

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

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Abstract

We study the causal connection between trade and development 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, the location of islands, and the distance to the opposing shore. We find an association between better connected locations and archaeological sites during the Iron Age, at a time when sailors began to cross open water very routinely and on a big scale. We corroborate these findings at the level of the world.

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1 Introduction

We investigate to what degree trading opportunities affected economic development at an early juncture of human history. In addition to factor accumulation and technical change, Smithian growth due to exchange and specialization is one of the fundamental sources of growth. An emerging literature on the topic is beginning to provide compelling empirical evidence for a causal link from trade to growth. We contribute to this literature and 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 from about 900 BC. 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. The particular shape of a coast has little influence over how many neighboring points can be reached from a starting location within a certain distance as long as ships sail mainly close to the coast. However, once sailors begin to cross open seas, coastal geography becomes more important: Some coastal points are in the reach of many neighbors while other can reach only few. The general shape of the coast and the location of islands matters for this. 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 interpretation of the results 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.

Humans have obtained goods from far away locations for many millennia. While some of the early trade involved materials useful for tools (like the obsidian trade studied by Dixon, Cann, and Renfrew 1968), as soon as societies became more differentiated a large part of this early trade involved luxury goods doubtlessly consumed by the elites. Such trade might have raised the utility of the beneficiaries but it is much less clear whether it affected productivity as well. Although we are unable to measure trade directly, our work sheds some light on this question. Since trade seems to have affected the growth of settlements even at an early juncture this suggests that it was productivity enhancing. The view that trade played an important role in early development has recently been gaining ground among economic historians; see e.g. Temin (2006) for the Iron Age Mediterranean, Algaze (2008) for Mesopotamia, and Temin (2013) for Ancient Rome.

Our approach avoids 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 when we talk about “trade” we interpret it in this broad sense. We do believe that coastal connectivity captures 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 not driven by a variety of other geographic conditions.

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.

The more recent literature has circumvented this by analyzing exogenous events related to changes in trade. 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. Redding and Sturm (2008) focus on the natural experiment created by the division and reunification in Germany, which changed the access to other markets sharply for some locations but not others. Various papers exploit the availability of new transport technologies; Feyrer (2009) uses air transport, Donaldson (forthcoming) and Donaldson and Hornbeck (2016) use railroads, and Pascali (forthcoming) steam ships. These papers generally find that regions whose trading opportunities improved disproportionately saw larger income growth. That we find similar results for a much earlier trade expansion suggests that the productivity benefits of trade have been pervasive throughout history.

Our 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, Bosker and Buringh 2017, Michaels and Rauch forthcoming). 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 (2011a). 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 1,500 AD, which is the opposite of our result. Our approach differs from Ashraf and Galor (2011a) 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 are not 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. Temin (2006) discusses the Iron Age Mediterranean through the lens of comparative advantage trade but offers no quantitative evidence as we do.

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 Strait 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 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 1997). 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.¹

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

¹The following discussion mainly draws on Abulafia (2011) and Broodbank (2013).

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 formation 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. Occasional 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 Mycenaeans 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 Otranto Strait (from Greece to the heel of Italy) were commonplace, coast hugging still prevailed among sailors during the 2nd millennium BC. After crossing the Otranto Strait,

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 manoeuvrability. 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. Traditionally, decline during the Bronze Age collapse 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 900 BC. 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 Sherratt (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 800 BC. ... 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 Ithaca 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 10km distance from each other, and that each cell has an equal area over the surface of the earth.² We define a grid-cell as water if falls completely into water, using a coastline map of the earth from Bjorn Sandvik’s public domain map on world borders³. 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_{di} , measures the number of other coastal cells which can be reached within distance d from cell i . 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

²As the Mediterranean is close enough to the equator distortions from using another projection are small in this area of interest.

³We use version 3, available from http://thematicmapping.org/downloads/world_borders.php.

often used circular routes on their travels (Arnaud 2007). Our measure is not supposed to mimic sailing routes directly but simply capture opportunities.

Figure 2 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 figure also highlights substantial variation of the connectedness measure within countries. The grid of our analysis allows for spatial variation at a fine scale. Since our measure of connectedness has no natural scale that is easy to interpret, we normalize each c_d to have mean 0 and standard deviation 1. Figure 3 shows a histogram of our normalized connectedness measure for a distance of 500km. Its distribution is somewhat bimodal, with a large spike at around -0.5, and a second, smaller one around 2. Basically all values above 1 are associated with locations in and around the Aegean, by far the best connected area according to our measure.

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 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 constant for the period since 3,000 BC, which we study (Agouridis 1997).

Another issue with our measure of connectivity is whether it only 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 openness involves opportunities as well as risks. 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 variable at the global level varies only 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 Anchorage, well north of climatic conditions particularly favorable to early settlement.⁴ 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 converges to a variable called “network centrality.” This is a standard measure

⁴In defining our connectedness measure, we restrict attention to the area between 78 and -54 degrees latitude, which roughly mark the northernmost and southernmost cities of the world. This excludes the Southern tip of Tierra del Fuego in South America as coastal destination, but should be fairly inconsequential.

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 (Bagnall et al. 2014) 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*.⁵ 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 starting point for the database is the *Barrington Atlas of the Greek and Roman World* (Talbert 2000); but it is an open source project and material from 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; including both those classified as “unknown” or with any other known classification in the wide version of the data.

⁵Available at pleiades.stoa.org. We use a version of the dataset downloaded in June 2014.

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, rough, and unlocated. We only keep units with a precisely measured location.⁶ 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 750 BC. Coverage 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 1,491 sites in 750 BC and 5,649 in 1 AD but only 63 in 1,500 BC. While economic activity and populations were surely lower in the Bronze Age, there are likely many earlier sites missing in the 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. Although there has been much additional excavation in the intervening period, there is little reason to believe that it is unrepresentative for the broad 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

⁶Pleiades 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 restriction affects around one percent of the Pleiades data. The remaining identifiers with several sites are dealt with by counting them as one unit, averaging their coordinates. For overlapping time spans, we use the minimum of such spans as the start date, the respective maximum as end date.

to choose the number of sites so as to fill each map without overcrowding it, 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 28 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 contain sites from multiple periods but give a classification of sites, which we use. Other maps straddle periods without more detailed timing information. In this case, we classified sites into the three broad periods ourselves using resources on the internet. In a few cases, it is not possible to classify sites clearly as either Neolithic or Bronze Age in which case we classified them as both (see the appendix for details).

To measure the urbanization rate near 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. 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:

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

where u_{it} is the urbanization 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 connectivity 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 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.

We use latitude, longitude, and distance to the Fertile Crescent, which all do not vary over time, as control variables. We 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 show results dropping North Africa to address concerns that there may be 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 degree following Bester, Conley and Hanson (2011). 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.

Our measure of connectedness depends only on coastal and maritime geography and therefore is plausibly exogenous. However, it might be spuriously correlated with other factors that affect early growth, such as agricultural productivity, topographic conditions, or

rivers, which provide inland connections. Those factors are hard to measure precisely. Hence, instead of including them on the right-hand side of our regression equation as control variables, we follow the suggestion of Pei, Pischke and Schwandt (2017) and show that they are not systematically related to our measure of coastal connectivity. The results of these balancing regressions are shown in table 1.

In the first row, we relate connectedness to agricultural productivity, which we construct using data from the FAO-GAEZ database and following the methodology of Galor and Özak (2016): In the first row, we relate connectedness to agricultural productivity, which we construct using data from the FAO-GAEZ database and following the methodology of Galor and Özak (2016): We convert agroclimatic yields of 48 crops in $5' \times 5'$ degree cells under rain-fed irrigation and low levels of input into caloric yields and assign the maximal caloric yield to 10×10 km cells. For each coast cell, we then calculate the average on the same landmass within 50km from the coast cell. In the second row, we use Nunn and Puga (2012)'s measure of ruggedness, again averaged over 50km radii around our coast cells. Finally, the third row looks at distance to the nearest river mouth. For this, we used Wikipedia to create a list of all rivers longer than 200km, geocoded their mouths and mapped them to our coast cells (Nile and Danube have large deltas that map to multiple cells). We then calculate the distance of each coastal cell to the nearest river mouth. All three measures are standardized to have mean 0 and standard deviation 1. As a result, the sizes of coefficients are directly comparable to those in our connectedness regressions.

Columns (1) starts by showing the results of balancing regressions just controlling for latitude and longitude. Column (2) also adds a control for distance to the Fertile Crescent. This may be important because agriculture spread from the Fertile Crescent throughout the Mediterranean Basin, and various authors have linked the timing of the Neolithic Revolution to later development (Diamond 1997; Hibbs and Olsson 2004; Comin, Easterly,

and Gong 2010). Conditional on the full set of controls we use in our analysis, neither agricultural productivity, ruggedness, nor distance to the nearest river mouth seem to have a large association with our measure of connectedness. Columns (3) and (4) show that dropping the Aegean from the sample leads to bigger associations but also impairs precision. Outside of North Africa, a slight negative association between connectedness and both ruggedness and agricultural productivity arises, but only the latter is statistically significant. Overall, our measure of connectedness does not appear to be systematically related to the three variables examined in table 1, especially once we control for distance to the Fertile Crescent. As a result, we will use all of latitude, longitude, and distance to the Fertile Crescent as controls in the analyses that follow.

4.1 Basic results

In table 2 then, we start by showing results for connections within 500km and the settlement densities in 750 BC from our different data sets. At this 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, and the association is highly significant. The coefficient is slightly lower for the narrow site definition, and for Iron Age sites from the Whitehouse Atlas. Dropping the Aegean in column (2) leads to a loss of precision, with standard errors going up noticeably for all three outcome variables. Coefficients are similar in magnitude or increase, indicating that the Aegean was not driving the results in column (1). Dropping North Africa in column (3) makes little difference compared to the original results.

The effects of better connectedness seem sizable: a one standard deviation increase in connectedness increases settlement density by 20 to 50 percent of a standard deviation. While the parameterization with variables in standard deviation units should aid the

interpretation, we offer an alternative view on the size of the coefficients in table 3. Here we presents results when we replace our previous density measure by a coarser binary variable that simply codes whether a coastal cell has at least one archaeological site within a 50km radius. The effects are basically positive but somewhat more sensitive to the particular specification and data set. Coefficients range from a high of 0.32 in the narrow Pleiades data excluding the Aegean to zero in the Whitehouse data excluding North Africa.

While this specification is much coarser than the previous one, it facilitates a discussion of the magnitude of our results. Recall that there are two modes around -0.5 and 2 in the distribution of the connectedness variable in figure 3. Going from -0.5 to 2 roughly corresponds to moving from a point on the coast of Southern France (say Toulon) to western Turkey (say Izmir). Using the coefficient for the wide Pleiades data in column (1) of 0.12, this move would increase the probability of having a site within 50km by 30 percentage points. Such an increase is sizable—the unconditional probability of having any site nearby in the wide Pleiades data is 61% and it is 49% among cells with connectivity below zero. Of course, a 2.5 standard deviations increase in connectedness is also a substantial increase. Most of our estimates of the effects of connectedness are far from trivial but they also leave lots of room for other determinants of growth.

We now return to our original site definition as in table 2. A potential concern with our results might be that we are not capturing growth and urbanization, but simply the location of harbors. To address this, table 4 repeats the analysis of table 2, but omitting coastal cells themselves from the calculation of settlement density. Here we are investigating whether a better connected coast gives rise to more settlements further inland. The results are similar to those from the previous table, indicating that the effects we observe are not driven by coastal locations but also manifest themselves in the immediate hinterland of the coast. This bolsters the case that we are seeing real growth

effects of better connections. The number of observations in table 4 is slightly lower than before since we omit coastal cells that have only other coastal cells within a 50km radius (e.g. the north-eastern tip of Cyprus).

Table 5 shows some further robustness checks of our results for different subsamples. Column (1) repeats our baseline results from table 2. Columns (2) to (4) use only continental cells as starting points, dropping island locations. In column (2), we keep both continent and island locations as potential destinations. Results are similar or, in the case of the Whitehouse data, 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 more 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 again very similar. These results suggest that the relationships we find are not driven only by a particular subsample or connection measure.

Our previous results are for connections within a 500km radius. Figure 5 displays coefficients for connectivities at different distances, using the basic specification with the wide Pleiades set of sites. It demonstrates that coefficients are fairly similar when we calculate our connectivity measure for other distances. This is likely due to the fact that these measures correlate pretty closely 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 wide Pleiades data over time. The figure has various features. Coefficients are small and mostly insignificant until 1,000 BC but increase sharply in 750 BC, consistent with the Iron Age expansion of open sea routes. There are smaller

and less significant effects of connectivity during the late Bronze Age in 2,000 and 1,500 BC. From 500 BC, the effects of connectivity decline and no correlation between sites and connectivity is left by the end of the Roman Empire. In table 2, we have demonstrated that the large association between connectedness and the presence of sites is replicated across various data sets and specifications for the year 750 BC, so we are fairly confident in that result. Figure 6 therefore raises two questions: Is the upturn in coefficients between 1,000 BC and 750 BC real or an artefact of the data? And does the association between sites and connectedness vanish during the course of the Roman Empire? On both counts there are reasons to be suspicious of the Pleiades data. Coverage of sites from before 750 BC is poor in the data while coverage during the Roman period may be too extensive.

We use the Whitehouse data to probe the findings for the earlier period. In figure 7 we plot coefficients again against distances varying from 100km to 1,000km. The red line, which refers to sites in the Iron Age and later, shows sizable and significant coefficients in the range between 0.2 and 0.3, as we had already seen in table 2, and these coefficients vary little by distance. The blue line shows coefficients for Bronze Age sites. Coefficients are small and insignificant for small distances and for very large ones but similar to the Iron Age coefficients for intermediate ones. The Bronze Age results are unfortunately a bit noisier and the pattern by distance unfortunately does not completely resolve the issue about the emergence of the sites - connections correlation either.

4.2 Persistence

Once geographical conditions have played a role in a site location, do we expect this relationship to be stable into the future? There are two reasons why the answer would be affirmative. Connections should have continued to play a role during the period of the Roman Empire when trade in the Mediterranean reached yet a more substantial level. Even

if the relative role of maritime connectivity declined—maybe because sailors got better and distance played less of a role, or other modes of transport, e.g. on Roman roads, also became cheaper—human agglomerations created during the Phoenician period may have persisted. 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, Bosker and Buringh 2017, Michaels and Rauch forthcoming among others). Either explanation is at odds with the declining coefficients over time in figure 6 after 750 BC.

We suspect that the declining coefficients in the Pleiades data stems from the fact that the site density is becoming too high during the Roman period. In 750 BC there are 1,491 sites the data set and this number increases to 5,640 in 1 AD at the height of the Roman Empire. There are only 3,464 coastal gridpoints in our data set. 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 a lot of useful variation within our data set: By the height of the Roman Empire most coastal grid points are located near some sites. Moreover, existing sites may be concentrated in well-connected locations already and maybe these sites grow further. New settlements after 750 BC, on the other hand, might arise in unoccupied locations, which are less well connected.

In order to investigate this, we split the sites in the Pleiades data into those which existed already in 750 BC but remained in the data in subsequent periods and those which first entered at some date after 750 BC. Figure 8 shows results for the period 500 BC to 500 AD. The blue, solid line shows the original coefficients for all sites. The black, broken line shows coefficients for sites present in 750 BC which remained in the data while the red, dashed line refers to sites that have newly entered since 750 BC. The coefficients for remaining sites are very stable, while the relationship between connectedness and the location of entering sites becomes weaker and even turns negative over time. Because the

new entrants make up an increasing share of the total over time, the total coefficients (solid line) are being dragged down by selective site entry during the Roman era. This is consistent with the results of Bosker and Buringh (2017) for a later period, who find that having a previously existing city close by decreases a location's chance of becoming a city seed itself.

4.3 Results for a world scale

Finally, we corroborate our findings for the Mediterranean at a world scale. We have only a single early outcome measure: population in 1 AD from McEvedy and Jones (1978). This is the same data as used by Ashraf and Galor (2011b) for a similar purpose. Population density is measured at the level of modern countries, and the sample includes 123 countries. Recall that we compute connectivity for coastal cells on a 50 x 50km grid points for this exercise.

Mimicking our estimates for the Mediterranean, we start by running regressions at the level of the coastal cell, of which we have 7,441. Both connectivity and population density are normalized again. We obtain an estimate of 0.20 with a standard error, clustered at the country level, of 0.16. Here we control for the absolute value of latitude (distance from the equator) only but this control matters little.⁷

Alternatively, we aggregate the world data to the level of countries, which is the unit at which the dependent variable is measured anyway. We normalize variables after aggregating. Figure 9 is a scatter plot of c_{500} against mean population density at the country level. The weights in this figure correspond to the number of coastal grid points in each country. The line in the figure comes from a standard bivariate regression and has a slope of 0.44 (0.33). These estimates are in the same ballpark of the ones for the Mediterranean

⁷Neither east-west orientation nor distance from the Fertile Crescent seems to make as much sense on a world scale. Unlike for the Mediterranean, there were various centers of early development around the world.

in table 2. Note that many Mediterranean countries can be found in the upper right quadrant of this plot, highlighting how connectivity in the basin may have contributed to the early development of this region.

5 Conclusion

We argue 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 expanded throughout the Mediterranean between 800 and 500 BC. 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 750 BC 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 in future work are the interactions between maritime connections and other locational advantages, like access to minerals. 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

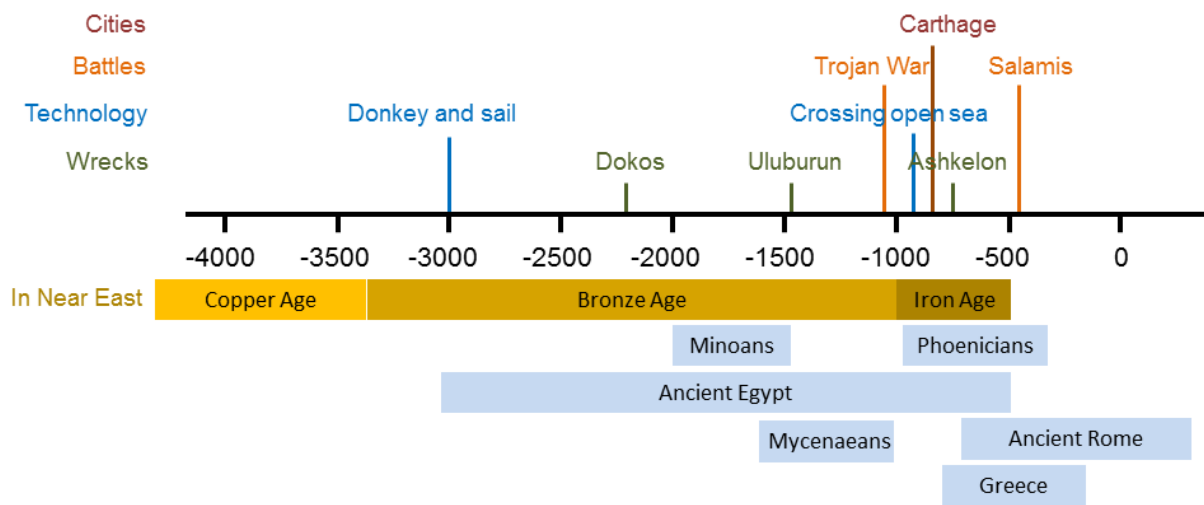


Figure 2: Connectedness in the Mediterranean for a 500 km distance



Figure 3: Distribution of our connectedness variable at 500km distance

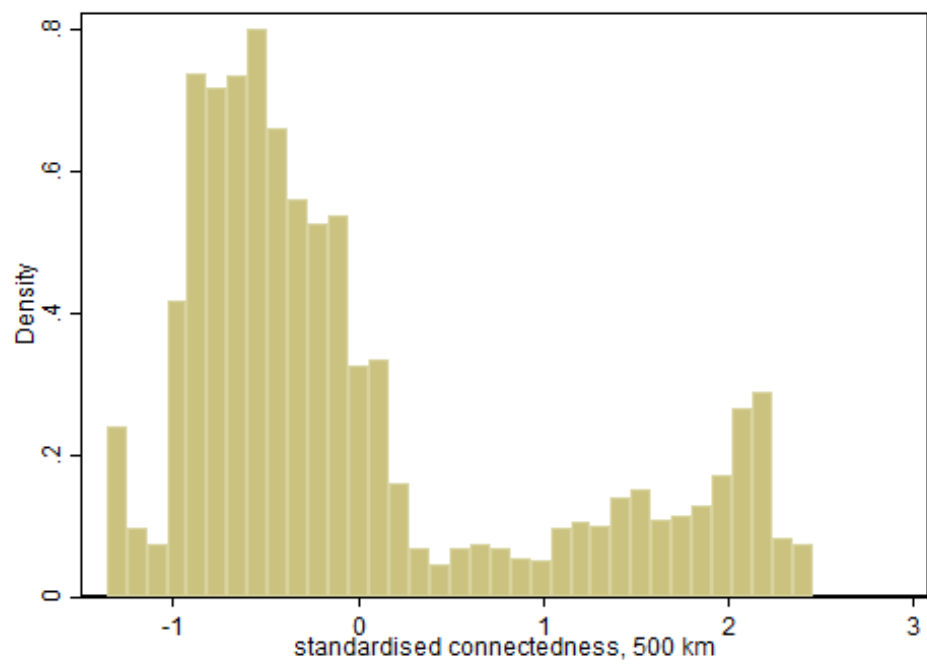


Figure 4: Connectedness in the world for a 500 km distance



Figure 5: Coefficients for wide Pleiades sites by distance

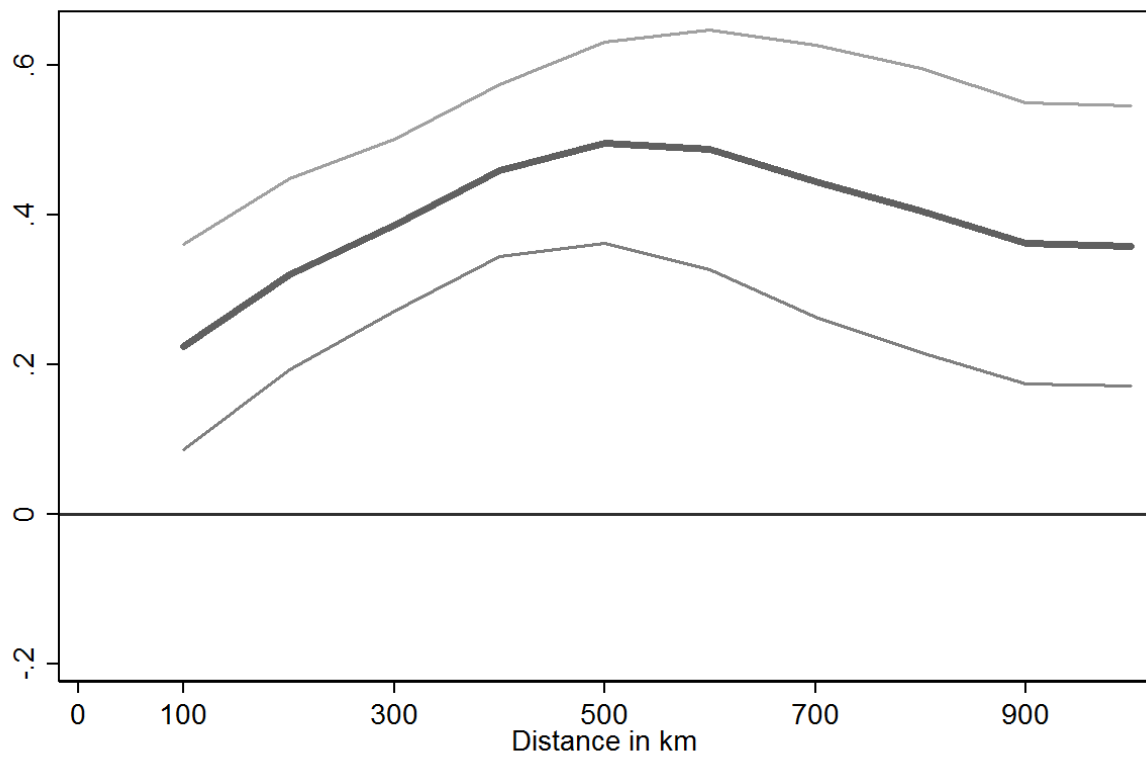


Figure 6: Coefficients for wide Pleiades sites over time

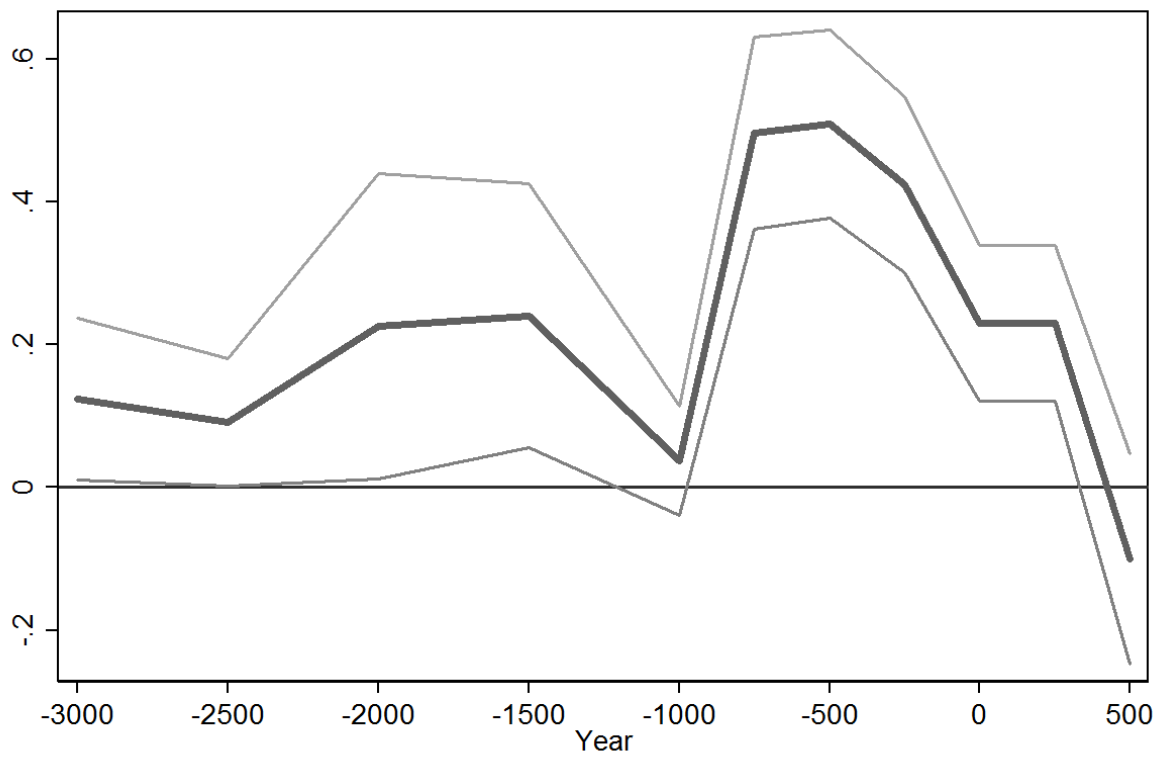


Figure 7: Coefficients for Whitehouse sites for different periods

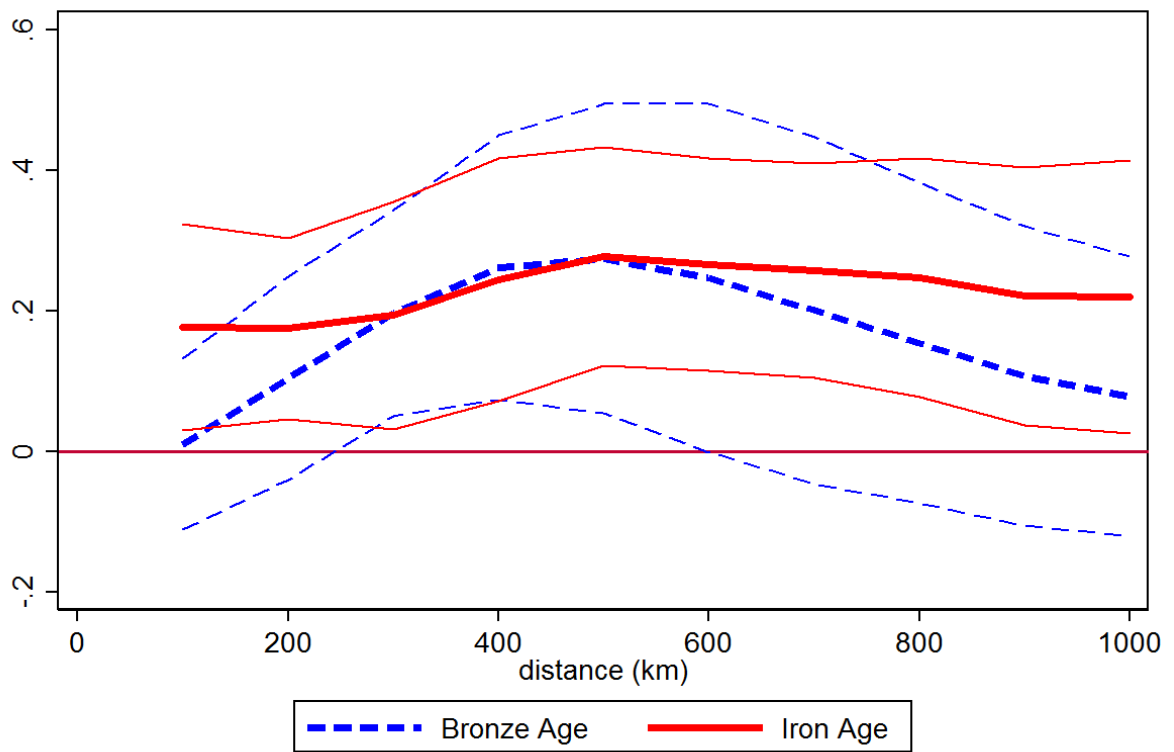


Figure 8: Coefficients for Wide Pleiades sites: Entry, Existing, Total

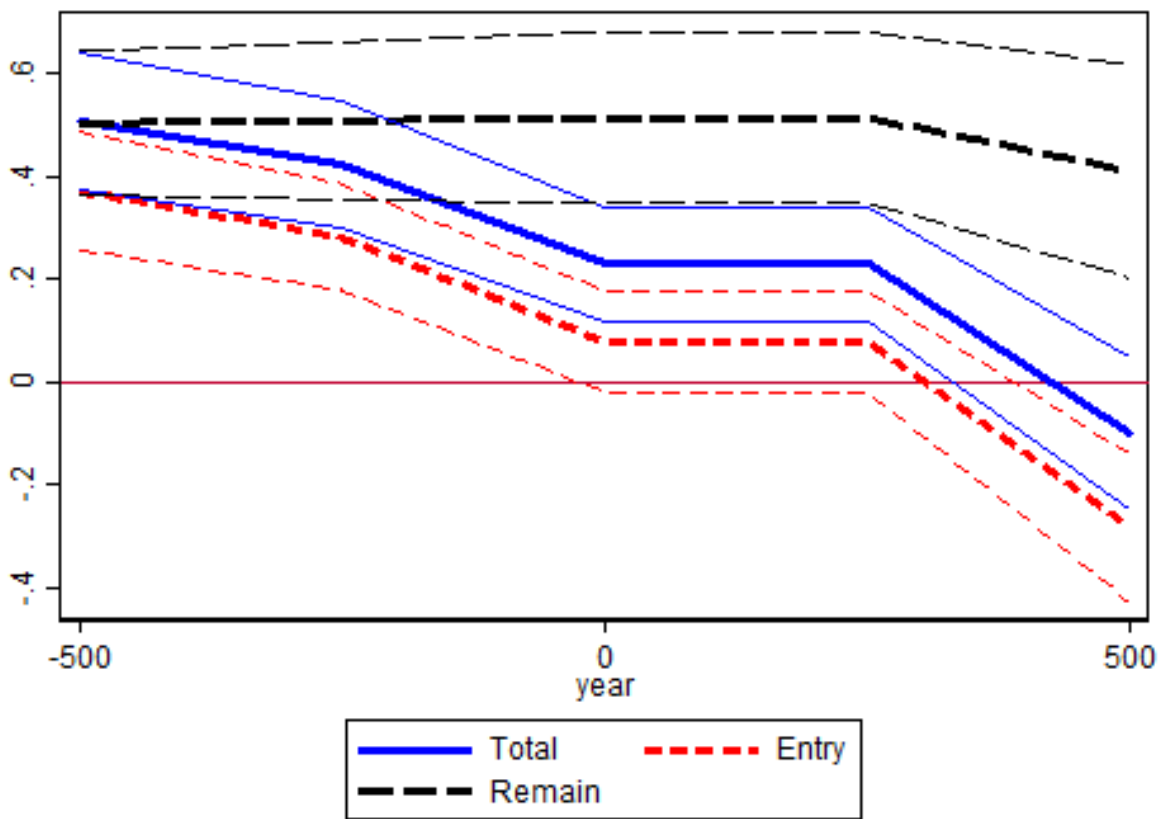
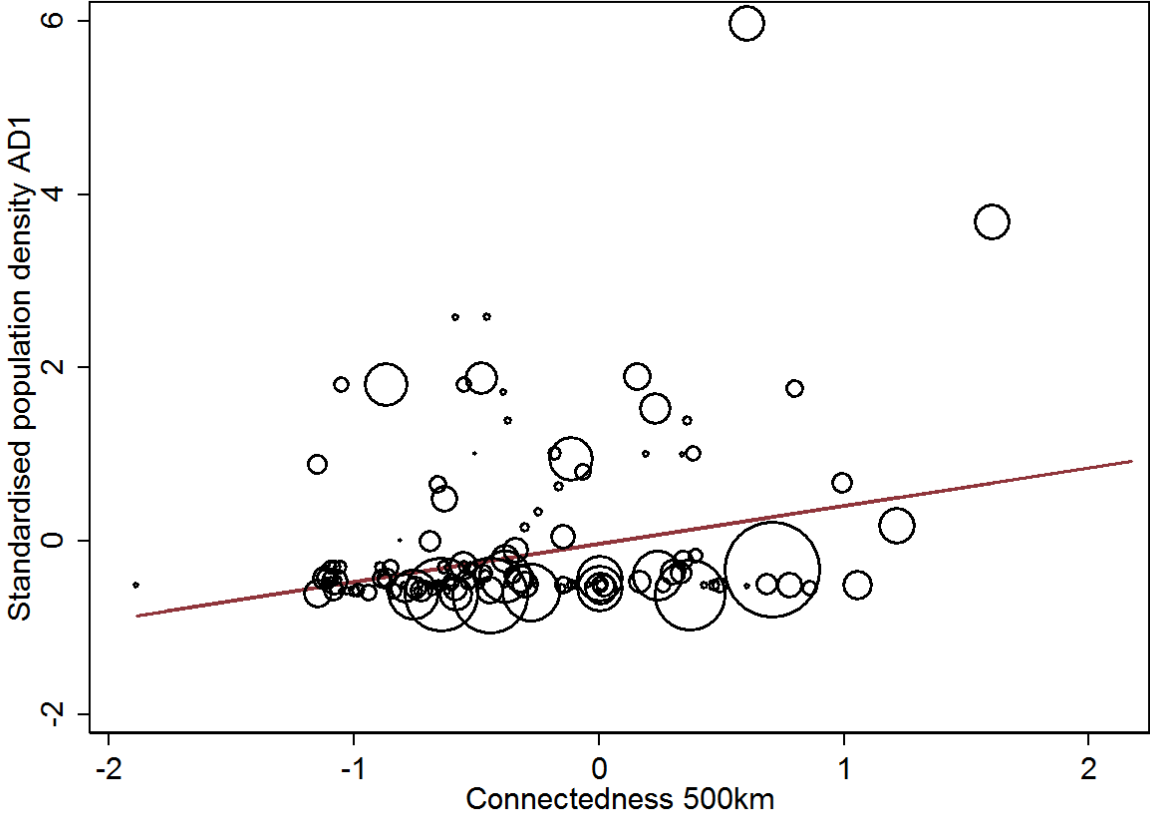


Figure 9: Global correlation between connectedness and population density around 1AD



Weights reflect length of coasts of countries.

Table 1: Balancing checks

| Dependent variable | (1) | (2) | (3) | (4) | (5) | (6) |
|--|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Agricultural productivity (following Galor and Ozak (2016)) | 0.11 (0.05) | -0.02 (0.06) | 0.24 (0.14) | 0.08 (0.13) | -0.06 (0.05) | -0.19 (0.05) |
| Ruggedness (following Nunn and Puga (2012)) | 0.10 (0.08) | 0.10 (0.10) | -0.23 (0.30) | -0.26 (0.28) | -0.16 (0.09) | -0.16 (0.10) |
| Distance to the nearest river mouth | -0.15 (0.09) | -0.12 (0.10) | -0.26 (0.27) | -0.30 (0.28) | -0.06 (0.08) | 0.00 (0.09) |
| Observations | 3646 | 3646 | 2750 | 2750 | 3044 | 3044 |
| Controls: | | | | | | |
| Longitude and Latitude | X | X | X | X | X | X |
| Distance to the Fertile Crescent | | X | | X | | X |
| Dropping Aegean | | | X | X | | |
| Dropping North Africa | | | | | X | X |

Coefficients from a regression of various dependent variables on 500km connectedness. Standard errors clustered at the level of 2x2 degree cells, in parentheses.

Table 2: Basic results

| Dependent variable | (1) | (2) | (3) |
|----------------------------------|----------------|----------------|----------------|
| Pleiades Wide 750 BC | 0.50 (0.07) | 0.42 (0.14) | 0.45 (0.08) |
| Pleiades Narrow 750 BC | 0.25 (0.08) | 0.48 (0.16) | 0.22 (0.09) |
| Whitehouse Atlas Iron Age | 0.28 (0.08) | 0.50 (0.18) | 0.20 (0.09) |
| Observations | 3646 | 2750 | 3044 |
| Controls: | | | |
| Longitude and Latitude | X | X | X |
| Distance to the Fertile Crescent | X | X | X |
| Dropping Aegean | | X | |
| Dropping North Africa | | | X |

Coefficients from regressions on 500km connectedness. Standard errors clustered at the level of 2x2 degree cells, in parentheses.

Table 3: Results with a binary outcome variable

| Dependent variable | (1) | (2) | (3) |
|----------------------------------|----------------|----------------|-----------------|
| Pleiades Wide 750 BC | 0.12 (0.04) | 0.17 (0.14) | 0.11 (0.04) |
| Pleiades Narrow 750 BC | 0.07 (0.05) | 0.32 (0.11) | 0.06 (0.06) |
| Whitehouse Atlas Iron Age | 0.04 (0.04) | 0.03 (0.10) | -0.01 (0.04) |
| Observations | 3646 | 2750 | 3044 |
| Controls: | | | |
| Longitude/Latitude | X | X | X |
| Distance to the Fertile Crescent | X | X | X |
| Dropping Aegean | | X | |
| Dropping North Africa | | | X |

Coefficients from regressions on 500km connectedness. Standard errors clustered at the level of 2x2 degree cells, in parentheses.

Table 4: Results excluding coastal cells from outcome definition

| Dependent variable | (1) | (2) | (3) |
|----------------------------------|----------------|----------------|----------------|
| Pleiades Wide 750 BC | 0.49 (0.09) | 0.34 (0.13) | 0.46 (0.09) |
| Pleiades Narrow 750 BC | 0.16 (0.15) | 0.38 (0.19) | 0.16 (0.15) |
| Whitehouse Atlas Iron Age | 0.31 (0.07) | 0.53 (0.27) | 0.30 (0.08) |
| Observations | 3234 | 2539 | 2647 |
| Controls: | | | |
| Longitude and Latitude | X | X | X |
| Distance to the Fertile Crescent | X | X | X |
| Dropping Aegean | | X | |
| Dropping North Africa | | | X |

Coefficients from regressions on 500km connectedness. Standard errors clustered at the level of 2x2 degree cells, in parentheses. Coastal cells and their sites are omitted from the outcome definition.

Table 5: Results for different measure of connectedness

| | Standard 500km connectedness | | | | Centrality |
|------------------------|------------------------------|------------------|---------------------|------------------------|----------------|
| | (1) | (2) | (3) | (4) | (5) |
| Pleiades Wide 750 BC | 0.50 (0.07) | 0.43 (0.15) | 0.47 (0.14) | 0.20 (0.12) | 0.46 (0.09) |
| Pleiades Narrow 750 BC | 0.25 (0.08) | 0.42 (0.13) | 0.46 (0.11) | 0.20 (0.12) | 0.19 (0.09) |
| Whitehouse Iron Age | 0.28 (0.08) | 0.49 (0.07) | 0.47 (0.05) | 0.29 (0.08) | 0.23 (0.09) |
| Observations | 3646 | 2658 | 2658 | 2658 | 3646 |
| From To | All All | Continent All | Continent Island | Continent Continent | All All |

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. All regressions control for longitude, latitude, and distance to the Fertile Crescent.

6 Appendix A: Coding of Whitehouse sites

We classified the maps contained in the *Whitehouse Atlas* into three broad time periods: Neolithic, Bronze Age, and Iron Age or later based on the map title, accompanying texts, and labels for individual sites. Table 6 provides details of our classification of the maps. The maps on pages 72, 76, 90, and 96 straddle both the Neolithic and Bronze Age period, while the map on page 102 could refer to either the Bronze or Iron Age. For these maps, we narrowed down the dating of sites based on resources we could find on the Internet about the respective site. Table 7 provides details of our dating.

Table 6: Classification of maps in the *Whitehouse Atlas*

| Pages | Map title/details | Time period |
|--------|--|------------------------|
| 72f. | Neolithic to Bronze Age sites in Anatolia | Bronze Age or earlier |
| 74f. | Hittites and their successors | Bronze Age |
| 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 | various |
| 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 or Iron Age |
| 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 | Bronze Age or earlier |
| 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 |
| 172f. | The spread of Urnfield Cultures in Europe | Iron Age or later |
| 174f. | The Hallstatt and La Tene Iron Ages | Iron Age or later |
| 176f. | Iron Age sites in Europe | Iron Age or later |

Table 7: Classification of specific sites in the *Whitehouse Atlas*

| Map page | Site name | Neolithic | Bronze Age | Iron Age | Source |
|----------|-------------------|-----------|------------|----------|------------------------------|
| 72 | Dundartepe | 1 | 1 | 0 | see notes |
| 72 | Fikirtepe | 1 | 1 | 0 | Whitehouse |
| 72 | Gedikli | 1 | 1 | 1 | TAY Project |
| 72 | Karatas | 0 | 1 | 1 | Wikipedia |
| 72 | Kayislar | 1 | 1 | 0 | TAY Project |
| 72 | Kizilkaya | 0 | 1 | 1 | Wikipedia (Kizilkaya/Burdur) |
| 72 | Kumtepe | 1 | 0 | 0 | Wikipedia |
| 72 | Maltepe | 1 | 1 | 1 | TAY Project |
| 72 | Mentese | 1 | 0 | 0 | TAY Project |
| 72 | Mersin | 1 | 1 | 1 | Wikipedia |
| 72 | Silifke | 0 | 1 | 1 | Wikipedia |
| 72 | Tarsus | 1 | 1 | 1 | Wikipedia |
| 72 | Tilmen Huyuk | 1 | 1 | 1 | TAY Project |
| 72 | Troy | 0 | 1 | 1 | Wikipedia |
| 76 | Amrit/Marathus | 0 | 1 | 0 | Wikipedia |
| 76 | Amuq | 1 | 1 | 0 | Whitehouse |
| 76 | Aradus | 0 | 1 | 1 | Wikipedia (Arwad) |
| 76 | Atchana/Alalakh | 0 | 1 | 0 | Wikipedia |
| 76 | Beisamoun | 1 | 0 | 0 | see notes |
| 76 | Byblos | 1 | 1 | 1 | Wikipedia |
| 76 | Gaza | 0 | 1 | 1 | Wikipedia |
| 76 | Gezer | 0 | 1 | 1 | Wikipedia |
| 76 | Hazorea | 1 | 1 | 0 | Whitehouse |
| 76 | Kadesh | 1 | 1 | 0 | Wikipedia (Kadesh (Syria)) |
| 76 | Megiddo | 1 | 1 | 1 | Wikipedia |
| 76 | Mersin | 1 | 1 | 1 | Wikipedia |
| 76 | Samaria | 1 | 1 | 1 | New World Encyclopedia |
| 76 | Sidon | 1 | 1 | 1 | Wikipedia |
| 76 | Tainat | 1 | 1 | 0 | Whitehouse |
| 76 | Tell Beit Mirsim | 0 | 1 | 1 | see notes |
| 76 | Tyre | 0 | 1 | 1 | Wikipedia |
| 76 | Ugarit/Ras Shamra | 1 | 1 | 0 | Wikipedia |
| 90 | Akrotiraki | 1 | 1 | 0 | see notes |
| 90 | Chalandriani | 0 | 0 | 0 | Wikipedia |
| 90 | Dhaskalio | 0 | 1 | 0 | Wikipedia |
| 90 | Dokathismata | 0 | 1 | 1 | Wikipedia (see notes) |
| 90 | Emborio | 1 | 1 | 0 | see notes |
| 90 | Fikirtepe | 1 | 1 | 0 | Whitehouse |
| 90 | Glykoperama | 1 | 1 | 0 | Whitehouse |
| 90 | Grotta | 0 | 1 | 0 | see notes |
| 90 | Heraion | 1 | 1 | 0 | Whitehouse |
| 90 | Kephala | 1 | 1 | 0 | Whitehouse |
| 90 | Kumtepe | 1 | 0 | 0 | Wikipedia |
| 90 | Mavrispilia | 1 | 1 | 0 | Whitehouse |
| 90 | Paroikia | 1 | 1 | 0 | Whitehouse |
| 90 | Pelos | 1 | 1 | 0 | Whitehouse |
| 90 | Phylakopi | 0 | 1 | 0 | Wikipedia |
| 90 | Poliochni | 1 | 1 | 0 | Wikipedia (see notes) |
| 90 | Protesilaos | 1 | 1 | 0 | Whitehouse |
| 90 | Pyrgos | 1 | 1 | 0 | Whitehouse |

Table 7: Classification of specific sites in the *Whitehouse Atlas*, continued

| Map page | Site name | Neolithic | Bronze Age | Iron Age | Source |
|----------|---------------------|-----------|------------|----------|--------------------|
| 90 | Saliagos | 1 | 0 | 0 | Wikipedia |
| 90 | Spedos | 0 | 1 | 0 | Wikipedia |
| 90 | Thermi | 0 | 1 | 0 | Wikipedia (Lesbos) |
| 90 | Tigani | 1 | 1 | 0 | Whitehouse |
| 90 | Troy | 0 | 1 | 1 | Wikipedia |
| 90 | Vathy | 1 | 1 | 0 | Whitehouse |
| 90 | Vryokastro | 0 | 1 | 0 | see notes |
| 94 | Alambra | 0 | 1 | 0 | Whitehouse |
| 94 | Amathous | 0 | 0 | 1 | Whitehouse |
| 94 | Anoyira | 0 | 1 | 0 | Whitehouse |
| 94 | Arpera | 0 | 1 | 0 | Whitehouse |
| 94 | Athienou/Golgoi | 0 | 0 | 1 | Whitehouse |
| 94 | Ayia Irini | 0 | 1 | 0 | Whitehouse |
| 94 | Ayios Iakovos | 0 | 1 | 0 | Whitehouse |
| 94 | Ayios Sozomenos | 0 | 1 | 0 | Whitehouse |
| 94 | Dhenia | 0 | 1 | 0 | Whitehouse |
| 94 | Enkomi | 0 | 1 | 0 | Whitehouse |
| 94 | Erimi | 1 | 0 | 0 | Whitehouse |
| 94 | Idalion | 1 | 1 | 0 | Whitehouse |
| 94 | Kalavassos | 1 | 0 | 0 | Whitehouse |
| 94 | Kalopsidha | 0 | 1 | 0 | Whitehouse |
| 94 | Karmi | 0 | 1 | 0 | Whitehouse |
| 94 | Karpasia | 0 | 0 | 1 | Whitehouse |
| 94 | Kato Paphos | 1 | 1 | 0 | Whitehouse |
| 94 | Khirokitia | 1 | 0 | 0 | Whitehouse |
| 94 | Kition | 0 | 0 | 1 | Whitehouse |
| 94 | Kouklia/ Old Paphos | 0 | 1 | 0 | Whitehouse |
| 94 | Kourion | 1 | 1 | 1 | Whitehouse |
| 94 | Krini | 0 | 1 | 0 | Whitehouse |
| 94 | Ktima | 0 | 0 | 1 | Whitehouse |
| 94 | Kyrenia | 0 | 0 | 1 | Whitehouse |
| 94 | Kythrea | 1 | 0 | 0 | Whitehouse |
| 94 | Lapithos | 1 | 0 | 0 | Whitehouse |
| 94 | Myrtou | 0 | 1 | 0 | Whitehouse |
| 94 | Nikosia | 0 | 1 | 1 | Whitehouse |
| 94 | Nitovikla | 0 | 1 | 0 | Whitehouse |
| 94 | Palaiokastro | 0 | 1 | 0 | Whitehouse |
| 94 | Palaioskoutella | 0 | 1 | 0 | Whitehouse |
| 94 | Petra tou Limniti | 1 | 0 | 0 | Whitehouse |
| 94 | Philia | 0 | 1 | 0 | Whitehouse |
| 94 | Pyla-Kokkinokremmos | 0 | 1 | 0 | Whitehouse |
| 94 | Salamis | 0 | 1 | 1 | Whitehouse |
| 94 | Sinda | 0 | 1 | 0 | Whitehouse |
| 94 | Soli/Ambelikou | 1 | 0 | 0 | Whitehouse |
| 94 | Sotira | 1 | 0 | 0 | Whitehouse |
| 94 | Troulli | 1 | 0 | 0 | Whitehouse |
| 94 | Vasilia | 0 | 1 | 0 | Whitehouse |
| 94 | Vouni | 1 | 1 | 0 | Whitehouse |
| 94 | Vounous | 0 | 1 | 0 | Whitehouse |

Table 7: Classification of specific sites in the *Whitehouse Atlas*, continued

| Map page | Site name | Neolithic | Bronze Age | Iron Age | Source |
|----------|----------------------|-----------|------------|----------|---------------------------|
| 96 | Amnisos | 0 | 1 | 0 | Wikipedia |
| 96 | Apesokari | 1 | 1 | 0 | Wikipedia |
| 96 | Apodhoulou | 1 | 1 | 0 | Whitehouse |
| 96 | Arkhanes | 0 | 1 | 0 | Wikipedia |
| 96 | Armenoi | 1 | 1 | 0 | Minoan Crete |
| 96 | Ayia Triadha | 0 | 1 | 1 | Wikipedia (Hagia Triadna) |
| 96 | Diktaean Cave | 1 | 1 | 0 | Wikipedia (Psychro Cave) |
| 96 | Erganos | 1 | 1 | 0 | Whitehouse |
| 96 | Fournou Korifi | 0 | 1 | 0 | Minoan Crete |
| 96 | Gournes | 1 | 1 | 0 | Whitehouse |
| 96 | Gournia | 0 | 1 | 0 | Minoan Crete |
| 96 | Idaeon Cave | 1 | 1 | 0 | Wikipedia |
| 96 | Kamares Cave | 1 | 1 | 0 | Wikipedia |
| 96 | Karfi | 0 | 1 | 0 | Wikipedia |
| 96 | Katsamba | 1 | 1 | 0 | Whitehouse |
| 96 | Khania | 1 | 1 | 1 | Wikipedia |
| 96 | Knossos | 1 | 1 | 1 | see notes |
| 96 | Krasi | 1 | 1 | 0 | Wikipedia (Malia, Crete) |
| 96 | Mallia | 0 | 1 | 0 | see notes |
| 96 | Mirsini | 1 | 1 | 0 | Whitehouse |
| 96 | Mirtos | 1 | 1 | 0 | Minoan Crete |
| 96 | Mitropolis | 1 | 1 | 0 | Whitehouse |
| 96 | Mochlos | 0 | 1 | 0 | Minoan Crete |
| 96 | Monastiraki | 0 | 1 | 0 | Wikipedia |
| 96 | Mouliana | 1 | 1 | 0 | see notes |
| 96 | Palaikastro | 0 | 1 | 0 | Minoan Crete |
| 96 | Petras | 0 | 1 | 0 | Wikipedia |
| 96 | Phaistos | 1 | 1 | 1 | Wikipedia |
| 96 | Pirgos (Nirou Khani) | 0 | 1 | 0 | Wikipedia |
| 96 | Platanos | 1 | 1 | 0 | Whitehouse |
| 96 | Plati | 1 | 1 | 0 | Whitehouse |
| 96 | Praisos | 1 | 1 | 1 | Wikipedia |
| 96 | Pseira | 1 | 1 | 0 | Wikipedia |
| 96 | Rousses | 1 | 1 | 0 | Whitehouse |
| 96 | Sklavokampos | 0 | 1 | 0 | Wikipedia |
| 96 | Stavromenos | 0 | 1 | 0 | see notes |
| 96 | Tylissos | 0 | 1 | 0 | Wikipedia |
| 96 | Vasiliki | 0 | 1 | 0 | Wikipedia |
| 96 | Vathypetro | 0 | 1 | 0 | Minoan Crete |
| 96 | Zakro | 0 | 1 | 0 | Wikipedia |
| 96 | Zou | 1 | 1 | 0 | Minoan Crete |

Table 7: Classification of specific sites in the *Whitehouse Atlas*, continued

| Map page | Site name | Neolithic | Bronze Age | Iron Age | Source |
|----------|-------------------|-----------|------------|----------|------------------------|
| 102 | Adana (Ataniya) | 1 | 1 | 1 | Wikipedia |
| 102 | Al Mina | 0 | 0 | 1 | Wikipedia |
| 102 | Amrit/Marathus | 0 | 1 | 0 | Wikipedia |
| 102 | Antioch | 0 | 0 | 1 | Wikipedia |
| 102 | Aradus | 0 | 1 | 1 | Wikipedia |
| 102 | Askalon | 1 | 1 | 1 | Wikipedia |
| 102 | Atchana/Alalakh | 0 | 1 | 0 | Wikipedia |
| 102 | Atlit | 0 | 1 | 1 | Wikipedia |
| 102 | Beersheba | 1 | 1 | 1 | Wikipedia |
| 102 | Berytus | 0 | 0 | 1 | Wikipedia |
| 102 | Byblos | 1 | 1 | 1 | Wikipedia |
| 102 | Enkomi | 0 | 1 | 0 | Wikipedia |
| 102 | Gaza | 0 | 1 | 1 | Wikipedia |
| 102 | Hazor | 0 | 1 | 1 | Wikipedia |
| 102 | Jaffa | 1 | 1 | 1 | Wikipedia |
| 102 | Kadesh | 1 | 1 | 0 | Wikipedia |
| 102 | Kourion | 1 | 1 | 1 | Wikipedia |
| 102 | Megiddo | 1 | 1 | 1 | Wikipedia |
| 102 | Minet el-Beida | 0 | 1 | 1 | see notes |
| 102 | Nikosia | 0 | 1 | 1 | Wikipedia |
| 102 | Salamis | 0 | 1 | 1 | Wikipedia |
| 102 | Samaria | 1 | 1 | 1 | New World Encyclopedia |
| 102 | Sarepta | 0 | 1 | 1 | Wikipedia |
| 102 | Shechem | 1 | 1 | 1 | Wikipedia |
| 102 | Sidon | 1 | 1 | 1 | Wikipedia |
| 102 | Simyra | 0 | 1 | 1 | Wikipedia |
| 102 | Tarsus | 1 | 1 | 1 | Wikipedia |
| 102 | Tripolis | 0 | 0 | 1 | Wikipedia |
| 102 | Tyre | 0 | 1 | 1 | Wikipedia |
| 102 | Ugarit/Ras Shamra | 1 | 1 | 0 | Wikipedia |
| 122 | Bahrija | 0 | 1 | 0 | Whitehouse |
| 122 | Borg in Nadur | 0 | 1 | 0 | Whitehouse |
| 122 | Ghar Dalam | 1 | 1 | 0 | Whitehouse |
| 122 | Skorba | 1 | 0 | 0 | Whitehouse |
| 122 | Tarxien | 1 | 1 | 0 | Whitehouse |

Sources and notes for site classification

Dundartepe: The Cambridge Ancient History, 3rd ed. Vol. 1, Part 2, Early History of the Middle East, eds. I. E. S. Edwards, C. J. Gadd, N. G. L. Hammond, 1971, p. 400 and Ancient West and East, Vol 1, Number 2, 2002, ed. Gocha R. Tsetskhladze, p.245

TAY Project: <http://www.tayproject.org/veritabeng.html> under the site name

Wikipedia: <https://en.wikipedia.org> under the site name

Beisamoun: Israel Antiquities Authority, Beisamoun (Mallaha), http://www.hadashot-esi.org.il/report_detail_eng.aspx?id=809

New World Encyclopedia: <http://www.newworldencyclopedia.org> under the site name

Tell Beit Mirsim: Biblewalks, <http://www.biblewalks.com/Sites/BeitMirsim.html>

Akrotiraki: <http://www.aegeanislands.gr/discover-aigaio/archaeology-aigiao/archaeology-aigaio.html>

Dokathismata: Entry under Amnorgos, end date unclear but clearly settled during the Classical period

Emborio: www.archaeology.wiki/blog/2016/03/07/history-chios-seen-exhibits-archaeological-museum/

Grotta: <http://www.naxos.gr/en/naxos/sights-and-sightseeing/archaeological-sites/article/?aid=19>

Poliochni: End date is unclear

Vryokastro: <http://www.tinosecret.gr/tour/museums/512-vryokastro.htm>

Minoan Crete: <http://www.minoancrete.comusingpull-downmenus>

Knossos: Wikipedia lists Knossos as abandoned around 1100 BC but the Whitehouse Atlas has it appear again on Iron Age map 106

Mallia: <http://www.perseus.tufts.edu/hopper/artifact?name=Mallia&object=Site>

Mouliana: <https://moulianaproject.org>

Stavromenos:

<https://greece.terrabook.com/rethymno/page/archaeological-site-of-stavromenos>

Minet el-Beida: Wikipedia. No independent dating info for Minet el-Beida. It is routinely referred to as the harbor of Ugarit. Hence dating the same as Ugarit

7 Appendix B: Additional specifications

As the historical record in section 2 has shown, seafaring at short distances was already common in the Mediterranean before the Iron Age. However, with the advent of the Phoenicians, regular long-distance travel and trade across the open sea emerged. Our measure of 500km connectedness might conflate short-distance connectedness with long-run one. In table 8, we therefore create a different version of connectedness that is based on points that can be reached at a distance of 100 to 500km, i.e. excluding points within 100km. The results are very similar to the basic ones in table 2.

Not only connections over sea mattered but land trade was important as well. Rivers constituted important entry points for land based trade. As a result, cells close to river mouths should be relatively advantaged. The inland connections afforded by river mouths might also interact with the maritime connections we have analyzed so far. Sea and inland trade maybe either complements or substitutes. Table 9 investigates these possibilities by entering a regressor for distance to the nearest river mouth in our regressions, and interacting it with our sea based connectivity measure. The main effect of the connectedness variable is affected little by these additions. The main effect for distance to a river mouth is positive, indicating that locations close to a river mouth have fewer settlements, not more. But the coefficients are small and not significant. The interaction terms are similarly small, except in the specification without the Aegean where we find a positive (but at most marginally significant) interaction effect. This would suggest that coastal and inland connections are substitutes rather than complements.

Table 8: Results when excluding short-distance connectedness

| Dependent variable | (1) | (2) | (3) |
|----------------------------------|----------------|----------------|----------------|
| Pleiades Wide 750 BC | 0.50 (0.07) | 0.43 (0.13) | 0.45 (0.08) |
| Pleiades Narrow 750 BC | 0.26 (0.08) | 0.51 (0.15) | 0.22 (0.09) |
| Whitehouse Atlas Iron Age | 0.27 (0.08) | 0.52 (0.17) | 0.19 (0.09) |
| Observations | 3646 | 2750 | 3044 |
| Controls: | | | |
| Longitude and Latitude | X | X | X |
| Distance to the Fertile Crescent | X | X | X |
| Dropping Aegean | | X | |
| Dropping North Africa | | | X |

Coefficients from regressions on connectedness between 100 and 500km. Standard errors clustered at the level of 2x2 degree cells, in parentheses.

Table 9: Results with interactions

| Regressor | (1) | (2) | (3) |
|----------------------------------|----------------|----------------|----------------|
| Connectedness | 0.49 (0.07) | 0.43 (0.14) | 0.45 (0.08) |
| Distance to river mouth | 0.08 (0.06) | 0.17 (0.13) | 0.07 (0.09) |
| Interaction | 0.09 (0.05) | 0.19 (0.11) | 0.02 (0.07) |
| Observations | 3646 | 2750 | 3044 |
| Controls: | | | |
| Longitude/Latitude | X | X | X |
| Distance to the Fertile Crescent | X | X | X |
| Dropping Aegean | | X | |
| Dropping North Africa | | | X |

Pleiades wide data. Coefficients from regressions on 500km connectedness. Standard errors clustered at the level of 2x2 degree cells, in parentheses.