The Diffusion of Epichoric Scripts and Coinage in the Ancient Hellenic Poleis [1]

Yuxian Chen* and Yannis M. Ioannides**

Version August 19, 2023

* Doctoral student, Department of Economics, Brown University Yuxian_Chen@brown.edu

** Neubauer Professor of Economics, Tufts University Yannis.Ioannides@tufts.edu

[1]Earlier versions of this paper were presented at the Urban Economics Association meetings, CRETE, Clark University, NBER Summer Institute – Urban Economics, BSE Summer Forum 2022 (Geography, Trade and Growth), and CEP/LSE Urban/Regional seminar. Thanks go to Xu Dong, Teddy Glaeser, Gengbin Piao, Nicholas Reynolds, and Zach Sowerby for their help with the data, to Alan Johnston, Jack Kroll and Jacques Melitz for exceptionally useful, thorough and constructive comments and numerous corrections, but also to Marios Angeletos, Panle Jia Barwick, Marcelo Bianconi, Giorgos Bourogiannis, Alain Bresson, John Brown, Alessandra Casella, Aureo de Paula, Yannis Evrigenis, Oded Galor, Ed Glaeser, Matt Kahn, Michael Kosmopoulos, Ch. E. Maravelias, Eoin McGuirk, David Nagy, Dimitri Nakassis, Theodore Papageorgiou, Eleftheria Pappa, Robert Pitt, Giacomo Ponzetto, Louis Putterman, Ferdinand Rauch, Albert Saiz, Enrico Spolaore, Adam Storeygard, Jacques Thisse, Matthew Turner, Etienne Wasmer, Roger Woodard, and Junfu Zhang for useful suggestions, and to Josh Ober and Peter Van Alfen for data and many related suggestions and comments. We are grateful to Christopher Barnett, Uku-Kaspar Uustalu, Carolyn Talmadge and the other members of the Tufts Data Lab team for the construction of the data set for sailing times across the coastal segments of the Mediterranean and the Black Seas. We are also grateful to Sotiris Kampanelis and his coauthors for lending us their data on Phoenician sites. Thanks also go to Stelios Michalopoulos, whose contribution to preliminary research leading to a companion piece, Chen, Ioannides and Rauch (2022), titled "Asymmetric Trading Costs and Ancient Greek Cities," was an important part early in this research effort. Comments by Jan Bakker and Claudia Steinwender at CEPR Conference ERWIT/CURE, Turin, 2023, are gratefully acknowledged. The usual caveats apply.

This research was entirely funded by Tufts University resources.

SUPPLEMENTARY DATA – NOT FOR PUBLICATION
APPENDICES A – D

A Additional Institutional and Historical Facts

The ancient Greek city-states, the Hellenic poleis, were independent entities with each its own political structure, hence the terms "political" and "politics," that provided a basic infrastructure in the form of a legal system, a process of collective-decision making, and several other institutions that constitute key predecessors of modern ones [Castoriadis (1991)].

A.1 Epichoric Scripts and the Greek Alphabet

Whereas it is hard to argue with Herodotus, who claims to have seen the particular inscription, the present paper is exploring quantitatively data on the diffusion of the Greek alphabet via the epichoric Hellenic scripts for several reasons. One is to help track the diffusion of the invention from the Phoenician script to the Hellenic scripts and their transmission over space and time as an instance of ancient diffusion of technology. It is premised on the notion, succinctly put by Jeffery (1961), p. 6, among several arguments, that the Greek alphabet "must have had its birth either in a part of the Greek area where people whom the Greeks called Phoenicians (*Φοίνικες*) [Quinn (2018)] were active, or in part of the North Semitic area where Greeks were active." In considering alternative sites where this might have happened, Jeffery and Johnston emphasize three points: one, the alphabet must have originated in a limited area and was not created independently at a number of different sites where Greeks and Phoenicians had interactions; two, such a site had to be an established bilingual settlement of Greeks and Phoenicians rather than a mere trading North-Semitic trading post, of which there were many; and three, the alphabet's birth place must have itself been on a well-frequented trading route and/or with good connections with some of main trading centers in that of the world over the period 900 – 700 BCE.[47]

Another reason is to gain a better understanding of how the emergence of the epichoric scripts interacted with urbanization in the ancient Greek world. Even though Linear B, a syllabic script for an archaic version of Greek that was used in some parts of Greece down to 1400 BCE and disappeared around 1200 BCE along with the Bronze Age administrations

[47]See Bourogiannis (2018b) for a discussion of the scope of cultural as well as economic contacts between Greeks and Phoenicians in the Aegean during the Early Iron Age.

that seem to have used it, the "Dark Ages" that followed for hundreds of years were not associated with writing until the emergence of epichoric scripts. Yet another reason is the interaction with the emergence of coinage, itself an important new technology that influenced urbanization in both similar, like in facilitating trade, and different ways, such the dependence of coinage on access to precious metals and costly enforcement of standards.

As there exist many variants of the epichoric scripts, this paper argues that the key element underlying the diffusion is the *idea* of the alphabet itself, the *tacit agreement* whereby a sequence made up of a consonant and a vowel, with letters denoting sounds and together denoting a syllable, which constituted a fundamental step in establishing a standardized writing for the Greek language. Thus, a small number, 24, of symbols, formed the Greek alphabet before it diffused into the Latin one in the form of the Euboean script via the Etruscans. What motivated the emergence of the alphabet itself, is less well understood. Furthermore, the various epichoric scripts are quite similar to one another, so that users of one could decipher writing in others. It is reasonable to assume that it was interaction of Greek speakers with Phoenicians arguably most likely in bilingual communities, that allowed the invention of the alphabet. What appears to still be subject of debate is exactly where and when this occurred, namely the development of the form of writing in what came to be known as the Greek alphabet in the ancient Hellenic world. The emergence of the Greek alphabet must have had profound influence on the cultural and economic development of the Hellenic world.[48]

A.1.1 What did motivate the invention of the alphabet?

Were the needs of literature or the needs of trade? These questions continue to be hotly debated. The principal arguments in favor of the former is that there exist early attestations of writing in the Greek alphabet in the form of literature and casual writing, such as inscriptions that may indeed have been graffiti [Powell (1991; 1993)]. This is quite a contrast with *Linear B*, the earliest form of syllabic (though not alphabetic) writing of the Greek language, which preceded the Greek alphabet by the several centuries of the so-called Greek Dark Ages, which is entirely devoted to records of economic transactions, tax records, and interactions between rulers, palace authorities and craftsmen ("contractors", a point forcefully made by Nakassis (2013)), all in the absence of money [Schaps (2004)]. Therefore, the question could arise as to why the next form of Greek writing, would not have been invented in order to record details of, and to facilitate, the conduct of economic life.

[48]Search for the origin of Greek alphabet using theory and ancient data is conceptually reminiscent of search for lost ancient cities by Barjamovic *et al.* (2019).

Even if the primary motivation was the accommodation of the emerging Greek literature [Powell (1991); and Powell (1993), an entertaining contribution], it would still have served as a general purpose technology, in effect a non-rival public good, and its emergence being a total factor productivity (TFP) shock [*c.f.* Ashraf and Galor (2011)] within those trade-oriented communities. Therefore, evidence on the timing of presence of a script in different locations may be critical in understanding economic development in archaic and preclassical Greece, in addition to understanding the pattern of the spatial evolution itself of Hellenic scripts as propagation of total factor productivity shocks.

The first known records of the Greek language in the form of the Linear B tablets have been found in a small number of locations, with their locations (and numbers in parentheses) being as follows: Knossos (4228), Pylos (1004), Thebes (438), Mycenae (107), Tiryns (76), Chania (52), and much fewer at a number of other locations, with writing on objects other than clay tablets. In most of those cases, the tablets were not meant to be permanent.[49] They have been preserved accidentally due to fires that destroyed the structures where they were stored. Therefore, those finds are hardly random; they are sparsely distributed and arguably very unrepresentative. The paucity of those data makes us ponder about how to further use them and therefore we have not yet merged them with the scripts data.[50]

Several scholars have argued that the Linear B writing system might have indeed been used first to record economic life, but those records were on perishable materials such as papyrus[51] and others [Waal (2020), p. 113]. This suggests that we should not adhere too closely to attested dates of script adoption and allow for errors, which we actually do in the empirical analysis.

A.1.2 Emergence of the Greek Alphabet

The humanities and linguistics literature dwells at length on the precise nature of the innovation that the invention of the Greek alphabet amounted to, especially because it has served not only as the "mother of all European alphabets," but also of several Asian alphabets, though through different routes of transmission. The Latin alphabet, in particular, originated from the alphabet of Chalkis, Eretria, and Kyme, known as the Euboean script, through their colonies in Italy, especially Cumae, from which the alphabet was transmitted

[49]https://damos.hf.uio.no/1

[50]We thank Teddy Glaeser for his help with the Linear B tablets data and Albert Saiz for urging that we pursue this point.

[51]Jeffery and Johnston (1990), p. 57, state by appealing to Herodotus [v. 58] that before papyrus became an accepted medium, the Greeks of Ionia (the Aegean coast of Asia Minor) had been using leather for the same purpose.

to the Romans via the Etruscans. Numerous variations followed, such as its adaptation for the needs of some Slavic languages, whereas the Cyrillic scripts were deliberately developed from the Greek for the needs of those Slavic languages. Since the creation of *pinyin*, the writing system of romanization of Mandarin Chinese, its influence has been extended even further.

As Bourogiannis (2018a) details, proximity of Phoenicians and Greeks is attested in many places in the Aegean and indeed all around the Mediterranean. Most notable is Cyprus, though several scholars doubt that that is where the Hellenic alphabet emerged from the Phoenician script, because of the evidence that its Greek-speaking population held onto their own Cypriot syllabary over several centuries for political reasons [*ibid.* p. 252].[52] Critical to our empirical investigation is that scholars agree on the basis of linguistic arguments that the similarities among the epichoric scripts are so strong that the invention must have happened just once rather spontaneously in different places. It propagated thereafter and was adopted, with variations, by different Greek speaking populations at various sites and times ranging from 1100 BCE (as few argue) to 750 BCE and later. Generally, there is little (but still some) support for an even earlier date.

Until about 10 years ago, there was general agreement that later dates were more likely. Then firmly dated new archaeological findings at Methone, a northern Greek site in the region of Pieria and ancient colony of Eretria, argued in favor of the alphabet's being established by 733 BCE [*ibid.* p. 244]. Specifically, this finding strengthens the case for an Aegean origin due to findings of coexistence of Greek along with Phoenician (and Phrygian) letters at Methone [Papadopoulos (2016); Bourogiannis (2018a; 2018b)]. An even earlier date of 775 BCE for the existence of the Greek alphabet (though not necessarily representing Greek text) is attested at a site called Gabii in ancient Latium, Italy, for which there exists strong evidence of links with Eretria due to Eretrians' presence in Pithikoussai, a site on Ischia Island near Naples, Italy. The evidence of Greek writing that has been found in Ischia is associated with a later date. Scholars have argued that several sites around the Aegean might have accommodated Phoenician presence, including in addition to Eretria, Kyme (both in the region of Euboea) and Oropos (in Attica), such poleis as Athens, Delos, Thera, Rhodes and several ones on Crete. Scholars have discussed their potential as sites for the invention. However, the Euboeans seem to stand out for active and reciprocal contacts with the Eastern Mediterranean.[53] In sum, while we allow for many possibilities, we conjecture

[52] Woodard (1997), Ch. 6, argues that scribes literate in the Cypriot syllabary were responsible for the first Greek adaptation of the alphabet. Woodard's argument rests on investigations of the spelling principles of the Mycenaean and Cypriot syllabic scripts.

[53] An additional argument has been made that involves a Phrygian link. Linguistic arguments that involve

that it is somewhere in the Aegean where the Greek alphabet, via its variants, was invented. The paper tests this conjecture. Last, on a matter of terminology, we note that we adhere to the term *scripts* in deference to Jeffery (1961), but what did diffuse in the ancient Hellenic world were variants of what is nowadays known as the *Greek alphabet.*

A.1.3 Epichoric Scripts Data

We are employing the digitized archive of Jeffery's documents (http://poinikastas.csad.ox.ac.uk/) along with additional information from Jeffery and Johnston (1990)[54] to create our database of scripts. It is composed of 151 scripts, not necessarily very different and attested with individual poleis, and 23 regional scripts. In almost all cases for which we have evidence, a script associated with a particular polis is also used by their neighbors or other nearby poleis. The regional scripts were likely shared by poleis in the same historical region, especially as in most cases they are associated with the same dialect. Still, as the evidence of Euboea and Ionia attest, those two regions spoke similar dialects but used different scripts, and likewise with Corinth and Sparta. Johnston (1998) in discussing the potential significance of script adoption for polis identity, *polisism*, argues that the evidence in favor of a link between script and dialect is not very persuasive, but perhaps epichoric scripts were more likely a " 'slip of the pen' than being associated with polis identity. Johnston does grant nonetheless that "polisism, did have some effect in perpetuating the use of home-town lettering in the propagandistic situation afforded in these sanctuaries [Delphi and Olympia] ..." [*ibid.* p. 428].

We do not know exactly why some scripts are regional while others are not, but we test for the potential explanation of whether regions with better within-region communication are more likely to share a script. Specifically, we compute the average travel cost between all poleis within each region. We find that the 22 regions that do not have a regional script have greater average within-region travel costs than the 23 regions that do have regional scripts: the mean of the average within-region travel cost for regions with regional scripts is about

vowels in early Greek and Phrygian, together with the Phoenician symbols from which they seem to have been derived, plus the testimony of Herodotus, argue that the place of the adoption and adaptation of the Phoenician script must have been where Greeks, Phoenicians but also Phrygians interacted. This, again, points to somewhere in the Aegean. A Phrygian connection has been elaborated most recently by Quinn (2023).

[54]It lists by order of appearance all 1640 items in Jeffery (1961), with details as follows: *Local Scripts of Ancient Greece* reference (with hyperlink to image), name of local script, region found (classified by means of maps), subregion, archaeological context, object type, and date range. For example, for the first line, the entries are: link to image, Attica, Central Greece (CG), Attica, Athens, Oinochoe, c. 725. In principle, these items may be classified in further detail.

67% of the respective mean for regions without regional scripts, evaluated in terms of our baseline distance measure; it is 76%, and 83% in terms of our alternative distance measures.

Waal (2020), p. 111, states "alternatively, one could see the regional diversity as the results of local developments, which must have taken place over a longer period of time." As Luraghi (2010) puts it, although the local alphabets were consciously created and associated with ethnic boundaries and dialects, the problem remains how this all happens so rapidly. For our purposes, if we believe that the local development takes a long time, then the distance from each polis to particular Phoenician sites as potential origins of the innovation might not be as important. However, distance could matter when it comes to trade and to the degree of cultural differences. Since the alphabet was ultimately adopted widely, a key question is how can we judge when the inhabitants of an area first saw and/or used an alphabet? A trade-related motive could be one potential explanation, as it led to cultural mixing. On the one hand, trade increases wealth and state capacity, which might go hand-in-hand with script adoption; on the other hand, the greater prosperity brought by trade could generate additional demand for record keeping and therefore for script. Yet, there exists no evidence of record keeping in early archaeological material. Coinage was of course crucial for trade, too, but unlike the case of script, it does depend on access to sources of precious metal, and therefore a joint treatment is appropriate.

While we are accustomed to evidence on such media as stone and objects made of clay, writing seems to have been present on numerous other objects, including coins, decorative objects and tools. The variety of objects mentioned in the *Local Scripts of Ancient Greece* database from *Poinikastas* is telling. In addition, most likely non-permanent media were used, such as hides and papyrus, just as we even today use all kinds of non-durable media. Indeed, the modern Greek word for book, *biblion* (*βιβλίον*), derives from the name of Byblos, modern Jbeil, one of the most ancient cities that have been inhabited continuously since at least 7000 BCE.[55]

Alphabets were a great departure from the Linear B or the Cypriot syllabary, that preceded them. The various epichoric scripts differed in many ways. To give examples, they differed in the use of the consonant symbols X, Φ, Ψ, in the use of the innovative long vowel letters ω, and η; and many others, and in many details of the individual shapes of each letter. The now standard 24-letter Greek alphabet was originally the regional variant of the Ionian cities in Asia Minor by the late fifth century. Yet the classics scholarship maintains that they were mutually intelligible. After Athens officially adopted the Ionian script in 403-402

[55]It lies on the coast of Lebanon from where trade with Egypt, the origin of papyrus, a common raw material for writing in antiquity, was known to have taken place.

BCE with Eucleides as archon [D'Angour (1999)], it became the standard in most of the rest of the Greek world by the middle of the 4th century BCE. Our coding of adoption dates adheres to these events.

We use the *Poinikastas* Database to get the earliest date when each local script is attested and in merging with our poleis data match with the nearest polis. Our database of scripts is composed of 151 scripts, attested with individual poleis but not necessarily different, and 23 regional scripts. See figure 2b for the locations of poleis with scripts.

A.2 Coinage

As Bresson (2005) and Schaps (2004; 2006) argue, coinage of precious metal was an innovation, over and above commodity money (skins, cattle, shells, pieces of metal, etc.). It signaled authority of the state via its stamp, allowed exchange rates with all commodities, and thus served as unit of account, store of value and medium of exchange. These properties coincide with the modern definition of money. However, we do not claim that it was coinage that signalled the invention of money or credit. A well established literature has argued that money existed even starting in the Stone Age, when various substances served as money, to be followed by metals in various forms in the Bronze Age with the establishment of weights and scales to be followed by bullion. Ultimately, in the Iron Age, money took the form of coinage [Kroll (2008); Rahmstorf (2016)], clearly the most convenient form of money, given the technology of the time, and fully consistent with Aristotle's argument in favor of coinage.[56] While coinage was certified by the issuing authority, it continued to be weighed, in part as protection against counterfeiting. Yet, coins "as stamped pieces of metal enabled the differentiation between face and intrinsic value for the first time" [Rahmstorf (2016)]. This argument is bolstered by the fact that strictly speaking, issue of coinage in a full set of denominations by a state might not have been profitable. However, the state expends resources in order to communicate its authority, facilitate trade, and also reduce the costs of its revenue collection [Melitz (2016)].[57]

The emergence of coinage in India and China appears to come later. Schaps (2004), p. 231-233, acknowledges the controversy and dates coinage in India to probably before

[56] We thank Jack Kroll and Jacques Melitz for insisting on this point in private communications.

[57] We thank Jacques Melitz for bringing to our attention that availability of coinage fluctuated widely after the Fall of the Roman Empire and, not unlike during the classical Hellenic era, not all polities continued issuing coinage through the Middle Ages. However, the fact that alphabetic writing never did disappear should not diminish to invention of coinage as a major innovation whose availability depended on resources, just as use of writing did depend on available media.

the invasion by Alexander the Great in the late fourth century BCE, but not earlier than Lydia. The case of China is similarly complicated, and coinage with similar functions to that of Lydia appears first in the early fifth century BCE [Kakinuma (2014)]. The fact that the technologies involved were different, punch marked silver coins in the former, and elaborate bronze cast in the latter, makes it likely that they were independent inventions. As Schaps (2004) argues, the roughly contemporaneous Indian and Chinese societies were too sophisticated to have settled on clumsy imitations of the Lydian and Greek process. Coinage must have been independently invented there and curiously did not immediately spread to equally sophisticated societies elsewhere.[58]

Our data on the times of first issue of coinage are taken from two sources. One, which is available in the original database of the Stanford Polis Project, records time of issue by century; the second, which we hand-coded ourselves, uses the more detailed information available in Hansen and Nielsen, *op. cit.,* either according to attested approximate year or approximation by interval midpoints. Silver coinage is the most prevalent form, with 339 vs. 187 observations, from the first and second sources respectively, followed by 284 vs. 148 for bronze. Figures 2c and 2d shows the locations of poleis with coins. In the simple cross-sectional probit model for coinage, we define the coinage issue indicator using either source. But for the survival and pseudo panel analyses, we exclude the poleis for which we only know the date of coinage by century only. Gold and electrum coinage are much rarer. In our data 21 poleis issued gold coins and 9 poleis issued electrum coins. However, the classics literature has concluded that electrum coins were the first ones to be issued; see Hodos (2020), Ch. 3, Kallet and Kroll (2020), Van Alfen and Wartenberg (2020).

In our empirical analysis, we do not differentiate the coins by their types. We are tempted to treat silver and gold coins as substitutes. They are both made of precious metal with much higher intrinsic value than bronze and were used as money first, indeed originally in the form of bullion or *Hacksilber* [Kroll (2013)]) in trade prior to the invention of coinage. Bronze coins seemed to have been used very differently. They were issued both by larger poleis in small denominations to facilitate retail trade, and by smaller ones because they were cheaper to manufacture (though did depend on imports of tin), but still served as unit of account and medium of exchange. Several poleis issued multiple types of coins during their history. We do not differentiate, in this paper, among the types of coins and rely on

[58] As Schaps (2006) p. 32, puts it, "Whether they each invented it independently or whether it passed from one to the other, Lydia/Greece, India, and China all proved fertile ground for an institution that neither originated nor was quickly adopted in other civilizations no less advanced culturally and economically. In fact, there are some parallels in the development of the economies of Lydia, India, and China that may be significant for our understanding of their role."

the earliest date of any coinage issue when a polis issued multiple coins in the history.

B Autarky vs. Interpolis Trade Equilibrium and Issue of Coinage

This Appendix takes off from Casella (1992) and develops a model of the system of the ancient Hellenic poleis as sovereign entities, polities, that engage in trade and may issue commodity money, in the form of coinage. The coinage was minted originally in electrum, but later primarily in silver and to a lesser extent gold. Bronze was also used to strike coins of smaller denominations. Models of monetary economies, like that of Casella (1992), need minimal modification to allow for commodity money, namely essentially imposing a condition that the monetary value for the commodity used as a medium of exchange must exceed its intrinsic value [Champ and Freeman (2004), Ch. 2]. It is also straightforward to allow for the cost of coinage. In the remainder of this Appendix we adapt the two-country model of Casella (1992) to many poleis as sovereign polities, and assume interpolis trade takes place under the Armington assumption and is subject to shipping costs.

B.1 Interpolis Trade with Shipping Costs: Many Poleis

The present section is novel and combines the static model of Chen, Ioannides, and Rauch (2022), itself a simplification of Allen and Donaldson (2018), but closely related to Allen and Arkolakis (2016). It is a dynamic model that retains the two-overlapping generations structure of Casella (1992), with money, understood as coinage issue, as the only asset.

Trade presumes information: there is ample historical evidence of awareness of the geographical extent of trade [Ioannides (2019); Chen, Ioannides and Rauch (2022)]. We assume that each polis produces a single differentiated good and employ the Armington assumption that goods are differentiated by origin, so that as many goods are traded as the number of poleis. Labor, supplied inelastically in quantity S_i, is the only factor of production in each polis i, and may be mobile, as in the so-called economic geography case, as we discuss briefly below [see also Chen, Ioannides and Rauch (2022)]. It may also be immobile, as in the standard international trade case. Each polis-specific good is produced with constant returns to scale according to the following production function

$$Q_i = A_i S_i, i = 1, \ldots, J, \tag{23}$$

where A_i denotes TFP that may proxy for geographical features and local productivity attributes, such crop suitability, etc.

Individuals work when they are young and receive their nominal wage w_i, which they save in the form of coinage. In the second period of their lives they spend their money holdings on differentiated consumption goods. They have identical CES preferences, as in (2) above: they value a composite consumption good, defined as a CES aggregate of quantities of all J goods produced in the economy,

$$H_i := \left(\sum_{j=1}^{J} c_{ji}^{\theta} \right)^{1/\theta}, \tag{24}$$

and a public good, whose quantity is Γ_i. The individual lifetime utility function in (3) is rewritten here as:

$$U_i = (1-g)\ln H_i + g \ln \Gamma_i, \quad , j = 1, \ldots J. \tag{25}$$

To the component involving $\ln H_i$, defined in (24) above, there corresponds an indirect subutility $\ln \left(\frac{Y_i}{P_i} \right)$, where Y_i denotes nominal spending on the differentiated goods and P_i the Dixit-Stiglitz ideal price index,

$$P_i := \left[\sum_k \left(\tau_{ki} \frac{w_k}{A_k} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \ \sigma > 1, \tag{26}$$

where $\sigma := (1-\theta)^{-1}$, is the elasticity of substitution across intermediate varieties, w_i is the equilibrium nominal wage, $\tau_{ij} > 1$ denotes shipping costs from i to j, that is, the units of the good i that must be shipped from origin site i for one unit to arrive at a destination site j. Shipping costs combine overland travel costs and sailing times; due to wind patterns, the latter costs are asymmetric: $\tau_{ij} \neq \tau_{ji}$. We note that in spite of the "love for variety" expressed by CES preferences the given number of poleis implies a fixed number of goods. In the case of the Armington assumption with goods being differentiated by origin, the optimum value of the consumption subutility does not depend on polis size. That is so unlike the Dixit-Stiglitz model with monopolistic competition and endogenous number of goods, in which case it would depend on polis size. However, optimum utility does increase with the number of poleis in the entire system of poleis. This confers benefits from the expansion of the urban system though colonization. In any of the modes of financing the public good, its quantity does depend on polis size, which introduces dependence of individuals' welfare on polis size.

B.1.1 Autarky

In the case of autarky, the public good may be financed by polis-own coinage issue or a local tax. However the provision of the public good may be financed, it absorbs a share g of the total output of each polis. With coinage issue and in the absence of trade, only the local good is consumed. Then: $w_i = A_i p_i$, $H_i = A_i(1-g)$, $\Gamma_i = gS_i$, and

$$V_{i,aut,nocoinage} = \ln\left[(1-g)^{1-g} g^g\right] + (1-g)\ln A_i + g \ln S_i. \tag{27}$$

In the case of coinage issue by polis i, the above expression is modified by subtracting the cost of coinage, $g \ln \mu_i$, from the r.h.s. of (27).

B.1.2 Interpolis Trade

For equilibrium in the goods market in polis i, the value of total spending, that is spending to provide the public good, $w_i\Gamma_i$, plus the sum-total of spending by all poleis including polis i, each of which demands

$$X_{ij} = \left(\frac{\tau_{ij}}{A_i}\right)^{1-\sigma} w_i^{1-\sigma} P_j^{\sigma-1} w_j y_j, \tag{28}$$

where $Y_i = w_i y_i$, must be equal to total income, $S_i w_i$. The polis issues new coinage in the amount M_i, whose nominal cost is $\mu_i M_i$ and uses to pay for the public good, $w_i \ell_{\Gamma,i} = M_i$. That is, $\Gamma_i = \frac{M_i}{w_i} := m_i$, the provision of the public good is financed by the inflation tax.

If poleis trade with one another by using their own coinage, each polis is subject to an equilibrium condition in the inter-polis exchange market: total payments to all other poleis must be equal to total receipts from it own sales. Such a condition must reflect exchange rates. This is much too complicated to deal with unless poleis treat the coinage of all other poleis on par, in which case all exchange rates are equal to 1. Otherwise, in the absence of such a system-wide monetary standard, the simultaneous existence of J different types of coins and their respective exchange rates makes for a setting that is much too complicated to deal with for our purposes.

In the case of an agreed-to system-wide monetary standard, in other words a coinage union, nominal wages are equalized and they will thus be referred to without subscripts (except when accounting for lags/leads). This allows us to define the equilibrium values for real spending as functions of real money issues, that is the m_i's, and exogenous variables. A real price index, $\tilde{P}_j := w^{-1}P_i$, follows:

$$\tilde{P}_i = \left[\sum_k \left(\frac{\tau_{ki}}{A_k}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \ \sigma > 1, \tag{29}$$

and the conditions for general equilibrium express that real spending on the public good and on the differentiated goods produced in i and demanded by all poleis, $j = 1, \ldots, J$, is equal to local labor supply:

$$\mu_i m_i + \sum_j \frac{(\tau_{ij}/A_i)^{1-\sigma}}{\tilde{P}_j^{1-\sigma}} y_j = S_i, \ j = 1, \ldots, J. \tag{30}$$

The J equations (30) define a linear system which yields the vector of real spending $\mathbf{y}$ as a linear function of the S_i's and the m_i's, as we clarify shortly.

Let

$$\tilde{\mathbf{T}}_{ij} := \frac{\left(\frac{\tau_{ij}}{A_i}\right)^{1-\sigma}}{\tilde{P}_j^{1-\sigma}} = \frac{\left(\frac{\tau_{ij}}{A_i}\right)^{1-\sigma}}{\sum_k \left(\frac{\tau_{kj}}{A_k}\right)^{1-\sigma}} \tag{31}$$

define a column-stochastic matrix. Its row$-i$ enters the l.h.s. of (30). The solution of the system of equations (30) may be written in matrix form as

$$\mathbf{y} = \tilde{\mathbf{T}}^{-1}[\mathbf{S} - \mu\mathbf{m}], \ j = 1, \ldots, J, \tag{32}$$

where $\mu\mathbf{m}$ denotes the $J-$vector with elements $\mu_i m_i$ and $\mathbf{S}$ denotes the vector of all polis sizes. This solution expresses the vector of real spending in terms of $\mathbf{S}$ and the vector of real coinage issues, $\mu\mathbf{m}$.

Taking as given the solution for polis i spending (income) from (32), polis i chooses m_i so as to maximize (25), which may be rewritten as:

$$(1-g)[\ln Y_i - \ln P_i] + g \ln \Gamma_i = (1-g)\ln y_i - (1-g)\ln \tilde{P}_i + \ln \frac{w}{w_{+1}} + g \ln m_i - g \ln \mu_i,$$

where $\frac{w}{w_{+1}}$, the rate of wage deflation, may be obtained as follows in the case of a uniform monetary standard. With free flow of specie, all exchange rates are equal to 1 and equalization of wage rates, polis i faces a monetary budget constraint:

$$S_i w_{i,+1} = S_i w_i + \mu_i M_i. \tag{33}$$

With equalization of nominal wage rates, equation (33) may be aggregated for the entire economy to yield:

$$w_{+1}\bar{S} = w\bar{S} + w\sum_i \mu_i m_i, \tag{34}$$

where $\bar{S} = \sum_i S_i$, and the m_i's denote the real money supplies at the uniform wage standard. This condition underscores that seignorage is shared in the coinage union. Solving for the rate of inflation, we have:

$$\frac{w_{+1}}{w} = \frac{\bar{S}}{\bar{S} - \sum_i \mu_i m_i}. \tag{35}$$

Therefore, polis i sets m_i so as to maximize:

$$V_{i,trade,\, union} := (1-g)\ln y_i - (1-g)\ln \tilde{P}_i + (1-g)\ln\left[\frac{\bar{S} - \sum_i \mu_i m_i}{\bar{S}}\right] + g\ln m_i - g\ln \mu_i. \tag{36}$$

In order to focus on the role of local productivities and shipping costs, we ignore the presence of $\mu_i m_i$ in the term expressing the inflation rate, given $\ln\left[\frac{\bar{S}-\sum_i \mu_i m_i}{\bar{S}}\right]$. Indeed, with a large number of poleis, it is appropriate to take that term, an aggregate impact on polis welfare, as given when deriving first-order conditions in a Nash equilibrium setting. The resulting system of equations corresponding to first-order conditions with respect to the m_i's is tractable. That is:

$$(1-g)\frac{1}{y_i}\frac{\partial y_i}{\partial m_i} + g\frac{1}{m_i} = 0. \tag{37}$$

In view of the dependence of the y_i's on the m_i's from (32), the system in matrix form yields the following solution for the vector of the $\mu_i m_i$'s:

$$\mu\mathbf{m} = \frac{g}{1-g}\left[\mathrm{Diag}[\tilde{\mathbf{T}}^{-1}]\right]^{-1}\mathbf{y}, \tag{38}$$

where $\mathrm{Diag}[\tilde{\mathbf{T}}^{-1}]$ denotes the matrix composed of the diagonal elements of matrix $[\tilde{\mathbf{T}}^{-1}]$. The solution for the vector $\mathbf{y}$ follows:

$$\left[(1-g)\tilde{\mathbf{T}} + g\left[\mathrm{Diag}[\tilde{\mathbf{T}}^{-1}]\right]^{-1}\right]\mathbf{y} = (1-g)\mathbf{S}. \tag{39}$$

If g is small, that is, the public good does not contribute substantially to individual utility, then no money is issued and the solution (39) simplifies to: $\mathbf{y} = \tilde{\mathbf{T}}^{-1}\mathbf{S}$. The intuition of this result is immediate, when seen as $\tilde{\mathbf{T}}\mathbf{y} = \mathbf{S}$, that supply of goods in each polis is equal to demand.

The resulting solution of (39) for the vector of real spending corresponds to a Nash equilibrium in the system of poleis when coinage issue is uncoordinated. As we discussed earlier, heeding Casella (1992), the outcome of uncoordinated coinage issue might be disadvantageous to a polis, relative to autarky. In such a case, in order to elicit participation in a coinage union, a system of utility weights may be designed, such that under a coordinated coinage issue, outcomes for all poleis of interest may above the value of autarky. In any case, the value of trade together with participation in a coinage union for each polis depends on all sizes, via $\mathbf{S}$, and the entire structure of shipping costs and productivities, via $[\tilde{\mathbf{T}}^{-1}]$ and $\text{Diag}[\tilde{\mathbf{T}}^{-1}]$, all of which are exogenous.

Therefore, participation by polis i in trade and coinage union would be attractive if the optimum utility from (36) exceeds that of autarky from (27). That is:

$$(1-g)\ln y_i + \frac{1-g}{\sigma-1}\ln\sum_k\left(\frac{\tau_{ki}}{A_k}\right)^{1-\sigma} + (1-g)\ln\left[\frac{\bar{S}-\sum_i \mu_i m_i}{\bar{S}}\right] + g\ln m_i - g\ln\mu_i$$

$$\geq (1-g)\ln A_i + g\ln S_i, \tag{40}$$

where y_i and m_i are obtained, respectively, from solving (39) and (38) above. These conditions involve all parameters, that is all sizes, productivities and shipping costs. Notably, all productivities and shipping costs enter via the matrix of parameters $\tilde{\mathbf{T}}$. *Cet. par.,* from comparing $\frac{1}{\sigma-1}\ln\sum_k\left(\frac{\tau_{ki}}{A_k}\right)^{1-\sigma}$ with A_i, the smaller are the shipping costs and the larger the productivities the more attractive is trade and participation in a coinage union.

If the actual sizes of poleis are not known, then we can make progress by assuming spatial equilibrium, that is, equilibrium utility is equalized across all poleis, and labor supply is infinitely elastic from the perspective of every site. For a full development along those we can work in like manner to Allen and Arkolakis (2014) and express demands, as in (28) in terms of utility. We may do that by first solving for the optimal value of Γ_i, substitute in for the price index P_j in terms of utility and impose spatial equilibrium. Because of the presence of Γ_i, the derivations are more involved then in *ibid.* However, we may simplify by imposing consistency and setting $\mathbf{y} = \mathbf{S}$ in (39). Therefore, sizes are determined up to scale from the unique right Perron-Frobenius eigenvector of the positive matrix on the l.h.s. of (39), that are associated with the maximal eigenvalue of

$$\mathbf{T}^* := \left[(1-g)\tilde{\mathbf{T}} + g\left[\text{Diag}[\tilde{\mathbf{T}}^{-1}]\right]^{-1}\right]. \tag{41}$$

Returning to (40), we recall the comparison between the utility from trade and coinage union vs. that from autarky, and note that the solutions for y_i, from (39), and for m_i, from (38), their earliest date of attestation, we do not know when each polis in the respective region actually did adopt the regional script. We therefore assign the earliest date of attestation for the regional script to all poleis within the region, while in reality some poleis might have adopted at later times. The regional scripts are the cause of steep “jumps” in the script adoption curve. A third limitation stems from the fact that there exist a few scripts in Poinikastas that we have been unable to matched to our poleis database and are thus ignored.

Figure 4b reports the adoption curve for coinage. Our observations for coinage issue by poleis lie between 610 BCE and 280 BCE. Like with scripts, the adoption process for coinage does not reflect entirely voluntary decisions by poleis though for different reasons. Athens, the coinage hegemon of the Delian League, made its own coinage mandatory on the League members, requiring them after some point to turn in their coinage to the Athenian mint in exchange for Athenian coinage.

Since we have two sources of coinage issue dates, we draw two separate adoption curves: the solid line is based on “exact” dates attested, while the dashed line is based on an augmented sample that also include poleis for which information is attested in terms of centuries, within which coinage was issued. We therefore compute the numbers of coinage issues in each century. The vagaries of the archaeological record are responsible for the differences, including the period of observation. E.g., we only have one observation in the 3rd century BCE, that is, 280 BCE.

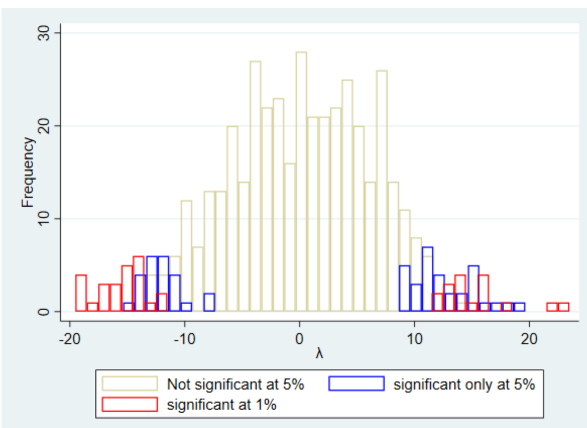
Caution is needed when interpreting the adoption curve with century level dates. Essentially, there are only five data points (7th to 3rd century BCE). We match the starting date and ending date in the 7th century BCE and the 3rd century BCE to be the accurate date (610 and 280 BCE), but note that there are only two observation of coinage in the 7th century BCE, at 610 BCE, which marks the beginning of the coinage era in the Hellenic world in our data, and as mentioned above, there is only one observation in the 3rd century BCE, that is, 280 BCE. For 6th to 4th century BCE, the data points are drawn at the mid point of each century. Thus, the slopes from 7th century to the 6th century BCE, and from 4th century to 3rd century BCE, can be misleading. The exact numbers of coinage issues by century, based on our data, is: 2 in 7th century BCE, 94 in 6th century BCE, 144 in 5 century BCE, 197 in 4th century BCE, and 1 in 3rd century BCE.

Table A1: Placebo regressions for spatial diffusion: count of significant estimated λ out of 500 runs

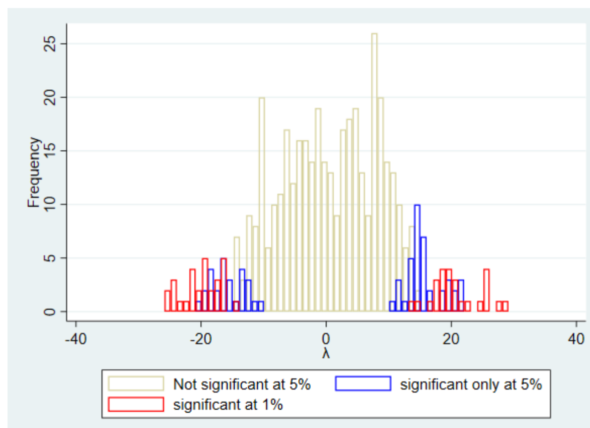
	(1) + (5%)	(2) + (1%)	(3) - (5%)	(4) - (1%)
Panel A: Placebo Regressions for Script				
To	49	17	49	25
From	65	26	56	29
Panel B: Placebo Regressions for Coinage				
To	34	11	6	3
From	64	31	7	3

Notes: Placebo regressions corresponding to the spatial diffusion regression. Col (1) to (4) are the counts of λ that are: positive and significant at the 5% level, positive and significant at the 1% level, negative and significant at the 5% level, negative and significant at the 1% level, respectively.

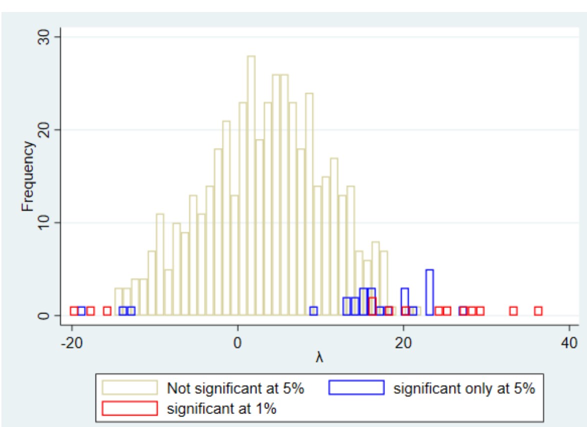
Figure A1: Plot of λ out of 500 placebo runs



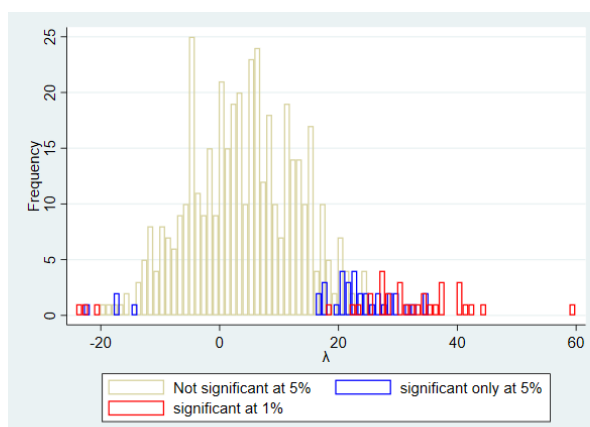
(a) Script, To



(b) Script, From



(c) Coinage, To



(d) Coinage, From

Table A2: Spatial Diffusion: the Impact of Being Close to Previous Adopters (Horse Race Specification for measures in different directions: To versus From)

	(1) script	(2) coin
Panel A: Contagion Model Parameter Estimation		
1-MA: ζ (To)	-1.646	-2.930
	(1.206)	(2.733)
MA(1-MA): λ (To)	-2.421	-0.794
	(2.554)	(4.512)
1-MA: ζ (From)	2.398	4.776
	(1.607)	(3.003)
MA(1-MA): λ (From)	12.05***	9.717**
	(4.284)	(4.882)
1-MA (Crow-Flies)	0.607	-0.836***
	(1.018)	(0.140)
MA(1-MA) (Crow-Flies)	2.493	-4.353***
	(2.284)	(0.830)
Panel B: Quadratic Form Model Parameter Estimation		
MA (To)	-0.775	2.135
	(2.212)	(2.173)
MA^2 (To)	2.421	0.794
	(2.554)	(4.512)
MA (From)	9.655***	4.941**
	(3.294)	(2.352)
MA^2 (From)	-12.05***	-9.717**
	(4.284)	(4.882)
MA (Crow-Flies)	1.887	-3.517***
	(1.412)	(0.847)
$MA(Crow\text{-}Flies)^2$	-2.493	4.353***
	(2.284)	(0.830)
Observations	1151	1499
N(Script=1/Coin=1)	410	358

Notes: Pseudo panel OLS regressions. Panel A and B are equivalent specification, with different parameters being estimated: panel A estimates the contagion model and panel B estimates the quadratic form model. Col (1) is result for scripts while (2) is result for coinage adoption. Centralities, geographical variables including ruggedness, malaria index, temperature, precipitation, elevation, and crops (barley, millet, summer wheat and winter wheat) suitability, as well as proximity to origins (for script regressions) to origins/mines (for coinage regressions) are also controlled for but are not shown to save space.

Standard errors clustered at 1 by 1 degree grid in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A3: Survival Regressions: the Role of Market Access, Proximity to Origin, and Poleis Size

	No MA			MA: from i			MA: to i		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Dependent var: survival time until adopting a script									
MA_to	-0.0298	-0.00482	-0.0154	0.0166	0.0370	0.0268	0.0600*	0.0901**	0.0795**
	(0.0183)	(0.0238)	(0.0256)	(0.0243)	(0.0292)	(0.0309)	(0.0306)	(0.0360)	(0.0368)
MA_from	-0.0565***	-0.0487**	-0.0555**	0.0165	0.0238	0.0147	-0.0874***	-0.0903***	-0.0923***
	(0.0203)	(0.0246)	(0.0242)	(0.0295)	(0.0313)	(0.0313)	(0.0233)	(0.0293)	(0.0292)
size			-0.0903**			-0.0825*			-0.0714*
			(0.0442)			(0.0430)			(0.0411)
MA: Phoenician Sites				3.614**	3.376	3.587	3.125*	2.194	2.473
				(1.781)	(2.098)	(2.185)	(1.655)	(2.142)	(2.202)
MA: Potential Origins				-10.16***	-9.589***	-9.302***	-10.49***	-11.84***	-11.41***
				(3.361)	(3.407)	(3.439)	(3.403)	(3.890)	(3.838)
Elasticity: MA: Phoenician Colonies				0.104	0.094	0.100	0.136	0.092	0.103
Elasticity: MA: Potential Origins				-0.320	-0.314	-0.305	-0.380	-0.457	-0.441
Observations	894	631	631	894	631	631	894	631	631
Panel B: Dependent var: survival time until issuing a coin									
MA_to	0.108***	0.100***	0.0462**	0.107***	0.102***	0.0484**	0.174***	0.139***	0.0784***
	(0.0200)	(0.0239)	(0.0198)	(0.0182)	(0.0237)	(0.0198)	(0.0284)	(0.0288)	(0.0237)
MA_from	-0.000565	-0.0506**	-0.0564***	0.0615**	-0.0144	-0.0314	0.0386	-0.0259	-0.0349*
	(0.0217)	(0.0217)	(0.0182)	(0.0301)	(0.0253)	(0.0211)	(0.0278)	(0.0237)	(0.0199)
size			-0.327***			-0.318***			-0.323***
			(0.0342)			(0.0339)			(0.0340)
MA: Origins/Mines				-5.765***	-3.410***	-2.308**	-5.286***	-2.952***	-2.443**
				(1.581)	(1.196)	(0.916)	(1.837)	(1.130)	(0.952)
Elasticity: MA: Origins/Mines				-0.335	-0.212	-0.144	-0.324	-0.194	-0.161
Observations	693	452	452	693	452	452	693	452	452

Notes: Survival analysis. Panel A: regressions for script adoption. All poleis are assumed to adopt a script at 400 BCE (censored at 400 BCE); Panel B: regressions for coinage adoption. Poleis known to have a coinage, but with century level date information only are excluded. In both panels, geographical variables include ruggedness, malaria index, temperature, precipitation, elevation, and crop (barley, millet, summer wheat and winter wheat) suitability are not shown to save space.

Elasticity is computed as coefficient times standard deviation.

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A4: Survival Regressions: the Role of Centrality, Proximity to Origin, and Poleis Size; for coinage, with imprecise date

	No MA			MA: from i			MA: to i		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Authority Centrality (To)	308.5***	424.0***	222.2**	261.9***	387.7***	210.9**	549.9***	593.3***	306.3***
	(88.14)	(102.4)	(87.22)	(89.01)	(103.9)	(87.22)	(134.2)	(151.3)	(106.0)
Hub Centrality (From)	-74.38	-199.6*	-281.5***	123.9	-46.11	-214.1**	-6.867	-132.7	-253.6***
	(98.77)	(106.6)	(92.58)	(122.4)	(134.4)	(100.8)	(106.3)	(117.5)	(94.31)
Poleis Size			-0.298***			-0.294***			-0.295***
			(0.0216)			(0.0216)			(0.0215)
MA: Origins/Mines				-3.106***	-2.428**	-1.071	-3.230**	-2.433	-1.117
				(1.017)	(1.228)	(0.705)	(1.363)	(1.613)	(0.766)
Elasticity: Hub Centrality	0.169	0.231	0.121	0.144	0.211	0.115	0.301	0.323	0.167
Elasticity: MA: Phoenician Colonies				-0.169	-0.137	-0.060	-0.188	-0.148	-0.068
Elasticity: MA: Potential Origins	894	631	631	894	631	631	894	631	631

Notes: Survival analysis. Regressions for coinage adoption. Poleis known to have a coinage, but with century level date information only are included. In both panels, geographical variables include ruggedness, malaria index, temperature, precipitation, elevation, and crop (barley, millet, summer wheat and winter wheat) suitability are not shown to save space.
Elasticity is computed as coefficient times standard deviation.

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A5: Survival Regressions: Effects of Delian League and Regional Federations; for coinage, with imprecise date

	No MA			MA: from i			MA: to i		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Authority Centrality (To)	310.5***	404.5***	233.2***	266.7***	363.7***	216.5**	449.1***	519.6***	292.6***
	(78.31)	(94.44)	(87.48)	(80.83)	(96.75)	(88.58)	(115.6)	(136.7)	(106.6)
Hub Centrality (From)	30.72	-15.27	-201.7**	184.3	123.8	-137.1	61.47	28.04	-184.9*
	(94.09)	(115.5)	(93.85)	(114.0)	(138.4)	(104.4)	(97.47)	(124.7)	(95.43)
Poleis Size			-0.288***			-0.285***			-0.287***
			(0.0205)			(0.0206)			(0.0205)
MA: Origins/Mines				-2.520**	-2.335*	-1.096	-1.888*	-1.726	-0.824
				(1.049)	(1.245)	(0.839)	(1.111)	(1.490)	(0.855)
Delian	-0.419***	-0.515***	-0.263***	-0.367***	-0.477***	-0.242***	-0.385***	-0.492***	-0.248***
	(0.0768)	(0.0955)	(0.0786)	(0.0817)	(0.0968)	(0.0798)	(0.0792)	(0.0955)	(0.0801)
Koinon	-0.259***	-0.266***	-0.259***	-0.305***	-0.308***	-0.275***	-0.268***	-0.274***	-0.263***
	(0.0679)	(0.0734)	(0.0700)	(0.0700)	(0.0760)	(0.0728)	(0.0668)	(0.0724)	(0.0705)
Elasticity: Hub Centrality	0.170	0.220	0.127	0.146	0.198	0.118	0.246	0.283	0.159
Elasticity: MA: Phoenician Colonies				-0.137	-0.132	-0.062	-0.110	-0.105	-0.050
Elasticity: MA: Potential Origins	890	631	631	890	631	631	890	631	631

Notes: Survival analysis. Regressions for coinage adoption. Poleis known to have a coinage, but with century level date information only are included. In both panels, geographical variables include ruggedness, malaria index, temperature, precipitation, elevation, and crop (barley, millet, summer wheat and winter wheat) suitability are not shown to save space.

Elasticity is computed as coefficient times standard deviation.

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A6: Coin-Script indicator regressions, with controls added sequentially

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Dependent Var: Coin Indicator						
Script Indicator	0.0597*	0.111***	0.125***	0.126***	0.197***	0.154***
	(0.0362)	(0.0382)	(0.0384)	(0.0376)	(0.0457)	(0.0435)
Panel B: Dependent Var: Date of Coin (Century*100; larger values mean later dates)						
Script Indicator	-20.16***	-33.53***	-38.64***	-38.87***	-56.37***	-46.17***
	(7.236)	(7.982)	(7.895)	(7.697)	(9.282)	(8.718)
N(Script=1)	622	622	622	622	464	464
Panel C: Dependent Var: Coin Indicator						
Script Date	-0.000240	-0.000343*	-0.000393**	-0.000482**	-0.000582**	-0.000462**
	(0.000181)	(0.000193)	(0.000193)	(0.000190)	(0.000229)	(0.000204)
Panel D: Dependent Var: Date of Coin (Century*100; larger values mean later dates)						
Script Date	0.0821**	0.108**	0.125***	0.144***	0.186***	0.157***
	(0.0388)	(0.0424)	(0.0422)	(0.0415)	(0.0506)	(0.0428)
Geo vars		X	X	X	X	X
Centrality			X	X	X	X
MA.Mines				X	X	X
size						X
Observations	894	894	894	894	631	631

Notes: OLS regressions for coinage against script adoption. Geographical variables here include ruggedness, malaria index, temperature, precipitation, elevation, and crops (barley, millet, summer wheat and winter wheat) suitability. Centrality here includes authority and hub centrality. MAMines here is the sum of inverse distances from a polis to known mines. For date related variables, we assume all poleis adopted at the censored date.

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$