Of Mice and Merchants: Trade and Growth in the Iron Age

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PRELIMINARY AND INCOMPLETE

Abstract

The causal connection between trade and development is typically obscured by reverse causality, the endogenous location of economic activities, and confounding factors like institutions. To avoid these problems, we study this question using one of the earliest massive trade expansions in prehistory: the first systematic crossing of open seas in the Mediterranean during the time of the Phoenicians. For each point on the coast, we construct the ease with which other points can be reached by crossing open water. This connectivity differs depending on the shape of the coast and the location of islands. We show that an association between better connected locations and archaeological sites emerges during the Iron Age when sailors routinely crossed open water. We corroborate these findings at the world scale.

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1 Introduction

We investigate to what degree trading opportunities affect economic development. In addition to factor accumulation and technical change, Smithian growth due to exchange and specialization is one of the fundamental sources of growth. While there is a sizable literature on the topic, a prominent contribution is Frankel and Romer (1999), there is little compelling empirical evidence whether the correlation between trade and growth reflects causality. Answering this question is difficult for a variety of reasons, reverse causality, the endogenous location of economic activities, path dependence, intervening variables like institutions, unobservables which are correlated with trade, and measurement problems. In order to circumvent many of these problems, we focus on one of the earliest trade expansions in pre-history: the systematic crossing of open seas in the Mediterranean at the time of the Phoenicians. We relate trading opportunities, which we capture through the connectedness of points along the coast, to early development as measured by the presence of archaeological sites. We find that locational advantages for sea trade matter for the foundation of Iron Age cities and settlements, and thus helped shape the development of the Mediterranean region, and the world.

A location with more potential trading partners should have an advantage if trade is important for development. As long as ships sail mainly along the coast, the particular shape of a coast does not influence how many neighboring points can be reached from a starting location within a certain distance. However, once sailors began to cross open seas, coastal geography becomes important: a sailor starting at a coastal stretch where the sea is convex can reach more destinations within a certain distance than one starting at a stretch of concave coast. The location of islands also matters. We capture these geographic differences by dividing the Mediterranean coast into grid cells, and calculating how many other cells can be reached within a certain distance. Parts of the Mediterranean are highly advantaged by their geography, e.g. the island-dotted Aegean and the "waist

of the Mediterranean" at southern Italy, Sicily, and modern Tunisia. Other areas are less well connected, like most of the North African coast, parts of Iberia and southern France, and the Levantine coast.

We relate our measure of connectivity to the number of archaeological sites found near any particular coastal grid point. This is our proxy for economic development. It is based on the assumption that more human economic activity leads to more settlements and particularly towns and cities. While these expand and multiply, there are more traces in the archaeological record. We find a pronounced relationship between connectivity and development in our data set for the Iron Age around 750 BC, when the Phoenicians had begun to systematically traverse the open sea, using various different data sources for sites. We find a weaker and less consistent relationship between connectivity and sites for earlier periods. This is consistent with the idea that earlier voyages occurred, maybe at intermediate distances, at some frequency already during the Bronze Age. Our best evidence suggests that the relationship between coastal geography and settlement density, once established in the Iron Age, persists through the classical period. This is consistent with a large literature in economic geography on the persistence of city locations. While our main results pertain to the Mediterranean, where we have good information on archaeological sites, we also corroborate our findings at a world scale using population data for 1 AD from McEvedy and Jones (1978) as outcome.

Our approach offers various advantages compared to the existing literature. We avoid issues of reverse causality and many confounders by using a geography based instrument for trade. In fact, we do not observe trade itself but effectively estimate a reduced form relationship, relating opportunities for trade directly to economic development. This means that we do not necessarily isolate the effect of the exchange of goods per se. Our results could be driven by migration or the spread of ideas as well, and we when we talk about "trade" we interpret it in this broad sense. We do believe that coastal connectivity cap-

tures effects due to maritime connections. It is difficult to imagine any other channel why geography would matter in this particular manner, and we show that our results are robust to a variety of geographic controls. Since we do not use any trade data we avoid many of the measurement issues related to trade. We measure trading opportunities and development at a fine geographic scale, hence avoiding issues of aggregation to a coarse country level. Both our measure of connectedness, and our outcome variable are doubtlessly extremely crude proxies of both trading opportunities and of economic development. This will likely bias us against finding any relationship and hence makes our results only more remarkable.

The periods we study, the Bronze and Iron Ages, were characterized by the rise and decline of many cultures and local concentrations of economic activity. Many settlements and cities rose during this period, only to often disappear again. This means that there were ample opportunities for new locations to rise to prominence while path dependence and hysteresis may have played less role compared to later ages. The political organization of the Mediterranean world prior to the Romans was mostly local. The Egyptian Kingdoms are the main exception to this rule but Egypt was mostly focused on the Nile and less engaged in the Mediterranean. As a result, institutional factors were less important during the period we study.

There is a large literature on trade and growth. Canonical studies are the investigations by Frankel and Romer (1999) and Redding and Venables (2004). These papers use distance from markets and connectivity as measured by gravity relationships to capture the ease with which potential trading partners can be reached. However, these measures do not rely purely on geography but conflate economic outcomes like population and output, which are themselves affected by the development process. Redding and Sturm (2008) is a rare example of a study breaking this relationship. They focus on the division and reunification in Germany, exploiting a natural experiment which changed the access to

other markets sharply for some locations but not others.

Most similar to our study are a series of papers which also exploit new trade relationships arising from discoveries, the opening of new trade routes, and technological change. Acemoglu, Johnson, and Robinson (2005) link Atlantic trade starting around 1,500 AD to the ensuing shift in the focus of economic activity in Europe from the south and center of the continent to the Atlantic periphery. Feyrer (2009) and Pascali (2014) exploit the availability of new transport technologies, air transport and steam ships respectively, and find that countries whose trading opportunities improved disproportionately saw larger income growth. We find similar results for a much earlier trade expansion.

This paper also relates to a literature on how changes in locational fundamentals shape the location of cities (Davis and Weinstein 2002, Bleakley and Lin 2012, Michaels and Rauch 2015, Bosker and Buringh 2011). Our contribution to this literature is to give evidence on one of the most important locational fundamentals, market access. In a world with multiple modes of transport for the transportation of different goods, it is typically hard to measure market access and changes of market access of a city. Our measure relates to a world where much long distance trade took place on boats, which makes it easier to isolate a measure of market access.

Also closely related is the paper by Ashraf and Galor (2011). They relate population density in various periods to the relative geographic isolation of a particular area. Their interest is in the impact of cultural diversity on the development process, and they view geographic isolation effectively as an instrument for cultural homogeneity. Similar to our measure, their geographic isolation measure is a measure of connectivity of various points around the world. They find that better connected (i.e. less isolated) countries have lower population densities for every period from 1 to 1,500AD, which is the opposite of our result. Our approach differs from Ashraf and Galor (2011) in that we only look at coasts and not inland locations. They control for distance to waterways in their regressions, a

variable that is strongly positively correlated with population density. Hence, our results so different are not necessarily in conflict with theirs.

Our paper is also related to a number of studies on pre-historic Mediterranean connectivity and seafaring. McEvedy (1967) creates a measure of “littoral zones” using coastal shapes. He produces a map which closely resembles the one we obtain from our connectivity measure but does not relate geography directly to seafaring. This is done by Broodbank (2006), who overlays the connectivity map with archaeological evidence of the earliest sea-crossings up to the end of the last Ice Age. He interprets the connections as nursery conditions for the early development of nautical skills, rather than as market access, as we do for the later Bronze and Iron Ages. Also related is a literature in archaeology using network models connecting archaeological sites; Knappett, Evans, and Rivers (2008) is an excellent example for the Bronze Age Aegean. None of these papers relate to the changes arising from open sea-crossings, which is the focus of our analysis.

2 Brief history of ancient seafaring in the Mediterranean

The Mediterranean is a unique geographic space. The large inland sea is protected from the open oceans by the Straight of Gibraltar. The tectonics of the area, the African plate descending under the Eurasian one, have created a rugged northern coast in Europe and a much straighter one in North Africa. Volcanic activity and the more than 3,000 islands also tend to be concentrated towards the north. The ruggedness implies that few navigable rivers flow into the Mediterranean. The climatic conditions in the Mediterranean are generally relatively favorable to agriculture, particularly in the north. The Mediterranean is the only large inland sea with such a climate (Broodbank, 2013). Its east-west orientation facilitated the spread of agriculture from the Levant (Diamond 1998). Despite these

common features, the size of the Mediterranean and an uneven distribution of natural resources also implies great diversity. Modern writers on the Mediterranean, most notably Horden and Purcell (2000) have stressed that the area consists of many micro-regions. Geography and climate make the Mediterranean prone to many risks, such as forest fires, earthquakes, plagues of locusts, droughts, floods, and landslides. As a consequence, trade networks that allow to moderate shocks are of great mutual interest in the region, and trade has played a central role since its early history.

Clear evidence of the first maritime activity of humans in the Mediterranean is elusive. Crossings to islands close to the mainland were apparently undertaken as far back as 30,000 BC (Fontana Nuova in Sicily). In a careful review of the evidence, Broodbank (2006) dates more active seafaring to around 10,000 BC based on the distribution of obsidian (a volcanic rock) at sites separated by water (see Dixon, Cann, and Renfrew, 1965, 1968). This points to the existence of active sea-faring of hunter-gatherer societies, and suggests that boats must have traveled distances of 20-35 kilometers around that time. We have no evidence on the first boats but they were likely made from skin and frame or dugout canoes.

The beginning of agriculture around the Mediterranean happened in the Levant between 9,500 BC and 8,000 BC. From there it spread initially to Anatolia and the Aegean. Signs of a fairly uniform Neolithic package of crops and domesticated animals can be found throughout the Mediterranean. The distribution of the earliest evidence of agriculture, which includes islands before reaching more peripheral parts of the mainland, suggests a maritime transmission channel.

The Neolithic revolution did not reach Iberia until around 5,500 BC. By that time, many islands in the Aegean had been settled, there is evidence for grain storage, and metal working began in the Balkans. Because of the uneven distribution of ores, metals soon became part of long range transport. Uncertainty must have been a reason for the for-

mation of networks both for insurance and exchange. The first archaeological evidence of a boat also stems from this period: a dugout canoe, about 10 m long, at La Marmotta north of Rome. A replica proved seaworthy and allowed travel of 20 - 25 km per day in a laden boat.

The Levant, which was home to the first cities, remained a technological leader in the region, yet there is little evidence of sea-faring even during the Copper Age. This changed with the rise of large scale societies in Mesopotamia and Egypt. Inequality in these first states led to rich elites, who soon wished to trade with each other. Being at the cross-roads between these two societies, the Levant quickly became a key intermediary.

Two important new transport technologies arrived in the Mediterranean around 3,000 BC: the donkey and the sail. The donkey was uniquely suited to the climatic conditions and rugged terrain around the Mediterranean (better than camels or horses). Donkeys are comparable in speed to canoes. Sailboats of that period could be around 5-10 times faster in favorable conditions, ushering in a cost advantage of water transport that would remain intact for many millennia to come. The land route out of Egypt to the Levant ("The Way of Horus") was soon superseded by sea routes leading up the Levantine coast to new settlements like Byblos, with Levantine traders facilitating much of Egypt's Mediterranean trade. Coastal communities began to emerge all the way from the Levant via Anatolia to the Aegean and Greece.

There is no evidence of the sail spreading west of Greece at this time. Canoes, though likely improved into high performance water craft, remained inferior to sail boats but kept facilitating maritime transport in the central and western Mediterranean. The major islands there were all settled by the early Bronze Age. While not rivaling the maritime activity in the eastern Mediterranean, regional trade networks arose also in the west. One example is the Beaker network of the 3rd Millennium BC; most intense from southern France to Iberia, with fewer beakers found in the western Maghreb, northern Italy, and

Sardinia but also stretching all the way into central Europe, the Baltic, and Britain. Land routes probably dominated but sea trade must have played a role. The Cetina culture of the late 3rd Millennium BC in the Adriatic is another example. Sea-crossings up to 250 km were undertaken.

A drying spell around 2,200 BC and decline in Egypt disrupted the active maritime network in the eastern Mediterranean and the population it supported. The oldest known shipwreck in the Mediterranean at the island of Dokos in southern Greece dates from this period. The 15 meters long boat could carry a maximum weight of 20 tons. The wreck contained largely pottery, which was likely the cargo rather than carrying liquids, and also carried lead ingots. The ship probably was engaged in local trade.

Decline in the eastern Mediterranean soon gave rise to new societies during the 2nd millennium BC: palace cultures sprang up all over the eastern Mediterranean. Minoan Crete and Mycenae in Greece were notable examples but similar cities existed along the Anatolian coast and in the Levant. The palaces did not simply hold political power, but were centers of religious, ceremonial, and economic activity. At least initially, craftsmen and traders most likely worked for the palace rather than as independent agents. Sail boats still constituted an advanced technology, and only the concentration of resources in the hands of a rich elite made their construction and operation possible. The political reach of the palaces at coastal sites was local; larger polities remained confined to inland areas as in the case of Egypt, Babylon, or the Hittite Empire.

An active trade network arose again in the eastern Mediterranean stretching from Egypt to Greece during the Palace period. The Anatolian land route was replaced by sea trade. Some areas began to specialize in cash crops like olives and wine. A typical ship was still the 15 m, 20 ton, one masted vessel as evidenced by the Uluburn wreck found at Kas in Turkey, dating from 1,450 BC. Such vessels carried diverse cargoes including people (migrants, messengers, and slaves), though the main goods were likely metals, textiles,

wine, and olive oil. Evidence for some of these was found on the Uluburun wreck; other evidence comes from archives and inscriptions akin to bills of lading. Broodbank (2013) suggests that the value of cargo of the Uluburun ship was such that it was sufficient to feed a city the size of Ugarit for a year. Ugarit was the largest trading city in the Levant at the time with a population of about 6,000 - 8,000. This highlights that sea trade still largely consisted of high value luxury goods. The Ugarit archives also reveal that merchants operating on their own account had become commonplace by the mid 2nd millennium. Levantine rulers relied more on taxation than central planning of economic activities. Trade was both risky and profitable; the most successful traders became among the richest members of their societies.

Around the same time, the Myceneans traded as far as Italy. Sicily and the Tyrrhenian got drawn into the network. While 60 - 70 km crossings to Cyprus or Crete and across the Otrano Straight (from Greece to the heel of Italy) were commonplace, coast hugging still prevailed among sailors during the 2nd millenium BC. After crossing the Otrano Straight, Greek sailors would continue along the coast of the Bay of Taranto, the instep of Italy's boot, as is suggested by the distribution of Greek pottery at coastal sites. Indigenous seafarers from the central Mediterranean now joined these routes, and the sail finally entered the central Mediterranean around 1,200 BC. While there were no big breakthroughs, naval technology also improved in the late 2nd millennium. Better caulking and keels added to sea-worthiness (Abulafia, 2011), while brail rigging and double prows improved maneuverability. Most notably, latitude sailing was developed and allowed sailors to steer a straight east-westerly course. "This was a leap in the scope of connections, a permanent shift in Mediterranean history and a crucial stage in tying together the basin's inhabitants across the soon-to-be shrinking sea," observes Broodbank (2013, p. 431) before warning that"we should not exaggerate, nor anticipate, the importance of such connections at this early juncture. Not until the Iron Age did relations become close enough to fundamentally reshape the culture and economies of outlying regions." (p. 441)

A new period of decline around 1,200 BC reduced the power of Egypt, wiped out cities like Ugarit, and ended the reign of the last palace societies in the eastern Mediterranean. In the more integrated world that the eastern Mediterranean had become, troubles spread quickly from one site to others. The Bronze Age came to an end with iron coming on the scene. Rather than being technologically all that much superior to bronze, iron ore was far more abundant and widespread than copper and hence much more difficult to monopolize. As was the case many times before, decline and change opened up spaces for smaller players and more peripheral regions. Cyprus flourished. Many Levantine cities recovered quickly. Traders from the central Mediterranean also expanded and challenged. Traditionally, decline during this "Dark Age" was often blamed on the anonymous "Sea Peoples." Modern scholarship seems to challenge whether these foreigners were simply just raiders and pirates, as the Egyptians surely saw them, rather than also entrepreneurial traders who saw opportunities for themselves to fill the void left by the disappearance of imperial connections and networks. Some of these new interlopers settled in the Levant (Broodbank, 2013).

While there is much academic debate about the origin of the Phoenicians, there is little doubt that the Levantine city states which had taken in these migrants were the origin of a newly emerging trade network. Starting to connect the old Bronze Age triangle formed by the Levantine coast and Cyprus, they began to expand throughout the entire Mediterranean after 900BC. The Phoenician city states were much more governed by economic logic than was the case for royal Egypt. One aspect of their expansion was the formation of enclaves, often at nodes of the network. Carthage and Gadir (Cadiz) are prime examples but many others existed. At least initially these were not colonies; the Phoenicians did not try to dominate local populations. Instead, locals and other settlers were invited to pursue their own enterprise and contribute to the trading network. The core of the network consisted of the traditional sea-faring regions, the Aegean and the Tyrrhenian. The expanding trade network of the early 1st millennium BC did not start

from scratch but encompassed various regional populations. Tyrrhenian metal workers and Sardinian sailors had opened up connections with Iberia at the close of the 2nd millennium. But the newly expanding network not only stitched these routes together, it also created its own, new, long-haul routes.

These new routes began to take Phoenician and other sailors over long stretches of open sea. While this had long been conjectured by earlier writers like Braudel (2001, writing in the late 1960s) and Sherratt and Sherrat (1993), contemporary scholars are more confident. Cunliffe (2008) writes about the course of a Phoenician sailor: "Beyond Cyprus, for a ship's master to make rapid headway west there was much to be said for open-sea sailing. From ... the western end of Cyprus he could have sailed along the latitude to the south coast of Crete ... where excavation has exposed a shrine built in Phoenician fashion. Travelling the same distance again ..., once more following the latitude, would have brought him to Malta" (p. 275-276), a route which became known as the "Route of the Isles." Abulafia (2011) describes their seafaring similarly: "The best way to trace the trading empire of the early Phoenicians is to take a tour of the Mediterranean sometime around 800BC. ... Their jump across the Ionian Sea took them out of the sight of land, as did their trajectory from Sardinia to the Balearics; the Mycenaeans had tended to crawl round the edges of the Ionian Sea past Ithaka to the heel of Italy, leaving pottery behind as clues, but the lack of Levantine pottery in southern Italy provides silent evidence of the confidence of Phoenician navigators." (p. 71).

This involved crossing 300 - 500 km of open sea. One piece of evidence for sailing away from the coast are two deep sea wrecks found 65 km off the coast of Ashkelon (Ballard et al., 2002). Of Phoenician origin and dating from about 750 BC, the ships were 14 meters long, and each carried about 400 amphorae filled with fine wine. These amphorae were highly standardized in size and shape. This highlights the change in the scale and organization of trade compared to the Uluburun wreck with its diverse cargo. It also

suggests an early form of industrial production supporting this trade.

An unlikely traveler offers a unique lens on the expansion of trade and the density of connections which were forged during this period. The house mouse populated a small area in the Levant until the Neolithic revolution. By 6,000 BC, it had spread into southern Anatolia before populating parts of north eastern Africa and the Aegean in the ensuing millennia (there were some travelers on the Uluburun ship). There were no house mice west of Greece by 1,000 BC. Then, within a few centuries, the little creature turned up on islands and on the mainland throughout the central and western Mediterranean (Cucchi, Vigne, and Auffray, 2005).

The Phoenicians might have been at the forefront of spreading mice, ideas, technology, and goods all over the Mediterranean but others were part of these activities. At the eve of Classical Antiquity, the Mediterranean was constantly criss-crossed by Greek, Etruscan, and Phoenician vessels as well as smaller ethnic groups. Our question here is whether this massive expansion in scale led to locational advantages for certain points along the coast compared to others, and whether these advantages translated into the human activity which is preserved in the archaeological record. A brief, rough time line for the period we investigate is given in Figure 1.

3 Data and key variables

For our Mediterranean dataset we compute a regular grid of 10×10 kilometers that spans the area of the Mediterranean and the Black Sea using a cylindrical equal area projection. This projection ensures that horizontal neighbors of grid points are on the same latitude at 10 kilometers distance from each other, and that each cell has an equal area over the surface of the earth.[1] We define a grid-cell as water if falls completely into water, using a

[1] As the Mediterranean is close enough to the equator distortions from using another projection are small in this area of interest.

coastline map of the earth from Bjorn Sandvik's public domain map on world borders in the ESRI database. We define it as coastal if it is intersected by a coastline. We classify grid cells that are neither water nor coastal as land. Our estimation dataset consists of coastal cells only, and each cell is an observation. There are 3,646 cells in the data set.

We compute the distance between coastal point i and coastal point j moving only over water d_{ij} using the cost distance command in ArcGIS. Our key variable in this study, called c_d, captures the ease with which other coastal grid points can be reached within a certain distance d. This captures how coastal shape influences the potential for trade in each location. Consider Figure 2: Coastal points in the left panel, where the sea forms a convex shape, are connected with more other locations within the distance given by the blue ray compared to coastal points located on a concave coastline as in the right panel.

To capture this difference we measure connectedness by counting the number of grid points that can be reached by traveling up to distance d over water from each coastal grid point. We compute the distance between coastal point i and coastal point j moving only over water d_{ij} using the cost distance command in ArcGIS. Destinations may include islands but we exclude islands which are smaller than $20km^2$. We also create separate measures, one capturing only connectedness to islands, and a second measuring connectedness to other points on the mainland coast. While we use straight line or shortest distances, we realize that these would have rarely corresponded to actual shipping routes. Sailors exploited wind patterns and currents, and often used circular routes on their travels (Arnaud, 2007). Our measure is not supposed to mimic sailing routes but simply capture opportunities.

Figure 3 displays the measure c_{500} for a distance of 500km; darker points indicate better connected locations. Measures for other distances are strongly positively correlated and

maps look roughly similar. The highest connectedness appears around Greece and Turkey partly due to the islands, but also Western Sicily and the area around Tunis. The figures also highlight substantial variation of the connectedness measures within countries. The grid of our analysis allows for spatial variation at a fine scale. We normalize each measure c_d to have mean 0 and standard deviation 1.

We interpret the measure c_d as capturing connectivity. Of course, coastal shape could proxy for other amenities. For example, a convex coastal shape forms a bay, which may serve as a natural harbor. Notice that our or 10×10 kilometer grid is coarse enough to smooth out many local geographic details. We will capture bays $50 kilometers across but not those 5$ kilometers across. It is these more local features which are likely more relevant for locational advantages like natural harbors. Our grid size also smooths out other local geographic features, like changes in the coastline which have taken place over the past millennia, due, for example, to sedimentation. The broader coastal shapes we capture have been roughly the for the period since 3,000 BC, which we study (Agouridis, 1997).

Another issue with our measure of connectivity is whether it also captures better potential for trade or also more exposure to external threats like military raids. Overall, it was probably easier to defend against coastal attacks than land-based ones (e.g. Cunliffe, 2008, p. 447) so this may not be a huge concern. But at some level it is obvious that connectivity is bidirectional. In this respect we measure the net effect of better connectivity.

We also compute a global dataset based on a global grid. We increase the cell size to 50×50 kilometers. This is for computational convenience, but also our outcome variables at the global level are at the country level and thus spatial precision is less relevant than in the Mediterranean data set. We focus on the part of the world between -60 degrees and 60 degrees latitude, as units outside that range are unlikely candidates for early urbanization for climatic reasons. In the Southern Hemisphere there is hardly any landmass apart from the Antarctic below 60 degrees, while in the Northern Hemisphere 60 degrees is close to

Helsinki, Aberdeen, and Juneau, Alaska, well north of climatic conditions particularly favorable to early settlement. We again compute the distance from each coastal grid point to each other coastal grid point by moving only over water. Figure 4 shows the global connectedness measure c_{500}. The most connected coastal points are located again near Greece, but also in Southeast Asia, Chile, Britain, and Northern Canada, while Western Africa and Eastern South America have few well connected coastal points.

One limitation of the proposed connectivity measure c_d is that it gives all coastal points that can be reached within distance d equal weight. We would however expect a connection with a well connected coastal point to be more beneficial than a connection with a remote coastal cell. To address this limitation we could weight destination cells by their own c_d, and recompute a weighted version called $c2_d$. After normalization we could compute an additional measure $c3_d$, where we use $c2_d$ as the weight. Repeating this infinitely often, the measure converge to a variable called "network centrality." This is a standard measure in various disciplines to capture the importance of nodes in a network. To compute the centrality measure, we create a symmetric matrix A for all binary connections, with entries that consist of binary variables indicating distances smaller than d. We set the diagonal of the matrix to zero. We solve equation $Ax = \lambda x$ for the largest possible eigenvalue λ of matrix A. The corresponding eigenvector x gives the centrality measure.

Our main source of data on settlements in pre-history is the Pleiades dataset at the University of North Carolina, the *Stoa Consortium*, and the *Institute for the Study of the Ancient World* at New York University maintained jointly by the *Ancient World Mapping Center*.[2] The Pleiades dataset is a gazetteer for ancient history. It draws on multiple sources to provide a comprehensive summary of the current knowledge on geography in the ancient world. The *Barrington Atlas of the Greek and Roman World* (Talbert, 2000) is the main source the database is build on; it is an open source project and material from

[2]Available at pleiades.stoa.org. We use a version of the dataset downloaded in June 2014.

multiple other scholarly sources has been added.

The Pleiades data are available in three different formats of which we use the "pleiades-places" dataset. It offers a categorization as well as an estimate of the start and end date for each site. We only keep units that have a defined start and end date, and limit the data set to units that have a start date before 500 AD. We use two versions of these data, one more restricted (which we refer to as "narrow") and the other more inclusive ("wide"). In the narrow one we only keep units that contain the word "urban" or "settlement" in the categorization. These words can appear alongside other categorizations of minor constructions, such as bridge, cemetery, lighthouse, temple, villa, and many others. One problem with the narrow version is that the majority of Pleiades sites do not have a known category. So that we do not lose these sites we include all sites irrespective of their category and including those classified as "unknown" in the wide version of the data.

Some of the entries in the Pleiades dataset are located more precisely than others. The dataset offers a confidence assessment consisting of the classifications precise, related, rough, and unlocated. We only keep units with a precisely measured location in the narrow set while we keep all entries in the wide set.[3] For both datasets, as we merge the Pleiades data onto our grid we round locations to the nearest 10×10 kilometers and are thus robust to some minor noise.

Since the Pleiades data is originally based on the *Barrington Atlas* it covers sites from the classical Greek and Roman period well and adequate coverage seems to extend back to about 750BC. The coverages of older sites seems much more limited as the number of sites with earlier start dates drops precipitously. For example, our wide data set has 1,509

[3]In both data sets, Pleiades contains some sites that have the same identifier, but different locations. This could reflect, among others, sites from different eras in the same location or different potential locations for the same site. We deal with this by dropping all sites that have the same Pleiades identifier and whose coordinates differ by more than 0.1 degree latitude or longitude in the maximum. The latter restrictions affects around one percent of the Pleiades data. The remaining identifiers with several sites are dealt with by counting them as one unit, with the start given by the minimum, the end by the maximum date of overlapping time spans.

sites in 750 BC and 2,882 in 500 BC but only 63 in 1500 BC. While economic activity was surely less in the Bronze Age and earlier, there are likely many earlier sites missing in data. As a consequence, our estimation results with the Pleiades data for earlier periods may be rather unreliable.

We therefore created an additional data set of sites from the *Archaeological Atlas of the World* (Whitehouse and Whitehouse, 1975). The advantage of the *Whitehouse Atlas* is that it focuses heavily on the pre-historic period, and therefore complements the Pleiades data well. A disadvantage is that it is 40 years old. While there has been much additional excavation in the intervening period, there is little reason to believe that it is unrepresentative for the coverage of sites and locations. The interpretation of the archaeological evidence may well have changed but this is of little consequence for our exercise. Another drawback of the *Whitehouse Atlas* is that the maps are much smaller than in the *Barrington Atlas*. As a result, there may have been a tendency by the authors to choose the number of sites so as to fill each map, leading to a distribution of sites which is too uniform (something that would bias our results against finding any relationship with our connectivity measure). This, however, is offset by the tendency to include maps for smaller areas in locations with many sites. For example, there are separate maps for each of Malta, Crete, and Cyprus but only three maps for all of Iberia.

We geo-referenced all entries near the coasts on 25 maps covering the Mediterranean in the *Whitehouse Atlas* ourselves. Using the information in the map titles and accompanying text, we classified each map as belonging to one of three periods: the Neolithic, the Bronze Age, or the Iron Age and later. Some maps straddle periods and some contain more detailed classification of sites, which we use (see the appendix for details). However, in some cases it is not possible to classify sites clearly by period particularly between the Neolithic and Bronze Age.

Our final data source is the *Barrington Atlas* (Talbert, 2000). The *Barrington Atlas*

consists of two parts; actual maps and map by map directories. The Pleiades data is based on the information in these directories, which record names, grid references, period information, and references to sources. The maps contain one piece of information not in the directory, which is size categories. These are displayed through different typefaces. We classified the sizes of all the sites on Map I in the *Barrington Atlas*, an overview map of the Mediterranean. This map distinguishes three size classes. We coded these by hand and combined the results with the information in Pleiades (geographic coordinates, timing information, etc.). Although these sizes are doubtlessly rough, we believe they contain some valuable information, particularly for the height of the Roman Empire when the site density was high. It allows us to distinguish the biggest agglomerations like Rome and Carthage from more minor sites. We assign the largest sites a value of 3, the intermediate ones 2, and the smallest ones 1.

To measure the urbanization rate of each coastal grid point for time t we count the number of sites from either Pleiades or Whitehouse that exist at time t within 50 kilometers of that coastal point on the same landmass. For the Barrington data we count add the size values of the sites within 50 kilometers. We also count the number of land cells that are within 50 kilometers of that coastal grid point on the same landmass. We normalize the number of sites by the number of land cells within this radius. We prefer this density measure to the non-normalized count of sites in order to avoid that coastal shape (which enters our connectivity measure) mechanically influences the chance of having an archaeological site nearby. On the other hand, we want to classify a small trading islands as highly urbanized. We normalize our measure of urban density to have mean 0 and standard deviation 1 for each period to facilitate comparison over time when the number of settlements changes.

4 Specification and results

We run regressions of the following type:

$$u_{it} = X_i \gamma_t + c_{di} \beta_{dt} + \epsilon_{it}, \tag{1}$$

where u_{it} is the urbanisation measure for grid point i, X_i are grid point control variables and c_{di} is a connectivity measure for distance d. We only measure connectiivity of a location, not actual trade. Hence, when we refer to trade this may refer to the exchange of goods but could also encompass migration and the spread of ideas. u_{it} measures the density of settlements, which we view as proxy for the nominal GDP of an area. Growth manifests itself both in terms of larger populations as well as richer elites in a Malthusian world. We would expect that the archaeological record captures exactly these two dimensions.

As control variables, we use distance to the Fertile Crescent, distance to the Route of the Isles, distance to Rome, longitude, and latitude, which all do not vary over time. We also explore dropping the Aegean, to address concerns that our results may be driven exclusively by developments around the Greek islands, by far the best connected area in the Mediterranean. We also drop North Africa to address concerns that there are fewer archaeological sites in North Africa due to a relative lack of exploration. This may spuriously correlate with the fact that the coast is comparatively straight. We cluster standard errors at the level of a grid of 2×2 degrees.[4]. We normalize u_{it} and c_{di} to mean 0 and standard deviation 1 to make our estimates comparable across years with different numbers of cities, and different magnitudes of connectedness measures.

In Table 1, we start by showing results for 750BC from our different data sets. At this

[4]This is slightly coarser than in Bester, Conley and Hanson (2011) but should take better care of the potential of spatial correlation in our setting

time we expect sailors to make extensive use of direct sea connections, and hence the coefficients β_{dt} from Equation 1 should be positive. This is indeed the case for a wide variety of specifications. We find the strongest results in the Pleiades data with the wide definition of sites. This result is highly significant. The coefficient is slightly lower for the narrow site definition, and for Iron Age sites from the Whitehouse Atlas. We find the smallest coefficients for our size adjusted sites, which we obtained from the Barrington Atlas directly, and the coefficient is only marginally significant now.

Results are fairly similar when add the control variables in column (2). Dropping the Aegean in column (3), the wide Pleiades coefficient drops but all the others remain much the same. Adding the controls to this narrower data set in column (4) leads to much smaller estimates, particularly in the wide Pleiades data and the Barrington data, where the coefficient is now negative. None of the results in column (4) is still significant. It is the interaction between dropping the Aegean and including distance to Rome, a variable which shouldn't matter for this time period before Rome was actually founded (but might be important later during the time of the Roman Empire). Though not particularly sensible, this is the only specification we tried where our results are very weak for 750BC or 500BC. Dropping North Africa in column (5) makes little difference compared to the original results.

Figure 5 shows coefficients from the basic specification with the wide Pleiades set of sites. It demonstrates that coefficients are fairly similar for various distances for our connectivity measure. This is likely due to the fact that these measures are correlated across the various distances. There is a small hump with a peak around 500km, probably distances which were important during the Iron Age when sailors started to make direct connections between Cyprus and Crete or Crete and Sicily. But we don't want to make too much of that.

Figure 6 shows results from the Pleiades data over time. Coefficients are small and

mostly insignificant before 750BC. There is a very sharp increase in the coefficient value at 750BC, followed by a slow decline in the coefficients thereafter. The increase of coefficients in 750BC is consistent with the systematic open sea crossing at the time of the Phoenicians from about 900BC. Nevertheless, we are skeptical about reading too much into the Pleiades results. The Pleiades database is originally based on the Barrington Atlas and has incorporated primarily other sources also focusing on the classical period. The coverage of sites in 1,000BC and earlier in the Pleiades is poor. We suspect that results in Figure 6 might reflect this under-coverage, rather than a true upturn in the effect of connectedness.

We have demonstrated in Table 1 that the large association between connectedness and the presence of sites is replicated across various data sets and specifications for the 750BC. So we are fairly confident in that result. Figure 6 raises two questions: Is the sharp upturn in coefficients between 1000BC and 750BC real and does this association vanish later during the Roman Empire? On both counts there are reasons to be suspicious of the Pleiades data. Coverage of sites from before 750BC is poor in the data while coverage during the Roman period may be too extensive.

In order to address the issue that the Pleiades data do not cover the pre-Iron Age periods well, we compare our results to those using the Whitehouse data in Figure 7. Here we plot coefficients again against distances varying from 100km to 1,000km. The solid line shows sizable and significant coefficients in the range between 0.2 and 0.3, as we had already seen in Table 1. The line with dashes and dots shows coefficients for sites from all the maps dated earlier. Coefficients are small and insignificant for small distances but similar to the Iron Age coefficients for larger distances. This hints at the possibility that long range connections already mattered during the Bronze Age. Unfortunately, dating of maps in the Whitehouse Atlas is often not precise, and it is not possible to make a clean distinction between Bronze Age sites and earlier neolithic ones. If we focus on sites which

are clearly labeled as Bronze Age only, we obtain the coefficients shown in the broken line. These coefficients are smaller, below 0.1 and insignificant. This suggests indeed indeed that a stronger association between connectedness and sites emerged with the advent of the Iron Age.

Once geographical conditions have played a role in a site location, do we expect human agglomerations to persist? A large literature in urban economics and economic geography has addressed this question and largely found substantial persistence of city locations, sometimes across periods of major historical disruption (Davis and Weinstein 2002, Bleakley and Lin 2012, Michaels and Rauch 2015, Bosker and Buringh 2011 among others). This evidence is at odds with the declining coefficients over time in Figure 6 after 750BC.

We suspect that this result stems from the fact that the site density in the Pleiades data is becoming too high during the Roman period. For example, in 500BC there are already almost 2000 sites in our data set, which only contains 3,464 gridpoints. The number of gridpoints really overestimates the number of distinct data points we use since we measure sites within overlapping 50km radii from a coastal grid cell. As a result, our coastal grid is quickly becoming saturated with sites after the start of the Iron Age. We suspect that this simply eliminates any useful variation within our data set: By the height of the Roman empire most coastal grid points are located near some sites.

Hence, we feel that the Barrington data is better suited to address the question of whether the effects we find persist during the Roman period as we might expect. There are fewer sites in the Barrington data to begin with (because we only focus on an overview map hence selecting more important sites). But we also have the size information to draw on which gives us additional variation.

Figure 8 shows the comparison of coefficients from the Pleiades and Barrington data for the period 750BC to 500AD. Coefficients start out higher in the Pleiades data, around 0.5 and then decline monotonically to zero by 500AD. The baseline coefficient in the

Barrington data is smaller at around 0.2, but in contrast to the Pleiades pattern remains relatively stable over this period with at most a minor decline towards the end of the Roman Empire by 500AD. This suggests that our results are consistent with the literature on the persistence of agglomeration effects.

Table 2 shows some further robustness checks of our results for different subsamples. Column (1) repeats our baseline results from table 1. Columns (2) to (4) use only continental cells, dropping island locations. Results in column (2) are similar or stronger. Columns (3) and (4) explore whether it is coastal shape or the locations of islands which drive our results. Here, we calculate connectedness using either only island cells as destinations (in column 3) or only continental cells (in column 4). Both matter but islands are important for our story. Coefficients for island connections in column (3) are about twice the size of those in column (4). Finally, column (5) replaces our simple connectedness measure with the eigenvalue measure of centrality; results are very similar.

We corroborate our findings for the Mediterranean at a World scale. Unfortunately, we have only a single early outcome measure: population in 1AD. Figure 9 is a scatter plot of c_{500} against mean log population density at the country level. The weights in this figure correspond to the number of coastal grid points in each country. We add a regression line from standard OLS. As is clear from the figure, the relationship between population density and connectedness at the country level is strongly positive around the world as well. Many Mediterranean countries can be found in the upper right quadrant of this plot, highlighting that connectivity in the basin may have contributed to the early development of this region.

5 Conclusion

We have argued that connectedness matters for human development. Some geographic locations are advantaged because it is easier to reach a larger number of neighbors. We exploit this idea to study the relationship between connectedness and early development around the Mediterranean. We argue that this association should emerge most potently when sailors first started crossing open seas systematically. This happened during the time when Phoenician, Greek, and Etruscan sailors and settlers exapanded throughout the Mediterranean between 800 and 500BC. Barry Cunliffe (2008) calls this period at the eve of Classical Antiquity "The Three Hundred Years That Changed the World" (p. 270).

This is not to say that sea trade and maritime networks were unimportant earlier. While we find clear evidence of a significant association between connectedness and the presence of archaeological sites for 750BC our results are more mixed as to whether this relationship began to emerge at that period because the data on earlier sites are more shaky. On the other hand, we find that once these locational advantages emerged the favored locations retain their urban developments over the ensuing centuries. This is in line with a large literature on urban persistence.

While our paper speaks to the nexus between trade and growth we are unable to link connectedness directly to trade in goods or other channels of sea based transport like migrations or the spread of ideas. Some of the issues we hope to explore further in this research are the interactions between maritime connections and other locational advantages, like access to land routes or minerals. It should also be possible to link connectedness to what is known about actual sailing routes during the Roman era. Finally, we hope to probe the persistence of these effects more by linking the results to data on more modern city locations.

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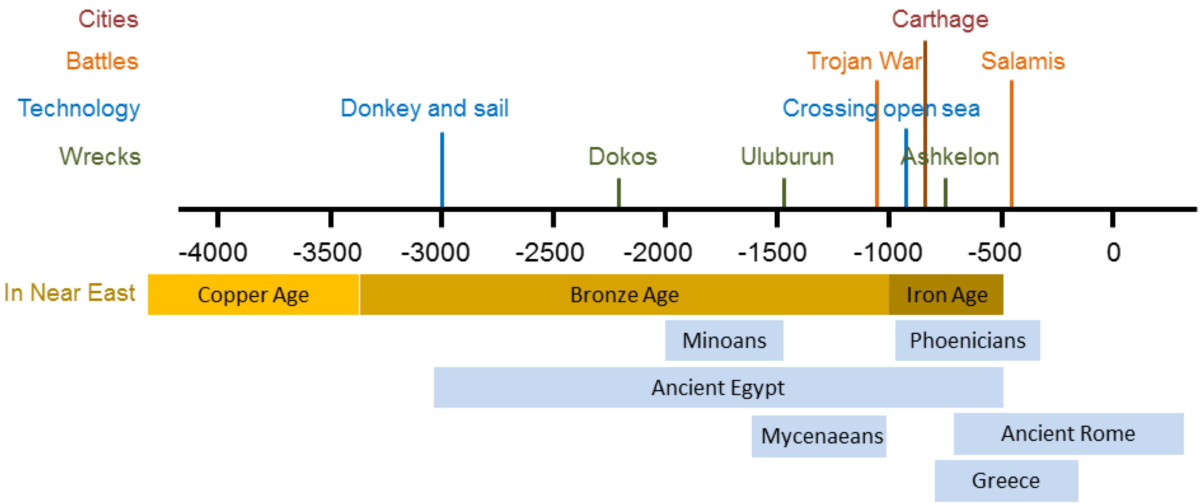

Figure 1: Timeline

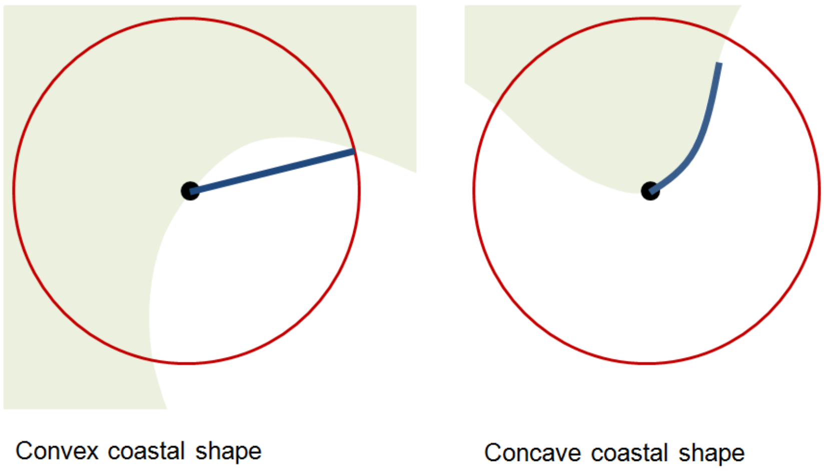

Figure 2: Convexity of coastline and connectedness. Coastal points in the convex left panel can reach more other coastal points in the same distance than coastal points located on a concave coastline as in the right panel.

Figure 3: Connectedness in the Mediterranean for a 500 km distance

Figure 4: Connectedness in the world for a 500 km distance

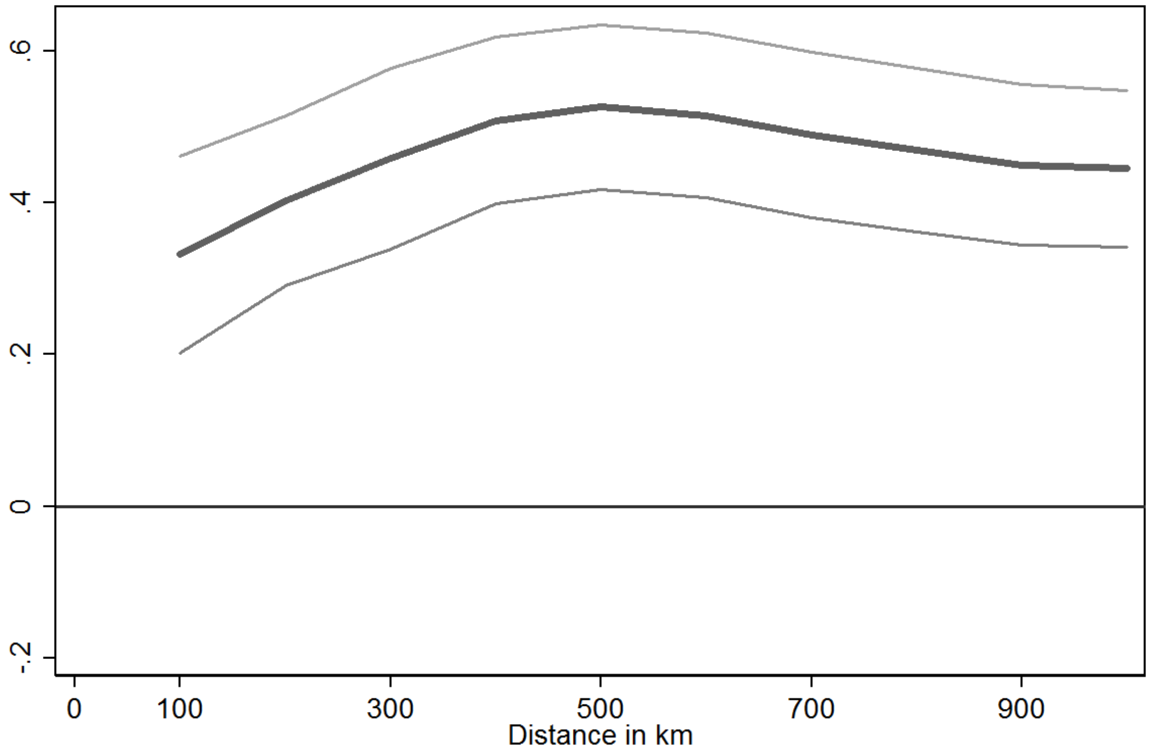

Figure 5: Coefficients for wide Pleiades sites by distance

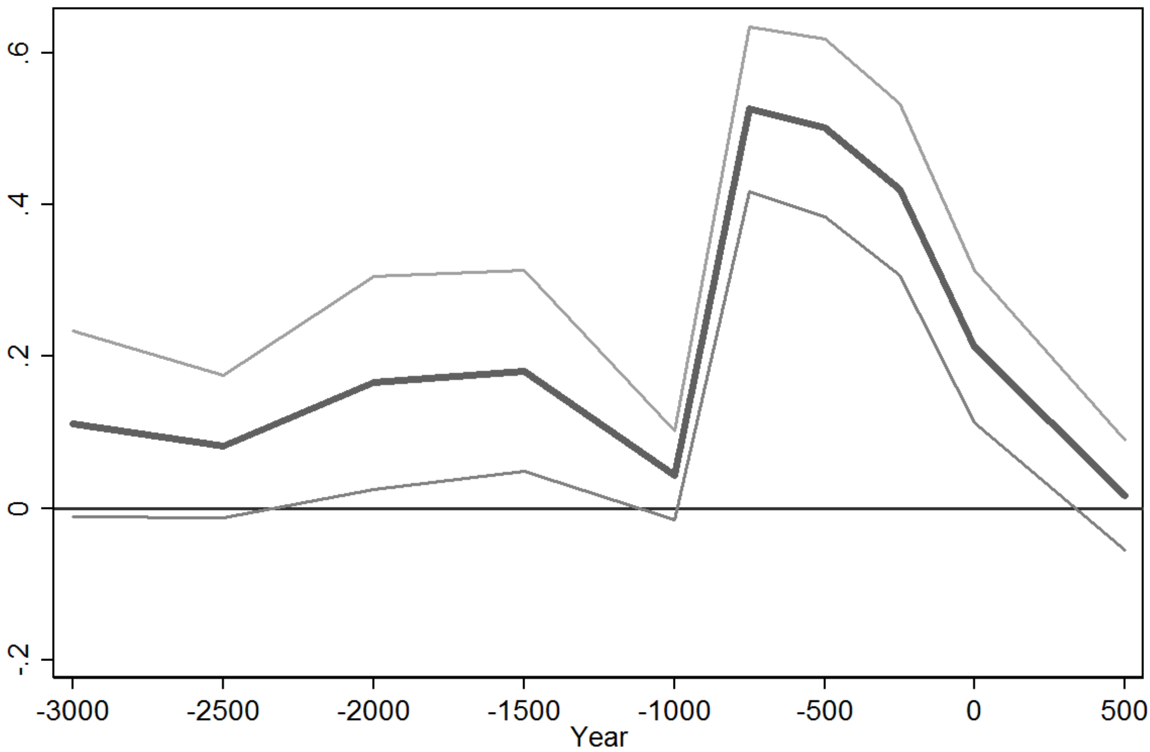

Figure 6: Coefficients for wide Pleiades sites over time

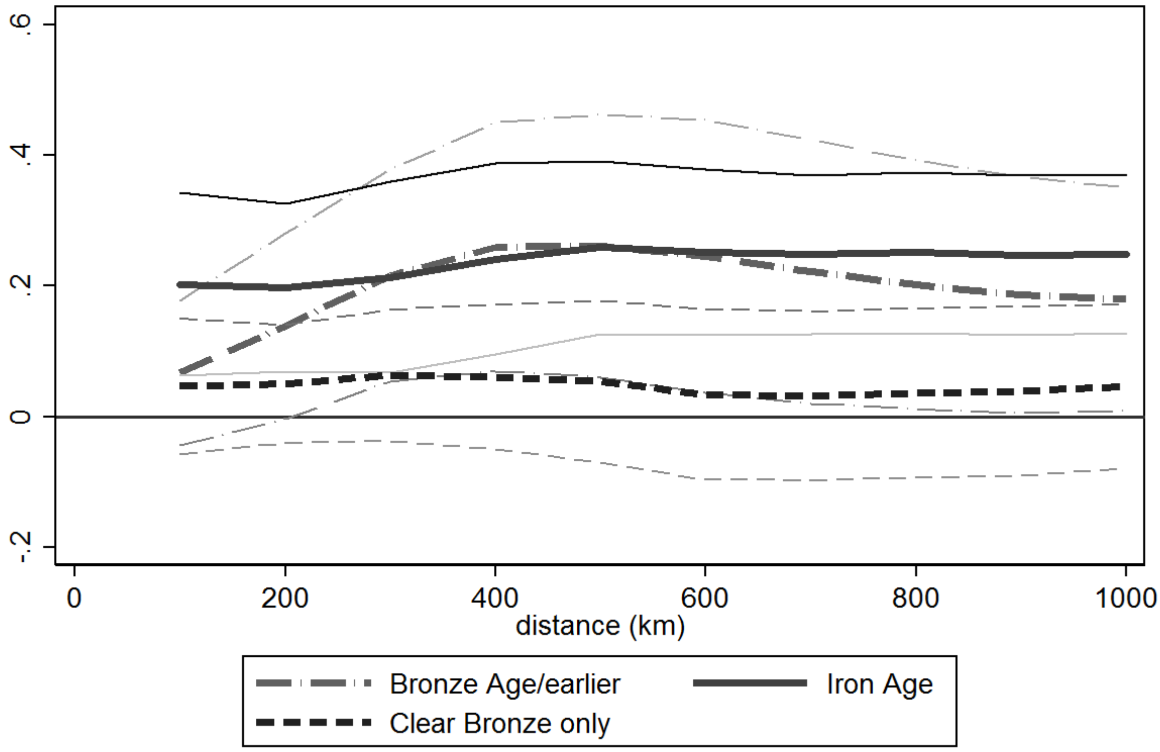

Figure 7: Coefficients for Whitehouse sites for different periods

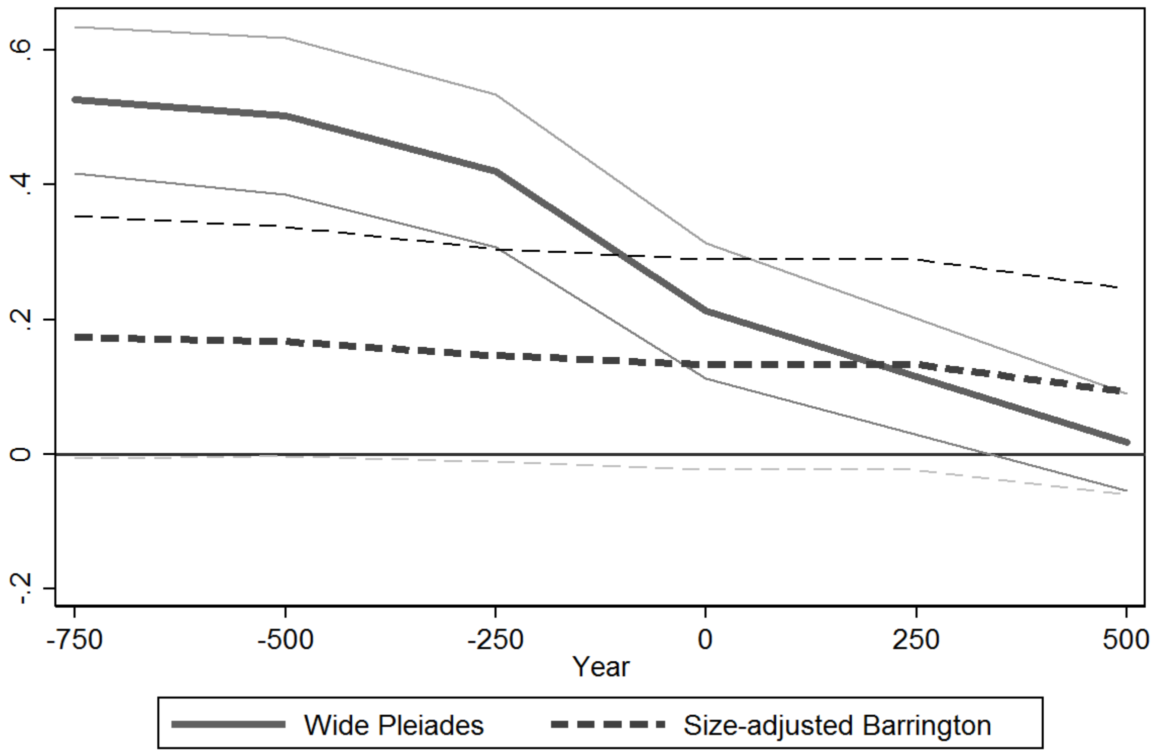

Figure 8: Coefficients for wide Pleiades and size adjusted Barrington sites

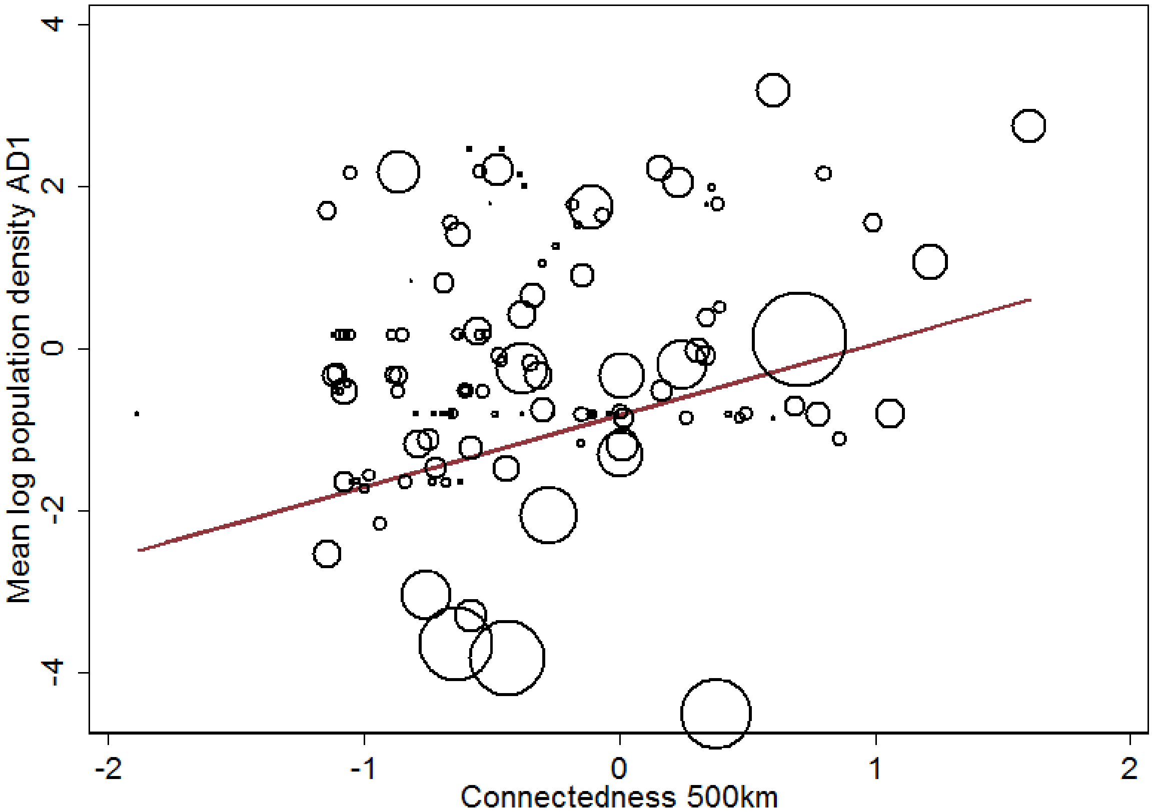

Figure 9: Global correlation between connectedness and log population density around the year 0, weights reflect length of coasts of countries.

Table 1: Basic results for various datasets

Dependent variable	(1)	(2)	(3)	(4)	(5)
Pleiades Wide 750BC	0.52	0.51	0.36	0.11	0.51
	(0.06)	(0.07)	(0.12)	(0.13)	(0.07)
Pleiades Narrow 750BC	0.31	0.27	0.38	0.17	0.30
	(0.06)	(0.08)	(0.13)	(0.17)	(0.07)
Whitehouse Atlas Iron Age	0.26	0.20	0.38	0.23	0.20
	(0.07)	(0.09)	(0.17)	(0.20)	(0.08)
Barrington Atlas 750BC	0.17	0.08	0.17	-0.08	0.15
	(0.09)	(0.11)	(0.13)	(0.17)	(0.10)
Observations	3646	3646	2750	2750	3044
Controls: Distance to Fertile Crescent, Route of the Isles, Rome, Longitude and Latitude		X		X	
Dropping Aegean			X	X	
Dropping North Africa					X

Notes: Coefficients from a regression of site density within 50km from different sources on 500km connectedness. Standard errors clustered at the level of 2x2 degree cells, in parentheses.

Table 2: Results for different connections

	Standard 500km connectedness				Centrality
	(1)	(2)	(3)	(4)	(5)
Pleiades Wide 750BC	0.52	0.45	0.44	0.20	0.51
	(0.06)	(0.14)	(0.12)	(0.11)	(0.07)
Whitehouse Iron Age	0.26	0.46	0.42	0.25	0.23
	(0.07)	(0.05)	(0.04)	(0.08)	(0.07)
Barrington 750BC	0.17	0.30	0.32	0.11	0.18
	(0.09)	(0.13)	(0.10)	(0.10)	(0.09)
Observations	3646	2658	2658	2658	3646
From	All	Continent	Continent	Continent	All
To	All	All	Island	Continent	All

Notes: Coefficients from a regression of density measures from different sources on measures of 500km connectedness or eigenvalue centrality. Robust standard errors, clustered at the level of 2x2 degree cells, in parentheses.

6 Appendix

We classified the maps contained in the Whitehouse atlas into three broad categories: Neolithic, Bronze Age, and Iron Age or later. Maps were classified based on their title, accompanying texts, and labels for individual sites. The following table provides details of our classification.

Table 3: Classification of archaeological sites in the Whitehouse atlas

Pages	Map Title/Details	Classification
72f.	Neolithic to Bronze Age sites in Anatolia	Bronze Age or earlier
74f.	Hittites and their successors	Bronze Age or earlier
76f.	Late prehistoric and proto-historic sites in Near East	Bronze Age or earlier
90f.	Neolithic to Bronze Age sites in Western Anatolia and the Cyclades	Bronze Age or earlier
92f.	Neolithic sites in Greece	Neolithic
94f.	Cyprus	
	Ktima, Kourion, Amathous, Kition, Karpasia, Athienou/Golgoi, Idalion, Kyrenia, Vouni, Kouklia/Old Paphos	Iron Age or later
	Kalavassos, Kirokitia, Kythrea, Lapithos, Petra tou Limniti, Sotira, Troulli, Erimi	
	Remainder	Bronze Age
96f.	Crete	Bronze Age or earlier
98f.	Mycenaean and other Bronze Age sites in Greece	Bronze Age
100f.	The Mycenaeans abroad	Bronze Age
102f.	The Phoenicians at home	Bronze Age / Iron Age or later
104f.	The Phoenicians abroad	Iron Age or later
106f.	Archaic and Classical Greece	Iron Age or later
108f.	The Greeks overseas	Iron Age or later
110f.	Neolithic sites in the central Mediterranean	Neolithic
112f.	Copper and Bronze Age sites in Italy	Bronze Age
114f.	Copper and Bronze Age sites in Sicily and the Aeolian Islands	Bronze Age
116f.	Copper and Bronze Age sites in Corsica and Sardinia	Bronze Age
118f.	Early Iron Age sites in the central Mediterranean	Iron Age or later
120f.	The central Mediterranean: Carthaginians, Greeks and Etruscans	Iron Age or later
122	Malta	
	Skorba	Neolithic
	Ghar Dalam, Tarxien	Bronze Age or earlier
	Bahrija	Bronze Age
123ff.	Neolithic sites in Iberia	Neolithic
126ff.	Copper and Bronze Age sites in Iberia	Bronze Age
129ff.	Early Iron Age sites in Iberia	Iron Age or later
140f.	Neolithic and Copper age sites in France and Switzerland	Neolithic
164f.	Bronze Age sites in France and Belgium	Bronze Age