape Finisterre	Sacred Island	300 BCE	2	500	10.4	28.9	NA	Plythea		
Carthage	Ostia	200 BCE	3	360	5	13.9	NA	Plutarch	Roman Republic	
Lilybaeum	Cape Bon	200 BCE	1	65	2.7	7.5	1	Titus Livius	Roman Republic	Lilybaeum = Marsala. Fleet
Marseilles	Ostia	200 BCE	2.5	330	5.5	15.3	NA	Casson	Greek - Hellenistic-	estimation
Messina	Cephallenia	200 BCE	4.5	250	2.3	6.4	NA	Titus Livius	Roman Republic	Probably under favorable winds (unstated). Fleet
Ostia	Carthage	200 BCE	3	360	5	13.9	NA	Plutarch	Roman Republic	

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Ostia	Marseilles	200 BCE	5.25	330	2.6	7.3	NA	Casson	Greek - Hellenistic-	estimation
Pisa	Marseilles	200 BCE	4.5	260	2.4	6.7	NA	Polybius	Greek - Hellenistic-	Via Ligurian coast. Winds were variables (both favorable and unfavorable). Fleet
Sason	Cephallenia	200 BCE	1.75	160	3.8	10.6	NA	Polybius	Greek - Hellenistic-	"Cephallenia = Kefalonia, probably under favorable winds (unstated). Fleet"
Ibiza	Gibraltar	100 BCE	3	400	5.6	15.4	1	Diodorus Siculus	Roman Empire	
Sea of Azov	Rhodes	100 BCE	9.5	880	3.9	10.7	1	Diodorus Siculus	Roman Empire	
Syracuse	Cape Bon	100 BCE	6	220	1.5	4.2	NA	Diodorus Siculus	Roman Empire	Probably under unfavorable winds (unstated). Fleet
Utica	Ostia	100 BCE	4	360	3.8	10.4	1	Plutarch	Roman Republic	
Rhodes	Alexandria	50 BCE	3.5	325	3.9	10.7	1	Appianus	Roman Empire	Fleet
Utica	Carales	50 BCE	3	160	2.2	6.2	NA	Julius Caesar	Roman Republic	Probably under unfavorable winds (unstated). Carales = Cagliari. Fleet
Lilybaeum	Ruspina	50 BCE	3.5	140	1.7	4.6	1	Julius Caesar	Roman Republic	"Ruspina = Monastir, Tunisia. Fleet"

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Lilybaeum	Anquillaria	50 BCE	2.5	90	1.5	4.2	NA	Julius Caesar	Roman Republic	Anquillaria was somewhere on the Cape Bon. Fleet
Alexandria	Cyrene	1 CE	8	420	2.2	6.1	NA	Casson	Roman Empire	estimation
Alexandria	Myra	1 CE	6.25	310	2.1	5.7	NA	Casson	Roman Empire	estimation
Alexandria	Puteoli	1 CE	60	1710	1.2	3.3	0	Casson	Roman Empire	"Via Cyprus, Myra, Rhodes, south of Crete, Malta, Syracuse, Messina. Puteoli = Pozzuoli (Naples). estimation"
Alexandria	Rhodes	1 CE	8.75	550	2.6	7.3	NA	Casson	Roman Empire	Via Myra. estimation
Alexandria	Ostia	1 CE	63	1820	1.2	3.3	0	Casson	Roman Empire	"Via Cyprus, Myra, Rhodes, south of Crete, Malta, Syracuse, Messina, Naples. estimation"
Berytus	Rhodes	1 CE	8	600	3.1	8.7	NA	Casson	Roman Empire	Via Syria and coast of Asia Minor. estimation
Crete	Egypt	1 CE	3	310	4.3	12	1	Strabo	Roman Empire	Specific point in Egypt is unstated
Cyrene	West Point of Crete	1 CE	2	160	3.3	9.3	0	Strabo	Roman Empire	
Cyrene	Alexandria	1 CE	4.5	420	3.9	10.8	NA	Casson	Roman Empire	estimation

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Gibraltar	Ostia	1 CE	8.5	935	4.6	12.7	NA	Casson	Roman Empire	estimation
Messina	Alexandria	1 CE	6	830	5.8	16	1	"Pliny, the Elder"	Roman Empire	
Messina	Alexandria	1 CE	7	830	4.9	13.7	1	"Pliny, the Elder"	Roman Empire	
Myra	Alexandria	1 CE	3	310	4.3	12	NA	Casson	Roman Empire	estimation
Narbo	Ostia	1 CE	3	400	5.6	15.4	NA	Casson	Roman Empire	estimation
Ostia	Cape Bon	1 CE	2	270	5.6	15.6	1	"Pliny, the Elder"	Roman Empire	unusual fast voyage
Ostia	Gibraltar	1 CE	7	935	5.6	15.5	1	"Pliny, the Elder"	Roman Empire	
Ostia	Tarraco	1 CE	4	510	5.3	14.8	1	"Pliny, the Elder"	Roman Empire	
Ostia	Narbo	1 CE	3	380	5.3	14.7	1	"Pliny, the Elder"	Roman Empire	
Ostia	Alexandria	1 CE	11.5	1000	3.6	10.1	NA	Casson	Roman Empire	estimation
Puteoli	Alexandria	1 CE	9	1000	4.6	12.9	1	"Pliny, the Elder"	Roman Empire	Puteoli = Pozzuoli (Naples)
Rhodes	Berytus	1 CE	3.5	400	4.8	13.2	NA	Casson	Roman Empire	estimation
Troy	Alexandria	1 CE	7	550	3.3	9.1	1	Lucan	Roman Empire	Fleet
Rhegium	Puteoli	30 CE	1.5	175	4.9	13.5	1	The Bible. Acts 28:13	Roman Empire	Rhegium = Reggio Calabria

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Malao	Mundus	50 CE	2	130	2.7	7.5	1	Periplus Maris Erythraei	Roman Empire	Malao = Berbera. Mundus = Maydh (according to Prof. Dr. Muhammad Shamsaddin Megalommatis)
Mundus	Mosyllum	50 CE	2.5	120	2	5.6	1	Periplus Maris Erythraei	Roman Empire	"Mundus = Maydh (according to Prof. Dr. Muhammad Shamsaddin Megalommatis). According to W. Desborough Cooley, Mosyllum was 300 miles probably eastward of the modern Berberah. According to Prof. Dr. Muhammad Shamsaddin Megalommatis, Mosyllum is Bossaasso"

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Mosyllum	Cape Elephant	50 CE	2	130	2.7	7.5	1	Periplus Maris Erythraei	Roman Empire	“According to W. Desborough Cooley, Mosyllum was 300 miles probably eastward of the modern Berberah. According to Prof. Dr. Muhammad Shamsaddin Megalommatis, Mosyllum is Bossaasso”
Opone	Pyralax Island	50 CE	19	1000	2.2	6.1	1	Periplus Maris Erythraei	Roman Empire	Opone = Hafun. Pyralax Island = Pane Island
Pyralax Island	Menuthias	50 CE	3	240	3.3	9.3	1	Periplus Maris Erythraei	Roman Empire	Menuthias = Zanzibar
Menuthias	Raphta	50 CE	2	100	2.1	5.8	1	Periplus Maris Erythraei	Roman Empire	“The location of Raphta has not yet been firmly identified, although there are a number of plausible candidate sites. The archaeologist Felix Chami suggests that it was located on the coast of Tanzania, in the region of the Rufiji River and Mafia Island”

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Ocelis	Muziris	50 CE	40	2500	2.6	7.2	NA	"Pliny, the Elder"	Roman Empire	Muziris = Qillom
Berenice	Ocelis	50 CE	13	800	2.6	7.1	NA	"Pliny, the Elder"	Roman Empire	
Strait of Hurmuz	Ommana	50 CE	6	250	1.7	4.8	NA	Periplus Maris Erythraei	Roman Empire	"The exact location of the port of Ommana is uncertain owing to the limited knowledge yet at hand concerning this coast. Muller, Fabricius, and McCrindle locate Ommana in the bay of Chahbar on the Makran coast"
Corinth	Puteoli	100 CE	4.5	670	6.2	17.2	1	Philostratus	Roman Empire	Puteoli = Pozzuoli (Naples)
Ostia	Puteoli	100 CE	1.25	120	4	11.1	NA	Casson	Roman Empire	estimation
Puteoli	Tauromenium	100 CE	2.5	205	3.4	9.5	1	Philostratus	Roman Empire	"Tauromenium = Taormina, Puteoli = Pozzuoli (Naples) "
Puteoli	Ostia	100 CE	2.5	120	2	5.6	0	Philostratus	Roman Empire	Puteoli = Pozzuoli (Naples)
Puteoli	Corinth	100 CE	6.75	670	4.1	11.5	NA	Casson	Roman Empire	Puteoli = Pozzuoli (Naples). estimation
Alexandria	Cyprus	150 CE	6.5	250	1.6	4.5	0	Lucian	Roman Empire	

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Alexandria	Byzantium	150 CE	18.5	850	1.9	5.3	NA	Lucian	Roman Empire	Via Myra and Rhodes. estimation
Alexandria	Crete	150 CE	12.5	550	1.8	5.1	NA	Lucian	Roman Empire	Via Myra and Rhodes. estimation
Crete	Alexandria	150 CE	3.5	360	4.3	11.9	1	Casson	Roman Empire	estimation
Sidon	Chelidonian Isles	150 CE	9.5	350	1.5	4.3	0	Lucian	Roman Empire	
Alexandria	Ephesus	200 CE	4.5	475	4.4	12.2	1	Achilles Tatius	Roman Empire	
Alexandria	Marseilles	300 CE	30	1500	2.1	5.8	0	Sulpicius Severus	Roman Empire	
Alexandria	Marseilles	300 CE	68	1400	0.9	2.4	0	Casson	Roman Empire	estimation
Marseilles	Alexandria	300 CE	25	1400	2.3	6.5	NA	Casson	Roman Empire	estimation
Narbo	Utica	300 CE	5	470	3.9	10.9	NA	Sulpicius Severus	Roman Empire	
Syrtes	Alexandria	300 CE	6.5	700	4.5	12.5	1	Sulpicius Severus	Roman Empire	
Ascalon	Thessalonica	400 CE	13	800	2.6	7.1	0	Marcus Diaconus	Byzantine Empire	
Ascalon	Thessalonica	400 CE	16	800	2.1	5.8	NA	Casson	Byzantine Empire	estimation
Byzantium	Rhodes	400 CE	5	445	3.7	10.3	1	Marcus Diaconus	Byzantine Empire	
Byzantium	Gaza	400 CE	10	855	3.6	9.9	1	Marcus Diaconus	Byzantine Empire	
Byzantium	Alexandria	400 CE	9	750	3.5	9.6	1	Casson	Byzantine Empire	estimation

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles[†]	Speed[‡] (Knots)	KM/H[††]	Favorable Winds	Reference	Civilization	Note
Caesarea	Rhodes	400 CE	10	400	1.7	4.6	0	Marcus Diaconus	Byzantine Empire	
Gaza	Byzantium	400 CE	20	850	1.8	4.9	0	Marcus Diaconus	Byzantine Empire	
Gaza	Rhodes	400 CE	11	750	2.8	7.9	NA	Mark the Deacon	Byzantine Empire	Via Syria and coast of Asia Minor. estimation
Phycus	Alexandria	400 CE	4.5	450	4.2	11.6	1	Synesius	Byzantine Empire	Phycus = Ras-es-Sem (Libya)
Rhodes	Gaza	400 CE	7	410	2.4	6.8	0	Marcus Diaconus	Byzantine Empire	This voyage reported included a severe storm
Rhodes	Byzantium	400 CE	10	445	1.9	5.2	0	Marcus Diaconus	Byzantine Empire	
Rhodes	Caesarea	400 CE	3.5	400	4.8	13.2	NA	Casson	Byzantine Empire	estimation
Rhodes	Gaza	400 CE	3.5	410	4.9	13.6	NA	Casson	Byzantine Empire	estimation
Rhodes	Tyre	400 CE	4	450	4.7	13	NA	Casson	Byzantine Empire	estimation
Thessalonica	Ascalon	400 CE	12	800	2.8	7.7	1	Marcus Diaconus	Byzantine Empire	"Thessalonica = Thessaloniki, Ascalon = Ashkelon"
Tyre	Rhodes	400 CE	10	570	2.4	6.6	NA	Casson	Byzantine Empire	Via Syria and coast of Asia Minor. estimation

[†] estimation by author; [‡] calculation based on the nautical miles and length in days of the voyage; [††] based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Euripus	Phalerum	450 BCE	3	96	1.3	3.7	NA	Herodotus	Greek - Hellenistic-	Phalerum = Palaio Faliro. Winds were variables (both favorable and unfavorable). Fleet
Carales	Numidia-Mauretania border	500 CE	2.5	200	3.3	9.3	NA	Procopius	Byzantine Empire	Carales = Cagliari. After seeing the map of Numidian borders (after 2th punic war) We assigned the border of Numidia to Al Hoceima (ad hoc). Probably under favorable winds (unstated). Fleet
Carthage	Syracuse	500 CE	2.5	260	4.3	12	1	Procopius	Byzantine Empire	
Epidamnus	Ostia	500 CE	4.5	600	5.6	15.4	1	Procopius	Byzantine Empire	Epidamnus = Durrs (Albany)
Gibraltar	Carthage	500 BCE	7	820	4.9	13.6	NA	Casson	Greek - Classical-	estimation
Ostia	Epidamnus	500 CE	5.5	600	4.5	12.6	NA	Casson	Byzantine Empire	estimation
Zacynthus	Mt. Etna	500 CE	15.5	320	0.9	2.4	1	Procopius	Byzantine Empire	Very light winds. Fleet
Kalah Bar	Sanf Fulaw	800 CE	30	1300	1.8	5		Akhbar al-Sin wa al-Hind	Islamic Abbasid Caliphate	"Kalah Bar = Region of Kedha (We use the coordinates for its capital city i.e: Alor Setar, Kedha, Malaysia)"

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Sanf Fulaw	Canton	800 CE	30	700	1	2.7		Akhbar al-Sin wa al-Hind	Islamic Abbasid Caliphate	Sanf Fulaw (Champa Kingdown) = Qui Nhon (by approximation). Canton = Guangzhou
Kalah Bar	Tiuman I	850 CE	10	510	2.1	5.8		Akhbar al-Sin wa al-Hind	Islamic Abbasid Caliphate	"Kalah Bar = Region of Kedha (We use the coordinates for its capital city i.e: Alor Setar, Kedha, Malaysia). Tiuman I = Tioman Island (Malaysia)"
Kulam Mali	Kalah Bar	850 CE	29	1580	2.3	6.4		Akhbar al-Sin wa al-Hind	Islamic Abbasid Caliphate	Kulan Mali = Quilon/Kollam (India)
Masqat	Kulam Mali	850 CE	29	1450	2.1	5.8		Akhbar al-Sin wa al-Hind	Islamic Abbasid Caliphate	Kulan Mali = Quilon/Kollam (India)
Nicobar Is.	Kalah Bar	850 CE	6	400	2.8	7.8		Ibn-Khurdadhbah	Islamic Abbasid Caliphate	
al-Qulzum	Juddah	900 CE	25	630	1.1	3.1		Al-Maqdisi	Islamic Abbasid Caliphate	minimum time. Juddah = Jeddah (Saudi Arabia)
Siraf	Al-Basrah	900 CE	5	320	2.7	7.5		Al-Maqdisi	Islamic Abbasid Caliphate	minimum time

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Kalah Bar	Shihr Luban	950 CE	41	3300	3.4	9.4		Buzurg ibn Shahriyar	Islamic Abbasid Caliphate	"Kalah Bar = Region of Kedha (We use the coordinates for its capital city i.e: Alor Setar, Kedha, Malaysia). Shihr Luban (or Hadhramaut) was a region so We assigned the coordinates of the city of al-Shihr"
Kulam Mali	Raysut	950 CE	16	1250	3.2	8.9		Buzurg ibn Shahriyar	Islamic Abbasid Caliphate	
Bergen	New Foundland	1000 CE	28	2000	3	8.3	NA	Captain Magnus Andersen	Viking Era	This record is based on a voyage realized in 1893 using a Norwegian replica of the Gökstadt ship
Stad	Höfn	1000 CE	7	550	3.3	9.1	NA	Landnámabók	Viking Era	
Bergen	Reykjavik	1000 CE	14	850	2.5	7	NA			
Snæfellsnes	Ammassalik	1000 CE	4	350	3.6	10.1	NA	Landnámabók	Viking Era	
Reykjavik	Joldulaup	1000 CE	5	700	5.8	16.2	NA	Landnámabók	Viking Era	
Langanes	Jan Mayen	1000 CE	4	300	3.1	8.7	NA	Landnámabók	Viking Era	
Ostia	Rhodes	NA	9	1000	4.6	12.9	NA	Casson	NA	estimation based on data from 500 BCE to 500 CE
Rhodes	Cyprus	NA	2	250	5.2	14.5	NA	Casson	NA	estimation based on data from 500 BCE to 500 CE

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Table 5: Historical shipping speeds (continued).

From	To	Period	Days	Nautical Miles†	Speed‡ (Knots)	KM/H††	Favorable Winds	Reference	Civilization	Note
Rhodes	Ostia	NA	54	1000	0.8	2.1	NA	Casson	NA	estimation based on data from 500 BCE to 500 CE
Tarraco	Ostia	NA	4.25	510	5	13.9	NA	Casson	Roman Empire	estimation based on data from 500 BCE to 500 CE

† estimation by author; ‡ calculation based on the nautical miles and length in days of the voyage; †† based on the assumption that travel by ship can only be made during 16 continuous hours per day.

Sources:

Table 6: Speeds on sea. Assignation based on the information of table 5.

Sea	Number of Voyages	Average Speed	Min. Speed	Max. Speed	Std. Deviation	Speed on Cell i	Time Required (hours)
Arabian Sea	9	6.99	4.82	9.45	1.46	7.56	0.13
Atlantic Ocean	8	11.6	3.47	28.94	7.35	12.55	0.08
Bay of Bengal	2	7.92	6.39	9.45	1.53	8.57	0.12
Black Sea	2	12.6	10.72	14.47	1.88	13.62	0.07
Gulf of Thailand	2	5.43	5.02	5.83	0.41	5.87	0.17
Indian Ocean	13	6.97	5.02	9.45	1.44	7.54	0.13
Malacca Strait	5	6.89	5.02	9.45	1.56	7.46	0.13

Table 6: Speeds on sea (continued). Assignation based on the information of table 5

Sea	Number of Voyages	Average Speed	Min. Speed	Max. Speed	Std. Deviation	Speed on Cell i	Time Required (hours)
Mediterranean	87	9.62	2.14	17.23	4.06	10.4	0.1
North Sea	3	8.13	7.03	9.09	0.85	8.79	0.11
Persian Gulf	2	6.16	4.82	7.5	1.34	6.66	0.15
Red Sea	3	5.8	3.06	7.23	1.94	6.28	0.16
South China Sea	3	4.52	2.7	5.83	1.33	4.89	0.2
Bay of Bizcay	NA	NA	NA	NA	NA	12.55	0.08
Phillipine Sea	NA	NA	NA	NA	NA	4.89	0.2
Sea of Japan	NA	NA	NA	NA	NA	4.89	0.2
East China Sea	NA	NA	NA	NA	NA	4.89	0.2
Gulf of Tonkin	NA	NA	NA	NA	NA	4.89	0.2
Taiwan Strait	NA	NA	NA	NA	NA	4.89	0.2
Mozambique Channel	NA	NA	NA	NA	NA	7.54	0.13
English Channel	NA	NA	NA	NA	NA	12.55	0.08
Baltic Sea	NA	NA	NA	NA	NA	8.79	0.11
Caspian Sea	NA	NA	NA	NA	NA	13.62	0.07

Table 7: Distances and transportation costs among capitals.

Table 8: Distribution of distance from historical locations to Optimal Paths and Random Linear Networks.

Network	Distance from OWTRAD Nodes to Network.				
	Edges†	Average	Std	Median	Max (Max)‡
OPRIX	2.55	160	199	81	1,143
OPHMI		84	155	27	2,207
OPHMISea		35	56	15	610
RLN4	4	173	238	77	2,062 (3,219)
RLN6	6	143	218	54	1,995 (3,171)
RLN8	8	124	206	41	1,976 (2,852)
LN135	135	8	53	1	1,121

† For OPRIX, OPHMI, and OPHMISea it is the actual average number of edges. For the RLN's it is the number edges before eliminating the ones crossing over water bodies. For LN135 it is the actual number of edges that connect *all* 135 capitals in the Old World, without eliminating any crossings.
‡ Average maximum and in parenthesis maximum over all maxima.
Distance in Kilometers. Calculations by author.

Table 9: Deciles of the distribution of distance from historical locations to OPRIX and Random Linear Networks.

Network	Decile Distance from OWTRAD Nodes to Network.								
	1	2	3	4	5	6	7	8	9
OPRIX	3	12	28	49	81	117	193	285	437
OPHMI	2	5	10	17	28	42	68	119	243
OPHMISea	1	3	6	10	15	24	35	52	90
RLN4	6	17	31	51	77	113	171	282	502
RLN6	4	11	21	35	54	83	128	220	428
RLN8	3	8	15	26	41	64	102	181	380
LN135	0.06	0.16	0.26	0.41	0.61	0.89	1.37	2.39	5.08

Distance in Kilometers. Calculations by author.

Table 10: Distance to Venice from various cities as measured by the number of days travelled.

	Braudel (1972)						HMI			HMISea		
City	Total Cases	Normal Cases	Maximum	Average	Normal	Minimum	HMI	HMI days of 12 hours	HMI days of 8 hours	HMISea	HMISea days of 12 hours	HMISea days of 8 hours
Alexandria	266	19	89	65	55	17	43	86	129	10	20	30
Antwerp	83	13	36	20	16	8	7	15	22	7	15	22
Augsburg	110	19	21	11	12	5	2	4	6	2	4	6
Barcelona	171	16	77	22	19	8	10	19	29	6	13	19
Blois	345	53	27	14	10	5	9	18	27	9	18	26
Brussels	138	24	35	16	10	9	7	15	22	7	15	22
Budapest	317	39	35	18	19	7	6	12	18	5	11	16
Burgos	79	13	42	27	27	11	14	28	42	11	23	34
Calais	62	15	32	18	14	12	9	19	28	9	18	27
Candia	56	16	81	38	33	20	NA	NA	NA	8	15	23
Cairo	41	13	10	7	8	3	41	83	124	12	24	36
Constantinople	365	46	81	37	34	15	15	30	45	9	18	27
Corfu	316	39	45	19	15	7	NA	NA	NA	4	9	13
Damascus	56	17	102	80	76	28	34	69	103	12	24	37
Florence	387	103	13	4	3	1	1	3	4	1	3	4
Genoa	215	58	15	6	6	2	3	6	10	3	6	9
Innsbruck	163	41	16	7	6	4	1	2	3	1	2	3
Lisbon	35	9	69	46	43	27	20	40	59	13	26	39
London	672	78	52	27	24	9	NA	NA	NA	10	20	30
Lyons	812	225	25	12	13	4	6	12	18	6	12	18
Marseilles	26	7	21	14	12	8	6	12	18	5	9	14
Milan	871	329	8	3	3	1	3	5	8	3	5	8
Naples	682	180	20	9	8	4	NA	NA	NA	2	5	7
Nauplia	295	56	60	36	34	18	12	24	36	7	13	20
Nuremberg	39	11	32	20	21	8	2	5	7	2	5	7
Palermo	118	23	48	22	25	8	NA	NA	NA	4	7	11
Paris	473	62	34	12	12	7	8	17	25	8	17	25
Ragusa	95	18	26	13	14	5	NA	NA	NA	5	9	14
Rome	1053	406	9	4	4	2	2	5	7	2	4	6
Trani	94	14	30	12	12	4	NA	NA	NA	2	5	7
Trento	205	82	7	3	3	1	1	2	3	1	2	3
Udine	552	214	6	2	2	2	1	1	2	1	1	2
Valladolid	124	15	63	29	23	12	15	30	45	12	24	36
Vienna	145	32	32	14	13	8	4	7	11	3	7	10
Zara	153	28	25	8	6	1	3	7	10	1	3	4
Average	275	146	31	15	10	6	10	20	31	6	12	18
STD	265	132	23	14	11	5	12	23	35	4	8	11

Table 11: Distance to Venice from various cities (Comparison).

	Braudel (1972)		HMI			HMISea			
City	Average/Minimum	Normal/Minimum	Average/HMI	Normal/HMI	HMI/Minimum	Average/HMISea	Normal/HMISea	HMISea/Minimum	HMISea/HMI
Alexandria	382	323	152	128	252	643	544	59	24
Antwerp	250	200	274	219	91	274	219	91	100
Augsburg	220	240	589	642	37	589	642	37	100
Barcelona	274	237	229	197	120	343	297	80	67
Blois	311	222	154	110	202	160	114	194	96
Brussels	178	111	220	137	81	220	137	81	100
Budapest	257	271	308	325	83	335	353	77	92
Burgos	245	245	194	194	126	239	239	102	81
Calais	149	116	192	149	78	201	156	74	95
Candia	188	163	NA	NA	NA	500	434	38	NA
Cairo	233	266	17	19	1376	59	67	395	29
Constantinople	246	226	248	227	99	412	378	60	60
Corfu	271	214	NA	NA	NA	445	351	61	NA
Damascus	285	271	233	222	122	655	622	44	36
Florence	400	300	302	227	132	302	227	132	100
Genoa	300	300	188	188	159	211	211	142	89
Innsbruck	175	150	627	538	28	627	538	28	100
Lisbon	170	159	233	217	73	352	329	48	66
London	299	266	NA	NA	NA	266	236	113	NA
Lyons	300	325	204	221	147	204	221	147	100
Marseilles	175	150	234	200	75	298	256	59	78
Milan	300	300	110	110	272	110	110	272	100
Naples	225	200	NA	NA	NA	364	324	62	NA
Nauplia	199	188	298	281	67	547	516	36	54
Nuremberg	250	262	859	902	29	859	902	29	100
Palermo	275	312	NA	NA	NA	628	713	44	NA
Paris	171	171	141	141	121	141	141	121	100
Ragusa	260	280	NA	NA	NA	286	308	91	NA
Rome	266	266	169	169	157	200	200	133	85
Trani	300	300	NA	NA	NA	487	487	62	NA
Trento	300	300	310	310	97	310	310	97	100
Udine	133	133	288	288	46	390	390	34	74
Valladolid	241	191	195	155	123	242	192	99	81
Vienna	174	162	382	355	46	425	394	41	90
Zara	800	600	235	176	341	557	418	144	42
Average	270	252	179	178	118	306	269	113	80
STD	92	73	108	103	107	151	136	68	24

Table 12: Correlation between Braudel's estimates, HMI and HMISea.

	Maximum	Average	Normal	Minimum	HMI
HMI	0.61	0.72	0.71	0.60	1
HMISea	0.65	0.68	0.65	0.71	0.77

Table 13: F_{ST} genetic distance in 1500 and Mobility Measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: F_{ST} genetic distance in 1500											
HMI Cost (weeks)	0.560***				0.557***				0.880***			
	(0.032)				(0.059)				(0.081)			
HMISea Cost (weeks)		0.469***				0.508***				0.797***		
		(0.027)				(0.063)				(0.076)		
RIX distance (1000's km)			0.235***				0.341***				0.405***	
			(0.013)				(0.048)				(0.042)	
Geodesic Distance				1.038***				0.692***				1.279***
				(0.085)				(0.115)				(0.124)
Standardized β	0.619	0.505	0.487	0.503	0.615	0.547	0.706	0.335	0.972	0.858	0.839	0.620
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.383	0.255	0.237	0.254	0.613	0.594	0.595	0.572	0.651	0.502	0.517	0.435
Observations	9454	9454	9454	9454	9454	9454	9454	9454	9454	9454	9454	9454

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 14: *Nei* genetic distance in 1500 and Mobility Measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: *Nei* genetic distance in 1500											
HMI Cost (weeks)	0.096***				0.112***				0.142***			
	(0.005)				(0.010)				(0.013)			
HMISea Cost (weeks)		0.081***				0.101***				0.130***		
		(0.004)				(0.011)				(0.012)		
RIX distance (1000's km)			0.040***				0.064***				0.065***	
			(0.002)				(0.008)				(0.007)	
Geodesic Distance				0.161***				0.091***				0.195***
				(0.015)				(0.022)				(0.021)
Standardized β	0.626	0.517	0.487	0.464	0.733	0.647	0.785	0.262	0.932	0.830	0.804	0.562
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.393	0.267	0.238	0.215	0.587	0.558	0.550	0.495	0.640	0.507	0.516	0.421
Observations	9454	9454	9454	9454	9454	9454	9454	9454	9454	9454	9454	9454

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 15: F_{ST} genetic distance (dominant group) current period and Mobility Measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: F_{ST} genetic distance dominant group											
HMI Cost (weeks)	0.392***				0.403***				0.642***			
	(0.049)				(0.093)				(0.109)			
HMISea Cost (weeks)		0.289***				0.316***				0.497***		
		(0.045)				(0.097)				(0.097)		
RIX distance (1000's km)			0.136***				0.185***				0.253***	
			(0.021)				(0.069)				(0.051)	
Geodesic Distance				0.817***				0.761***				0.943***
				(0.102)				(0.130)				(0.165)
Standardized β	0.431	0.309	0.281	0.394	0.443	0.339	0.381	0.367	0.705	0.533	0.523	0.455
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.186	0.096	0.079	0.156	0.455	0.437	0.431	0.462	0.529	0.411	0.418	0.417
Observations	9454	9454	9454	9454	9454	9454	9454	9454	9454	9454	9454	9454

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 16: *Nei* genetic distance (dominant group) current period and Mobility Measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: *Nei* genetic distance dominant group											
HMI Cost (weeks)	0.073***				0.083***				0.108***			
	(0.008)				(0.015)				(0.018)			
HMISea Cost (weeks)		0.057***				0.068***				0.085***		
		(0.007)				(0.016)				(0.016)		
RIX distance (1000's km)			0.026***				0.037***				0.043***	
			(0.003)				(0.011)				(0.008)	
Geodesic Distance				0.132***				0.103***				0.146***
				(0.017)				(0.025)				(0.028)
Standardized β	0.460	0.345	0.305	0.364	0.520	0.413	0.432	0.284	0.676	0.519	0.502	0.402
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.212	0.119	0.093	0.132	0.441	0.418	0.406	0.411	0.504	0.399	0.403	0.387
Observations	9,454	9,454	9,454	9,454	9,454	9,454	9,454	9,454	9,454	9,454	9,454	9,454

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 17: F_{ST} genetic distance (weighted) current period and Mobility Measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: F_{ST} genetic distance weighted											
HMI Cost (weeks)	0.331***				0.286***				0.538***			
	(0.040)				(0.085)				(0.103)			
HMISea Cost (weeks)		0.235***				0.200**				0.393***		
		(0.033)				(0.089)				(0.087)		
RIX distance (1000's km)			0.108***				0.089				0.202***	
			(0.015)				(0.065)				(0.046)	
Geodesic Distance				0.719***				0.638***				0.862***
				(0.093)				(0.127)				(0.163)
Standardized β	0.413	0.287	0.254	0.394	0.358	0.243	0.209	0.350	0.671	0.478	0.474	0.473
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.174	0.084	0.066	0.155	0.487	0.472	0.465	0.504	0.484	0.362	0.370	0.396
Observations	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 18: *Nei* genetic distance (weighted) current period and Mobility Measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: *Nei* genetic distance weighted											
HMI Cost (weeks)	0.062***				0.060***				0.090***			
	(0.006)				(0.014)				(0.017)			
HMISea Cost (weeks)		0.046***				0.045***				0.066***		
		(0.005)				(0.015)				(0.015)		
RIX distance (1000's km)			0.021***				0.019*				0.034***	
			(0.002)				(0.011)				(0.008)	
Geodesic Distance				0.118***				0.092***				0.135***
				(0.015)				(0.024)				(0.028)
Standardized β	0.442	0.321	0.280	0.371	0.431	0.311	0.256	0.288	0.642	0.463	0.453	0.424
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.199	0.105	0.080	0.137	0.458	0.438	0.426	0.448	0.476	0.367	0.372	0.382
Observations	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912	8,912

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 19: F_{ST} genetic distance (current period), Initial Genetic Distance and Mobility Measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: F_{ST} genetic distance							
	Dominant Group				Weighted			
HMI Cost (weeks)	-0.255***				-0.200***			
	(0.060)				(0.055)			
Interaction HMIcost-$F_{ST_{1500}}$	0.002**				-0.005*			
	(0.001)				(0.002)			
HMISea Cost (weeks)		-0.307***				-0.249***		
		(0.052)				(0.044)		
Interaction HMISeacost-$F_{ST_{1500}}$		0.002**				-0.005*		
		(0.001)				(0.003)		
RIX distance (1000's km)			-0.155***				-0.116***	
			(0.026)				(0.024)	
Interaction RIXdist-$F_{ST_{1500}}$			0.001				-0.003**	
			(0.001)				(0.001)	
Geodesic Distance				-0.248***				-0.106
				(0.074)				(0.078)
Interaction Geodesic Distance-$F_{ST_{1500}}$				0.006*				-0.004
				(0.003)				(0.004)
$F_{ST_{1500}}$	0.956***	0.941***	0.957***	0.842***	0.968***	0.938***	0.943***	0.807***
	(0.052)	(0.041)	(0.040)	(0.052)	(0.045)	(0.036)	(0.034)	(0.043)
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Adjusted R-squared	0.862	0.870	0.871	0.853	0.872	0.887	0.887	0.850
Observations	9,454	9,454	9,454	9,454	8,912	8,912	8,912	8,912

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 20: *Nei* genetic distance (current period), Initial Genetic Distance and Mobility Measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: *Nei* genetic distance							
	Dominant Group				Weighted			
HMI Cost (weeks)	-0.035***				-0.029***			
	(0.008)				(0.009)			
Interaction HMIcost-Nei_{1500}	-0.000				-0.007***			
	(0.002)				(0.003)			
HMISea Cost (weeks)		-0.045***				-0.038***		
		(0.008)				(0.007)		
Interaction HMISeacost-Nei_{1500}		-0.000				-0.007**		
		(0.002)				(0.003)		
RIX distance (1000's km)			-0.022***				-0.017***	
			(0.004)				(0.004)	
Interaction RIXdist-Nei_{1500}			-0.000				-0.004***	
			(0.001)				(0.001)	
Geodesic Distance				-0.030**				-0.002
				(0.012)				(0.013)
Interaction Geodesic Distance-Nei_{1500}				-0.002				-0.016***
				(0.005)				(0.005)
Nei_{1500}	1.016***	0.999***	1.014***	0.932***	1.026***	0.988***	0.991***	0.902***
	(0.049)	(0.042)	(0.040)	(0.056)	(0.044)	(0.037)	(0.034)	(0.046)
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Adjusted R-squared	0.840	0.847	0.849	0.833	0.862	0.875	0.876	0.841
Observations	9,454	9,454	9,454	9,454	8,912	8,912	8,912	8,912

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 21: F_{ST} genetic distance (current period), Initial Genetic Distance and Mobility Measures in the Old World.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: F_{ST} genetic distance											
	$F_{ST_{1500}}$				Dominant Group				Weighted			
HMI Cost (weeks)	1.510***				0.159**				0.195***			
	(0.092)				(0.068)				(0.057)			
Interaction HMIcost-$F_{ST_{1500}}$					0.009**				0.009**			
					(0.004)				(0.004)			
HMISea Cost (weeks)		1.766***				0.091				0.096*		
		(0.135)				(0.063)				(0.053)		
Interaction HMISeacost-$F_{ST_{1500}}$						0.011**				0.010**		
						(0.005)				(0.005)		
RIX distance (1000's km)			1.282***				0.099**				0.142***	
			(0.083)				(0.049)				(0.043)	
Interaction RIXdist-$F_{ST_{1500}}$							0.009***				0.008**	
							(0.003)				(0.003)	
Geodesic Distance				2.296***				0.155*				0.206***
				(0.188)				(0.084)				(0.073)
Interaction Geodesic Distance-$F_{ST_{1500}}$								0.012**				0.008
								(0.005)				(0.005)
$F_{ST_{1500}}$					0.739***	0.812***	0.760***	0.812***	0.684***	0.770***	0.708***	0.782***
					(0.090)	(0.074)	(0.079)	(0.071)	(0.065)	(0.054)	(0.058)	(0.051)
Standardized β	0.869	0.722	0.805	0.791								
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Adjusted R-squared	0.706	0.499	0.675	0.594	0.913	0.910	0.912	0.911	0.938	0.933	0.937	0.933
Observations	6,670	6,670	6,670	6,670	6,670	6,670	6,670	6,670	6,216	6,216	6,216	6,216

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 22: Nei genetic distance (current period), Initial Genetic Distance and Mobility Measures in the Old World.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: Nei genetic distance											
	Nei_{1500}				Dominant Group				Weighted			
HMI Cost (weeks)	0.240***				0.020**				0.035***			
	(0.018)				(0.008)				(0.009)			
Interaction HMIcost-Nei_{1500}					0.005				0.002			
					(0.004)				(0.005)			
HMISea Cost (weeks)		0.285***				0.019**				0.025***		
		(0.025)				(0.009)				(0.009)		
Interaction HMISeacost-Nei_{1500}						0.006				0.004		
						(0.005)				(0.005)		
RIX distance (1000's km)			0.204***				0.013**				0.029***	
			(0.015)				(0.007)				(0.007)	
Interaction RIXdist-Nei_{1500}							0.004				0.001	
							(0.003)				(0.004)	
Geodesic Distance				0.360***				0.025**				0.046***
				(0.035)				(0.011)				(0.013)
Interaction Geodesic Distance-Nei_{1500}								0.004				-0.003
								(0.005)				(0.006)
Nei_{1500}					0.861***	0.900***	0.884***	0.916***	0.803***	0.852***	0.827***	0.882***
					(0.086)	(0.071)	(0.073)	(0.068)	(0.067)	(0.050)	(0.059)	(0.050)
Standardized β	0.853	0.718	0.790	0.765								
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Adjusted R-squared	0.670	0.477	0.639	0.551	0.912	0.912	0.912	0.911	0.934	0.932	0.934	0.932
Observations	6,670	6,670	6,670	6,670	6,670	6,670	6,670	6,670	6,216	6,216	6,216	6,216

Two-way clustered robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Table 23: Linguistic distance (dominant group) and Mobility Measures in the Old World.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: linguistic distance (dominant group)											
Ln. HMICost	0.032***				0.041***				0.051***			
	(0.006)				(0.008)				(0.007)			
Ln. HMISeaCost		0.025***				0.032***				0.054***		
		(0.005)				(0.007)				(0.008)		
Ln. RIX Dist.			0.040***				0.039***				0.048***	
			(0.007)				(0.007)				(0.007)	
Ln. Geodesic Dist.				0.035***				0.032***				0.051***
				(0.006)				(0.006)				(0.008)
Standardized β	0.373	0.282	0.449	0.376	0.469	0.354	0.440	0.350	0.584	0.602	0.537	0.552
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.135	0.077	0.194	0.136	0.317	0.294	0.312	0.291	0.477	0.450	0.458	0.444
Observations	6,117	6,117	6,117	6,117	6,117	6,117	6,117	6,117	6,117	6,117	6,117	6,117

Two-way clustered robust standard errors in parentheses

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

Table 24: Linguistic distance (weighted) and Mobility Measures in the Old World.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: linguistic distance (weighted)											
Ln. HMICost	0.041***				0.071***				0.071***			
	(0.012)				(0.023)				(0.010)			
Ln. HMISeaCost		0.032**				0.058***				0.068***		
		(0.014)				(0.020)				(0.010)		
Ln. RIX Dist.			0.061***				0.085***				0.072***	
			(0.014)				(0.024)				(0.011)	
Ln. Geodesic Dist.				0.048***				0.067***				0.067***
				(0.013)				(0.019)				(0.009)
Standardized β	0.131	0.099	0.189	0.143	0.225	0.181	0.263	0.200	0.226	0.212	0.222	0.200
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.017	0.010	0.036	0.020	0.055	0.052	0.066	0.055	0.631	0.621	0.633	0.622
Observations	6,215	6,215	6,215	6,215	6,215	6,215	6,215	6,215	6,215	6,215	6,215	6,215

Two-way clustered robust standard errors in parentheses

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

Table 25: Religious distance (dominant group) and Mobility Measures in the Old World.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: religious distance (dominant group)											
Ln. HMICost	0.020***				0.038***				0.018***			
	(0.007)				(0.011)				(0.007)			
Ln. HMISeaCost		0.028***				0.026***				0.015**		
		(0.008)				(0.010)				(0.006)		
Ln. RIX Dist.			0.024***				0.041***				0.017***	
			(0.007)				(0.011)				(0.006)	
Ln. Geodesic Dist.				0.034***				0.031***				0.015**
				(0.008)				(0.011)				(0.006)
Standardized β	0.111	0.152	0.133	0.180	0.213	0.141	0.223	0.162	0.099	0.084	0.090	0.079
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.011	0.021	0.015	0.028	0.100	0.094	0.104	0.096	0.541	0.539	0.540	0.539
Observations	5,544	5,544	5,544	5,544	5,544	5,544	5,544	5,544	5,544	5,544	5,544	5,544

Two-way clustered robust standard errors in parentheses

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

Table 26: Religious distance (weighted) and Mobility Measures in the Old World.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	Dependent variable: religious distance (weighted)											
Ln. HMICost	0.112***				0.126***				0.150***			
	(0.016)				(0.020)				(0.022)			
Ln. HMISeaCost		0.102***				0.104***				0.132***		
		(0.014)				(0.017)				(0.017)		
Ln. RIX Dist.			0.143***				0.140***				0.153***	
			(0.018)				(0.023)				(0.023)	
Ln. Geodesic Dist.				0.131***				0.114***				0.137***
				(0.016)				(0.019)				(0.016)
Standardized β	0.236	0.212	0.293	0.263	0.267	0.214	0.288	0.227	0.317	0.272	0.314	0.275
Continental FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Country FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Adjusted R-squared	0.056	0.045	0.085	0.068	0.111	0.106	0.119	0.109	0.278	0.248	0.284	0.257
Observations	6,216	6,216	6,216	6,216	6,216	6,216	6,216	6,216	6,216	6,216	6,216	6,216

Two-way clustered robust standard errors in parentheses

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

Table 27: Geodesic distance between the capitals of certain countries.

Country 1	Country 2	Distance†	Country 1	Country 2	Distance†
Costa Rica	Panama	514.3561	Germany	Poland	515.774
Bulgaria	Greece	520.6937	Malawi	Zimbabwe	522.3671
Kuwait	Syria	1201.754	Germany	Ukraine	1204.434
Great Britain	San Marino	1263.348	Great Britain	Spain	1263.379
Phillipines	Brunei	1262.339	Yemen	Sudan	1254.947
Mozambique	Zambia	1251.735	Mexico	El Salvador	1243.565
Cuba	El Salvador	1269.985	Costa Rica	Ecuador	1293.471
Guinea-Bissau	Côte d'Ivoire	1269.448	Turkey	Irak	1266.872
Andorra	Austria	1322.201	Andorra	Ireland	1335.314
Andorra	Malta	1340.487	Chile	Uruguay	1342.72
Irak	Romania	2002.218	Ghana	Gambia	2002.745
Liberia	Nigeria	2002.924	South Korea	Mongolia	2003.103
Afghanistan	Kuwait	2079.553	Afghanistan	Bhutan	2103.501
Azerbaijan	Egypt	2040.063	Azerbaijan	Kazakhstan	2050.058
China	Vietnam	2330.799	Brazil	Surinam	2540.839
Bolivia	Ecuador	2548.317	Barbados	Ecuador	2557.912
Botswana	Dem. Rep. Of Congo	2543.994	Ethiopia	Israel	2597.712

Table 27: Geodesic distance between the capitals of certain countries (continued).

Country 1	Country 2	Distance†	Country 1	Country 2	Distance†
Ireland	Syria	4001.898	Burkina Faso	Bosnia and Herzegovina	4002.188
Gabon	Somalia	4002.507	Bangladesh	Bahrain	4003.865
South Korea	Nepal	4022.39	Brazil	Kenia	4022.594
Canada	Costa Rica	4024.094	Lebanon	Rwanda	4024.98

† in kilometers. Data from CEPII distances database.

Table 28: Air transportation costs and geodesic distance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	SUR	OLS	OLS	OLS	SUR
	Dependent Variable is Air Cost Transportation							
	Internal Distance Omited				Internal Distance Included			
simple distance (most populated cities, km)	103.752***	103.482***	107.014***		103.796***	103.499***	-94.481	
	(0.193)	(0.245)	(2.323)		(0.191)	(0.244)	(82.006)	
Constant	186.821***	147.466***	110.758***	110.758***	186.362***	80.136***	97.469*	78.713*
	(1.817)	(32.186)	(38.328)	(38.328)	(1.799)	(8.461)	(55.429)	(41.571)
Country of Origin FE	NO	YES	YES	YES	NO	YES	YES	YES
Country of Destination FE	NO	YES	YES	YES	NO	YES	YES	YES
Interaction Country of Origin FE	NO	NO	YES	YES	NO	NO	YES	YES
Interaction Country of Destination FE	NO	NO	YES	YES	NO	NO	YES	YES
F-test: FE	-	0.00	0.00		-	0.00	0.00	
F-test: Interactions	-	-	0.00		-	-	0.00	
Adjusted R^2	0.941	0.949	0.978	0.978	0.941	0.949	0.978	0.978
Observations	44890	44890	44890	44890	45115	45115	45115	45115

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

Pairwise clustered robust standard errors in parentheses

B Figures

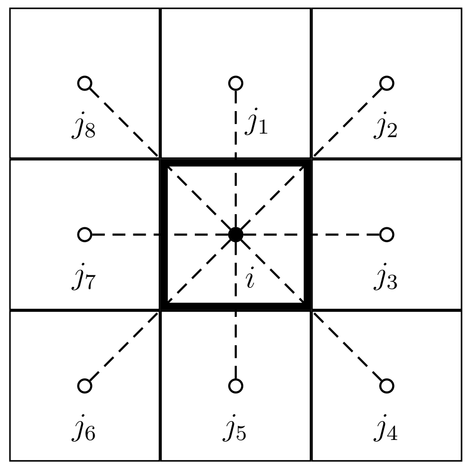


Figure 1: Movement from cell i to each possible neighboring cell can only occur at multiples of $45°$ and goes from the center of cell i to the center of neighboring cell j_k, $k = 1, \ldots, 8$, as indicated by the dashed lines.

Figure 2: Maximum sustainable speeds for fixed meteorological conditions (5% relative humidity and 20° Celsius temperature) for different slopes, as constructed Hayes (1994).

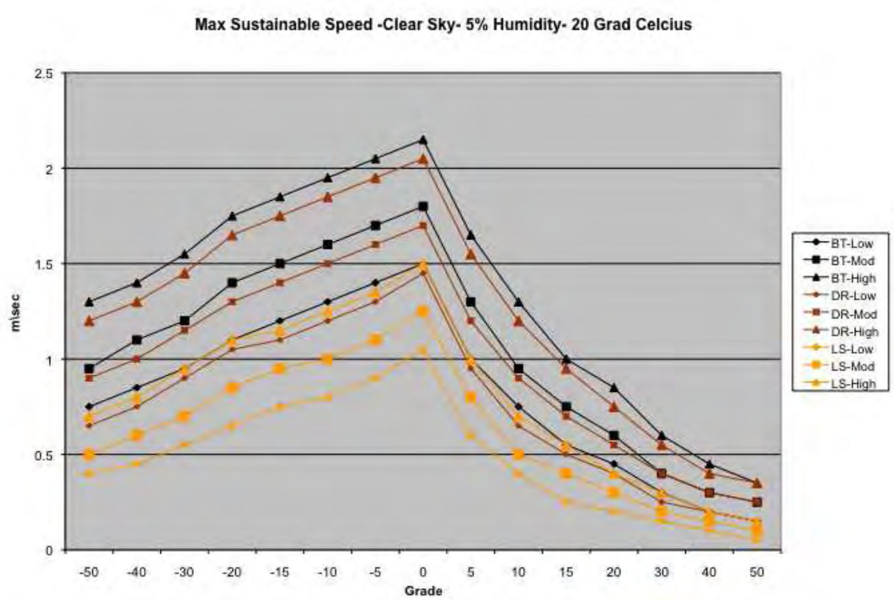
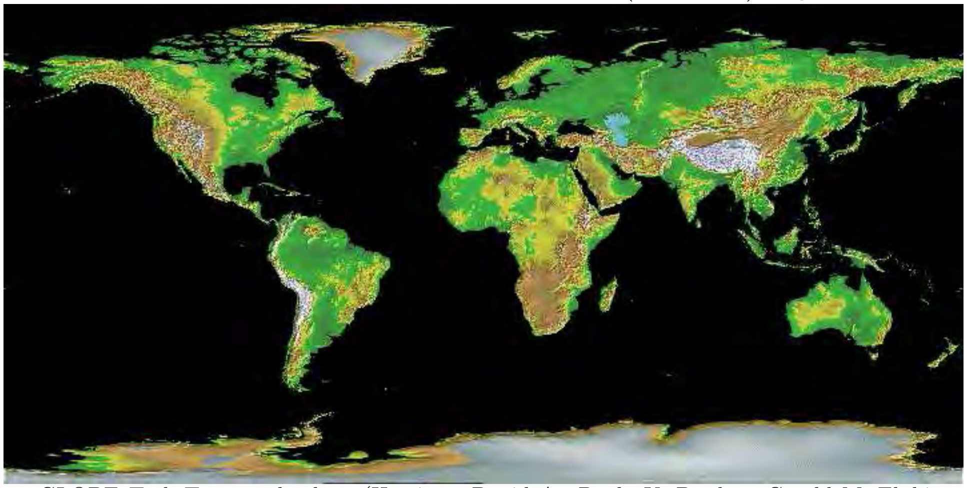


Figure 3: Global Land One-Kilometer Base Elevation (GLOBE) digital elevation model.



Source: GLOBE Task Team and others (Hastings, David A., Paula K. Dunbar, Gerald M. Elphingstone, Mark Bootz, Hiroshi Murakami, Hiroshi Maruyama, Hiroshi Masaharu, Peter Holland, John Payne, Nevin A. Bryant, Thomas L. Logan, J.-P. Muller, Gunter Schreier, and John S. MacDonald), eds., 1999. The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80303, U.S.A. Digital data base on the World Wide Web (URL: `http://www.ngdc.noaa.gov/mgg/topo/globe.html`) and CD-ROMs.

Figure 4: Ruggedness Index at 30 arc-seconds grid based on GLOBE dataset. Calculations by author using index by Riley, DeGloria, and Elliot (1999).

Figure 5: Average temperature constructed from data by Hijmans, Cameron, Parra, Jones, and Jarvis (2005).

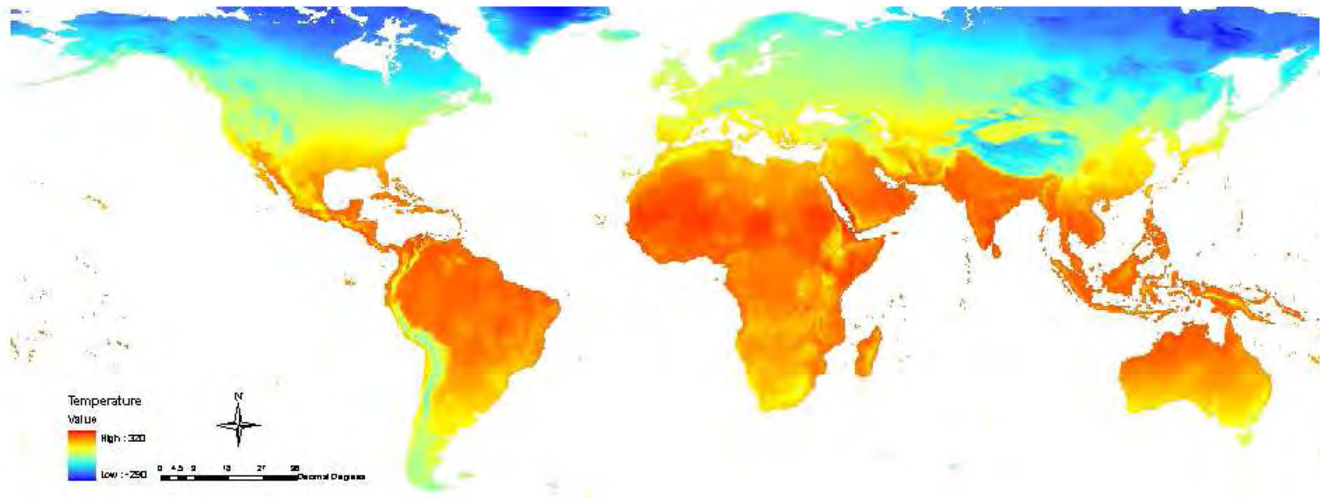


Figure 6: Average relative humidity constructed from data by New, Lister, Hulme, and Makin (2002).

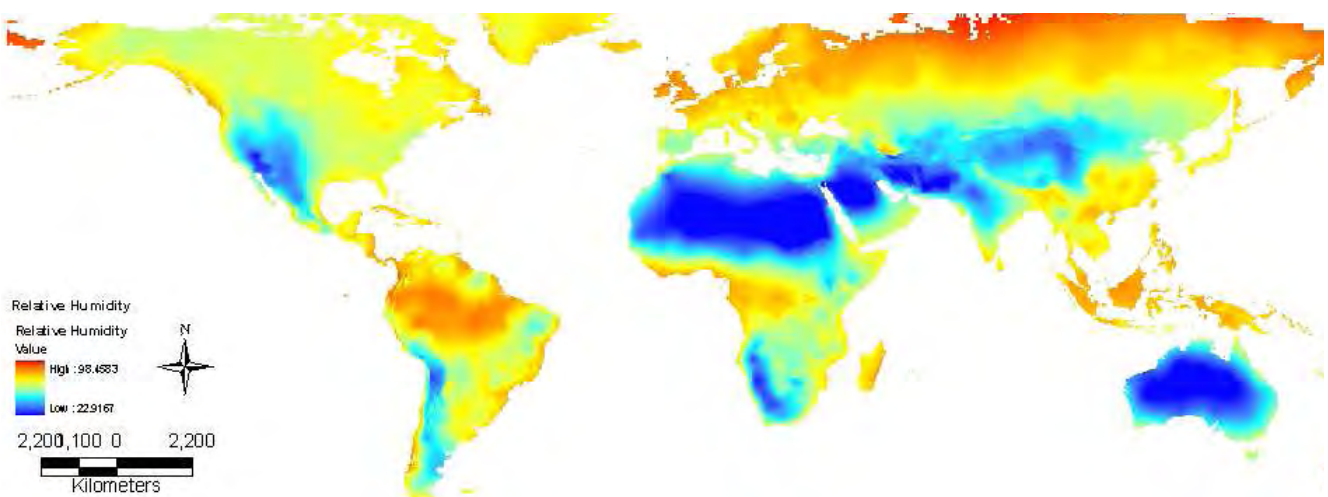
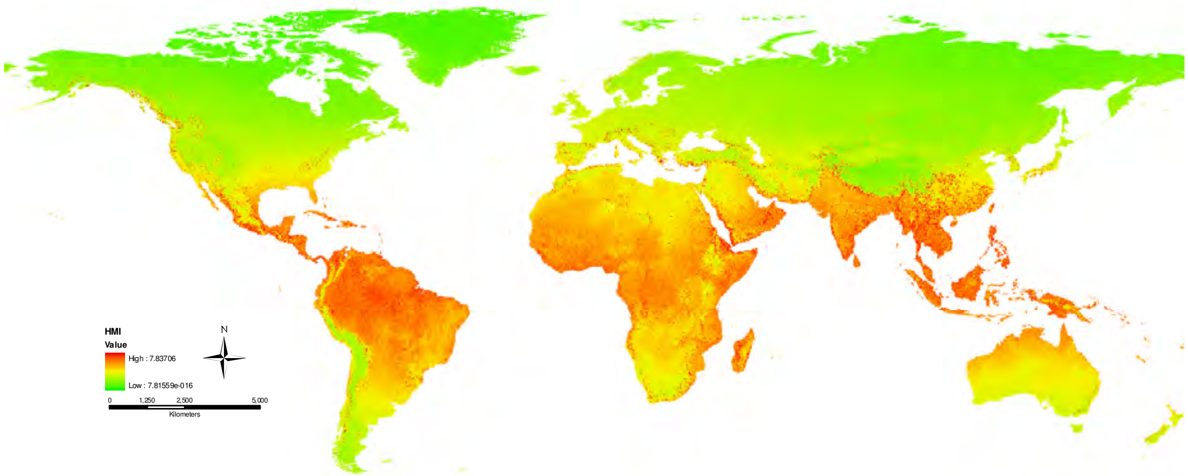
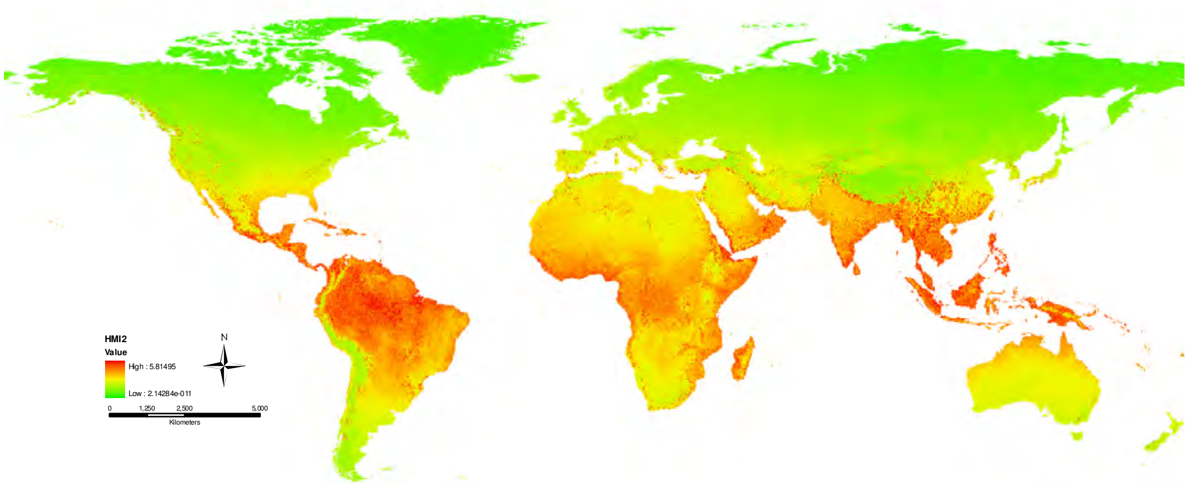


Figure 7: Human Mobility Index (HMI). Computations by author.



Cost surface implied by equations (1) and (3) in table 3.

Figure 8: Human Mobility Index (HMI2). Computations by author.



Cost surface implied by equations (2) and (4) in table 3.

Figure 9: The importance of coastal routes. Wrecks of ships headed to Venice (1592-1609).

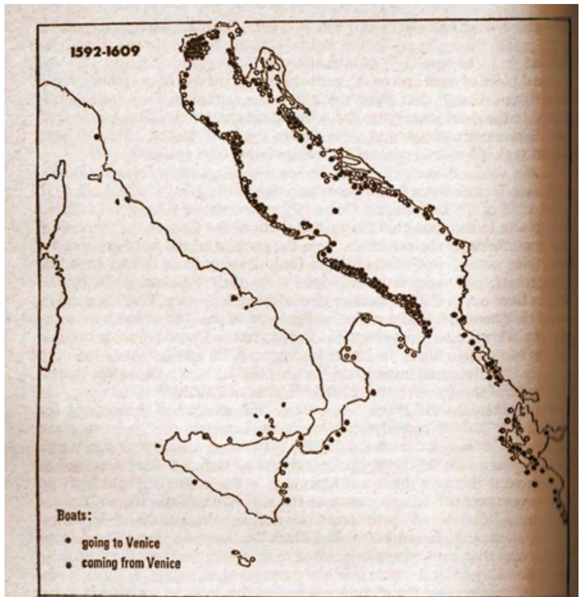


Fig. 8: ***The wrecks of boats sailing to Venice from 1592 to 1609***
(From A. Tenenti, *Naufrages, Corsaires et Assurances maritimes à Venise*, 1959). They indicate the importance of the coastal route.

Source: Braudel (1972)

Figure 10: The importance of coastal routes. Piracy of ships headed to Venice (1592-1609).

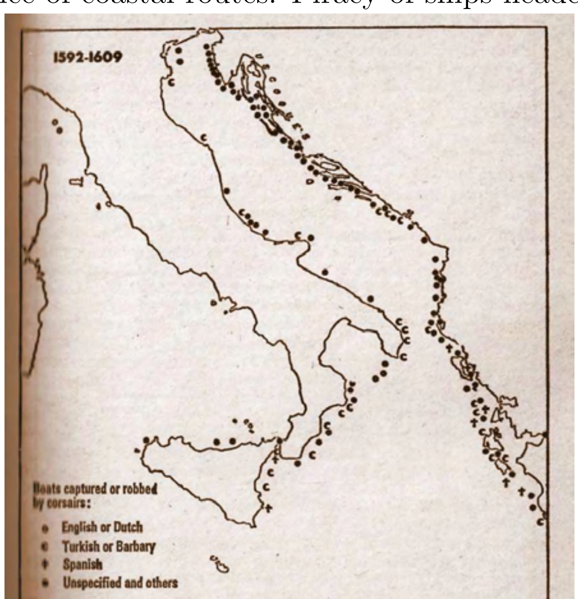
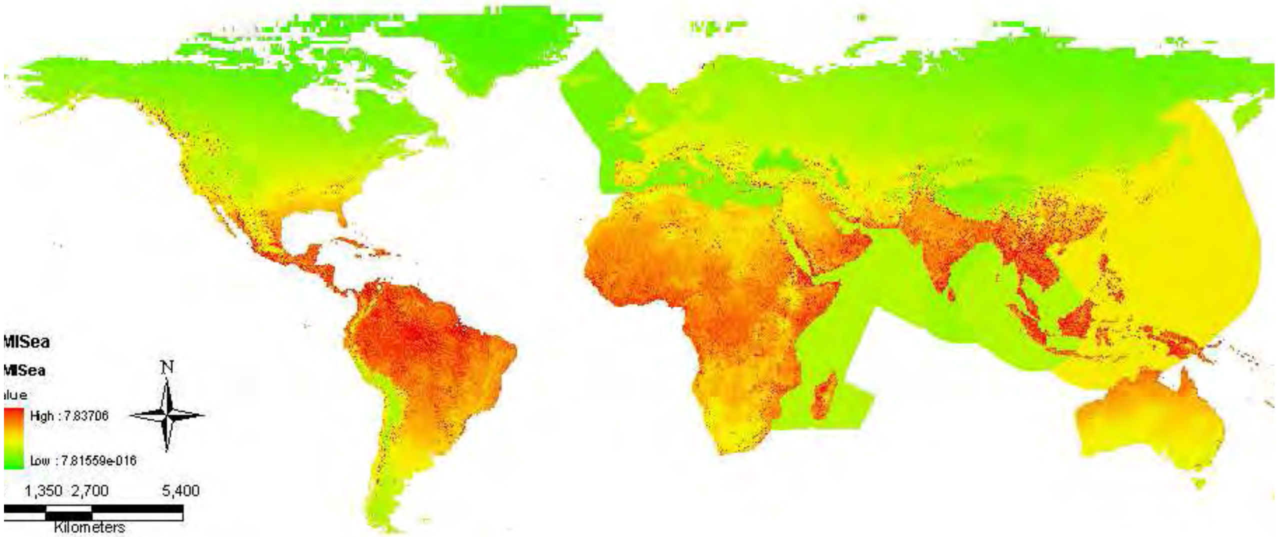


Fig. 9: ***Captured vessels during the same period, from the same source***

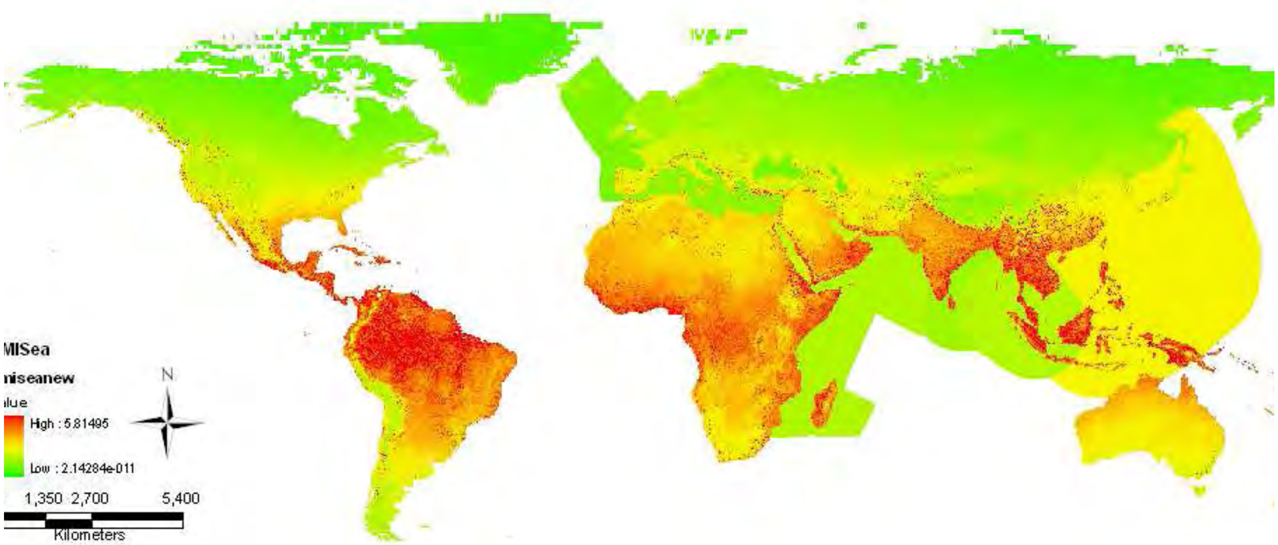
Source: Braudel (1972)

Figure 11: Human Mobility Index with Seafaring (HMISea). Computations by author.



Cost surface implied by equations (1) and (3) in table 3 and sea speeds in table 6.

Figure 12: Human Mobility Index with Seafaring (HMISea2). Computations by author.



Cost surface implied by equations (2) and (4) in table 3 and sea speeds in table 6.

Figure 13: Optimal (minimum cost) paths between capitals based on RIX dataset. Calculations by author.

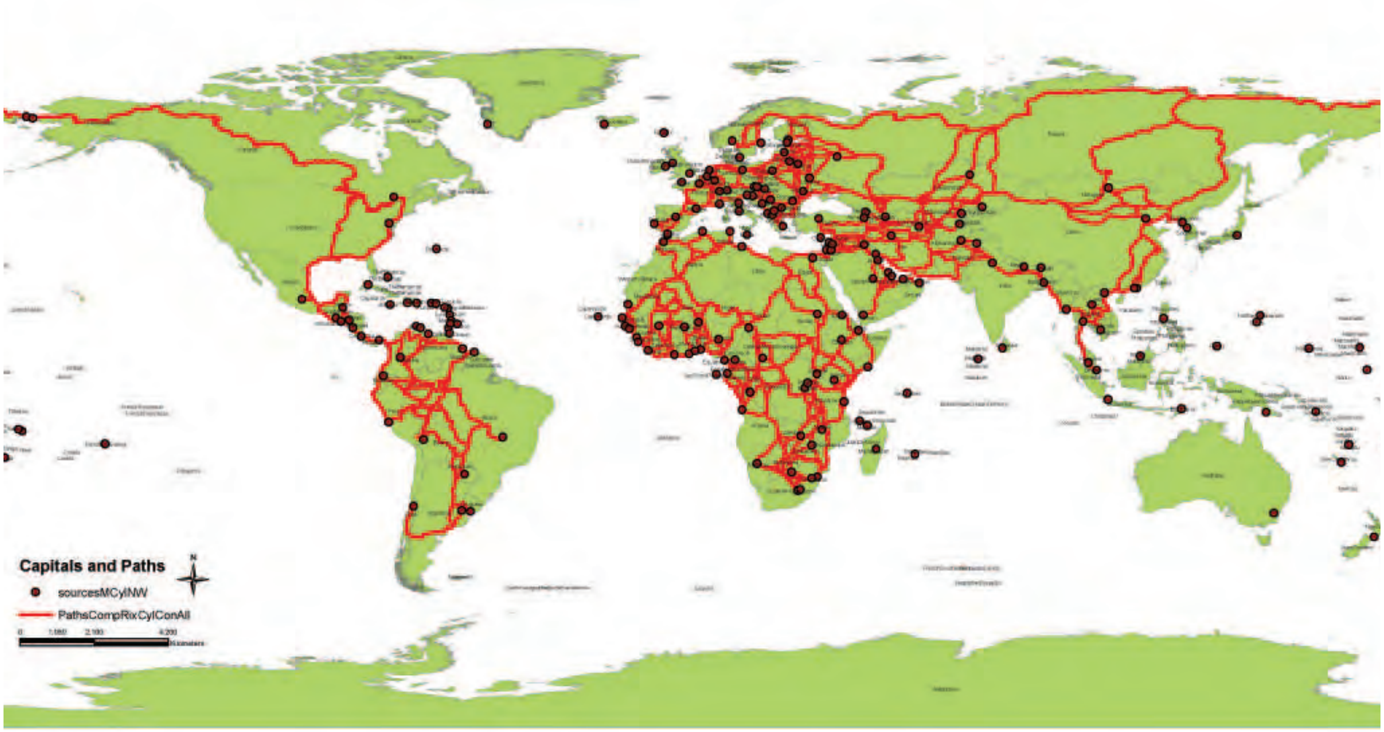


Figure 14: Optimal (minimum cost) paths between capitals based on HMI dataset. Calculations by author.

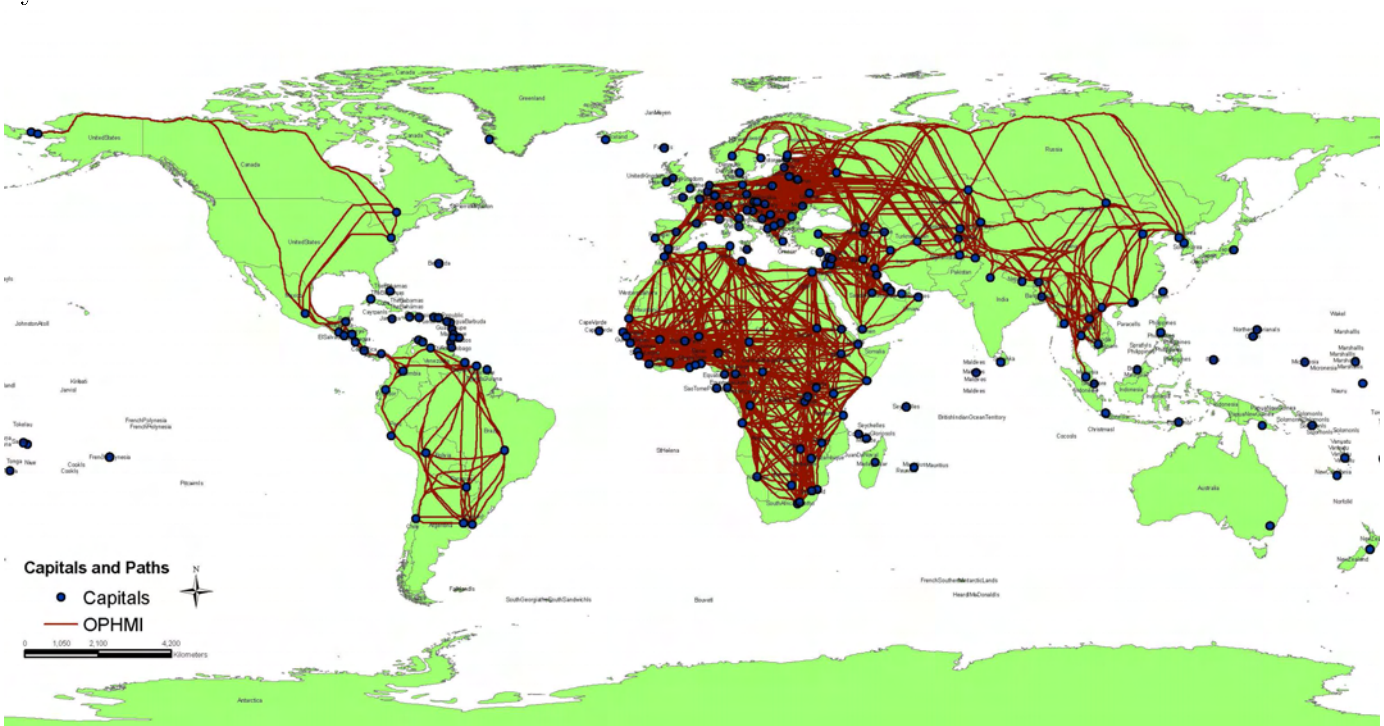


Figure 15: Optimal (minimum cost) paths between capitals based on HMISea dataset. Calculations by author.

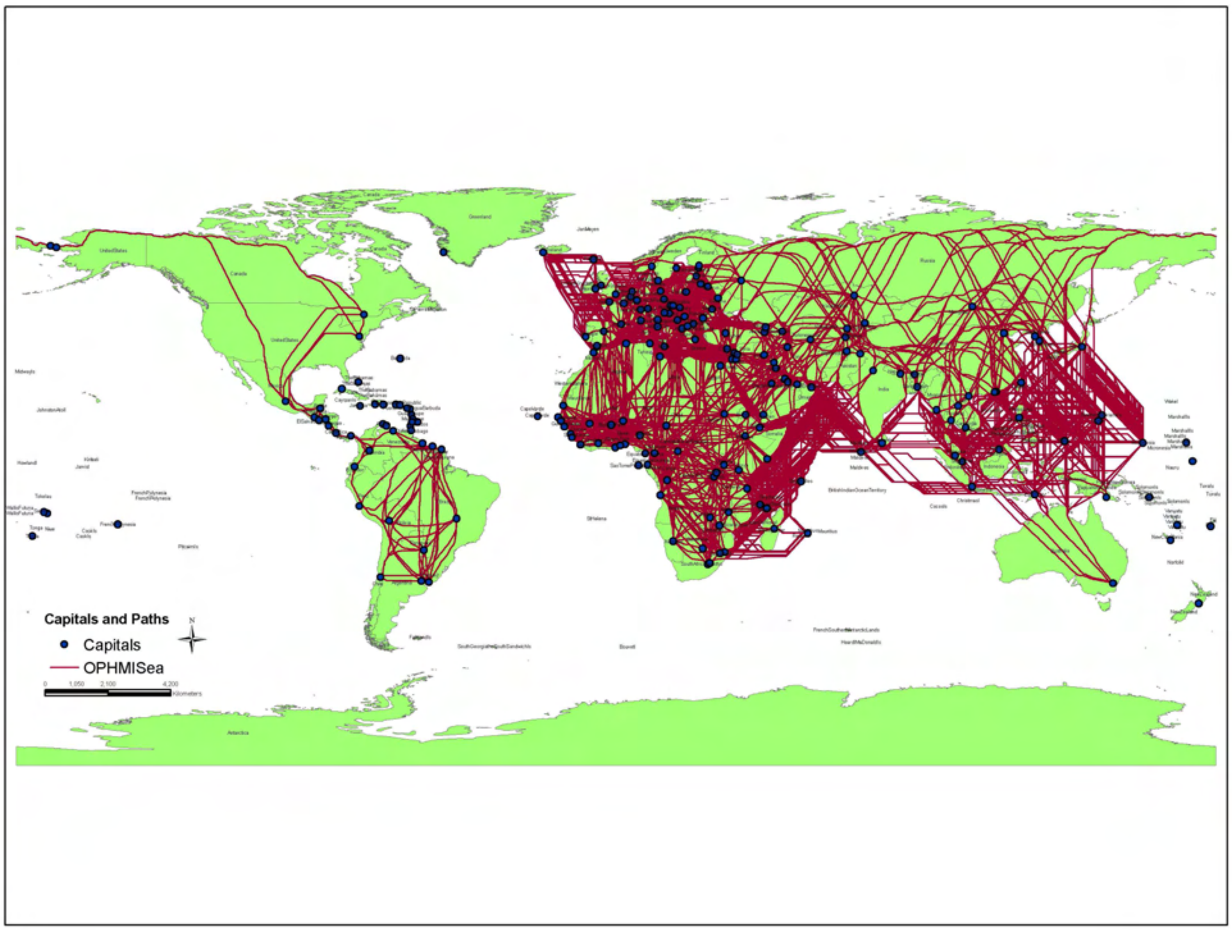


Figure 16: Trade and pilgrimage routes data compiled by Ciolek (2004).

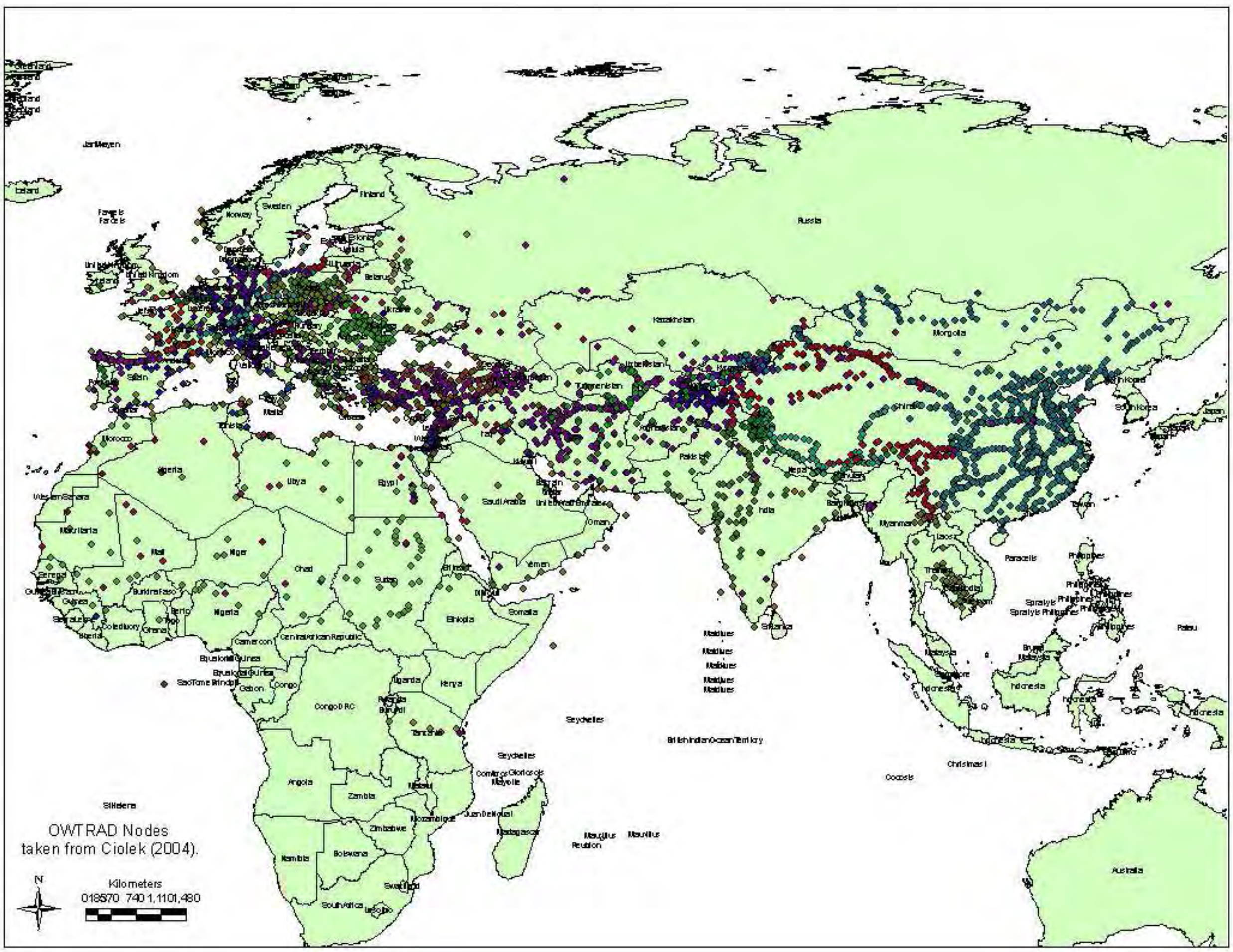


Figure 17: Optimal Paths for RIX, trade and pilgrimage routes data for Europe and North Africa. Computations by author and data by Ciolek (2004).

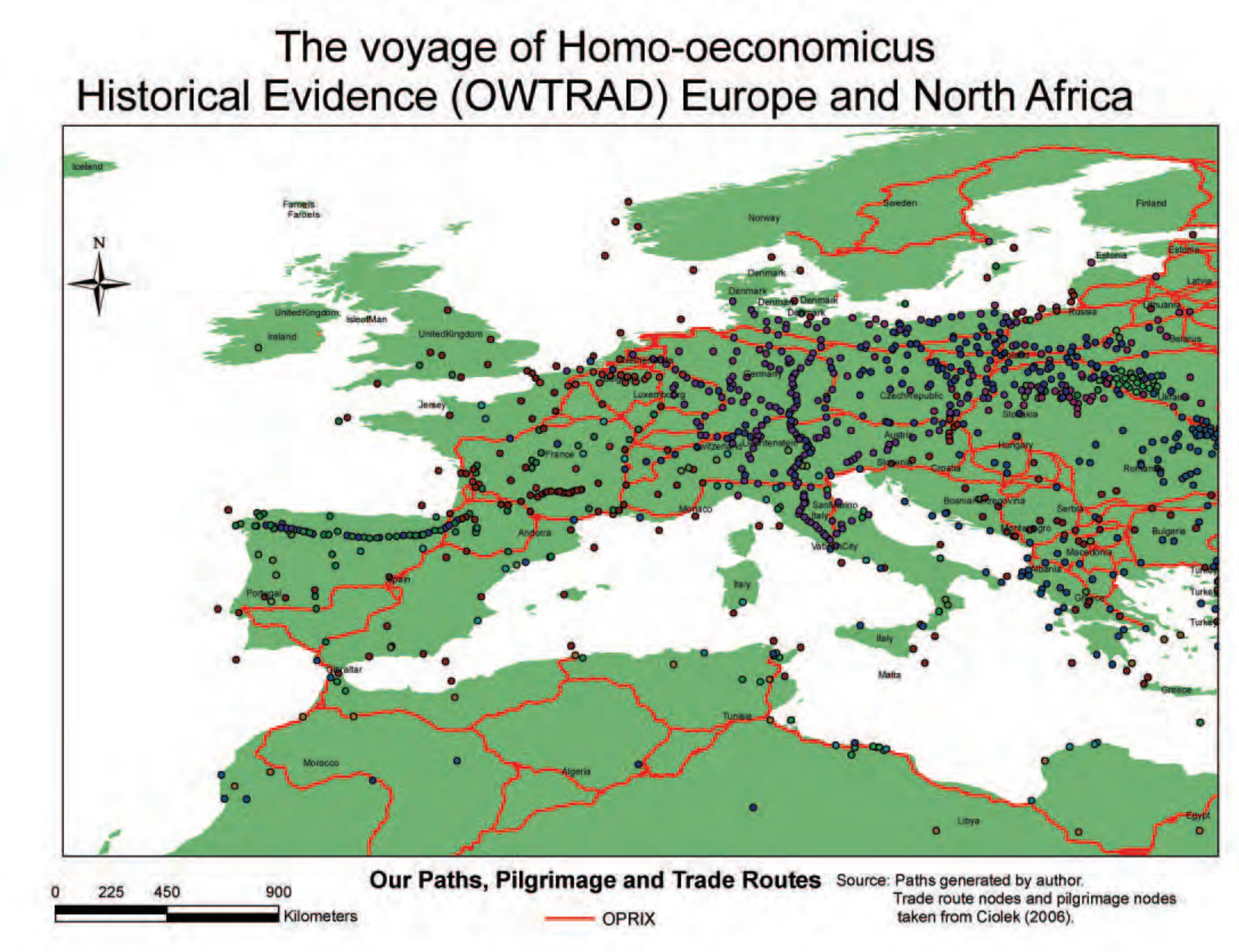


Figure 18: Optimal Paths for RIX, trade and pilgrimage routes for Africa and the Middle East. Computations by author and data by Ciolek (2004).

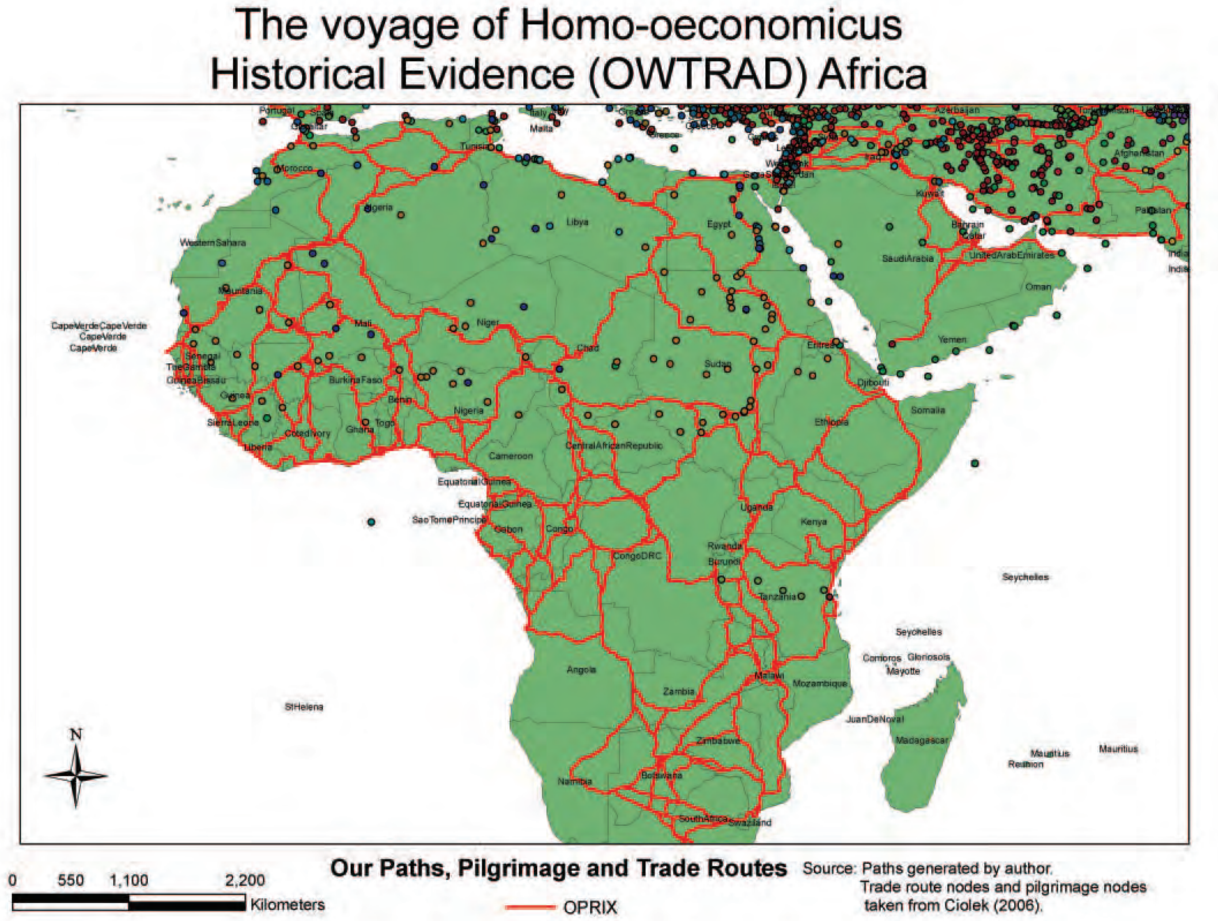


Figure 19: Optimal Paths for RIX, trade and pilgrimage routes for Asia and the Middle East. Computations by author and data by Ciolek (2004).

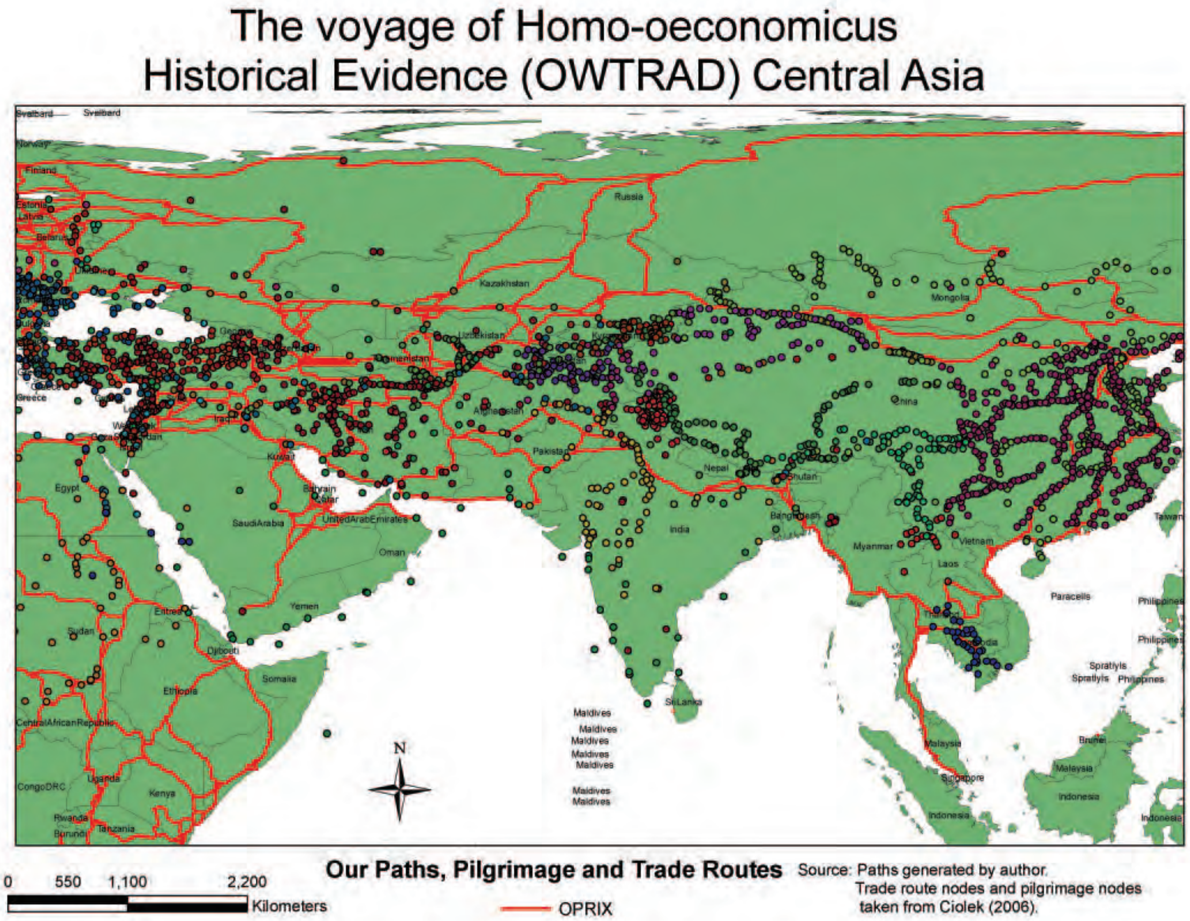


Figure 20: Optimal Paths for HMI, trade and pilgrimage routes data for Europe and North Africa. Computations by author and data by Ciolek (2004).

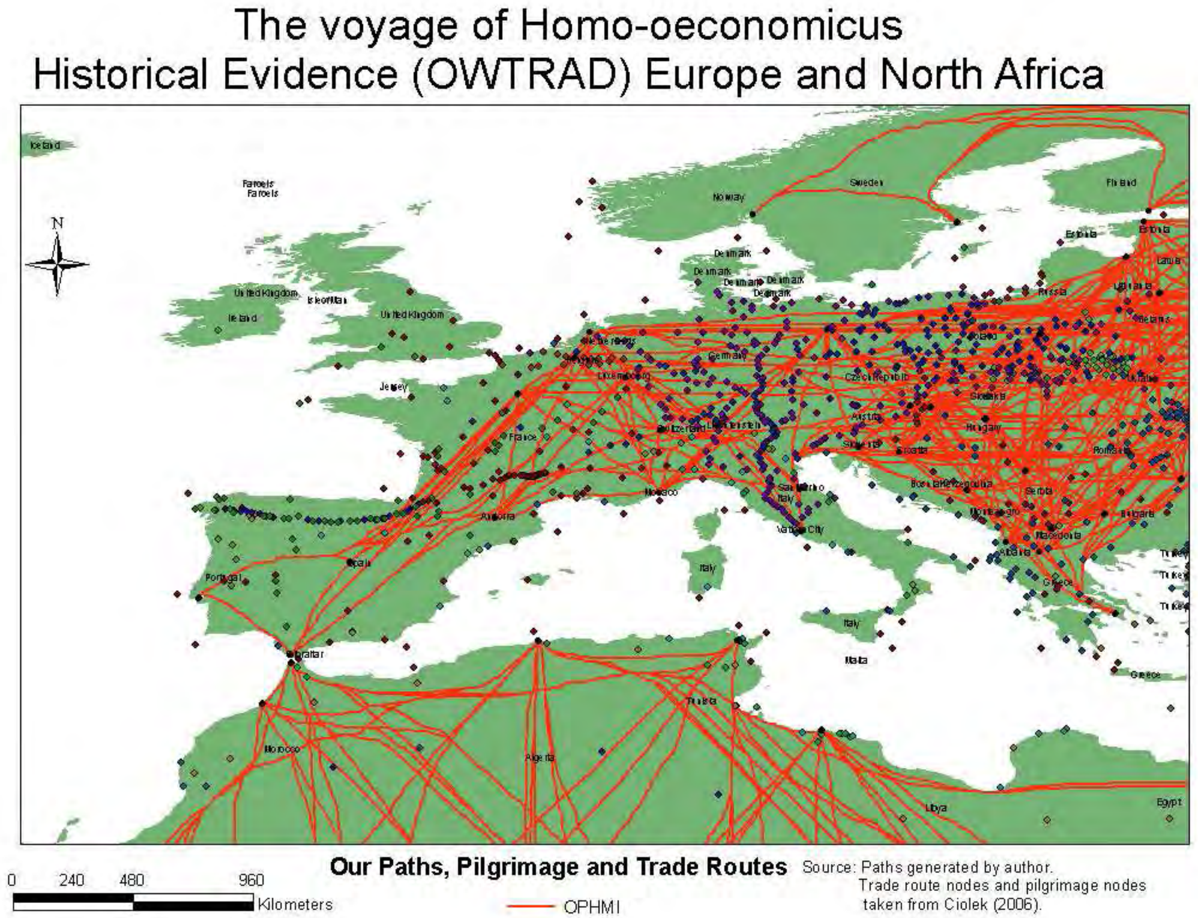


Figure 21: Optimal Paths for HMI, trade and pilgrimage routes for Africa and the Middle East. Computations by author and data by Ciolek (2004).

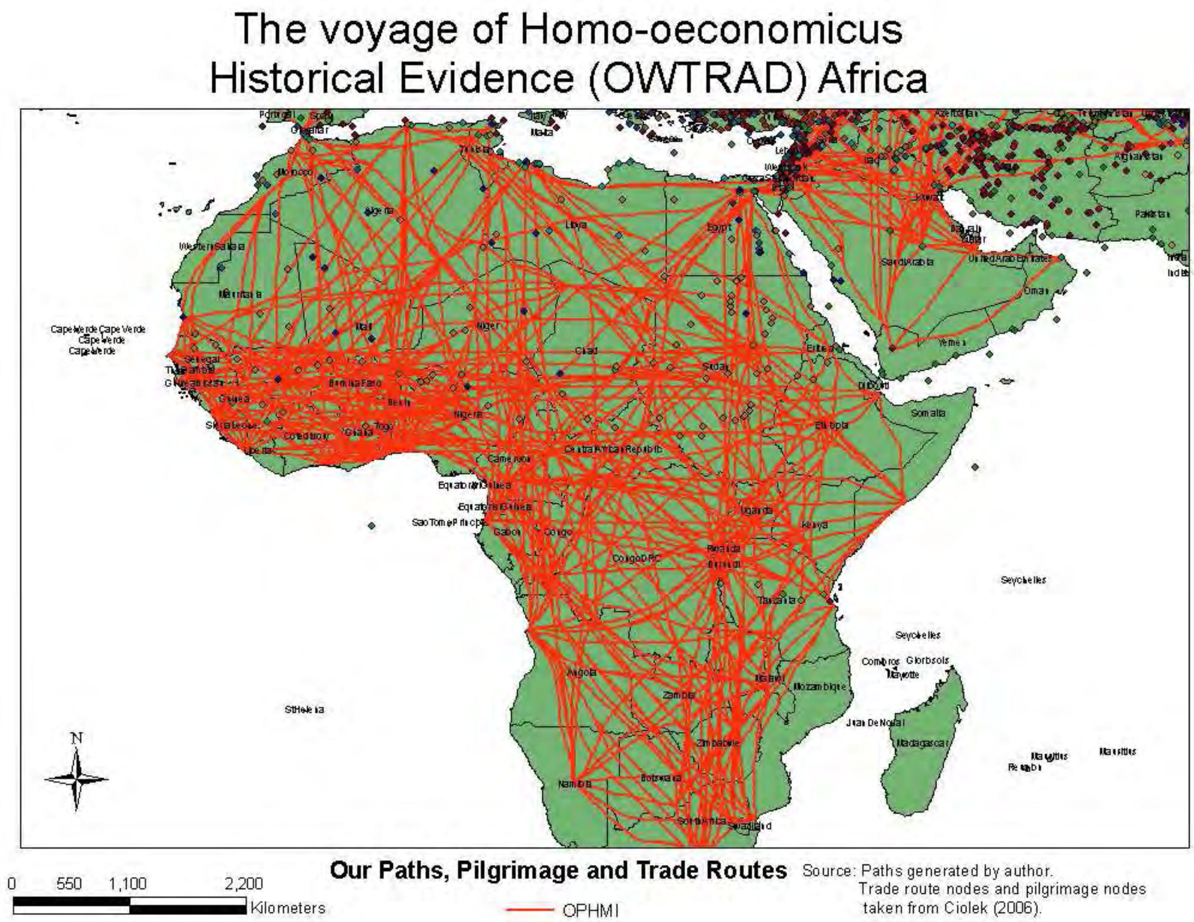


Figure 22: Optimal Paths for HMI, trade and pilgrimage routes for Asia and the Middle East. Computations by author and data by Ciolek (2004).

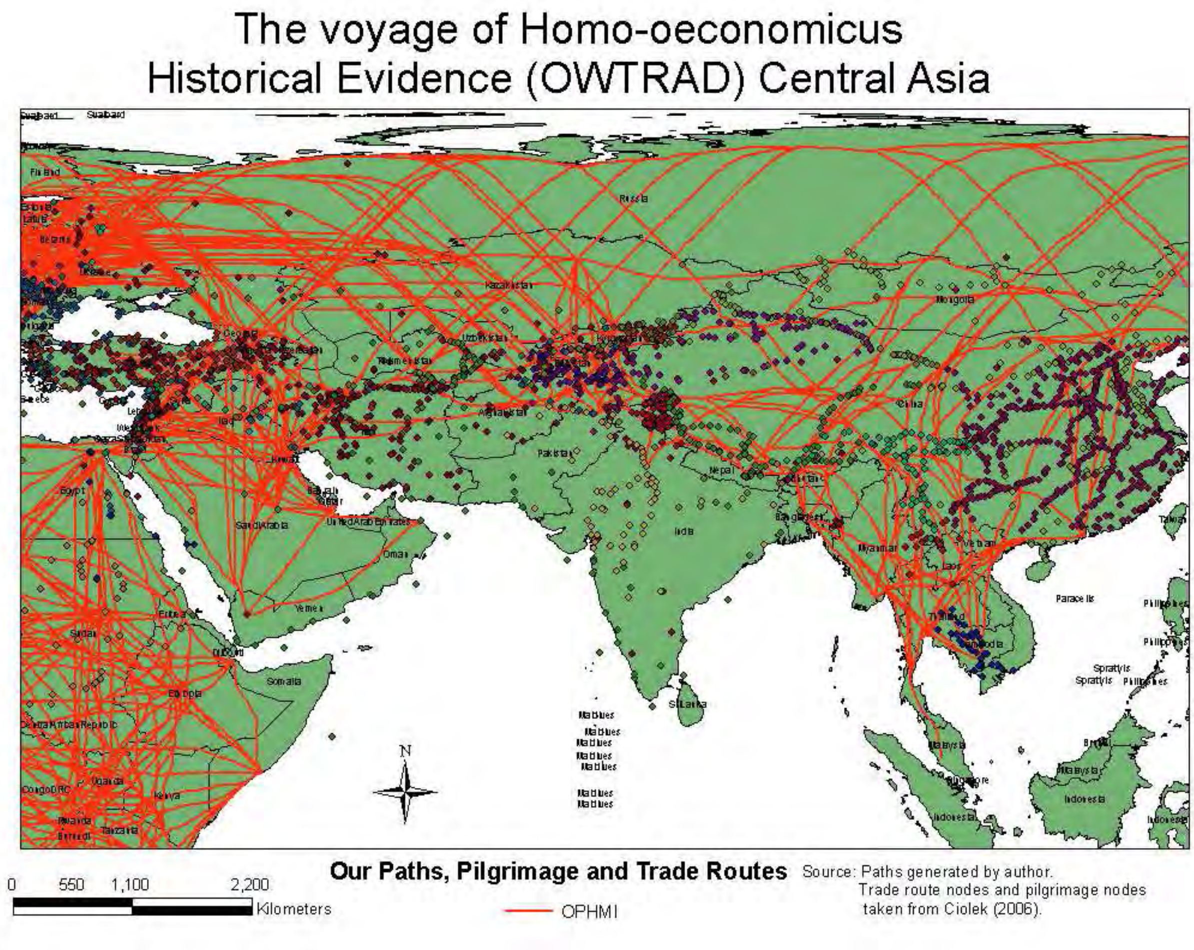


Figure 23: Optimal Paths for HMISea, trade and pilgrimage routes data for Europe and North Africa. Computations by author and data by Ciolek (2004).

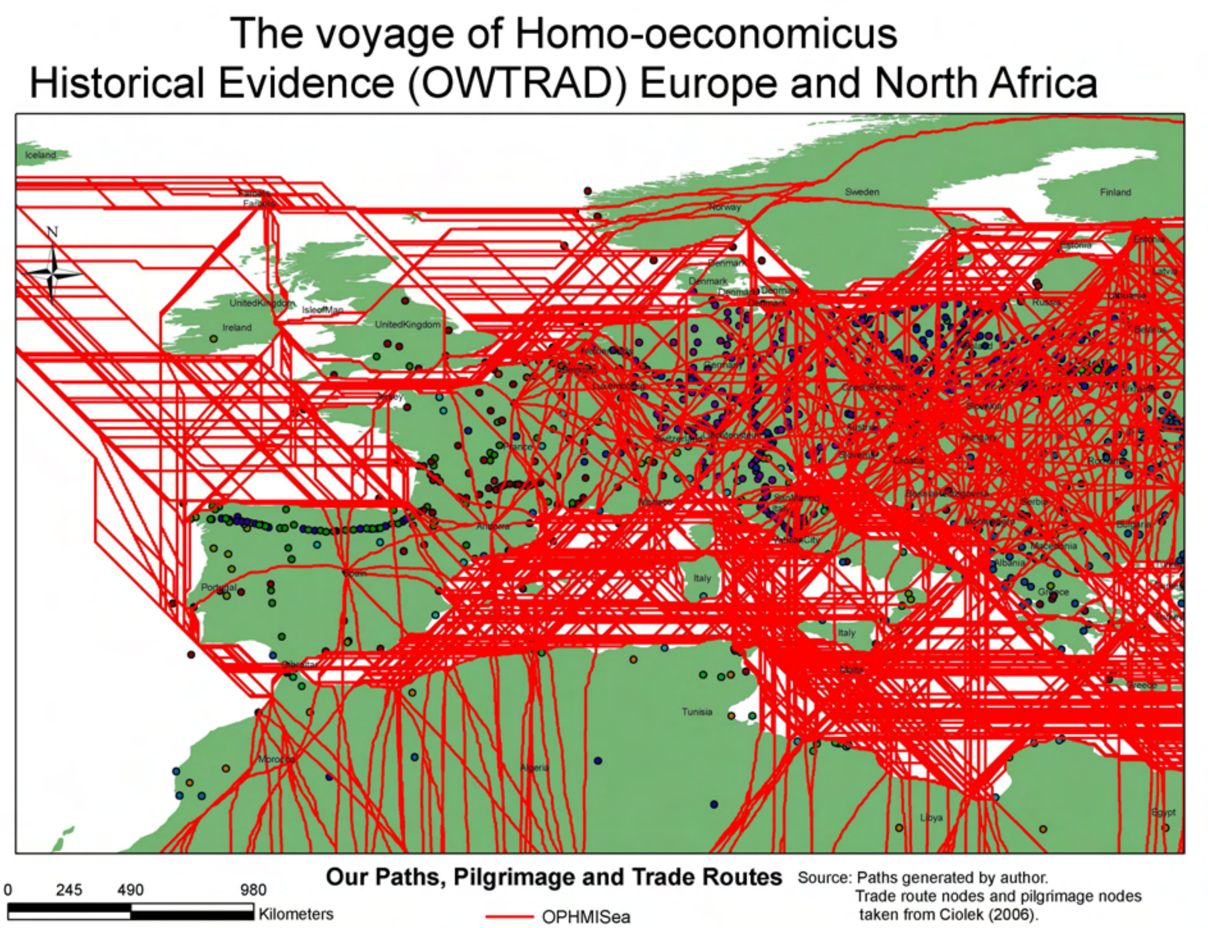


Figure 24: Optimal Paths for HMISea, trade and pilgrimage routes for Africa and the Middle East. Computations by author and data by Ciolek (2004).

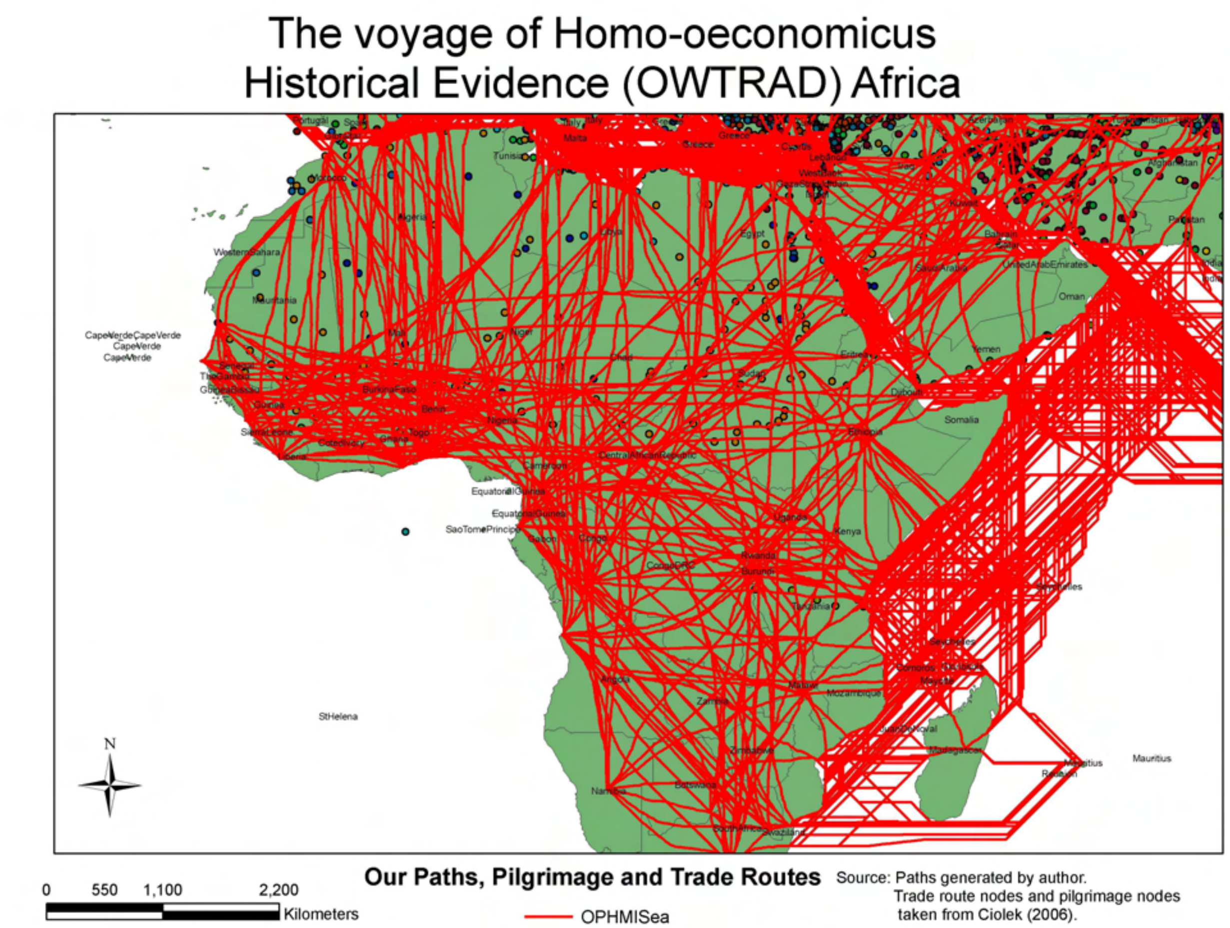


Figure 25: Optimal Paths for HMISea, trade and pilgrimage routes for Asia and the Middle East. Computations by author and data by Ciolek (2004).

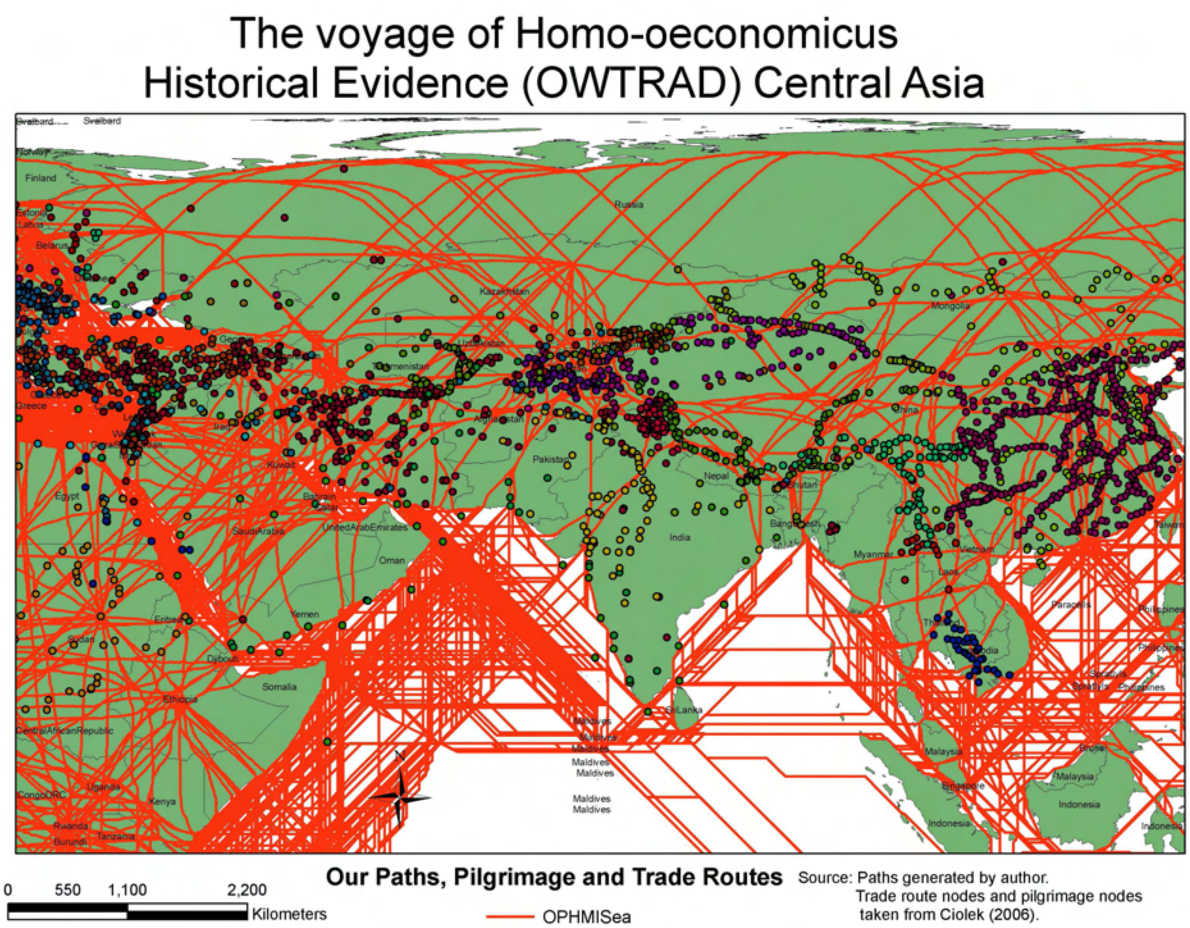
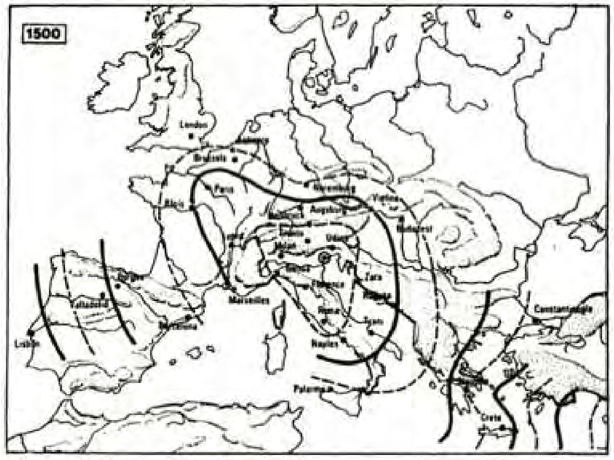
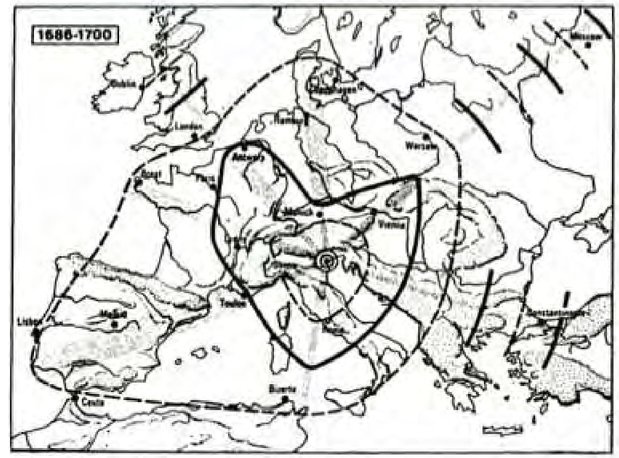


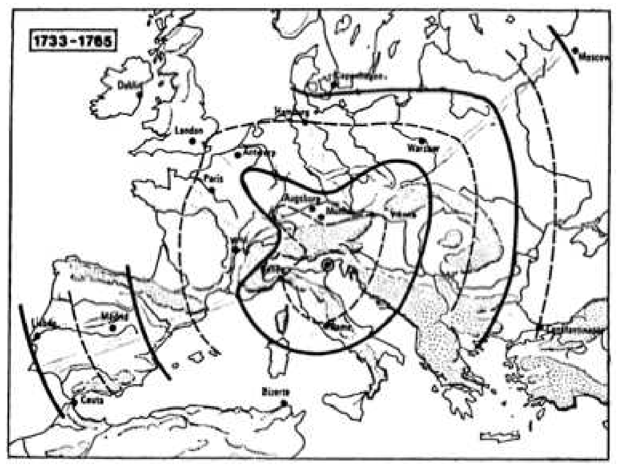
Figure 26: Diffusion of news from Venice.



(a) 1500 CE



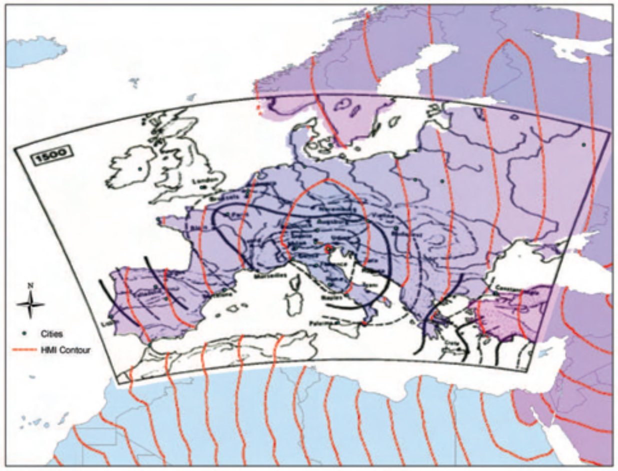
(b) 1686-1700CE



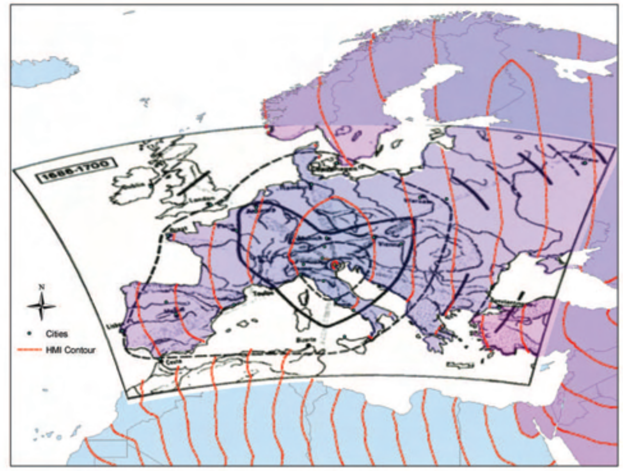
(c) 1733-1765CE

Source: Braudel (1972) Iso-chronic lines, representing intervals of one week, show all the locations that lie at the same travel time from Venice.

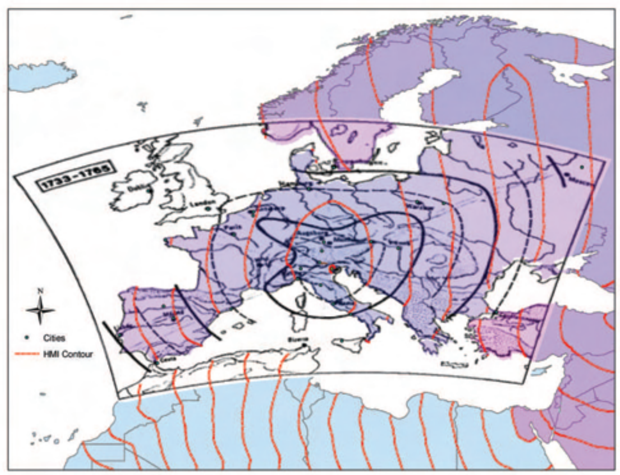
Figure 27: Distance from Venice (HMI).



(a) 1500 CE



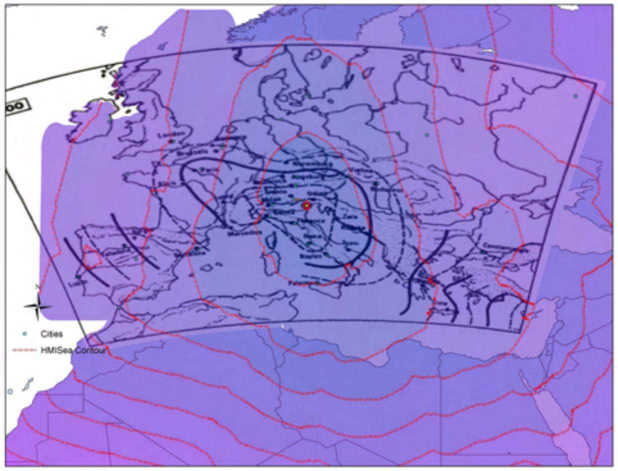
(b) 1686-1700CE



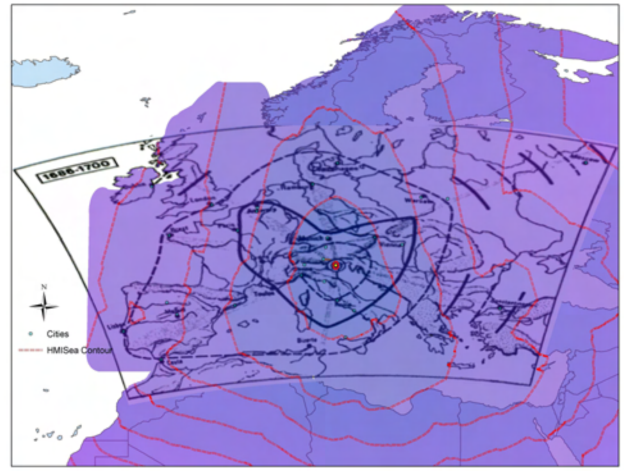
(c) 1733-1765CE

Georeferencing done by author. Original data by Braudel (1972). Red Iso-chronic lines, representing intervals of half week in HMI accumulated costs of travel to Venice. Under the assumption of a 12 hour travel per day, these iso-chronic lines can be interpreted as representing one week travel times.

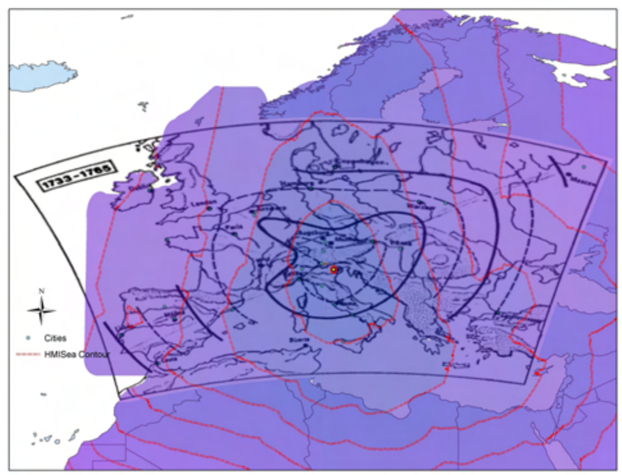
Figure 28: Distance from Venice (HMISea).



(a) 1500 CE



(b) 1686-1700CE



(c) 1733-1765CE

Georeferencing done by author. Original data by Braudel (1972). Red Iso-chronic lines, representing intervals of half week in HMISea accumulated costs of travel to Venice. Under the assumption of a 12 hour travel per day, these iso-chronic lines can be interpreted as representing one week travel times.

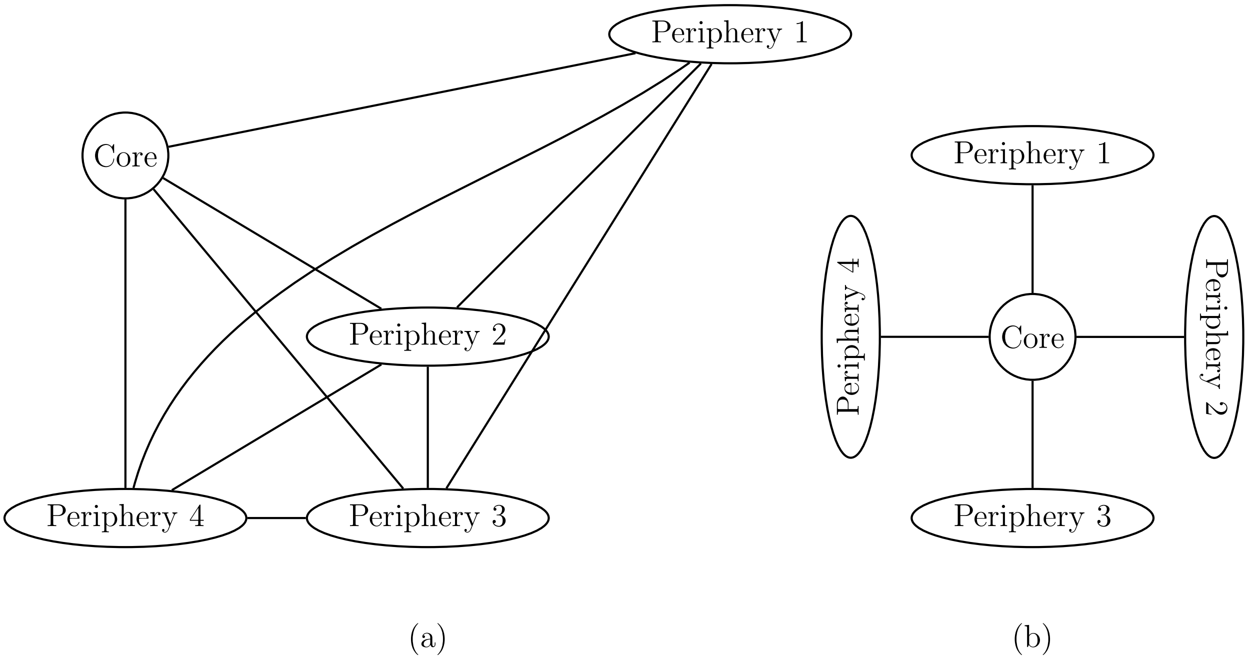


Figure 29: A spatial economy and two topologies. In panel (a) the edges represent the great circle distances between locations, while panel (b) represents the cost of transportation between locations.

Figure 30: Relationship between air and surface costs in IEW data.

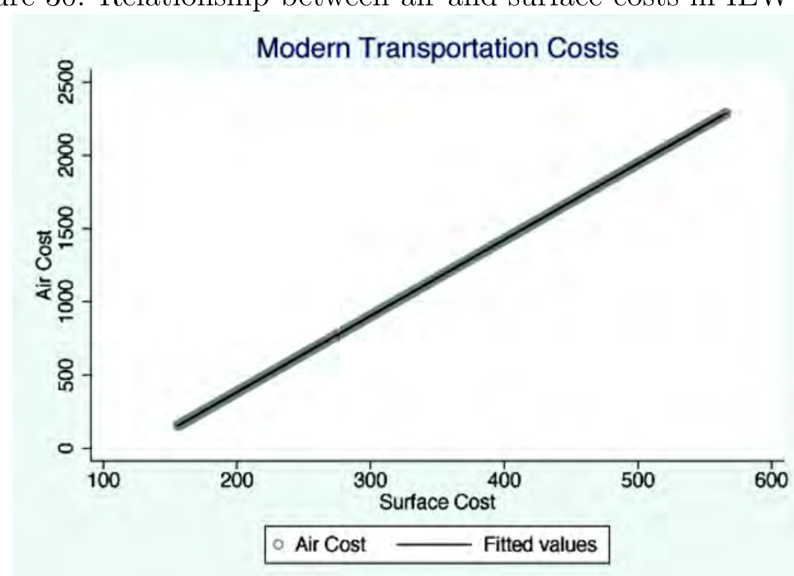


Figure 31: Modern transportation costs and geodesic distance in IEW data

Figure 32: Modern transportation costs and geodesic distance (continued)

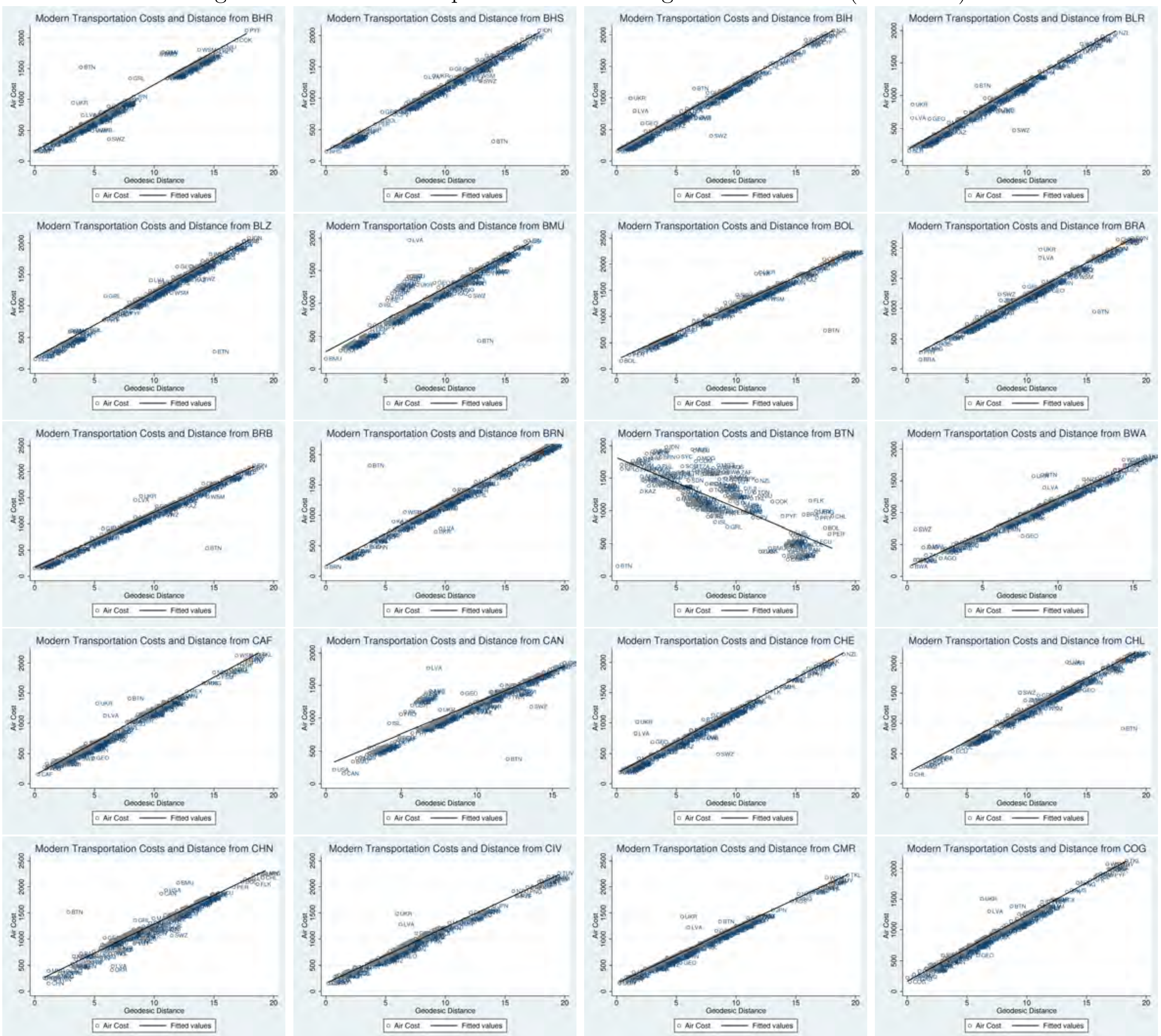


Figure 33: Modern transportation costs and geodesic distance (continued)

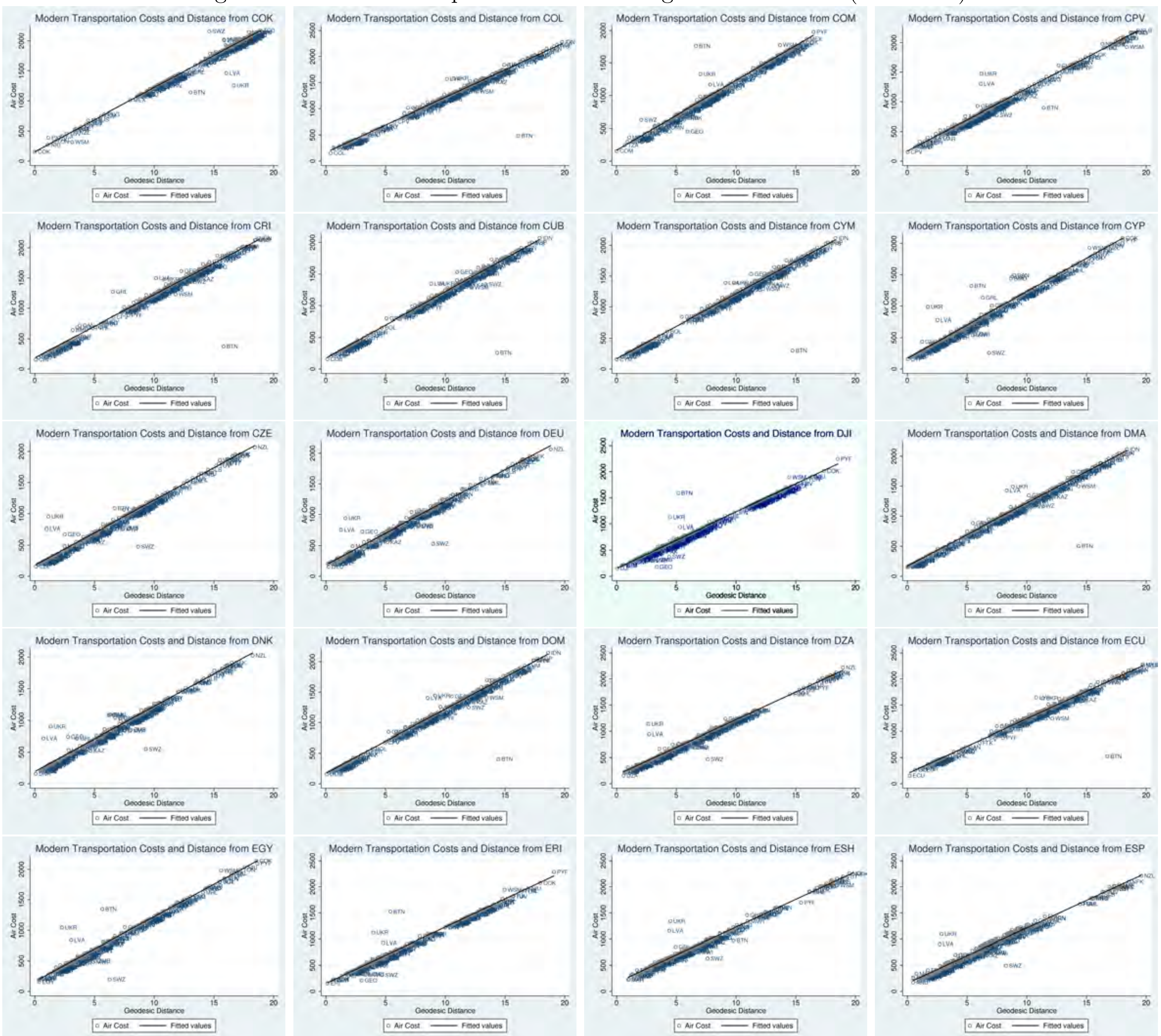


Figure 34: Modern transportation costs and geodesic distance (continued)

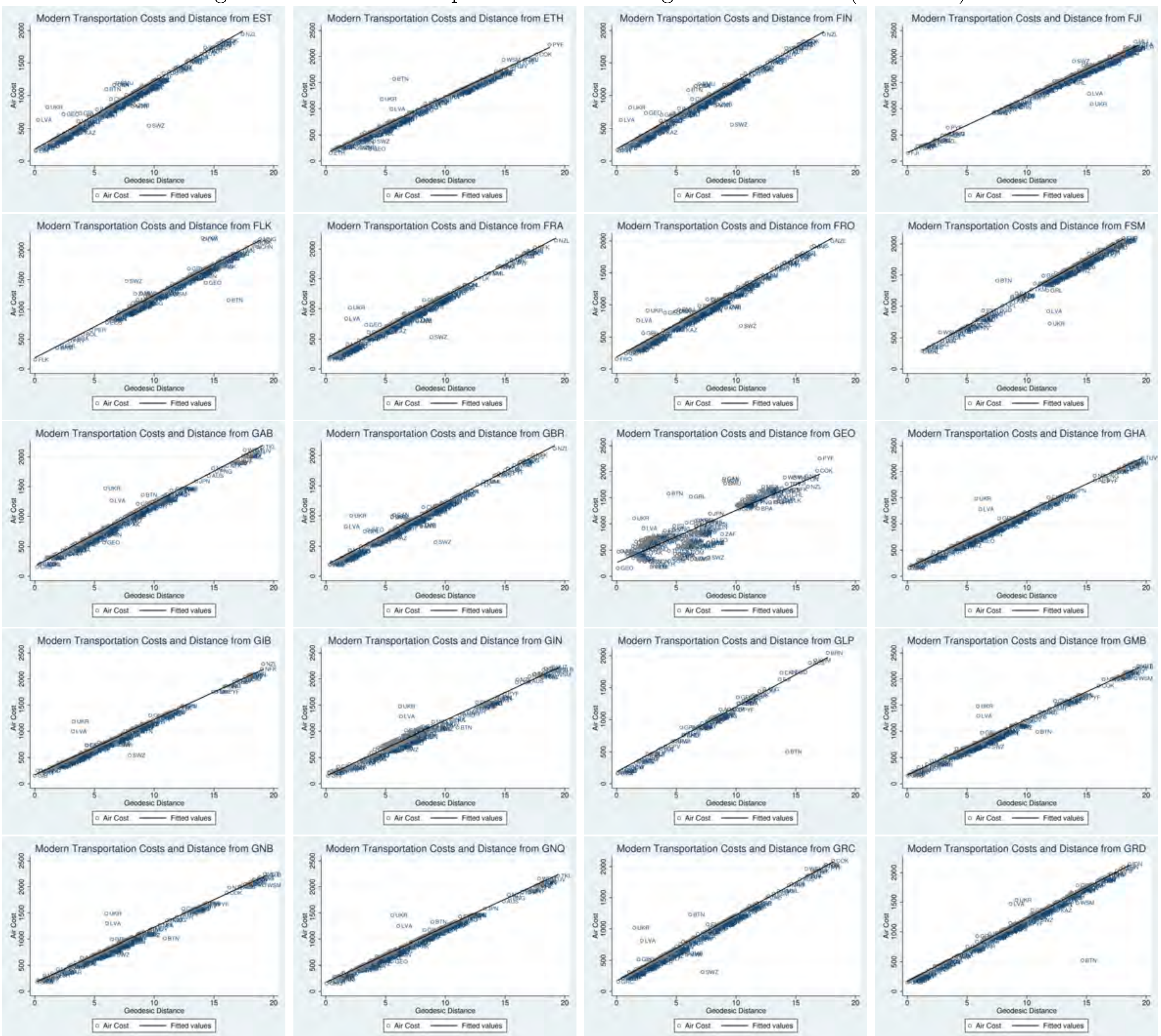


Figure 35: Modern transportation costs and geodesic distance (continued)

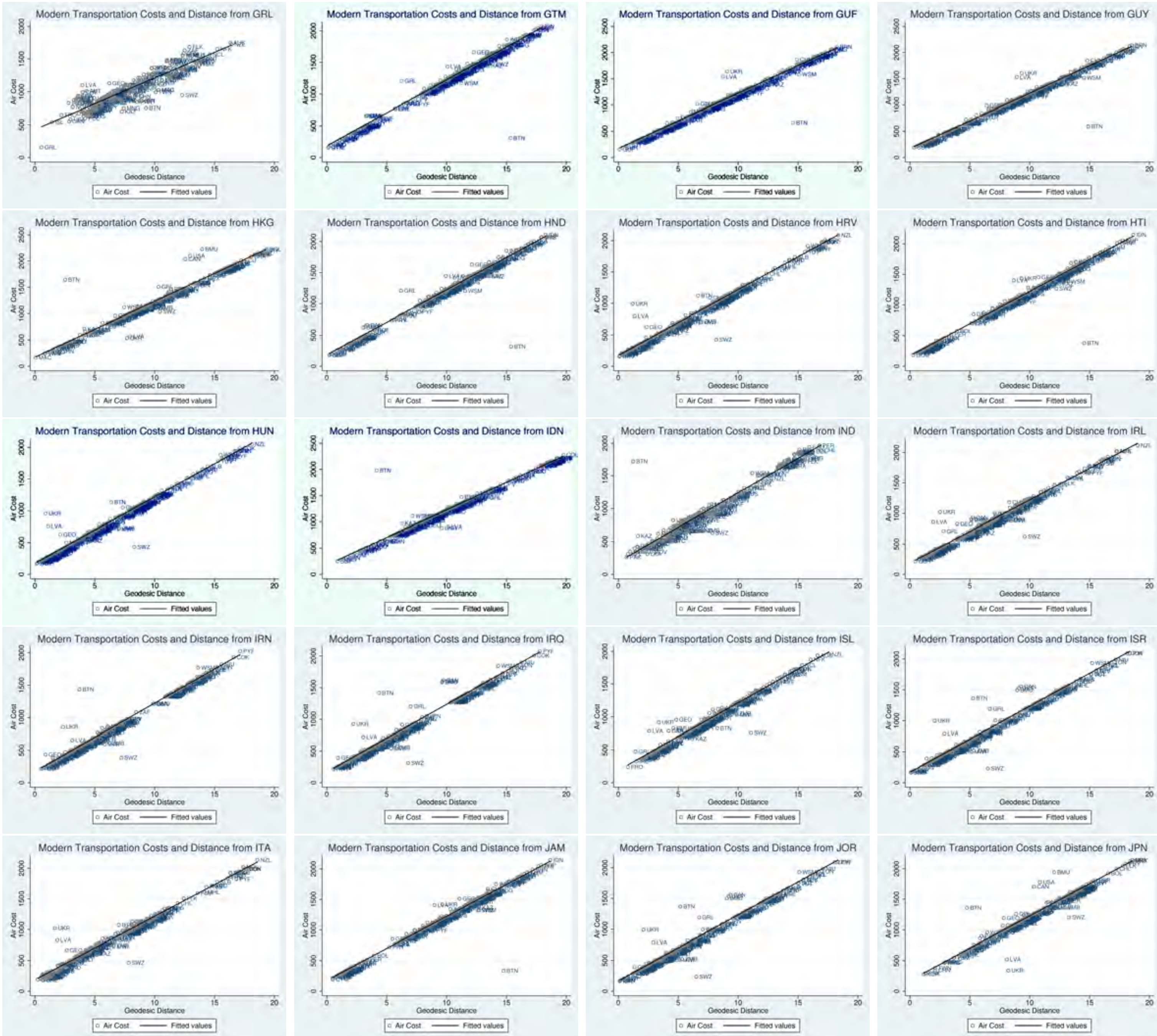


Figure 36: Modern transportation costs and geodesic distance (continued)

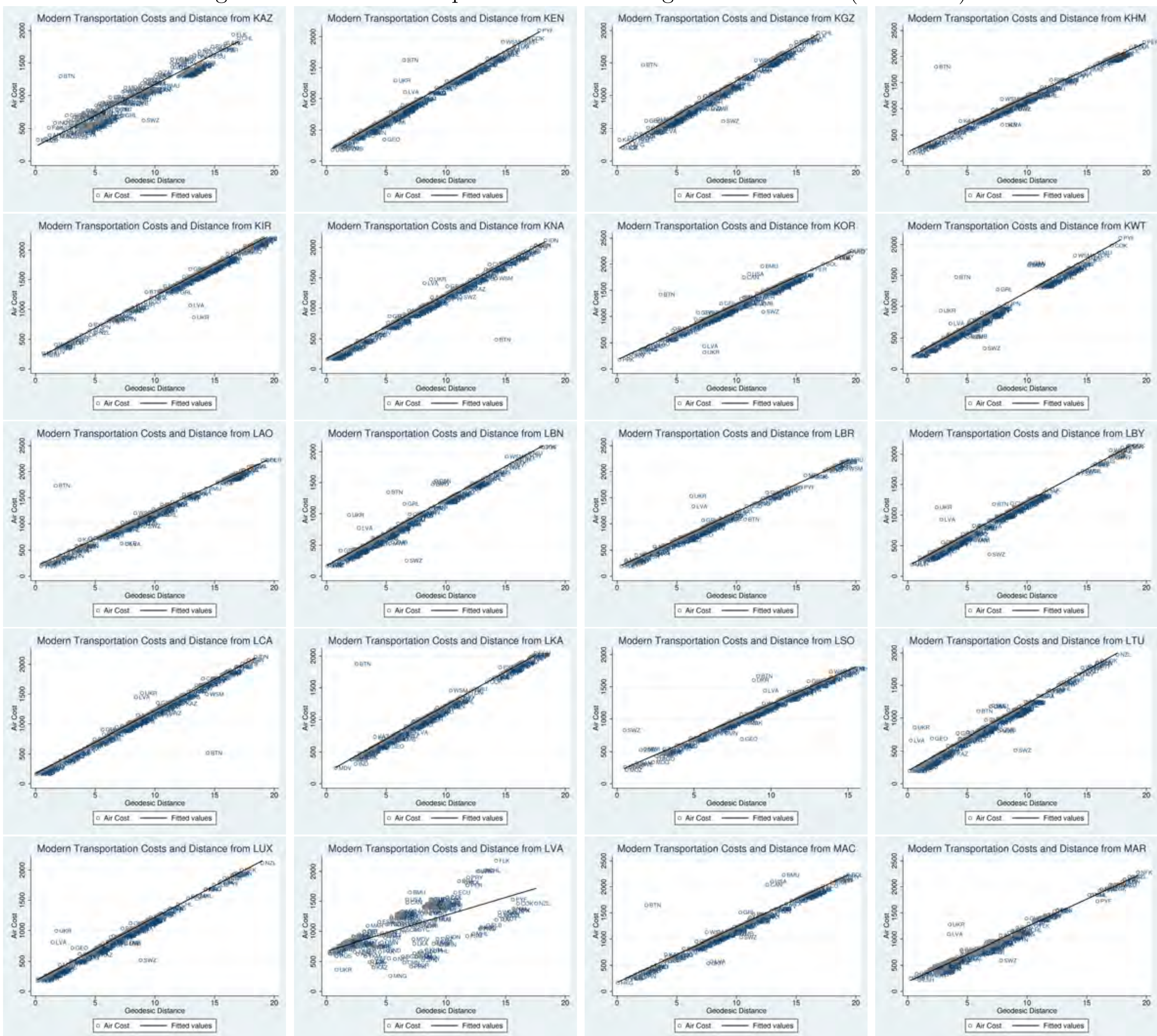


Figure 37: Modern transportation costs and geodesic distance (continued)

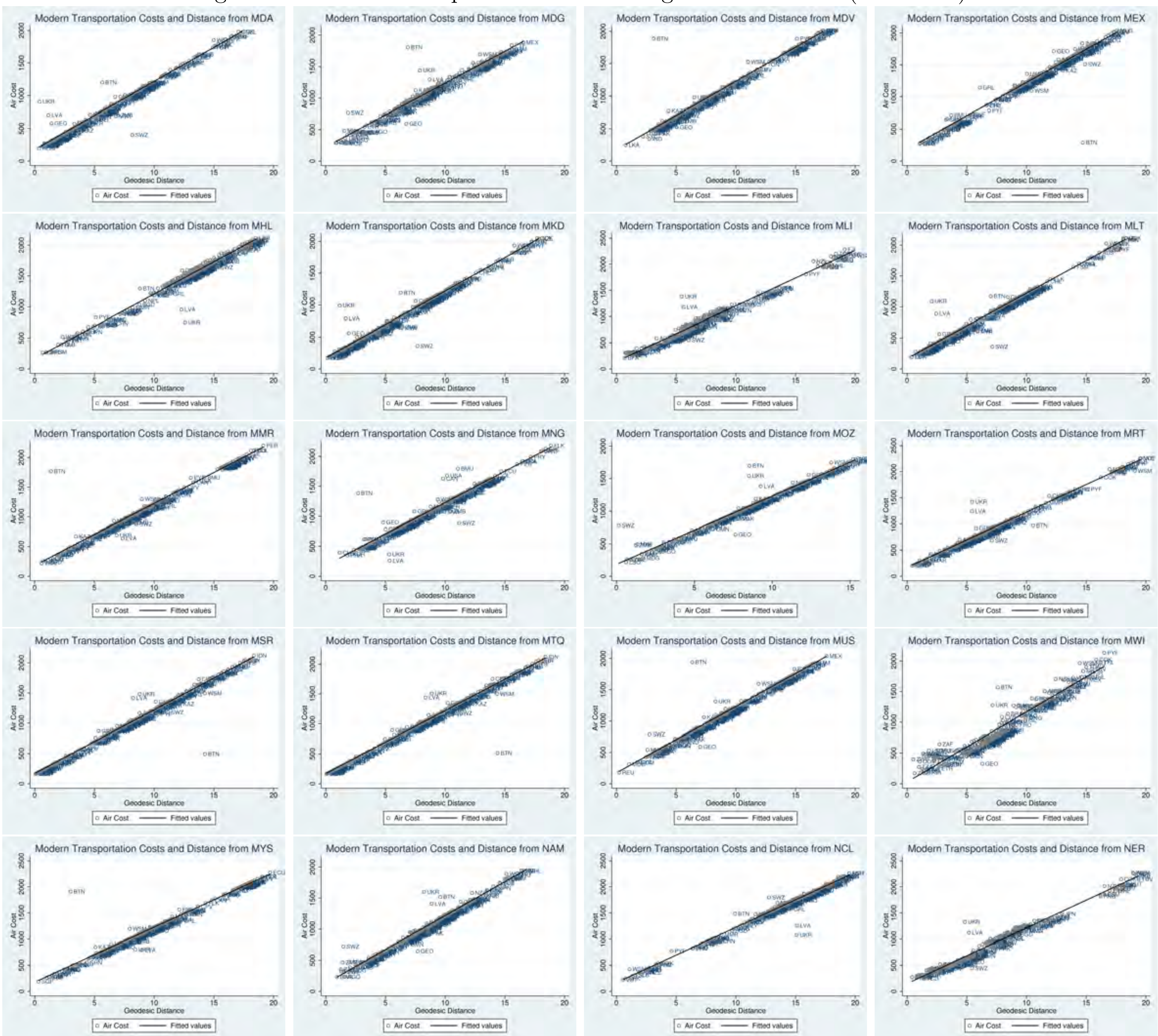


Figure 38: Modern transportation costs and geodesic distance (continued)

Figure 39: Modern transportation costs and geodesic distance (continued)

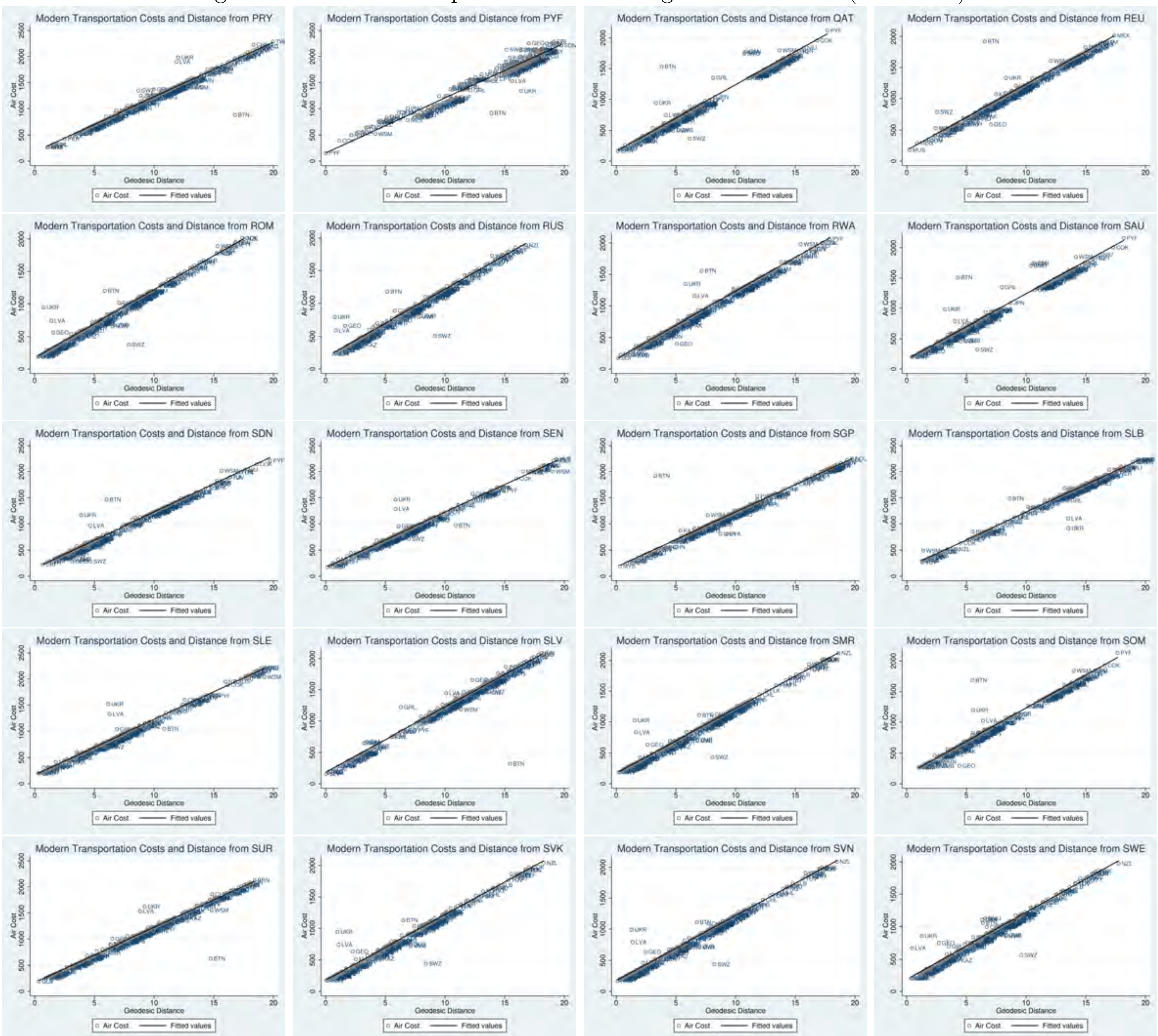


Figure 40: Modern transportation costs and geodesic distance (continued)

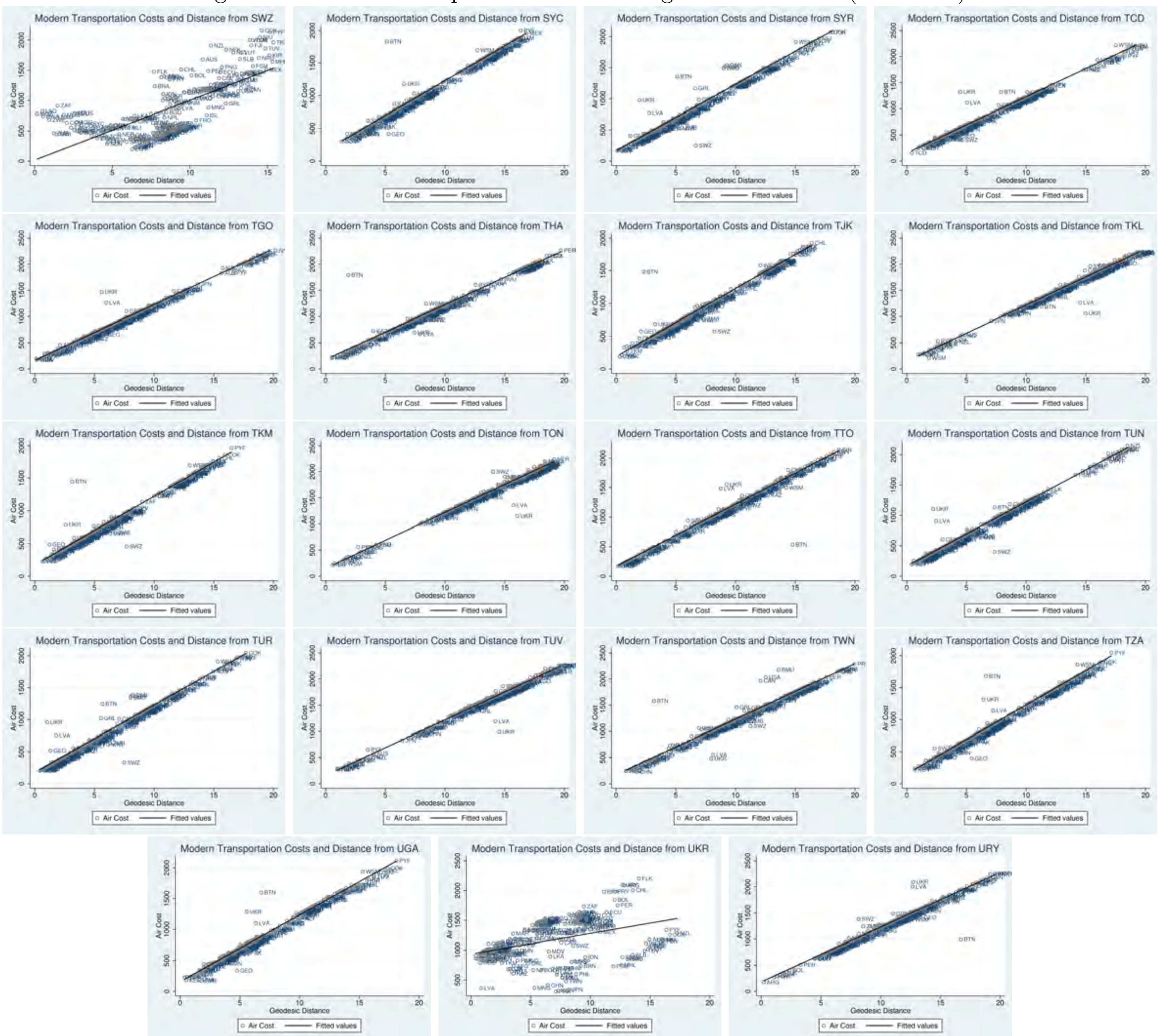
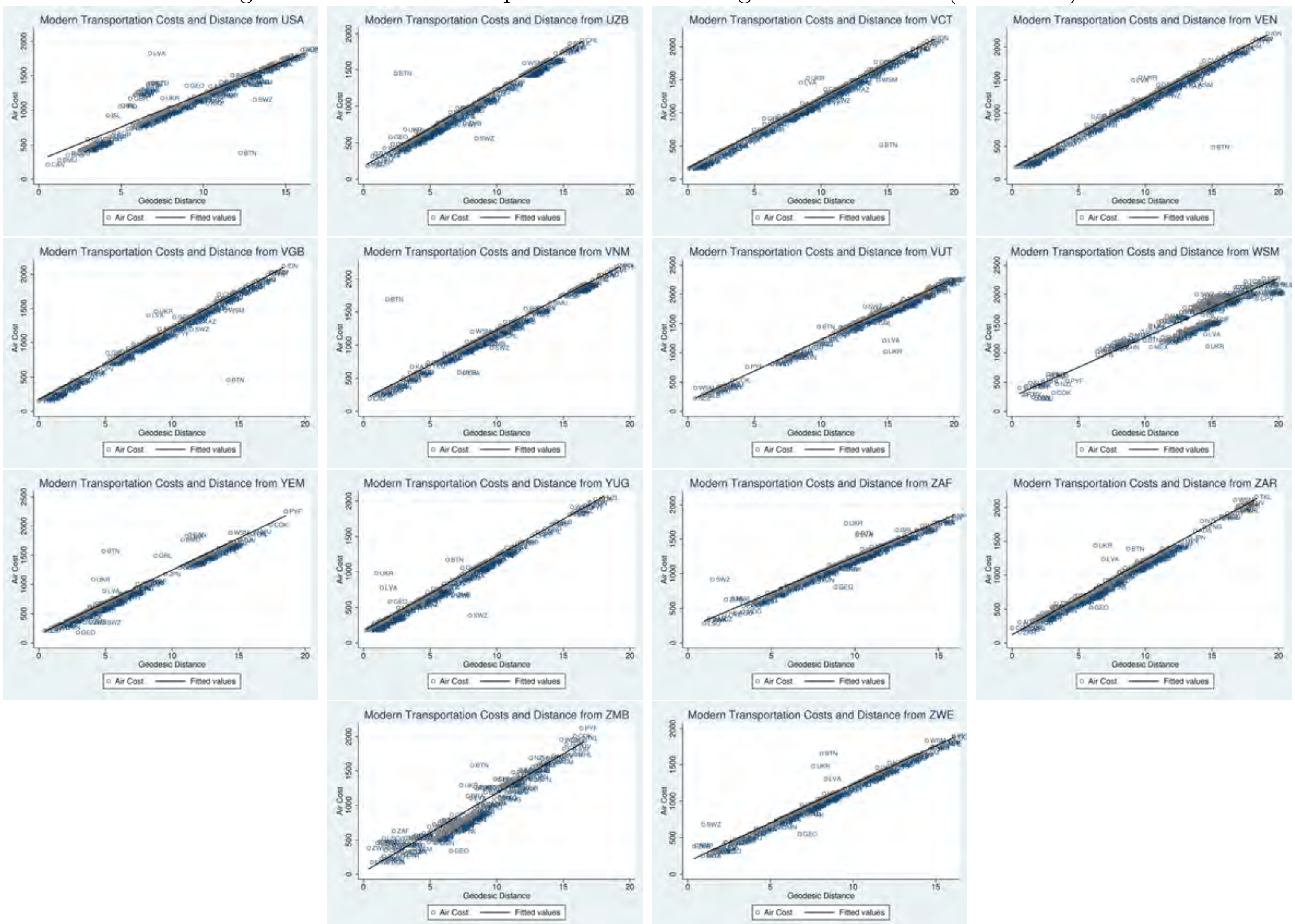


Figure 41: Modern transportation costs and geodesic distance (continued)



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