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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: the first systematic crossing of open seas in the Mediterranean during the time of the Phoenicians. We construct a measure of connectedness along the shores of the sea. This connectivity varies with the shape of the coast, the location of islands, and the distance to the opposing shore. We relate connectedness to local growth, which we measure using the presence of archaeological sites in an area. 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 massive expansions in maritime trade: 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 presence 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 others 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 straight 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. When these expand and multiply there are more traces in the archaeological record. We find a pronounced relationship between connectivity and development in our dataset for the Iron Age around 750 BC, when the Phoenicians began to systematically traverse the open sea. We have less evidence whether there was any relationship between connectivity and sites for earlier periods when the data on sites are poorer. Connectivity might already have mattered during the Bronze Age when voyages occurred at some frequency, maybe at more intermediate distances. 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 both economic historians and archaeologists; see e.g. Temin (2006) for the Iron Age Mediterranean, Algaze (2008) for Mesopotamia, Barjamovic et al. (2017) for

Assyria, 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 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 a lesser 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 (2018) and Donaldson and Hornbeck (2016) use railroads, and Pascali (2017) 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, Hanlon 2017, Michaels and Rauch 2018). 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 locations near the coast 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 prehistoric 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 example for the Bronze Age Aegean. Barjamovic et al. (2017) conduct a similar exercise for Assyria based on a gravity model. 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. Horden and Purcell (2000) stress that the area consists of many micro-regions. Geography and climate make the Mediterranean prone to 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

[1] The 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.

Agriculture around the Mediterranean began in the Levant some time 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 also have been a reason for the formation of networks. Trade networks facilitated both comparative advantage based exchange and insurance. 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 during this period.

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 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. 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 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. Traveling 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 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 based on a coastline map of the earth from Bjorn Sandvik's public domain map on world borders.[2] We use a Lambert Azimuthal Equal Area projection, with the coordinates 39N, 18.5E as reference point, which is close to the center of the part of the map we study. No projection avoids distortions completely but this one works well for the study of a limited geographical area. The distances of the edges of our 10×10 km grid are close to the true distances: Even at points furthest from the reference points, such as Gibraltar in the west and Sinai in the east, measurement error of both vertical and horizontal lines remains within less than 2 percent of true distances.

We define a grid-cell as coastal if its centroid is within 5 km of a coastline. Grid-cells whose centroid is more than 5 km away from a landmass are classified as sea, the remaining cells are classified as land. Our estimation dataset consists of land cells within 50 km of a coast cell, and each cell is an observation. There are 11,999 cells in this dataset of which 3,352 are coastal.

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 shipping

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

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 often used circular routes on their travels (Arnaud 2007). Our measure is not supposed to mimic sailing routes directly but simply capture opportunities.[3]

Figure 2 displays the measure c_{500} for a distance of 500 km; 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. Figure 3 shows a histogram of the log connectedness measure for a distance of 500 km. The modes in the rightmost part of the histogram are associated with points in the Aegean.

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 km grid is coarse enough to smooth out many local geographic details. We will capture bays 50 km across but not those 5 km 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

[3]We do not attempt to use wind patterns to calculate sailing times. Leidwanger (2013), combining modern data on wind speeds and prevailing directions with the sailing logs from sea trials with the replica of a 3rd century BC wreck on a Piraeus to Cyprus route, is an attempt to do this for a small area a few hundred kilometers across off the Turkish coast. He discusses shortcomings and problems with this approach. His work illustrates how far away we still are from being able to extend an exercise like this to an area like the entire Mediterranean.

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, using a Cylindrical Equal Area projection. 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 dataset. While we define our global connectedness measure for the whole world, our analysis focuses 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 no 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. 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.[4]

We measure economic development by counting archaeological sites of settlements. Historians and archaeologists have long debated to what extent the material evidence that has been discovered is representative of actual historical conditions. On one end of the

[4]We only show the connectedness measure for countries where we also have outcome data, hence some countries have missing cells in figure 4.

spectrum are warnings like that of Manning (2018, p. 64) that "archaeological evidence, especially for settlement history, is extremely uneven for the first millennium BCE." The idea of a "positivist fallacy" of "making archaeological prominence and historical importance into almost interchangeable terms: in equating what is observable with what is significant" goes back to at least Snodgrass (1987, p. 38). At the other end are optimists such as Broodbank (2013), who concludes that "only a single imbalance is so devastating that it threatens to undermine the integrity of the overall study of the Mediterranean. This is the dearth of information on the early societies of the Mediterranean North Africa" (p. 37). We deal with the North African exceptionalism by showing results excluding the North African coast. But Broodbank concludes that "the low archaeological profile of much of Mediterranean North Africa may not entirely be due to a lack of prospection ... In the coming chapters we shall encounter several indications that this was indeed the case" (2013, p. 39).

Whether the archaeological record is representative of history is one issue, another is to obtain a quantitatively useful snapshot of the archaeological record. Our data on settlements for our period of investigation come from the Pleiades Project, an electronic database (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.[6]

The Pleiades data consists of three different databases of which we use the "pleiades-

[5]Available at `pleiades.stoa.org`. We use a version of the dataset downloaded in September 2017.

[6]Various historians have assured us that the *Barrington Atlas* is probably the most representative source for the period we are studying.

places" dataset. It offers a categorization as well as an estimate of the start and end date for each place. We only keep units that have a defined start and end date, and limit the dataset 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. In the "wide" measure, we include any man-made structure, excluding only natural landmarks (e.g. rivers) and administrative units.[7]

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.[8] 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 dataset has 1,565 sites in 750 BC and 5,707 in 1 AD but only 142 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 less reliable.[9]

[7] The raw Pleiades dataset contains some sites that are duplicates and/or have been moved to the errata section of Pleiades. We drop those sites from our analysis.

[8] An exception to this are roads and canals, which typically cannot be interpreted as a single point, and where we therefore also include rough locations.

[9] In Appendix A we present some alternative estimates based on the much earlier *Archaeological Atlas of the World* (Whitehouse and Whitehouse 1975), which is more focused on the pre-Classical era but has problems of its own.

Our measure of urbanization for a given cell is the number of sites that exist at time t and fall into that cell. We prefer a count of sites over an indicator given that it is scale invariant with respect to the grid size. The maximum number of sites in a cell for the narrow Pleiades measure is 5 but for 98.5% of the cells the value is either 0 or 1.

For our global results, 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 our sample includes 123 countries.

4 Specification and results

We run regressions of the following type:

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

where u_{it} is the urbanization measure for grid point i, c_{di} is the log of the connectivity measure for distance d, and X_i are grid point control variables. For coastal cells, connectivity is simply the connectivity of the respective coastal cells. For inland cells, we assign the connectivity level of the closest coastal cell. 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 number of archaeological sites in each cell and year, 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 start by using only linear variables for latitude and longitude as control variables.

Latitude captures climatic variation due to the north-south gradient of the region. Climatic conditions also vary in the east-west orientation since proximity to the Atlantic moderates weather variability (Manning 2018, p. 85), and the longitude variable controls for this. Since some of our cells are up to 50 km inland, we also consider distance to the coast as an additional control variable, as well as 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). 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 200×200 km following Bester, Conley and Hanson (2011). Using a 400×400 km grid as cluster variable results in very similar standard errors.

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): We convert agroclimatic yields of 48 crops in $5' \times 5'$ cells under rain-fed irrigation and low levels of input into caloric yields and assign the maximal caloric yield of the closest $5' \times 5'$ to our grid cells. In the second row, we use Nunn and Puga's (2012) measure of ruggedness, averaged over our 10×10 km cells. Both ruggedness and agroclimatic conditions are standardized to have mean 0 and standard deviation 1. The third row looks at distance to the nearest river. For this, we used Wikipedia to create a list of all rivers longer than 200 km and geocoded their paths from FAO Aquamaps, dropping tributaries. We then calculate the distance from each cell to the nearest river, capping it at 50 km. To make the interpretation easier, we then take the negative of this measure, so that a positive coefficient on connectedness would mean that well-connected cells are closer to rivers. We use distance to the nearest mine, using data from the OXREP Mines Database (2017), coding distance in the same way as for rivers. For wind, we use the AMI Wind on ERS-1 Level 4 Monthly Gridded Mean Wind Fields provided by the Centre de Recherche et d'Exploitation Satellitaire (CERSAT), at IFREMER, Plouzané (France). This dataset contains monthly average wind speeds over oceans on a 1x1 degree grid. We average wind speed over the sailing period from March to October, using the data for 1993. Each coast cell is then assigned the value of the closest wind grid cell.

Column (1) in table 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 and the distance to the coast. Neither agricultural productivity, ruggedness, nor distance to rivers or mines seem to have a large association with our measure of connectedness once we control for the distance to the coast and the Fertile Crescent. The exception is wind speed, which correlates positively with connectedness.

Columns (3) and (4) show that dropping the Aegean from the sample sometimes leads to bigger associations but also impairs precision. When we control for distance to the coast and Fertile Crescent in the sample without the Aegean, associations between the balancing variables and connectedness tend to be small and insignificant, including for wind speed. The only exception is distance to rivers but this relationship is very imprecise. Outside of North Africa, a slight negative association between connectedness and agricultural productivity arises with controls. We are comforted by the fact that our measure of connectedness does not appear to be related to the five variables examined in the table in a systematic way across subsamples. This is especially true once we control for distance to the coast and the Fertile Crescent. As a result, we will use all of latitude, longitude, and distance to the coast and Fertile Crescent as controls in the analyses that follow.

4.1 Basic results

In table 2, we start by showing results for connections within 500 km and the settlement counts in 750 BC from our two datasets. 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 stronger results in the wide Pleiades data, and the association is highly significant. The magnitude of these estimates is large. Increasing the connectedness of a cell by one percent increases the number of archaeological sites by around 0.002. Table 2 reports the means of the dependent variables. A hundred percent increase in connectedness more than doubles the site count in the wide Pleiades data, suggesting an elasticity above one. The coefficient is slightly lower for the narrow site definition. Coefficients decrease in magnitude when we drop the Aegean in column (2), but they remain positive and substantial, indicating that the Aegean alone was not driving the results in column (1). Dropping North Africa in column (3) makes little difference compared to the original results.

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 3 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 same is true when we exclude short connections within 100 km from the connectedness variable in table 4. This is important as we are primarily interested in the longer range connections which opened up with open sea crossing.

The connectedness variable measures how many coastal points a ship can reach from a given starting destination. Coastal points are only a proxy for market access. A more direct measure would be to measure how many settlements a ship can reach, rather than how many coastal points. In table 5 we use such a more direct measure of market access by counting the number of sites within distance d. To account for the endogenous location of settlements we instrument this market access with the connectedness variable, both in logs. The first stage F-tests we report show that connectedness is strongly correlated with market access. The magnitude of the 2SLS effect is similar for all these specifications to the one seen in the connectedness estimation. A one percent increase in market access increases the number of sites by around 0.002.[10] This effect is large compared with existing estimates of the impact of market access. For example, it is about twice as large as the estimate for the land value elasticity in Donaldson and Hornbeck (2016). This may reflect the unusual importance of connections in the Iron Age Mediterranean, where trade served both comparative advantage and insurance functions, as well as facilitating migrations and the spread of ideas. It may also show that in a less technologically advanced economy, market access mattered more relative to other fundamentals.

Table 6 shows some further robustness checks of our results for different subsamples. Col-

[10]Table 7 in Appendix A contrasts these estimates with an OLS estimator. Magnitudes are similar when we exclude the Aegean. Otherwise the 2SLS estimates are larger.

umn (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. 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 4) or only continental cells (in column 3). Both matter, but islands are more important for our story. These results suggest that the relationships we find are not driven only by a particular subsample or connection measure.[11]

Our previous results are for connections within a 500 km radius. Figure 5 displays coefficients for connectivities at different distances, using the basic specification with the narrow Pleiades set of sites in the year 750 BC. 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 after 500 km, 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 this.

Figure 6 shows results from the narrow Pleiades data over time using the 500 km connectedness measure. The total number of sites differs by year. To enable comparison over time we divide the left hand side by the total number of sites in each year, turning the estimates effectively into elasticities. The figure has various features. Coefficients are positive and sizable but mostly insignificant until 1,000 BC but increase in 750 BC, consistent with the Iron Age expansion of open sea routes. 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

[11] We find very similar results using a measure of eigenvector centrality instead of our connectedness variable, which adds weighting to connecting cells, but it is very highly correlated to the original connections measure.

the presence of sites is replicated across various datasets 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 explore this last issue in the following subsection.

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 2018, 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 1,565 sites in the wide dataset and this number increases to 5,707 in 1 AD at the height of the Roman Empire.[12] There are only 11,999 cells in our dataset. As a result, our grid

[12]See table 8 in the appendix for more details on the numbers of sites in each dataset and time period.

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 dataset: By the height of the Roman Empire many grid points will be the location of archaeological sites. Moreover, existing sites may be concentrated in well-connected locations already and maybe these sites grow further but our data don't provide an extensive margin of settlement size. New settlements after 750 BC, on the other hand, might arise in unoccupied locations, which are actually 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 7 shows results for the period 500 BC to 500 AD. As in figure 6, we show coefficients divided by the mean number of sites in the period. 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 more stable (and only fall because site density rises), while the relationship between connectedness and the location of entering sites becomes weaker and even turns negative towards the end of the period. 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 towards the end of 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, using population in 1 AD from McEvedy and Jones (1978) as outcome variable. Population density is measured at the level of modern countries, and the sample includes 123 countries. Recall that we compute connectivity for coastal cells based on a grid of 50 x 50 km cells for this exercise.

We aggregate the world data to the level of countries, which is the unit at which the dependent variable is measured anyway. Figure 8 is a scatter plot of c_{500} against log 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 1.24 (0.99). This estimate very similar to the implied elasticity for the Mediterranean in table 2, although the nature of the dependent variable is different. 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.

Additionally, we regress log population density in 1 AD on log 500km connectedness, controlling for absolute values of latitude and again weighting by the number of coastal grid points in each country.[13] This results in a point estimate for connectivity of 1.67 with a standard error of 0.85.

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 Mediter-

[13]Neither 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.

ranean 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.

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Figure 1: Timeline

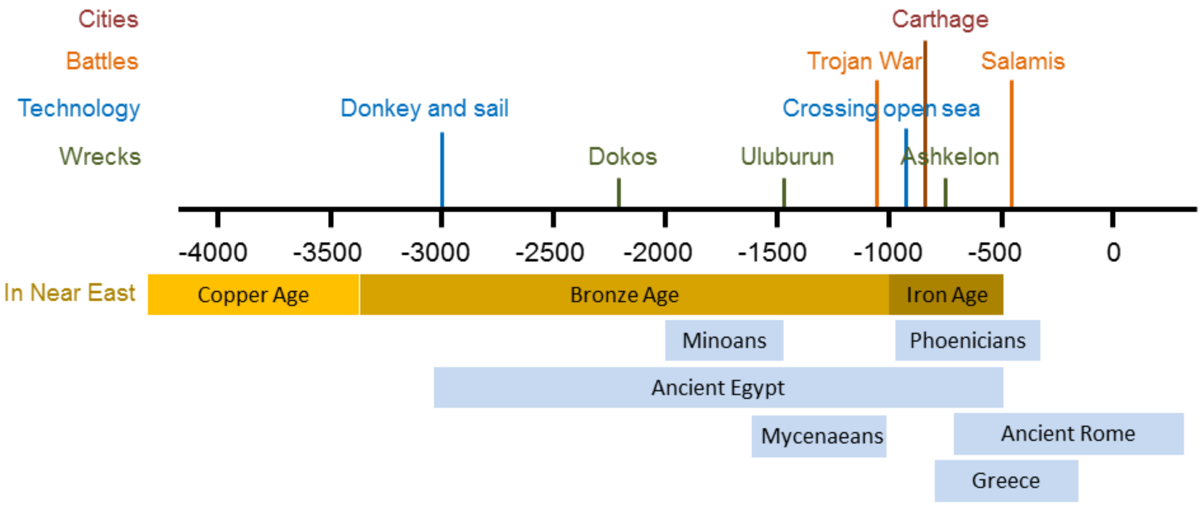


Figure 2: Connectedness in the Mediterranean for a 500 km distance

Figure 3: Distribution of log connectedness at 500 km distance

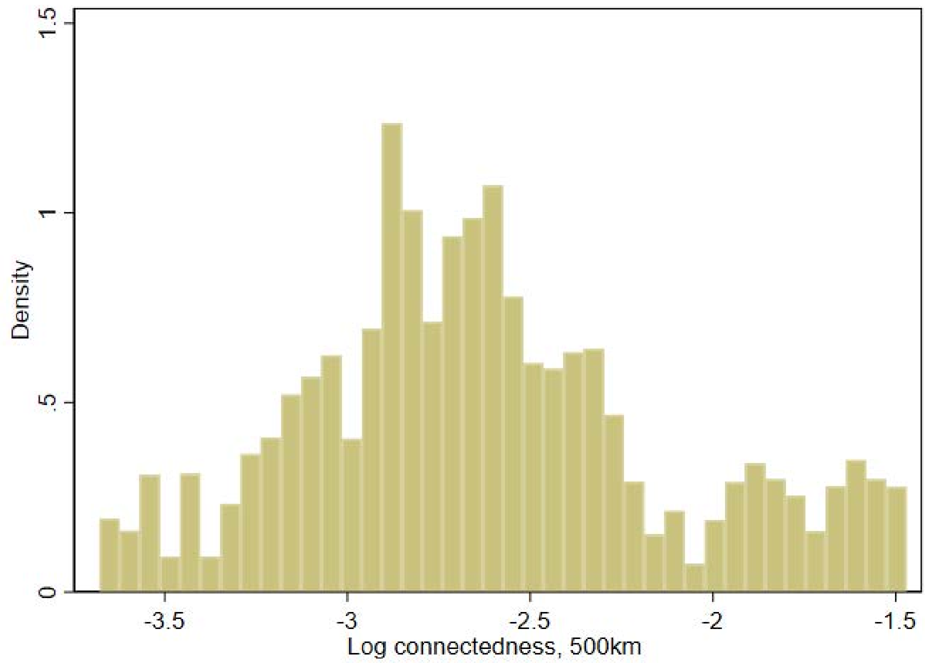


Figure 4: Connectedness in the world for a 500 km distance

Figure 5: Coefficients for narrow Pleiades sites by distance, 750BC

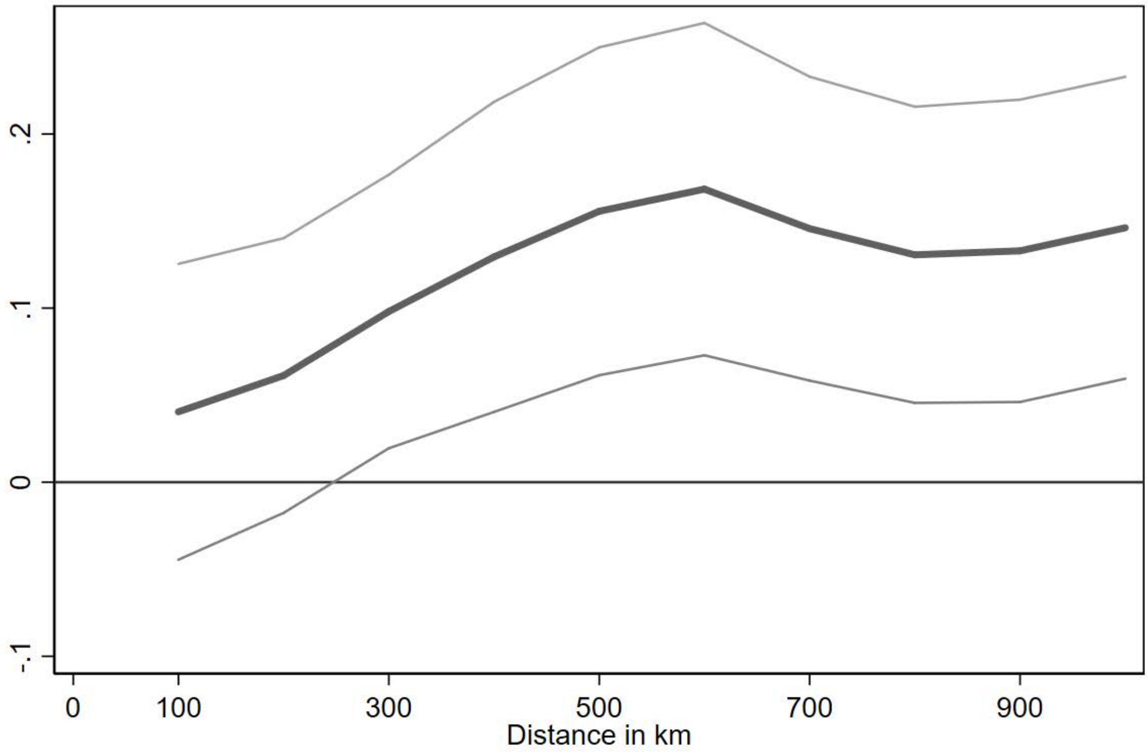


Figure 6: Scaled coefficients for narrow Pleiades sites over time, 500 km connectedness measure

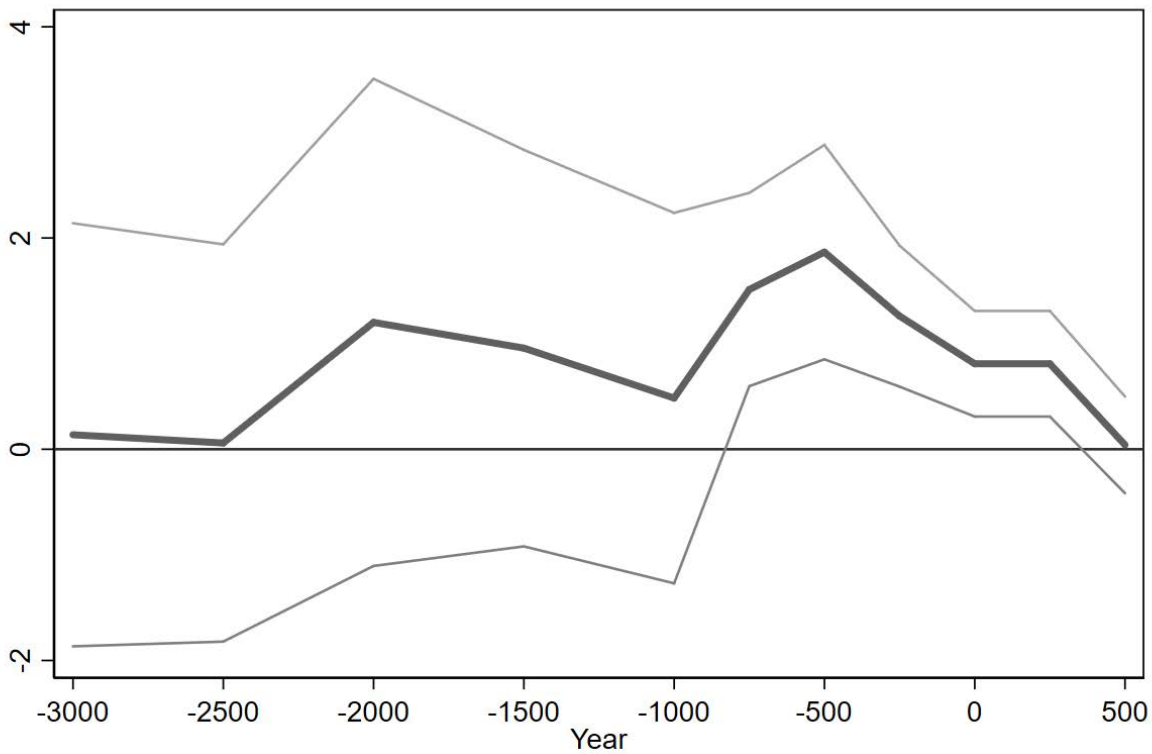


Figure 7: Scaled coefficients for wide Pleiades sites: Entry, existing, total

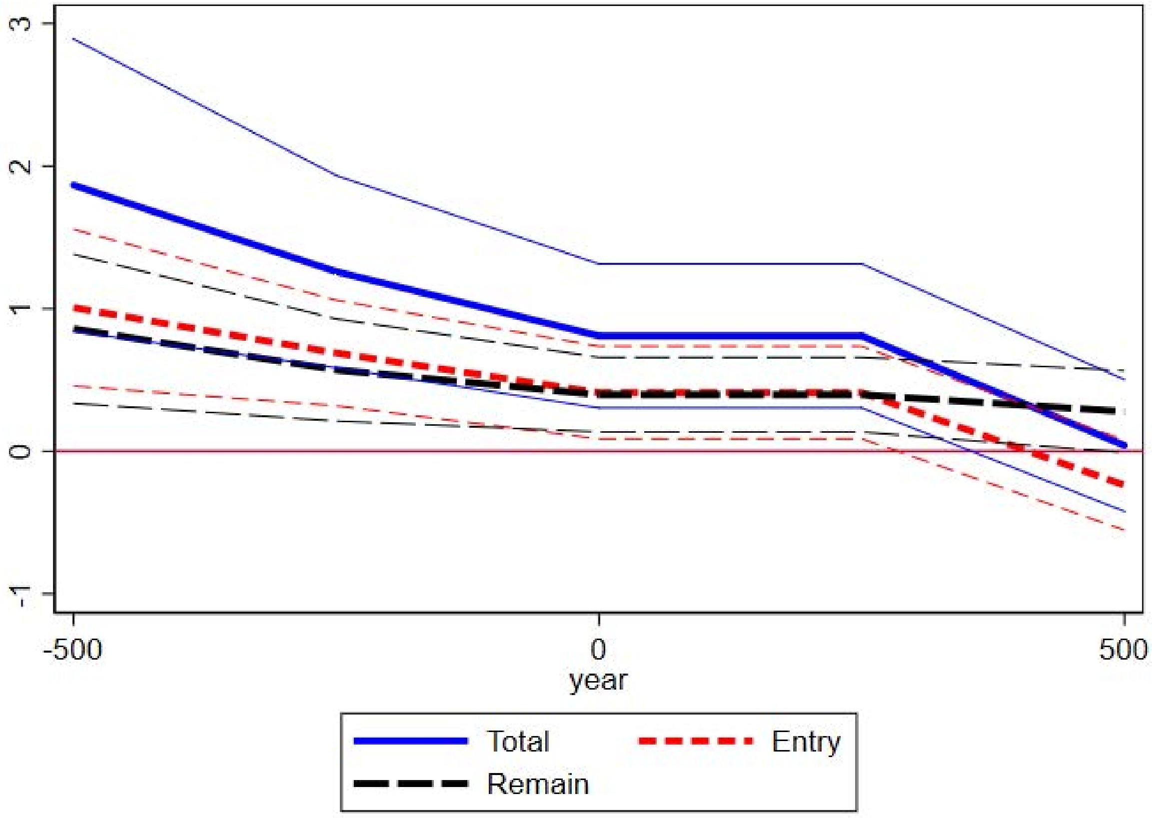
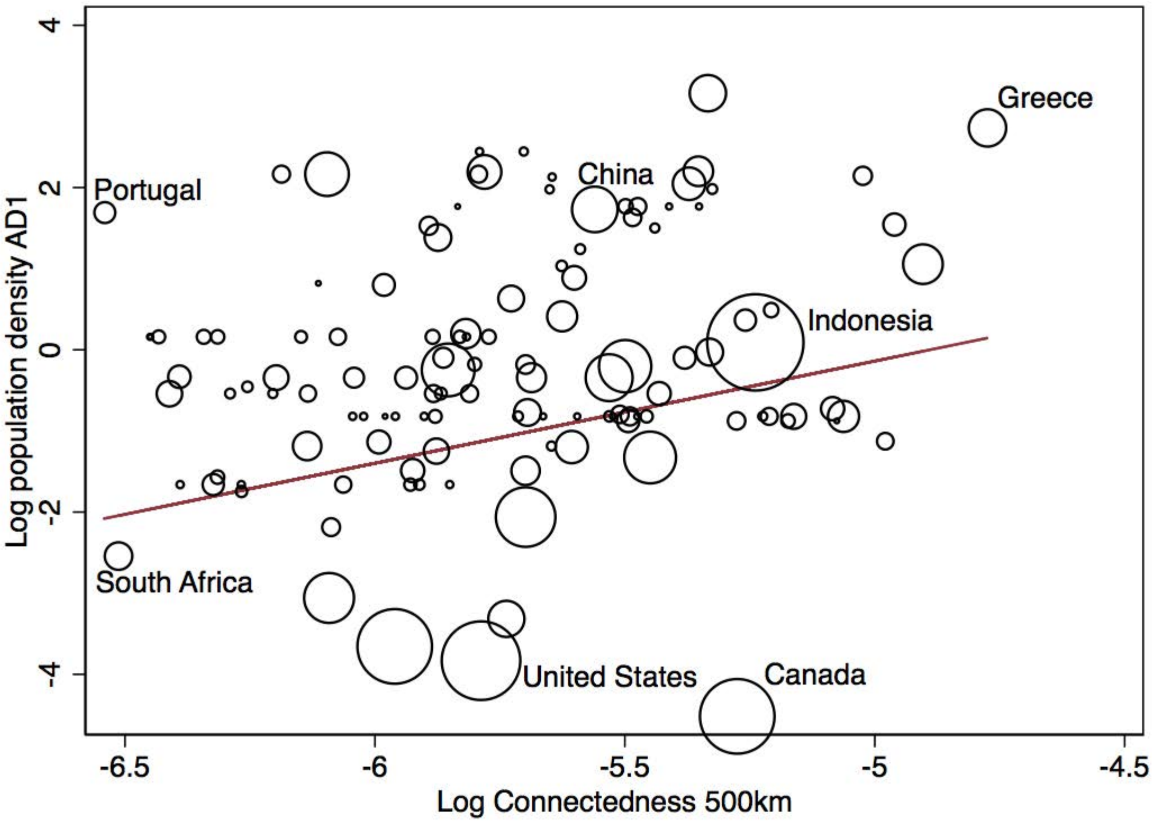


Figure 8: Connectedness and population density around 1AD at the world scale



Weights reflect length of coasts of countries. For graphical reasons, the figure omits Bermuda, which is an outlier in terms of connectedness. This is inconsequential for our estimates. The weighted slope (standard error) with Bermuda is 1.24 (0.99), as opposed to 1.26 (1.01) without it. When we include a control variable for the absolute latitude the slope becomes 1.67 (0.85) with Bermuda and 1.70 (0.86) without it.

Table 1: Balancing checks

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
Agricultural productivity	0.46	0.00	0.53	0.07	0.16	-0.17
(following Galor and Özak (2016))	(0.08)	(0.10)	(0.14)	(0.16)	(0.11)	(0.09)
Ruggedness	0.19	0.15	0.06	-0.05	-0.29	-0.13
(following Nunn and Puga (2012))	(0.14)	(0.19)	(0.29)	(0.28)	(0.16)	(0.16)
River proximity	-3.02	-2.86	-4.40	-3.83	-2.46	-2.94
	(1.73)	(2.14)	(2.96)	(3.33)	(2.09)	(2.19)
Mines proximity	-0.36	0.11	-0.12	0.42	-1.95	-0.03
	(0.37)	(0.74)	(1.21)	(1.47)	(0.74)	(0.67)
Wind	0.32	1.05	-0.52	0.24	0.68	1.20
	(0.16)	(0.23)	(0.30)	(0.34)	(0.17)	(0.22)
Observations	11999	11999	10049	10049	9448	9448
Controls:						
Longitude and latitude	X	X	X	X	X	X
Distance to coast and Fertile Crescent		X		X		X
Dropping Aegean			X	X		
Dropping North Africa					X	X

Coefficients from regressions of various dependent variables on 500 km log connectedness. Standard errors clustered at the level of 200×200 km cells, in parentheses.

Table 2: Basic results

Dependent variable	Dep. var. mean	(1)	(2)	(3)
Pleiades wide 750BC	0.130	0.207	0.102	0.203
		(0.056)	(0.043)	(0.056)
Pleiades narrow 750BC	0.103	0.156	0.074	0.155
		(0.048)	(0.035)	(0.048)
Observations		11999	10049	9448
Controls:				
Longitude and latitude		X	X	X
Distance to coast and Fertile Crescent		X	X	X
Dropping Aegean			X	
Dropping North Africa				X

Coefficients from regressions on 500 km log connectedness. Standard errors clustered at the level of 200×200 km cells, in parentheses.

Table 3: Results excluding coastal cells from outcome definition

Dependent variable	(1)	(2)	(3)
Pleiades wide 750BC	0.174	0.093	0.182
	(0.064)	(0.047)	(0.063)
Pleiades narrow 750BC	0.130	0.072	0.139
	(0.053)	(0.041)	(0.053)
Observations	8647	7552	6631
Controls:			
Longitude and latitude	X	X	X
Distance to coast and Fertile Crescent	X	X	X
Dropping Aegean		X	
Dropping North Africa			X

Coefficients from regressions on 500 km log connectedness. Standard errors clustered at the level of 200×200 km cells, in parentheses. Coastal cells and their sites are omitted from the sample.

Table 4: Results excluding short connections

Dependent variable	(1)	(2)	(3)
Pleiades wide 750BC	0.200	0.101	0.196
	(0.052)	(0.042)	(0.053)
Pleiades narrow 750BC	0.151	0.075	0.151
	(0.045)	(0.034)	(0.045)
Observations	11999	10049	9448
Controls:			
Longitude and latitude	X	X	X
Distance to coast and Fertile Crescent	X	X	X
Dropping Aegean		X	
Dropping North Africa			X

Coefficients from regressions on 100 km - 500 km log connectedness. Standard errors clustered at the level of 200x200 km cells, in parentheses.

Table 5: 2SLS regressions for market instrumenting with connectedness

Dependent variable	(1)	(2)	(3)
Pleiades wide 750BC	0.225	0.099	0.250
	(0.056)	(0.038)	(0.065)
First-stage F statistic	32	17	37
Pleiades narrow 750BC	0.178	0.073	0.213
	(0.050)	(0.031)	(0.060)
First-stage F statistic	30	16	32
Observations	11999	10049	9448
Controls:			
Longitude and latitude	X	X	X
Distance to coast and Fertile Crescent	X	X	X
Dropping Aegean		X	
Dropping North Africa			X

Coefficients from a 2SLS regression of various dependent variables on log market access for 500 km. In the first stage market access is instrumented using 500 km log connectedness. Standard errors clustered at the level of 200x200 km cells, in parentheses.

Table 6: Results for different connections

	Standard 500 km connectedness			
	(1)	(2)	(3)	(4)
Pleiades wide 750BC	0.207	0.170	0.065	0.078
	(0.056)	(0.076)	(0.071)	(0.026)
Pleiades narrow 750BC	0.156	0.141	0.062	0.062
	(0.048)	(0.062)	(0.057)	(0.021)
Observations	11999	10400	10400	8937
From	All	Continent	Continent	Continent
To	All	All	Continent	Island

Coefficients from a regression on 500 km log connectedness for different subsamples. Robust standard errors, clustered at the level of 200×200 km cells, in parentheses. All regressions control for longitude, latitude, and distance to the coast and the Fertile Crescent.

6 Appendix A: Additional specifications

6.1 OLS vs 2SLS

Table 7 provides the 2SLS market access results from table 5, and contrasts them with their corresponding OLS coefficients.

6.2 Alternative data sources

The results in the body of this paper rely on the Pleiades dataset. We repeat part of the exercise using two alternative data sources. First we created an additional dataset 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. We therefore hoped it would help resolve the issue of whether the association between sites and connectedness changed between the Bronze and Iron Ages.

One possible disadvantage of the Whitehouse data 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 to choose the number of sites so as to fill each map without overcrowding it. 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. Nevertheless, the particular choice of maps may have influenced which sites are recorded in different parts of the

Mediterranean.

The number of sites each period is very different in the Pleiades, Whitehouse, and Barrington data (which we discuss below). Table 8 displays the number of sites we have in each dataset. We repeat the exercise with the Pleiades data from figure 5 using the Whitehouse data in figure 9, showing coefficients scaled by the average number of sites per cell for comparability again. We find positive associations between the connectedness measure and sites in the *Whitehouse Atlas*, both for the Bronze and Iron Age. As in the Pleiades data, the association is strongest for the measure around 500km. To account for the possibly artificial difference in site density across space in the *Whitehouse Atlas*, we include map fixed effects, where each fixed effect corresponds to sites visible on one of the Whitehouse maps (a site can be shown on more than one map). Figure 10 shows that results change a bit and become noisier, which reflects the fact that the maps absorb some geographic variation and the relatively small number of sites in the Whitehouse data. Given the confidence intervals, no clear pattern emerges from 10.

As a second alternative, we record sites directly from the *Barrington Atlas* (Talbert et al 2000). This atlas provides a unified source of towns and cities in the Greek and Roman period. One advantage of the Barrington maps is that they display the sizes of sites in three broad size classes but these are not recorded in the Barrington gazetteer, on which the Pleiades data are based. We digitize the location of cites on the main overview map of this atlas to have one unified source of cities, and record the size of cities visible on that map. The three different size classes are indicated by different font sizes on the map. Instead of an indicator for a site, we code the dependent variable with weights of 1, 2, and 3 corresponding to small, medium and large cities. We believe that this coding corresponds roughly to log size. The largest cities during this period had populations in the 100,000s (e.g. Rome, Carthage), while the smallest ones would have had populations in the 1,000s. This weighting by size allows us to add an intensive margin to the analysis.

We merge the sites from the Barrington map with the Pleiades dataset, which records other attributes of the cities, like the time when the site was active. Our dependent variable is either the size class of the city in a cell or the sum of the size classes if multiple cities are present in a cell. We scale the dependent variable by dividing by its mean in the period again to facilitate comparisons over time.

Figure 11 displays the scaled regression coefficients over the period 750 BC to 500 AD. It shows a similar downward trend of coefficients as we found in the Pleiades dataset in figure 6. Whether we weight cities by their size or not has very little influence on the results. This suggests that connectedness did not lead sites in better connected places to grow; rather the effects we find must be explained by entry. We should note that the Barrington size classification is not ideal as we only have one single size indicator. Presumably the *Barrington Atlas* records the peak size of the city but it does not provide any information of size over time. We also note that the Barrington results are very noisy, which reflects the relatively small number of sites on the map we coded.

Table 7: Market access regressions: 2SLS & OLS

	2SLS			OLS		
Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
Pleiades wide 750BC	0.225	0.099	0.250	0.124	0.091	0.147
	(0.056)	(0.038)	(0.065)	(0.023)	(0.021)	(0.031)
First-stage F statistic	32	17	37			
Pleiades narrow 750BC	0.178	0.073	0.213	0.091	0.065	0.121
	(0.050)	(0.031)	(0.060)	(0.018)	(0.016)	(0.026)
First-stage F statistic	30	16	32			
Observations	11999	10049	9448	11999	10049	9448
Controls:						
Longitude and latitude	X	X	X	X	X	X
Distance to coast and Fertile Crescent	X	X	X	X	X	X
Dropping Aegean		X			X	
Dropping North Africa			X			X

Coefficients from 2SLS and OLS regressions using 500km market access. Standard errors clustered at the level of 200x200 km cells, in parentheses.

Table 8: Number of sites in the different datasets

Time period	Pleiades narrow	Pleiades wide	Whitehouse	Barrington
-3000	28	37		
-2000	85	119		
-1500	105	142	243	
-1000	100	116		
-750	1,235	1,565	322	75
-500	2,126	2,772		97
0	3,617	5,707		120
500	2,265	3,667		107

Figure 9: Scaled Whitehouse results by distance, different periods

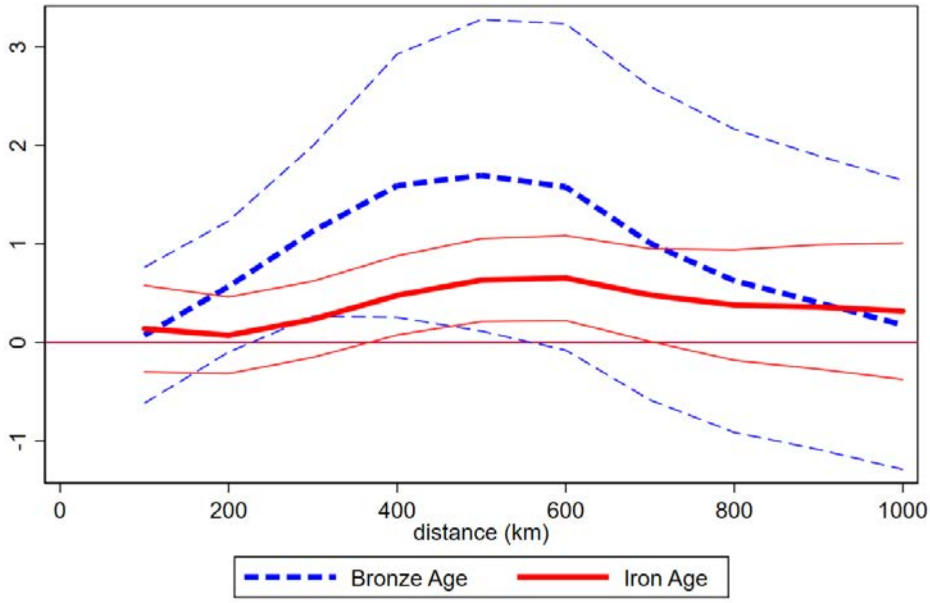


Figure 10: Scaled Whitehouse results by distance, different periods with map fixed effects

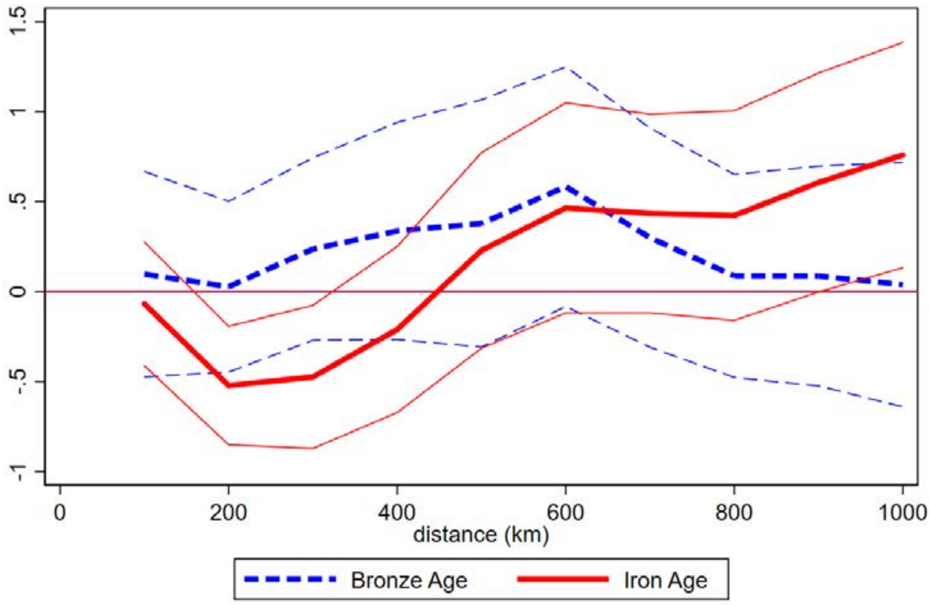
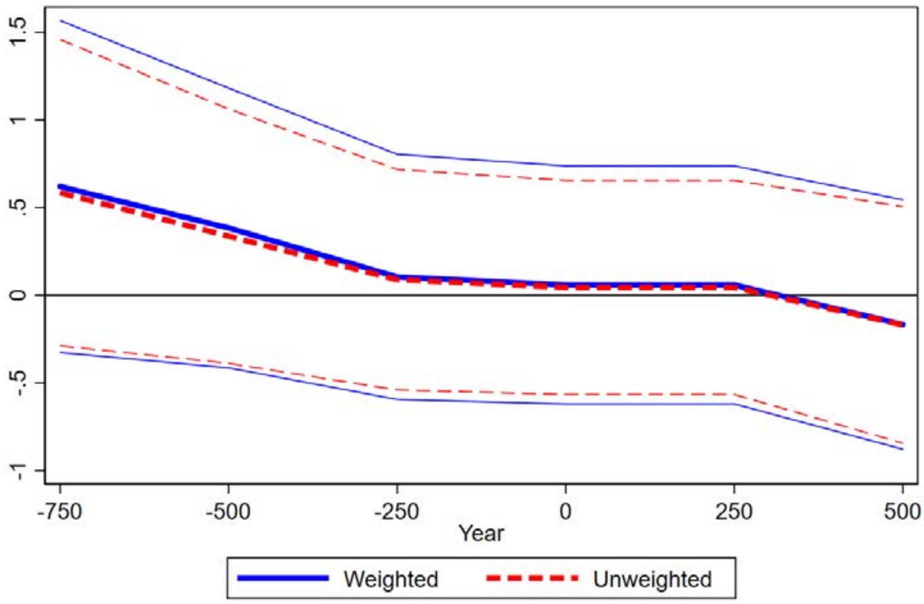


Figure 11: Scaled Barrington results over time, 500km connectedness measure



7 Appendix B: Coding of Whitehouse sites

To create the Whitehouse dataset, we geo-referenced all entries within 50km of the coasts on 28 maps covering the Mediterranean and Black Sea 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 below for details).

Table 9 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 10 provides details of our dating.

Table 9: 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 10: 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 10: 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 10: 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	Idaean 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 10: 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/archaelogical-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