Writing and the State: Information and State Capacity in Mesopotamia

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Abstract

The invention of writing can be considered one of the major technological innovations in human history. However, this giant leap in cognitive and information-processing capabilities is surprisingly ill understood. In this paper, we contribute to the limited empirical literature on the relation between writing and political development. We study the impact of writing on state capacity across 32 polities in Mesopotamia in the period between 3500 and 2900 BCE, which corresponds to the peak of the Urban Revolution. We find that polities that developed writing (i) constructed more and larger government buildings and (ii) were more likely to have multi-level bureaucracies. We interpret this as evidence that the adoption of writing led to improvements in infrastructural, fiscal, and administrative capacity. We find no evidence of the impact of writing on indicators of coercive capacity, which are correlated with prior stages of technological development. Our findings enable us to test arguments in the anthropological and archaeological literature about the mechanisms whereby innovations in communication technology affect the ability of (emergent) states to get things done. To address issues related to endogeneity, reverse causality, and potential unobserved confounders, we also study the patterns of diffusion of the technology after its invention: we find that, controlling for a number of geographic and institutional factors, political structure - in particular, whether the polity was ruled by religious corporations or clan-based elites - accounts for much of the observable variation in adoption patterns. Drawing from historical economics and the economics of religion, we trace this result to the organizational underpinning of elite power in Mesopotamia.

1 Introduction

The invention of writing can be considered one of the major technological innovations in human history. However, this giant leap in cognitive and information-processing capabilities is surprisingly ill understood. What were the consequences of this first information and communication technology (ICT) revolution? Did writing technology benefit public or private actors? How?

A large literature in archaeology and ancient history has long postulated positive effects of writing on the state, and extensively speculated about mechanisms (at least since Childe 1936). Empirical studies, however, are rare. Some of these have recently began to estimate the impact of writing on social complexity (e.g., Turchin et al. 2022; Feinman and Carballo 2022; Ellyson 2022), two more have focused on the impact of writing on state origins (Stasavage 2021; Stasavage et al. 2023). No empirical studies exist - as far as we are aware - on the impact of writing on state capacity.

In this paper, we fill this gap through an analysis of 4th millennium BCE Mesopotamia. Mesopotamia is one of the five (or six) places where writing developed independently (the others

being Egypt, China, the Indus Valley, Mesoamerica, and probably Easter Island); it is the region where writing and state-level societies developed first; and it is also comparatively better documented than other regions.[1] This is due to centuries of archaeological excavations and scholarship (Matthews 2004), to the durability of writing media, i.e. cuneiform texts written on clay tablets are virtually indestructible and account for the second largest corpus of ancient texts available today (Streck 2010), to the refinement of radiocarbon-based chronologies (Wencel 2018) and and the increasing availability of highly granular paleoenvironmental proxies (Armstrong et al. 2019). Thanks to this density of records, Mesopotamia provides the almost unparalleled possibility to precisely match large temporal and spatial variations in social, economic and political development trajectories with changes in ecological and productive conditions (Clarke et al. 2016; Benati and Guerriero 2021, 2023).

To assess the impact of writing technology on state capacity we built a novel dataset featuring 32 polities across northern and southern Mesopotamia and western Iran in the period between 3500 and 2900 BCE, before and after the invention of writing in Uruk around 3300 BCE.

Our empirical analysis suggests that polities that developed writing (i) constructed more and larger government buildings and (ii) were more likely to have multi-level bureaucracies. We interpret this as evidence that the adoption of writing led to improvements in infrastructural, fiscal, and administrative capacity. We find no evidence of the impact of writing on indicators of coercive (or military) capacity, which are correlated with prior stages of technological development.

These findings allow us to put to the test the mechanisms discussed in the archaeological and anthropological literature, which suggest that writing had a positive impact on state capacity by enhancing administration (Childe 1950; Nissen 1993; Hudson 2000) and revenue extraction (Goody 1986; Yoffee 2005). Although we lack robust proxies for revenue extraction, we can corroborate, specify, and elaborate on these claims.

However, the decision to adopt writing is endogenous. It is possible that our measures of state capacity are themselves affecting whether a state adopts writing. And there are a number of omitted variables that could affect both the adoption of writing and different measures of state capacity. These concerns arise because the adoption of writing was a decision made by local elites. This suggests that by understanding the diffusion of writing we might be able to address some of our endogeneity concerns.

The question of diffusion has been explored in prior work by archaeologists and anthropologists, who have put forth two explanations: one focused on demand, and another on supply. The demand side suggests that writing developed because states needed to tackle the challenges of scale and complexity, such as keeping track of storable produce or social relations, forecasting revenues, and coordinating and managing infrastructural work (Nissen 1986; Goody 1986; see also Turchin et al. 2022; Feinman and Carballo 2022; Ellyson 2022). The supply side argues instead that writing developed in polities whose neighbors had already developed the technology (Diamond 1997).

[1] We leave for the future a larger comparative project to test our results in other societies where writing arose independently (Egypt, China, Indus Valley, and Mesoamerica).

Our empirical analysis allows us to put pressure on both explanations. Size certainly mattered in determining where and when writing first developed - Uruk was by far the largest polity when the progress of technology enabled the leap to the stage of writing - or "true" writing - which is the focus of our analysis.[2] However, neither size nor proximity to Uruk explains the patterns of diffusion after writing was invented (TABLES 6 and 7).

Our data suggests instead that the type of political organization within a polity mattered more. After it was invented in Uruk, writing spread to polities governed by religious elites. In polities with more secular elites, instead, we see no evidence of adoption: these polities maintained prior systems of record keeping but did not develop true writing (they only adopted it in the latter part of the Bronze Age, see Quenet 2005).[3]

We search for an explanation in the influential body of literature in historical political economy, economic history, and the economics of religion focusing on the role of kin-based and religious structures in fostering or thwarting growth and development. In southern Mesopotamia, religious elites gained power in the context of non-kin, "corporate" social structures. The combination of religious power and corporate organizational structure makes southern Mesopotamia unique in the literature, where corporate organization is usually associated with European secular powers (Greif and Tabellini 2017). Like its secular European counterpart, corporate religious authority in Mesopotamia needed formal procedures to enforce social obligations. We argue that the written word may have been the first such procedure, preceding by several millennia legal codes and other formal institutions other scholars have studied in early modern Europe (Alesina and Giuliano 2010; 2015; Alesina et al. 2013; Greif and Tabellini 2017; Moscona et al. 2017, 2024; Schulz et al. 2019; Akbari et al. 2019; Schultz 2022; Barhami-Rad et al. 2022).

In highlighting the role of elite structure, our analysis challenges a competing view, common among archaeologists, that attributed the explosion in state capacity in the region in the period under analysis to idiosyncratic climatic shocks (3800-3100, peaking at 5.2ka BP, or 3250 BCE; Clarke et al. 2016). According to this view, climatic shocks stunted urbanization in the northern areas - the dry-farming regions of northern Iraq, northeastern Syria, and southeastern Turkey - and transformed southern marshes into productive agricultural lands, which triggered population growth, urbanization, and eventually the formation of Sumerian city-states - the so-called "Sumerian Takeoff" (Hole 1994; Clarke et al. 2016; Algaze 2005, 2008). Our analysis shows instead that climatic variables, like geographic and network-related variables, hold limited explanatory power.

Our paper contributes to several literatures. First and most obviously, it contributes to the empirical literature on the role of writing for state development with both new data and new

[2] We provide an account of the evolution of record keeping practices, and a justification for why we focus on true writing, in section 3.

[3] These structures are the product of an evolution from an earlier period (Ubaid/Early Chalcolithic) where both areas shared a mix of elites - sometimes identified as "chiefly" - to a later period where we see religious elites taking over in the south. The invention of writing takes place after this evolution.

findings. Moreover, unlike similar recent contributions, which are focused on state origins, we focus on state capacity.

Second, we contribute to the growing literature in historical political economy on the role of information technology for state formation and development. But unlike these studies, we do not focus on proxies consistent with the existence of centralized bureaucracies, like censuses or cadastral records. More generally, unlike much work on state capacity in political science and political economy, we do not assume that ancient states prioritized some functions - especially revenue extraction - over others. Instead, our proxies enable us to cast a wide net and capture coercive, fiscal, administrative, as well as infrastructural dimensions of state capacity. In other words, our study does not assume that the capacity that ancient states sought to build coincided with the capacity that *early modern European states* sought to build - as much work in historical economics and HPE does. As such, our conclusions should be of interest to those who study state capacity outside of early modern Europe.

Finally, our paper contributes to the literatures on the political economy of technological adoption and the economics of religion and social structure. Contrary to what happened in other historical periods, when individual entrepreneurship and impersonal secular power combined to give an edge to European states, in Mesopotamia, technological adoption and diffusion occurred in polities run by religious elites who deployed their ideological power to regulate productive functions, distributive justice, and social order (Liverani 2006). Interestingly, the organization of productive functions rested on a "corporate" social structure that enabled the evolution of impersonal bureaucracies that used the written word as a technology to enforce social and commercial obligations.

Our paper implies a tradeoff: in asking a big question - what was the impact of the first ICT revolution on state capacity - we rely on archaeological evidence that prevents the deployment of a clean identification strategy - a primary goal of much work in HPE. We believe the question is still worth asking, and we rely on a vast literature in several fields - political science, economics, archaeology, history, and anthropology - to scaffold our conclusions. We see this contribution as an alternative, not a substitute, to design-based inference approaches - one that might provide a template for future investigations (Benati and Carugati 2023; Verghese 2024).

The paper proceeds as follows: in the next section, we review a number of relevant literatures on state capacity, on writing, and on technological innovation and diffusion; section 3 provides some background to understand political development in 4th millennium BCE Mesopotamia and the nature and evolution of writing technology; section 4 presents our empirical analysis. Our conclusions follow.

2 Literature review

This section is divided into three parts. In part one, we review the social scientific literature on state capacity and suggest that it focuses on identifying core functions and drivers, but neglects the role of information; the recent branch of this literature that focuses on information studies institutions and functions associated with the early modern bureaucratic state. In part two, we focus

on the literature on early writing and suggest that the scholarship linking writing and early states has focused overwhelmingly on the question of state origins; when it focuses on capacity, qualitative studies point to several enhancements, but the mechanisms are vague and the magnitudes unknown. Finally, we review the literature in economic history and international relations studying the impact of technological innovation and diffusion, suggesting that only a fraction of this body of work focuses on indicators of political, as opposed to economic, development.

2.1 Information and the state

A multidisciplinary literature on state capacity has focused extensively on what functions are crucial to the rise and evolution of states, such as waging war, extracting revenue, and administering people and land (Tilly, 1990; Besley & Persson, 2009; 2011; Acemoglu et al., 2015). This literature has identified two main drivers of state capacity: external war and bargains among societal groups (Huntington 1968; Hintze 1975; Mann 1984; Tilly 1990; North Wallis and Weingast 2009; Besley and Persson 2009; 2011; Spruyt 2011; Fukuyama 2011; 2014; Dincecco and Katz 2012; Acemoglu et al. 2004; 2011; 2015). More recent contributions have also highlighted the role of religion and religious authorities (Rubin 2017; Grzymala Busse 2020; 2023).

The literature's emphasis on identifying core state functions and the drivers of state capacity has shifted the attention away from a core insight: to extract, administer, and coerce, the state needs information.[4] States need information to identify, monitor, and respond to potential threats – whether the coercive fetters are directed toward external or domestic opponents (Foucault 1977; Scott 1998). Information is also critical to the definition and enforcement of laws and norms, which depends on the ability of group members to know the rules and know that the others know – a process often referred to as the development of "common knowledge" (Ostrom 1990; Hadfield and Weingast 2012). Finally, information is critical to revenue extraction: in order to be able to tax its subjects, the state had to make the economic activity of its subjects easy to assess so it could know how much to collect (Scott 2017; Mayshar et al. 2017; Benati and Guerriero 2022; Mastrorocco and Teso 2023).

Political scientists have recently begun to conceptualize and measure information capacity in its own right. Several recent studies seek to establish the effects of increases in information capacity on core state functions, including administration and taxation, as well as how distributive politics affect capacity (D'Arcy and Nistotskaya 2017; Lee and Zhang 2017; Brambor et al. 2019; Rogowski et al. 2021; Christensen and Garfias 2021; Bowles 2023).

In a series of recent contributions, Carugati, Loyle and Steinberg (2022; 2023; 2024) study the impact of the digital revolution on state capacity. But little to no work yet exists on the impact of previous ICT shocks on state capacity. Analyses of the impact of the printing press have focused overwhelmingly on the spread of the Protestant Reformation and on economic growth (Dittmar,

[4] The same applies to market institutions: see Scott 1998; Fourcade and Healy 2017; Fourcade and Gordon 2020.

2011; Rubin 2014, 2017; Boerner et al. 2019; Becker et al. 2021); and only some limited work exists on the impact of the telegraph (Martland 2014; Kielbowics 1994; Parinandi 2023). Writing is no exception.

2.2 The invention of writing: causes and effects

Much of the early literature on the relation between writing and the state focused on the question of state origins: is writing necessary for the emergence of states? The answer seems a rather incontrovertible no: states emerged before writing, and there is plentiful evidence of large-scale states that never developed the technology, like the Inka or the Asante (Urton 2003; Goody 1986). Moreover, scholars have identified other drivers for the emergence of states: these include conflict (Dincecco 2017; Turchin et al. 2022) and biogeographical characteristics such as agricultural surplus (Childe 1936; Flannery and Marcus 2012; Blanton and Fargher 2008),[5] environmental circumscription (Carneiro 1970; Allen 1997), domesticability (Diamond 1997), and appropriability (Mayshar et al. 2022; Sanchez de la Sierra 2019).

However, writing also mattered in the process of early state formation. Arguments about the origins of writing include demand-driven (Nissen 1986; Goody 1986; see also Turchin et al. 2022; Feinman and Carballo 2022; Ellyson 2022) and supply-driven (Diamond 1997) theories: the former suggests that writing arose as early states began to face the challenges of scale and complexity - for example, keeping track of storable produce or social relations, forecast revenues, and coordinate and manage infrastructural work; the latter suggests that states developed writing because their neighbors developed writing.[6]

But what about the effects of writing on state capacity? Did writing enhance state capacity? And, if so, did it benefit all state functions, or only some? How, or through what mechanisms? And what kind of state did this technology foster?[7]

A vast literature in anthropology and archaeology attributes capacity-enhancing effects to writing technology. For V. G. Childe, writing enhanced administration, as it "enabled the leisured clerks to proceed to the elaboration of exact and predictive sciences - arithmetic, geometry and astronomy (1950: 14; cf. Nissen 1993; Hudson 2000). For Jack Goody (1986), writing enhanced legibility and extraction capacity, making it possible for rulers to more effectively manage economies based on storable produce (see also Yoffee 2005: 100-101).

These early accounts are confirmed by more recent contributions, which also document the evolution of writing practices - and of their implication for state capacity - over time and across the world (cf. Yoffee 2015: part 2). So, for example, for Bazerman (2022), writing in Mesopotamia begins with records of agricultural goods, but soon comes to spread to many areas of social life, including "administrative communication and cultural, medical, scientific, and prognostic

[5] Unlike previous scholarship, Blanton and Fargher (2008) suggest that not all states with surplus were hierarchical.
[6] According to Stasavage (2021: 92-4), across different places that adopted writing, including but not limited to Mesopotamia, both appear empirically robust.
[7] According to Stasavage (2021: 93), in the societies included in the SCCS, those with writing were just as likely to have council governance as those without writing." See also Stasavage et al. 2023, discussed below.

knowledge." For Moreno Garcia (2016; cf. Scott 2017; Graeber and Wengrow 2021), the function of writing varied significantly across the world: in Mesoamerica (Maya and Aztecs), "writing boasted of the achievements, rank and family connections of their rulers" (2016: 152); in Mesopotamia "writing was centered on the administration of the vast assets (land, grain, herds, labor) of otherwise rather impersonal institutions and not in celebrating early rulers and their deeds" (ibid 157); in Egypt, "royal tombs, ceremonial writing and monumental iconography represent the Egyptian variant of the civilisational package" (ibid. 160). Similarly, for Wang (2014), China used writing for a number of functions, including legitimizing the state through genealogies of rulers, counting and assessing people, assets and land, as well as creating a bureaucracy of administrators and law enforcers.

However, all these accounts are descriptive and potentially flawed: the impact of writing on state capacity, when considered, is inferred from the existence of records of activities, such as lists of criminal behaviors or land assessments; moreover, such lists may or may not actually represent the phenomena they are employed to capture. For example, as Moreno Garcia (2016: 157) points out, "the use of the Sumerian royal list as an historic source is… problematic, as it was a kind of ideal genealogy intended to provide prestigious links with a mythical past in order to legitimize kingship, not to record actual rulers, whose very existence is dubious in many cases."

In sum, writing seems to have done the state a great deal of good. However, the magnitude of these effects and the precise mechanisms remain unclear. Moreover, one can imagine that, as states developed new technology to make extraction, administration, and control more 'legible', non-state actors pushed back, as they do today (Carugati et al. 2023; 2024), by developing their own capacity and by withdrawing local knowledge.[8] But, perhaps, because writing technology - unlike, for example, the printing press or digital ICTs - emerged from within the state and lent itself to centralized control the pushback had little effect.[9] In the absence of more empirical studies, these dynamics and their implications remain essentially unknown.

But this conclusion may soon be reversed. Recent work by David Stasavage has begun to explore the relation between writing and the state empirically. In particular, a 2021 contribution to the *Handbook of Historical Economics* suggests that writing did have a significant impact on state origins - one comparable in magnitude to that of biogeographical characteristics (cereal suitability). Moreover, writing affected state presence by facilitating the emergence of bureaucrats and of formal tax collection. However, Stasavage's account relies on observations that are much later than the phenomenon under consideration.[10] In a more recent working paper, Stasavage,

[8] Local elites maintained a great deal of power in their regions. In addition, the evidence reveals that controlling local governors, like controlling tax farmers, was "a huge problem" (Jursa and Moreno Garcia 2015: 123) due to all sorts of information asymmetries and principal/agent problems.

[9] In Mesopotamia, for example, only a few people could read and even fewer could write: the former category was restricted to the palatial bureaucracy under the ruler; the latter category was restricted to the scribes who spent years learning the techniques and whose education was probably sponsored by, and certainly employed in, the palace itself (Veldhuis 2011; Stein 2001: 212). However, after 2000 BCE non-elite classes, such as merchants, started to use writing and we have a proliferation of private archives (Veldhuis 2011; Stein 2001: fig. 3).

[10] Most of the observations in the Standard Cross Cultural Sample date to the period between 1800 and 1950 CE. True writing first emerged in Mesopotamia in the second half of the 4th millennium BCE and later in China in 1400-1200 BCE and in Mesoamerica in 600-500 BCE.

Cheng and Wang (2023) suggest that the particular origin and spread of writing technology, not just its invention, affected the kind of state that emerged. The Chinese state, during the Tang and Northern Song dynasties, harnessed woodblock printing technology developed by Buddhist monks in competition with Taoist and Confucian doctrine to build a large bureaucracy that drew upon a large pool of talent. By contrast, in medieval Europe, the Church's monopoly on the written word, and the lack of competition by other religions, delayed the invention and spread of printing technology, and of state building. In this paper, we contribute to this limited empirical literature.

2.3 Technology and the State

The last body of literature worth discussing focuses on the impact of technological innovation and diffusion on political and economic outcomes. In the field of economic history, the focus is overwhelmingly on technology's impact on growth, rather than on state capacity. An important exception is Hoffman's paper (2012) on the role of gunpowder technology in the Great Divergence. Hoffman formalizes and expands Kennedy's (1987) argument about competition, suggesting that capacity gains accrued to European states through a process of learning-by-doing: Europe's incessant wars created incentives for rulers to invest in the development of gunpowder technology and provided plentiful opportunities to push the technology further. More commonly, in this literature, the state is relegated to the role of enforcer of property rights that create incentives for individual entrepreneurs to develop growth-enhancing technology (Allen 2009; Mokyr 2009; cf. Craft 2011). When the focus is not Europe, then the state becomes a malicious presence thwarting innovation: as in China, where, according to Lin (1995), the political environment disincentivized elites from pursuing scientific work.

International relations scholars have placed states in a more prominent position, even though political gains tend to be expressed in terms of power relations (namely, shifts in the balance of power) and to follow economic ones (Kennedy 1987). In a recent book, Jeffrey Ding (2024) reviews and challenges an influential theory of technological adoption and diffusion based on states' dominance over leading sectors, which placed emphasis on first-mover advantages and the fit between the first-mover's institutions and the technology itself (Gilpin 1987; cf. Drezner 2001). Ding - whose contribution focuses on general purpose technology (GPT) and economic growth as an outcome variable - shifts the focus away from the moment of invention, focusing instead on the process of diffusion, and argues that the greatest advantages come not immediately to the first-mover but to the states where GPTs spread across a number of productive sectors. The diffusion occurs during a period of gestation where ordinary engineers, rather than "heroic inventors," matter most. Analyzing three prior industrial revolutions, Ding concludes that "in all three periods, technological changes affected the rise and fall of great powers in a gradual, decades-long im–pact pathway that advantaged those that effectively diffused GPTs across a broad range of sectors. Education and training systems that cultivated broad pools of engineering skills proved crucial to GPT diffusion." (2024: 11).

Contrary to the literature in economic history, our account highlights the role of state actors in the adoption of new technology. In the next section, we describe and justify our case study.

3. Background

In this section, we provide a brief account of the evolution of Mesopotamian urban sites in the period in question. We then discuss the evolution of writing.

3.1 Mesopotamia in the 4th millennium BCE

The Onset of the Urban Revolution - the Early Chalcolithic (4200-3900 BCE) - The transition between the Neolithic and the Chalcolithic period is commonly considered as the starting point of the urbanization process in SW Asia, with a marked trend towards population concentration in main sites across the alluvium (Stein 2012: 139). This was possibly caused by a period of increased aridity around 4200-4100 BCE (Clarke et al. 2016), which seemingly triggered settlement intensification and more intense exploitation of high-resources areas (Nissen 2001: 171; Clarke et al. 2016: 19). Architectural and mortuary records provide clear evidence of economic differentiation and the emergence of formalized leadership and hereditary status, which can be seen as the rise of chiefly elites (Stein 1994: 38-39, 2012: 135; McMahon 2020: 309-310). The establishment of regular ''redistribution'' practices based on the centralization of primary resources in the hands of high-ranking individuals and their reallocation in public and elite environments generated the need for a centralized administrative system, which in turn set the stage for the emergence of leaders (Frangipane 2018: 10).[11]

North vs South Divergence - The Middle Chalcolithic (3900-3600 BCE) - The first half of the 4th millennium BCE is characterized by uneven political and social developments. The northern rainfed areas experienced strong urban growth and hierarchical differentiation early on, then plateaued on the tail of an aridification trend starting around 3700-3600 BCE (Clarke et al. 2016). In the irrigated alluvial lowlands, instead, this same climatic event fueled urbanism (McMahon 2020: 300; Stein 2012: 140; Matthews and Fazeli 2022: 159, fig. 6.51).[12] The growing rain-fed areas of the north experienced a significant increase in the wealth and power of leaders, bureaucratic and political centralization (Stein 2012: 140), and expansion of control over craft production, storage and trade (McMahon 2020: 316). Indeed, the concentration of feasting and redistribution practices in close proximity to productive and nonreligious buildings suggests the increasing reliance on secular leaders as providers of public goods (Benati 2018: 108-111; Frangipane 2018: 34-42, figs. 9-14; McMahon 2020: 310-314; Stein 2012: 141). The extensive use of seals and sealing devices indicates that ruling elites exerted control over surpluses, attached specialists and exotic commodities by means of specialized bureaucracies operating in their service (Stein 2012: 141; Benati 2018: 108-111; McMahon 2020: 313-314; Frangipane 2018: 18-30; Algaze 2023: 47-48).

Growing urban populations induced the expansion of cultivation, as attested by isotopic analyses of excavated crops from northern Mesopotamian sites (Styring et al. 2017), and the

[11] The social investments for the construction of monumental platforms in sites such as Uruk, Eridu and Susa were enormous. To cite an example, the bricks used to build the high terrace of Susa - a structure of 20m of height and a surface of ca 70x65m - could have covered a surface of 5.5 ha to a depth of 1 m (Matthews and Fazeli 2022: 150).

[12] Overall, it appears that the rapid urban growth in major sites was fueled by immigration from neighboring rural sites in the northern alluvium, whereas in the south it appears that population from more distant locations - i.e., Iran - was drawn in and resettled (McMahon 2020: 300; Algaze 2017, 2018).

consequent move of animal grazing in more marginal steppe areas away from settlements. The shift from labor to land-intensive agriculture dramatically increased the importance of land-based wealth and had three key implications: (i) it fueled inherited-wealth inequality as a source of power (Bogaard et al. 2018, 2019), (ii) it linked outputs to land inputs, making crop production more easily observable and thus facilitating control over surpluses (Strying et al. 2017: 9), (iii) it created the potential for territorial encroachments, fueling border disputes. In fact, in this phase, there is convincing evidence of large-scale organized violence, which has been associated with the rise of ruler-like figures and/or with rising external pressures (Stein 2012: 141; McMahon 2020: 324-325; Baten et al. 2023).

Urbanism in the southern alluvium and SW Iran took off only after 3700 BCE (McMahon 2020: 323; Matthews and Fazeli 2022: fig. 6.51), when the drying climate made it possible to gradually turn marshy lands into arable lots (Altaweel 2019; Wilkinson, Rayne and Jothery 2015; Benati, Guerriero and Zaina 2022). The ensuing flow of villagers to the major settlements of the lowlands made available large pools of laborers for the enterprises of urban elites, enabling the intensification of agricultural production, which yielded large surpluses (Algaze 2001a: 67; Benati 2018; Dow and Reed 2023: 368-369, 375; Matthews and Fazeli 2022: 160). Unlike in the north, where secular structures prevailed, southern elites were religious in nature and controlled some specialized productions and food distributions, although with a still embryonic use of bureaucratic technologies (Algaze 2023: 53-55). As a matter of fact, religious elites started to acquire supremacy in public goods provision because of their ideological prominence and their capacity to organize redistribution, a process that laid the groundwork for the transformation of temple households into formal institutions (Liverani 2006; Frangipane 2018: 11).

The South takes off - The Late Chalcolithic (3600-3100 BCE) - The final part of the Chalcolithic period saw the disappearance of satellite villages and consequent growth of major urban centers in the southern irrigated regions. Through this process, centers like Uruk, Nippur, and in SW Iran, Susa and Choga Mish transformed from regional powers into small states (Clarket et al. 2016: 15-16; Algaze 2001: 55; Matthews and Fazeli 2022: 172). Indeed, the construction of massive monumental compounds and the proliferation of sophisticated administrative technologies - now enumerating complex tokens, cylinder seals, hollow clay balls, and also numerical tablets (Matthews and Fazeli 2022: fig. 6.80) - indicates that elites achieved formal state-like capabilities, e.g. the authority to impose obedience, via ideological or coercive means, and the ability to delegate tasks, making possible to upscale territorial and social control (Frangipane 2018: 17-18; Matthews and Fazeli 2022: 157-158).[13]

At this point, true writing appeared for the first time in Uruk, the largest center of the time, allowing a massive expansion of information-processing capacity. Religious-ceremonial institutions operating in impressive monumental compounds - the Eanna complex in Uruk spread over 9ha (Butterlin 2018) - exploited the new technology to morph into bureaucratic corporations consisting of unrelated individuals enrolled as scribes, priests, and full-time administrators capable

[13] Pictorial representation of armed conflict in visual media (Frangipane 2018: fig. 3), and the diffusion of metal weapons (Gernez 2017), suggests that these polities started to compete to extend their control over the surrounding countryside (cf. Frangipane 2018: 16; Algaze 2001a: 55-56; Matthews and Fazeli 2022: 172)

of closely monitoring agricultural production, ceremonial events, infrastructural projects, labor allocation, and manufacture (Frangipane 2018: 15-16; Benati 2018: 112-116).

This period also witnessed the so-called "Uruk Expansion:" a rapid increase in inter-regional exchanges and the spread of southern Mesopotamian material culture along trade routes (Algaze 1993, 2001; Stein 1999, 2012; Butterlin 2018; Sauvage 2023: 36). The expansion manifested through the foundation of outposts characterized by Uruk material culture in the dry-farming regions - either merchant colonies or refugia for escapees (Frangipane 2018: 47; cf. Butterlin 2003: 131-137). The phenomenon was disruptive and far-reaching, yet short lived. In northern Mesopotamia some precocious urban sites were destroyed (Hamoukar), some contracted and changed settlement morphology (Tell Brak), while others show a gradual adoption of southern material culture, but only one step removed from true writing (Arslantepe; McMahon 2020: 303). Similarly, in western Iran, the culture of major cities, such as Susa and Choga Mish, became virtually identical to that of southern Mesopotamia without however developing writing beyond the stage of "proto" writing (Pittman 2013; Dahl 2018; Schmandt-Besserat 2018; Matthews and Fazeli 2022: 172; Englund 2004: 26-27). However, after 3200 BCE, in connection with the peak of the aridification event (Clarke et al. 2016), regional population densities declined in the rainfed north, the indigenous proto-states and the newly-founded settlements collapsed (Ristvet 2017: 36-38; Staubwasser and Weiss 2006: 379-380), whereas in Iran cultural connections switched eastwards (Richardson and Matthews 2018: 4-5).

Collapse and resilience - The Onset of the Bronze Age (3100-2900 BCE) - The transition from the Chalcolithic to the Early Bronze Age witnessed further climatic instability (Benati, Guerriero and Zaina 2022) and the breaking up of the Uruk interaction sphere into distinct regions with broadly divergent trajectories (Nissen 2001: 174-175; Matthews and Fazeli 2022: fig. 7.1). The northern plains underwent a long period of ruralization and regression to community-based organization (Ristvet 2017: 36, 39-40), the southern alluvium experienced profound socio-economic reorganization and a reorientation of trade towards the Gulf (Ristvet 2017: 38), and Iran witnessed the rise of the so-called "Proto-Elamite" culture.

In the northern dry-farming zones, the main Chalcolithic sites shrunk dramatically and the urban landscape was replaced by a system of village-based communities practicing subsistence economy (Ristvet 2017: 38; Schwartz 1994: 156). The remaining settlements displayed little or no evidence for social stratification, rich burials, monumental architecture, or elite culture (Ristvet 2017: 39). The only evidence about supra-domestic administration comes from storage facilities, which were administered by means of sealing technologies and tokens, but without writing (Ristvet 2017: 39-40; Schwartz 1994: 158). The central organization of staple storage through administrative tools has led some to hypothesize the existence of chiefly elites capable of controlling agrarian surpluses in some of the major towns (Schwartz 1994: 162-163),[14] while in the smaller ones, storage could have been coordinated collectively at community level (Ristvet 2017: 39).

In Iran, the climatic downturn severely impacted existing communities, causing widespread demographic decline and concentration of population in the few surviving regional

[14] Schwartz (1994: 163) notes that evidence for ideological basis for these chiefly elites is rather limited but that it is possible that they sought religious legitimation through the association with cultic activities.

centers (Matthews and Fazeli 2022: 188, 230). The Uruk cultural network was replaced by a fully local cultural horizon, the so-called Proto-Elamite (Steinkeller 2018; Pittman 2006; Matthews and Fazeli 2022: 189-192). Indeed, this pivotal shift is best illustrated by the abandonment of the Uruk accounting tradition (and glyptic, ceramic styles; Matthews and Fazeli 2022: 193-195), for the introduction of the Proto-Elamite script, probably developed at Susa, and then adopted across Iran as far east as Soktha (Dahl 2013, 2018; Dahl, Petrie and Potts 2013). Although inspired by the Uruk script, the Proto-Elamite was an entirely separate writing system and likely recorded an early form of the Elamite language, still largely undeciphered (Steinkeller 2018: 179-180; Dahl 2018: 383).[15] Based on the presence of ruler´s symbology, large-scale monumental architecture, accounts detailing the management of laborers, animals and products, and the widespread use of sealing devices for controlling stored commodities, it is possible to conclude that the main Iranian centers were dominated by powerful organizations composed of elite administrators and executives who exercised control over large-scale agrarian production (Matthews and Fazeli 2022: 199-204, 230). Notably, these Proto-Elamite elites made use of a distinctive ideology, grounded in the religious sphere, to create and sustain social identity at transregional scale (Matthews and Fazeli 2022: 233).[16]

The southern Mesopotamian alluvium, on the other hand, was able to better hedge against climatic deterioration by upscaling water management practices and experienced population takeoff with substantial growth of major urban sites (Marchetti et al. 2024: 28; Benati, Guerriero and Zaina 2022). Notably, Uruk undertook a complete reorganization of its monumental center (Heinrich 1982: fig. 142). Writing technology (Uruk III phase) made a quantum leap in terms of complexity and breadth of economic activities recorded,[17] and diffused widely within the alluvium, to sites such as Uqair, Ur, Jemdet Nasr, Larsa, and Umma, etc. (Englund 1998: 213). These early literate sites emerged as city-states dominated by major temple institutions, and possibly formal rulers (Steinkeller 2017), employing hundreds of full-time administrators and controlling vast agrarian resources (Benati 2015; Westenholz 2002; Garfinkle 2013).[18] In this phase major polities in the alluvium and some Proto-Elamite ones (Susa, Konar Sandal; Matthews and Fazeli 2022: 348; Benati 2015: fig. 6) were part of a network of collaborative cultic practices - the so-called "City-Seals Network" - which entailed inter-polity coordination for the organization of itinerant religious festivals (Matthews and Richardson 2018).

***

In sum, between the middle of the 5th and the beginning of the 3rd millennium BCE, Mesopotamian sites underwent significant developments. An environmental shock around 4200-4100 BCE jumpstarted urbanism and the development of proto states across Mesopotamia. Both

[15] Matthews and Fazeli (2022: 204-205) postulate that post-3200 Susiana witnessed the intrusion of new elite groups with strong links to Fars, who maintained the former bureaucratic structure in place albeit introducing a new language and culture.

[16] It is unclear whether the main Proto-Elamite centers (Susa, Geser, Malyan, Sialk, Sofalin, Yahya) were autonomous regional powers, or were part of a coherent state-like entity ruled by an a paramount center, such as Susa or Malyan (Matthews and Fazeli 2022: 232).

[17] According to Englund (1998: 123) the size of agricultural activity reflected in the Uruk III accounts must have been 10 times larger than that of the previous period.

[18] According to some historians (cf. Lecompte in Sauvage 2023: fig. 49), Uruk may have exerted a strong political influence on the southern alluvium, extracting tribute/taxes from the polities within its influence sphere.

in the north and in the south, the evidence reveals an increase in the wealth and power of leaders, bureaucratic and political centralization, as well as advances in the technology of record-keeping. While northern polities took advantage of this shift early on, attaining urban sizes and developing both priestly and chiefly ranks, but plateaued soon after, the south's late start proved longer lasting. Among the southern polities, one stood out: Uruk, where true writing was first developed in the context of religious household corporations. In the second half of the 4th millennium, Uruk experienced a proper takeoff and progressively drew other southern polities into its trade and cultural network. Climatic deterioration at the turn of the 3rd millennium yielded a significant downturn everywhere, with southern sites proving more resilient than those in other regions.

3.2 The introduction and evolution of writing

The introduction of true proto-cuneiform writing systems in southern Mesopotamia occurred around 3300 BCE. The first written documents, from Uruk, are clay tablets recording economic transactions (Nissen 2015).[19] As Englund (2011: 35) suggests, "[t]he archives from Uruk consist above all of administrative documents, accompanied by a group of texts generally known as lexical lists, although there is good reason to assert that we have among these lists the earliest known example of literature." The earlier texts, which number between 3000 and 5000, are overwhelmingly administrative, with lexical lists becoming more numerous in later periods.

But these documents do not come out of nowhere: instead, as Nissen (2015: 123) suggests, "the appearance of [true] writing is preceded by a long development of various means of information storage and processing, related to the evolution of a stratified social system and highly differentiated economy." This evolution occurred in phases.

For simplicity, we can distinguish an early and an intermediate phase, both of which predate the appearance of true writing. The early phase (pre-writing) saw a long evolution of systems of tokens that represented quantities of physical objects (Schmandt-Besserat 1992; 1996). As Englund describes, "First, the simple tokens were gathered in discrete assemblages and encased in clay balls in the periods immediately before the emergence of proto-cuneiform *c*. 3300 bc, and these balls were then sealed with impressions from cylinder seals… Second, the … tokens were themselves impressed on the outer surfaces of some [clay] balls, leaving marks which … conform exactly to the impressed numerical signs of the early so-called numerical tablets."

In the subsequent intermediate phase (proto-writing) "empty envelopes were flattened into flat tablets of clay, whose surfaces bore impressions of tokens and seals" (Moreno Garcia 2016: 153). These documents are "essentially numerical tables that indicate a certain quantity of a given commodity, using numerical symbols to indicate the quantity, and an ideographic symbol to indicate the kind of item being cataloged." (CDLI)

[19] According to Pittman (2013: 294): "The weight of accumulating evidence repeatedly confirms that writing was invented within the administrative environment of Uruk".

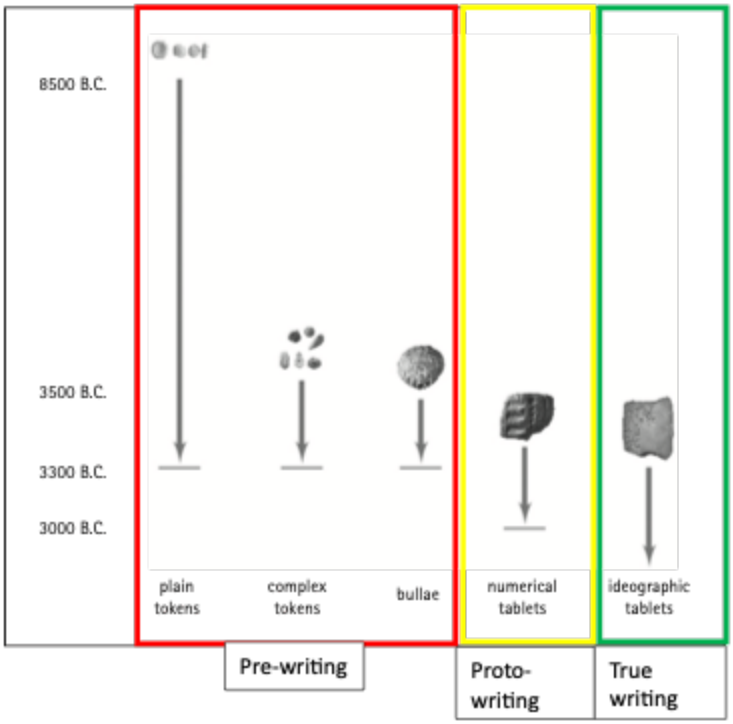

FIG 1. Evolution of writing systems (adapted from Englund 2011: fig. 2.2)

These earlier systems were widespread across Greater Mesopotamia. But true writing did not spread as consistently after its first appearance in Uruk. Our empirical analysis, to which we now turn, leverages this variation: why did true writing develop in some but not all polities, despite the fact that pre-writing systems were widespread? And what were the effects of its adoption on state capacity?

4. Empirical analysis

4.1 Data

We collected data for 32 polities across northern and southern Mesopotamia for every 50 years in the period between 3450 and 2900 BCE. The sites studied so far have been selected based on patterns of occupation and extent of evidence: we have considered sites with the longest occupation history throughout the period in question and systematically excavated. At a later stage in the project, we plan to collect data for all sites in the region larger than 5ha. This extension of the dataset should yield a total of around 70 sites. The selected period allows us to capture the steps in the introduction, evolution, and diffusion of early writing technologies in southern Mesopotamia and Iran.

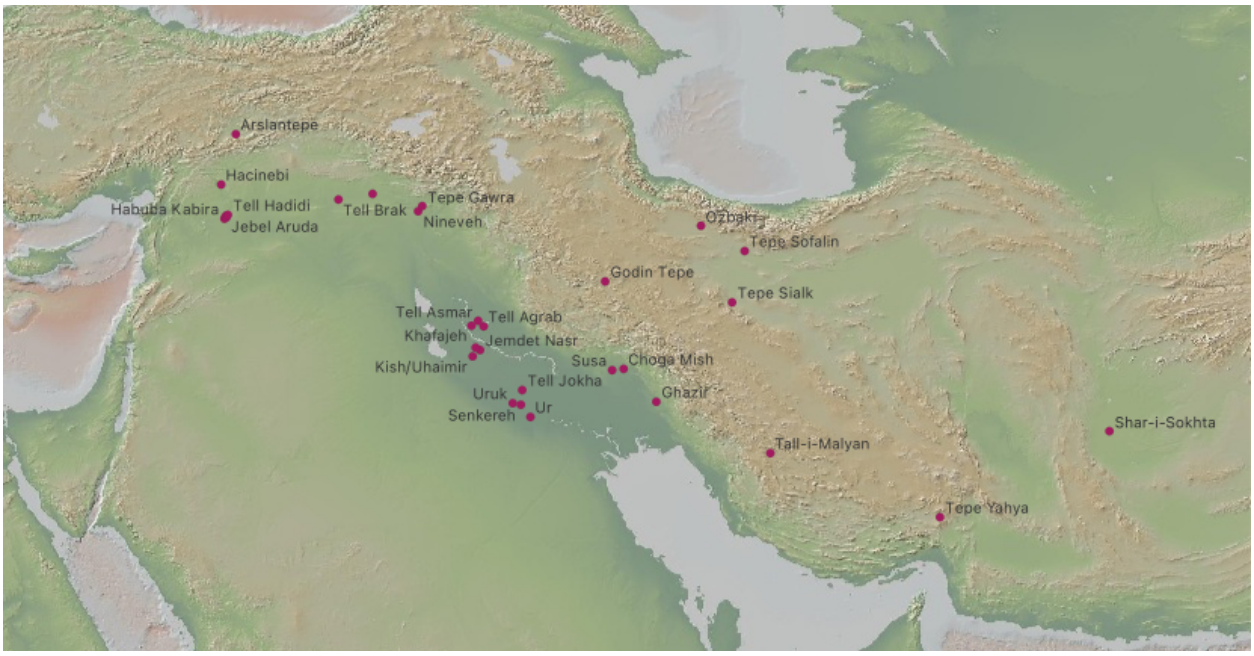

FIG.2 Geolocated Sites.

Our independent variable is "true writing." Unlike pre- and proto-writing, which were essentially notational systems to record individual quantities, true writing afforded a much broader range of functions, such as listing people and resources, as well as consolidating transactions into single documents.

Our dependent variable is "state capacity," which we proxy to capture coercive, infrastructural, fiscal, and administrative functions (as indicated below). As discussed, we cast our net wide because we prefer to remain agnostic as to which functions ancient states prioritized or privileged. In other words, we do not assume, as it is often the case in studies of early modern state formation, that fiscal capacity (or coercive capacity) would necessarily capture the priorities of ancient states.

In particular, we gather data for the presence of fortifications, distribution of metal weapons, the presence and size of government buildings (i.e., large-scale buildings with remains of administrative or collective activities), the presence and type of administrative seals, and the presence of a complex, multilevel bureaucracy. We describe each proxy in turn.

- Fortifications: The presence of fortifications is an obvious proxy for military (and infrastructural) capacity. Fortifications are quintessentially military constructions, and oftentimes the most visible remains in the archaeological records. Ancient fortifications were usually defensive walls constructed around cities to protect them from enemy attacks. In the close-knit competitive environment of ancient Mesopotamia, fortifications were a primary indication of the ability of a state to generate the kind of collective action that large scale public works require (Melville 2020).

- Distribution of metal weapons: Lacking historical evidence for the intensity of warfare (cf. Baten et al. 2023), we also proxy coercion capacity via the presence of metal weapons found in the sites under consideration, based on archaeological reports.
- Government buildings: According to B. Englund (1998: 213) the best "indicator of state strength" in these early periods is communal activity directed at monumental construction. Indeed, early states allocated revenues to the construction of public buildings as well as to the support of specialized personnel in charge of administrative functions (Dow and Reed 2023: 428, 377). As such, monumental architecture and bureaucratic complexity can be used as proxies for the state's administrative capacity. Their size points to the amount of manpower and resources that states directed toward administrative activities, which is a fundamental measure of power (Trigger 1990).
- Pictorial representations of authority or administration: While in earlier times seals and sealings were found dispersed in different contexts across sites and primarily depicted simple geometric or schematic imagery, in later periods, bureaucratic technologies are concentrated in specialized buildings and many seals carry complex imagery that directly depicts authority or economic production activities (Green 2020; Dittman 1986; Pittman 2013). Indeed, a variety of scenes from numerical tablets, bullae and sealings - depicting agricultural work, storage of produce, manufacturing, animal herding, hunting or marshaling captives - confirm a connection between an emerging administrative elite and the organization of different types of workers, which we employ as proxy for the presence of complex bureaucratic structures (Dahl, Hawkins and Kelly 2018: 16).
- Priest-kings: This variable captures the presence of "priest-kings" in glyptic imagery or statuary - a bearded man wearing a net skirt and shepherd´s cap interpreted as a ruler or a chief ritual official (Wang 2021; Marchesi and Marchetti 2011: 186-196) -, as proxy for the presence of a top level of hierarchy (Pittman 2013; Algaze 2023: 56-57). While seals with images of authority or administration indicate the presence of a multilevel bureaucracy, pictographic references to priest kings suggest a multilevel structure with top executives.

Table 1. Main variables

Variable	Description and sources	Proxy
true writing	Presence of true proto cuneiform writing, or "Uruk IV" stage (CDLI)	Writing
Fortifications	Presence of fortification works (Authors´ coding: See Appendix)	Infrastructural/defensive capacity
Distribution of metal weapons	Presence of excavated metal weapons in sites (Authors´ coding: See Appendix)	Offensive/coercive capacity
Government buildings	Share of time during which government buildings, i.e., large-scale buildings with remains of administrative/nondomestic activities, are archaeologically attested (Authors´ coding: See Appendix)	Infrastructural capacity

Government bldg. size	Size of largest monumental building excavated (Authors´ coding: See Appendix)	Infrastructural/fiscal capacity
Cylinder seals with authority/ administrative scenes	Presence of imagery depicting authority or administration scenes in glyptic materials (Authors´ coding: See Appendix)	Administrative capacity
Priest kings	Presence of "priest-king" in glyptic imagery or statuary as proxy for the presence of top executive layer (Pittman 2013)	Administrative capacity

We have also collected data for a number of control variables including variables for pre-existing technological (proto-writing) and economic (site size) development, as well as controls for existing interaction networks (the "city-seals" network - a network which Mesopotamian sanctuaries used to coordinate itinerant cultic festivals: Matthews & Richardson 2018), climate and geography (including temperature, rainfall, farming production, terrain roughness, based on Benati, Guerriero and Zaina 2022).

Table 2. Controls

Proxy	Variable	Definition	Sources
Pre-existing technological development	proto_writing	Presence of numero-ideographic documents corresponding to the so-called "Uruk V" development stage of proto cuneiform script	Cuneiform Digital Library Initiative (https://cdli.mpiwg-berlin.mpg.de/)
Development	site_size	Settlement size in hectares as recorded in archaeological surveys or calculated by archaeologists based on scatter area of artifacts, area circumscribed by walls or surface occupied by remains of buildings	Authors' coding from archaeological settlement data
City Seals network	cs_net	The City-Seals (CS) network indicates participation of the polity in a taxation system created to organize an intercity cultic network.[20]	Authors' coding based on Matthews & Richardson 2018
Geography	temperature	Rating curve for monthly temperature in degrees Celsius averaged over the previous 50 years	Armstrong et al. 2019
	precipitations	Rating curve for monthly precipitation in mm averaged over the previous 50 years	Armstrong et al. 2019
	farming_return	Synthetic harvest value corresponding to a normalized (to range between 0 and 1) product of an inverted U-shaped rating curve for the temperature (°C) and an inverted U-shaped rating curve for the monthly precipitation	Armstrong et al. 2019

[20] This system mirrors the later "mashdaria" tax and is most clearly illustrated as "a kind of tax on production, delivered to the political centre [probably Uruk], and there used to equip festivals" (Sallaberger 2018: 173)

		(mm/m) all averaged over the previous 50 years	
	farming_returnV	Variability of return F (before the averaging over the past 50 years) calculated as yearly average range divided by the yearly mean (maximum yearly value− minimum yearly value)/ yearly mean) in the previous 50 years	Armstrong et al. 2019
	Uruk-distance	Euclidean distance from Uruk, point of invention of writing	Authors´ calculation
	PDSI	Palmer drought severity index (PDSI) is an inverse measure of the inability of the supply of soil moisture to meet its demand and ranges between extreme droughts - i.e., -10 - and totally wet conditions - i.e., 10 and is calculated following Jacobi et al. (2013), as the combination between temperature, rainfall, latitude and the available water storage capacity - the mm/m of water that a soil can store for plants by the HWSD dataset - all averaged over a 30 km radius around each polity and for each 50 years.	Armstrong et al. 2019; FAO Harmonized World Soil Database: https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/harmonized-world-soil-database-v20/en/
	climate_volatility	First principal component between (standardized) monthly precipitation's (mm/m) average yearly range divided by the yearly mean in the previous 50 years and (standardized) temperature's (°C) average yearly range in the previous 50 years	Armstrong et al. 2019
	roughness	Terrain roughness	G-Econ

The data we collected is subject to several potential sources of bias, including sample selection, taphonomic (survival) bias, temporal uncertainty, epistemological biases, and missing evidence. We discuss these issues at greater length and illustrate our solutions in the technical appendix.[21]

4.2 Research design and results

Our data exhibits both cross-sectional and time variation, and so our estimation uses fixed effects estimators. Table 3 shows the effect of the presence of true writing on different measures of state capacity. For each site, the *true_writing_incidence* variable is a dummy set to 1 in the period true writing was adopted by the site and in every period afterwards. The variable *proto_writing_incidence* is the equivalent dummy but for the presence of proto writing. We control for temperature, precipitation and include site and time fixed effects.

[21] The technical appendix is not yet complete.

Table 3: writing on different types of state capacity

Dependent Variables:	gov_build	fortifications	ln_size_monument	priest_king	weapons	aut_adm_scenes
Model:	(1)	(2)	(3)	(4)	(5)	(6)
Variables						
true_writing_incidence	0.1455*	0.0310	0.6906+	0.0652***	0.0365	0.2196**
	(0.0470)	(0.0563)	(0.3448)	(0.0090)	(0.0410)	(0.0514)
proto_writing_incidence	0.1309	0.3785***	0.5594	0.2003**	0.5942***	0.5287***
	(0.0858)	(0.0708)	(0.3588)	(0.0489)	(0.1137)	(0.0568)
temperature	0.6384	0.3305	3.314	0.2251	0.0371	0.3279
	(0.4376)	(0.3391)	(2.634)	(0.2714)	(0.2631)	(0.3669)
precipitations	0.0667	0.0033	0.4153	0.0764*	-0.0077	0.0721
	(0.0517)	(0.0249)	(0.3374)	(0.0278)	(0.0260)	(0.0498)
Fixed-effects						
time_index	Yes	Yes	Yes	Yes	Yes	Yes
ID	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics						
Observations	396	396	396	396	396	396
R^2	0.52460	0.52890	0.60719	0.53034	0.65250	0.50355
Within R^2	0.02410	0.07034	0.01854	0.04704	0.18384	0.13771

Clustered (time_index) standard-errors in parentheses
*Signif. Codes: ***: 0.001, **: 0.01, *: 0.05, +: 0.1*

The incidence of true writing has a positive and significant effect on *gov_build* and *ln_size_monument*, variables that capture fiscal and infrastructural capacity. It has no effect on *fortification* or *weapons*, two variables that capture the defensive and offensive capacity of the state. For these variables it is proto writing that has explanatory power. This might indicate that variables related to defensive/offensive capacity capture priorities at earlier stages of development - for example the need to provide defense against wild animals, floods, as well as enemies, or the need to display chiefly status (Frangipane 2017: 177). Finally, the variable *priest_king* and *aut_adm_scenes*, the latter of which captures the images in seals, are both positive and statistically significant at the 1 percent level. Overall, the incidence of true writing is highly correlated with infrastructural and administrative measures.

Table 4 shows the same estimates but with the right-hand side variables lagged by one period (which in our case is equivalent to 50 years). We do this for two reasons. First, our hypothesis is that writing affects state capacity, and so we would expect to see the adoption of writing to be followed by increases in state capacity. It is easier to see whether this is the case if we lag true writing. Second, some of our measures of state capacity will adjust slowly after the adoption of true writing: it takes time to build a new government building or fortification. The lag gives the process enough time to reveal the full effect of true writing on state capacity. The results in Table 4 show that the use of the lag does not substantively change the results reported in Table 3.

Table 4: Lagged writing on different types of state capacity

Dependent Variables:	gov_build	fortifications	ln_size_monument	priest_king	weapons	aut_adm_scenes
Model:	(1)	(2)	(3)	(4)	(5)	(6)
Variables						
lag_true_writing_incidence	0.1092*	0.0410	0.7639*	0.0612**	0.0278	0.2341***
	(0.0408)	(0.0423)	(0.2943)	(0.0148)	(0.0354)	(0.0491)
lag_proto_writing_incidence	-8.31×10^{-5}	0.2458*	0.0881	0.1624+	0.4914*	0.3978*
	(0.1370)	(0.0816)	(0.7007)	(0.0735)	(0.1732)	(0.1413)
lag_temperature	0.8637*	0.4706	4.733+	0.3956	-0.0692	0.6052+
	(0.3736)	(0.2665)	(2.358)	(0.2335)	(0.3000)	(0.2849)
lag_precipitations	0.0860	0.0154	0.5783	0.0412	0.0060	0.0370
	(0.0576)	(0.0320)	(0.3534)	(0.0304)	(0.0257)	(0.0524)
Fixed-effects						
time_index	Yes	Yes	Yes	Yes	Yes	Yes
ID	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics						
Observations	363	363	363	363	363	363
R^2	0.52617	0.56996	0.61965	0.54346	0.64500	0.51482
Within R^2	0.02131	0.04159	0.02636	0.02750	0.13081	0.11407

Clustered (time_index) standard-errors in parentheses
*Signif. Codes: ***: 0.001, **: 0.01, *: 0.05, +: 0.1*

Table 5 combines the measures of state capacity into categories by adding up the component dummies. The first category, *infrastructure_complexity*, is equal to *gov_build* + *fortifications*. *Administrative complexity* is the sum of *priest_kings* and *aut_adm_scenes*. *Military complexity* is equal to *fortification* + *weapons*. *Total_state_capacity* is the sum of the five dummies used to create the measures in columns 1-3. This confirms our results: the incidence of true writing has a positive and statistically significant effect on different types of state capacity, with the exception of military complexity. For military complexity the positive correlation is with proto-writing.

Table 5: writing on different aggregate measures of state capacity

Dependent Variables:	infrastructure_complexity	administrative_complexity	military_complexity	total_state_capacity
Model:	(1)	(2)	(3)	(4)
Variables				
true_writing_incidence	0.1765+	0.2848***	0.0675	0.4979**
	(0.0965)	(0.0517)	(0.0760)	(0.1428)
proto_writing_incidence	0.5093***	0.7290***	0.9727***	1.833***
	(0.1101)	(0.0812)	(0.1731)	(0.2797)
temperature	0.9690	0.5530	0.3676	1.559
	(0.6753)	(0.5915)	(0.4408)	(1.284)
precipitations	0.0700	0.1485+	-0.0044	0.2109+
	(0.0605)	(0.0748)	(0.0399)	(0.1155)
Fixed-effects				
time_index	Yes	Yes	Yes	Yes
ID	Yes	Yes	Yes	Yes
Fit statistics				
Observations	396	396	396	396
R^2	0.49552	0.53735	0.63699	0.58484
Within R^2	0.04358	0.10866	0.19865	0.13821

Clustered (time_index) standard-errors in parentheses
*Signif. Codes: ***: 0.001, **: 0.01, *: 0.05, +: 0.1*

There are clearly a number of concerns related to endogeneity. It is possible that our measures of state capacity are themselves affecting whether a state adopts true writing. And there are a number of omitted variables that could affect both the adoption of true writing and different measures of state capacity. These concerns arise because historical evidence suggests that the adoption of true writing was a decision made by local elites.[22] This suggests that by understanding the diffusion of true writing we might be able to address some of our endogeneity concerns.

Tables 6 and 7 check for the two most likely determinants of diffusion. Table 6 looks at the distance from Uruk, the site where true writing was first developed. The table shows that distance was not a very good predictor of adoption. Table 7 looks at the average size of sites that adopted true writing in a given period. Again, size does not appear to be a good predictor of adoption.

Table 6: Average distance of sites that adopted writing in a given year

year_first_treated	average_distance_to_Uruk
-3,300	328,188.79
-3,250	614,593.20
-3,150	264,474.31
-3,050	375,311.42
-2,900	1,314,404.47
Never treated	673,205.75

Table 7: Average size of sites that adopt writing in a given year

year_first_treated	average_size_3300
-3,300	93.00
-3,250	3.50
-3,150	11.42
-3,050	9.33
-2,900	0.00
Never treated	13.36

Table 8 then examines the determinants of diffusion in more detail. Columns 1 and 2 show which variables predict the incidence of true writing. It shows that the presence of a religious elite is the main significant correlated of the incidence of true writing. A measure of drought (*PDSI*) shows a negative and borderline significant effect on the adoption of true writing. Column 2 interacts distance to Uruk with two other variables: membership in the "City Seals" network and the

[22] To illustrate, during the Bronze Age (after 2600 BCE), cuneiform writing spread from southern Mesopotamia to major polities in the northern regions along the Euphrates because local ruling elites that were in contact with the alluvium, via trade or otherwise, felt the need to acquire the technology from Mesopotamian scribes (Archi 2015: 18).

presence of religious authorities. Again, distance seems to not be a meaningful correlate of true writing.

Columns 3 to 8 replicate the regressions in Table 3 while controlling for some of the proposed drivers of diffusion. Columns 3 to 7 show that the effect of true writing on these measures of state capacity disappears. One possibility is that the variable *religious* picks up most of the variation. This result suggests that the presence of religious authorities may have led to the adoption of true writing, which in turn had an effect on different measures of state capacity. Column 8 presents a somewhat different result: it shows that true writing is still a positive and significant correlate of state capacity when this is measured as the presence of seals. This is evidence that true writing may have an effect on some measures of state capacity even once we control for some of the drivers behind its adoption.

Table 8: Drivers of diffusion; state capacity controlling for drivers of diffusion

Dependent Variables:	true_writing_incidence		gov_build	fortifications	ln_size_monument	priest_king	weapons	aut_adm_scenes
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables								
proto_writing_incidence	-0.0567	-0.0542	-0.0605	0.3242**	-0.4063	0.1407*	0.5532***	0.4640***
	(0.0546)	(0.0626)	(0.0675)	(0.0775)	(0.3639)	(0.0541)	(0.1102)	(0.0362)
cs_net	0.1632+	0.0994	0.0139	-0.0184	1.221***	0.1746**	-0.1594**	0.4885***
	(0.0809)	(0.0932)	(0.0283)	(0.0287)	(0.1824)	(0.0488)	(0.0438)	(0.0255)
religious	0.1341*	0.1939**	0.8965***	0.2442***	4.999***	0.3023***	0.1556***	0.3993***
	(0.0594)	(0.0610)	(0.0290)	(0.0475)	(0.1531)	(0.0270)	(0.0332)	(0.0194)
PDSI	-0.1584+	-0.1536+	-0.0841	0.0145	-0.6221	-0.0463	0.0371	-0.0794*
	(0.0755)	(0.0755)	(0.0986)	(0.0720)	(0.3957)	(0.0299)	(0.0421)	(0.0360)
temperature	-0.4787	-0.4934	0.5200	0.3186	2.578	0.1838	0.0422	0.2724
	(0.5158)	(0.5161)	(0.3332)	(0.2934)	(1.956)	(0.2048)	(0.2401)	(0.2227)
precipitations	-0.0149	-0.0173	0.0539	-0.0106	0.3465	0.0727*	-0.0188	0.0626*
	(0.0394)	(0.0400)	(0.0493)	(0.0334)	(0.2463)	(0.0236)	(0.0299)	(0.0251)
cs_net × distance_to_Uruk		7.27×10^{-7}						
		(5.32×10^{-7})						
distance_to_Uruk × religious		-1.17×10^{-7}						
		(1.01×10^{-7})						
true_writing_incidence			0.0036	-0.0006	-0.1576	-0.0003	0.0323	0.1134**
			(0.0413)	(0.0535)	(0.2542)	(0.0298)	(0.0435)	(0.0284)
Fixed-effects								
time_index	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ID	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics								
Observations	384	384	384	384	384	384	384	384
R^2	0.65925	0.66053	0.75860	0.56611	0.78860	0.61579	0.67326	0.65744
Within R^2	0.05958	0.06310	0.53132	0.14696	0.53094	0.22162	0.23405	0.40817

Clustered (time_index) standard-errors in parentheses
*Signif. Codes: ***: 0.001, **: 0.01, *: 0.05, +: 0.1*

4.3 Discussion

Our results enable us to empirically test the arguments proposed in earlier anthropological and archaeological literature concerning both processes of diffusion and the mechanisms whereby writing affects state capacity.

According to this literature, writing developed because of either demand or supply factors. A number of scholars has variously articulated the demand side, according to which writing

developed because states needed to tackle the challenges of scale and complexity, such as keeping track of storable produce or social relations, forecasting revenues, coordinating and managing infrastructural work (Nissen 1986; Goody 1986; see also Turchin et al. 2022; Feinman and Carballo 2022; Ellyson 2022). Others, instead, suggested that writing developed in polities whose neighbors had already developed the technology (Diamond 1997). Moreover, writing had a positive impact on state capacity by enhancing administration (Childe 1950; Nissen 1993; Hudson 2000) and revenue extraction (Goody 1986; Yoffee 2005).

Our analysis suggests that polities that developed writing (i) constructed more and larger government buildings and (ii) were more likely to have multi-level bureaucracies. We interpret this as evidence that the adoption of true writing led to improvements in infrastructural, fiscal, and administrative capacity. We find no evidence of the impact of writing on indicators of coercive capacity, which are correlated with prior stages of technological development (proto-writing).

Moreover, demand played an important role in the shift from proto-writing to true writing. In fact, when technological progress made the shift possible, Uruk was by far the largest site (but not before). This finding reflects broader arguments in the economic history literature about the relationship between size (and demography) and technological innovation (Lin 1995). However, neither size nor proximity to the inventor explains diffusion patterns.

Instead, diffusion occurred across polities that were ruled by religious elites. This finding runs against much literature in historical economics and the economics of religion suggesting instead that religious elites and institutions are detrimental to technological adoption and development, as well as to growth outcomes more broadly.

Kuran (2011) famously argued that the root cause of Middle East stagnation was Islamic law or Sharia — especially its inheritance system and partnership law — that governed most economic activities. For Rubin (2017), the persistence of Islamic law was at least partly a consequence of the role of the political power ceded to Muslim religious authorities due to their ability to provide legitimacy. This power was used to block technological advances such as the printing press.

More recently, however, advances in the economics of religion have stressed religion's (potential) contribution to growth. In a recent paper, Becker et al. (2023) reviewed the literature, highlighting four main mechanisms: physical capital formation (via thrift and saving behavior; financial development); human capital (via education); labor (via labor input; fertility); TFP (via technology; social institutions and cultural norms).

The literature on the impact of religion on technology is also mixed. Like Rubin (2017), others have suggested that religious elites, organizations, and culture can be bad for technological adoption and development. Seror (2018) suggests that economic prohibitions may be promoted by religious authorities when it improves their political bargaining power (see also Cosgel, Miceli and Rubin 2012). Naghavi (2019) argued that a relative lack of intellectual property rights in Islam has impeded technological development. Chaney (2023) suggested that scientific production dropped dramatically in the Islamic world in the 11th and 12th centuries as the rise of the madrasas shifted learning from secular to religious institutions. Finally, for Benabou, Ticchi and Vindigni

(2022) the negative relationship between religion and technology may be because scientific discoveries can erode religious beliefs.

Yet others have argued that religion is good for technology. The mechanisms run through both religious organizations and culture. According to Ma (2021) and Davids (2013, ch. 3), in the medieval period, monastic houses throughout Europe were the primary places where technical knowledge, books, and informal learning were preserved; similarly, in the 17th and 18th centuries, Jesuits acted as central conduits through which technical knowledge was passed between Europe and China. Cinnirella and Streb (2018) have also found that, in late-19th century Prussia, those cities that had greater religious toleration (as measured by the presence of different denominations) had greater patenting activity (see also Hornung 2019).

Similarly, our results suggest that polities governed by religious elites were more likely to adopt writing and to see concurrent increases in state capacity. Why?

Elite structures emerged from a particular evolution that, with the impulse of the urban revolution, led to a differentiation in social structures between the north and the south (Frangipane 2018; Stein 2020). In the rainfed north, the underlying tribal social structure and a lower degree of stratification produced more secular types of political and economic authorities, despite the continued importance of ritual practices (McMahon 2020: 310-311; Frangipane 2018: 21, 24; Stein 2020). Here, temples did not develop the capacity to organize agrarian resources and did not provide legitimacy to political leadership, who, instead relied primarily on their kinship network as a source of followers and supporters, reinforced by the wealth accumulated through long-distance trade in prestige goods (Stein 2020: 177, 179).

By contrast, in the south, leaders used their role in the temple-based ritual system as a means to mobilize economic surpluses from irrigation-based agriculture (Stein 2020: 175, 179). Ritual-based authority allowed leaders to extend their influence beyond the limits of their kinship networks, increasing their capacity to attract and reward followers that contributed labor and resources to cities that became "ideological" attraction poles (Stein 2020: 175-176).[23] As Liverani (2006: 30-31) put it, "[...] the urban revolution established a system of impersonal relations and bureaucracy, under the central administration of the temple…[it] liberated the remaining (and persistent) private sector from its traditional kinship ties, and started a long and slow historical process toward the management of labor and of the means of production on an individual basis."

To clarify how the evolution of social structures affected technological adoption, we rely and expand on an argument well-known in historical economics on how social organization affects economic and political outcomes. According to Greif and Tabellini (2017), kin-based "clan" structures - such as those that persisted in the north of Mesopotamia and were common in early modern China - rely on "reciprocal moral obligations and personal interactions" to enforce social obligations. By contrast, non-kin "corporate" structures - such as those that evolved in 4th millennium southern Mesopotamia and characterized early modern Europe - must invest in formal

[23] According to Stein (2020: 179) southern Iran political economies combined elements of both north and south Mesopotamia, but the sources of power were strongly ritually based.

and costly enforcement procedures to ensure cooperation and public goods provision - procedures that can however be scaled.[24]

Focusing on the early modern period, Grief and Tabellini highlight the importance of legal codes among such enforcement procedures. Focusing on a much earlier period, we argue that those advances would have been impossible without, and indeed depend on, an earlier invention: the written word. As a matter of fact, an economy based on large-scale redistribution cannot function on goodwill (Goetzmann 2016: 34). The ability to abstract and summarize information beyond the mnemonic capabilities of single individuals allowed not only to turn social obligations into formal commitments, making the deployment of labor more efficient, but it also allowed long-run planning, which are building blocks of finance and taxation (Algaze 2001b: 213; Goetzmann 2016).

As a matter of fact, proto-cuneiform can be defined as an "accountant's script", a powerful tool for formalizing control over economic procedures (Nissen, Damerow and Englund 1993: 30). Notably, the main concern of early scribes was not only recording the collection and disbursement of goods, labor, domestic livestock and parcels of agricultural land, but also computing future debts, standardized obligations and fluctuations in animal herds (Nissen, Damerow and Englund 1993: 11, 35). In particular, archaic accounts focus on quantifying dependent laborers and workers, divided into gender and age categories, based on the same accounting practices used for domestic animals (Englund 1998, 2004, 2011). This process of "domestication of human labor" has been seen as a proper "labor revolution", which allowed southern urban elites to organize work beyond traditional means - e.g., occasional feasting, reciprocal obligations -, unlocking the potential of economies of scale derived from economic and social specialization (Algaze 2001: 211-212).[25]

[24] For Greif and Tabellini (2017), the origins of the different social structures rest on migration patterns. In Mesopotamia, the divergence may rest on geography and the consequent systems of production (cf. Stein 2020).
[25] According to Algaze (2001: 211), while redistribution existed in northern Mesopotamian societies as well, these had no access to comparable labor labor pools.

FIG. 3 Account of grain product from Uruk, (3100 BCE, P005313)

Like Greif and Tabellini's, our findings echo a vast literature on the effects of kin-based structures for development. In this literature, kin-based structures are associated with detrimental political outcomes such as less democratically-oriented political attitudes (Alesina et al. 2013) and institutions (Schultz 2022); fewer impersonal institutions for cooperation and public goods provision (Greif and Tabellini 2017; Schulz et al. 2019); more violence and less interpersonal trust (Moscona et al. 2017, 2024); more corruption (Akbari et al. 2019). They are also associated with detrimental economic outcomes (Barhami-Rad et al. 2022; cf. Alesina and Giuliano 2010; 2015), affecting the organization of labor (high kinship intensity makes it difficult for a society to fully exploit opportunities created by specialization and trade), trust (kinship lowers interpersonal trust), the quality of institutions (higher expropriation risk and corruption) and innovation (fewer technical journals and patents per capita). The connection between kin-based structures and economic decline also runs through the channel of technology: according to de la Croix et al. (2018) kinship institutions slow down the diffusion of productive knowledge, constraining growth. In a similar vein, Gorodnichenko and Roland (2016) suggest that individualistic (and not kin-based) cultures create incentives for innovation by awarding greater social status to personal accomplishments such as making important discoveries.

Our focus on Mesopotamia allows us to make a further contribution to the study of social organization, technological adoption, and development: because much of the literature discussed

above focuses on early modern Europe, it tends to conceive of inventors as random geniuses or tinkerers, and of technological innovation as a decentralized process sparked by private entrepreneurship (Lin 1995; Mokyr 2002; 2009; Barhami-Rad et al. 2022; Gorodnichenko and Roland 2016). In Mesopotamia, by contrast, the corporation existed within the confines of temple-households and its inventors and tinkerers, as well as its investors, were groups of literate public administrators rather than private entrepreneurs and private institutions.

5. Conclusion

In this paper we examined the impact of the world's first ICT revolution - the invention of true writing in Mesopotamia - on state capacity. We proxied state capacity through several indicators, capturing infrastructural, fiscal, coercive as well as administrative function.

We find that polities that developed writing (i) constructed more and larger government buildings and (ii) were more likely to have multi-level bureaucracies. We interpret this as evidence that the adoption of writing led to improvements in infrastructural, fiscal, and administrative capacity. We find no evidence of the impact of writing on indicators of coercive (or military) capacity, which are correlated with prior stages of technological development.

To tackle some of the endogeneity problems that arise from the patchy archaeological record, we studied the channels of diffusion of the technology throughout the region. We find that political organization mattered a great deal: for most of our indicators of state capacity, the effects of writing disappear when we control for whether the polity was governed by religious elites. Delving in the literature on the effect of social structures on development, we argue that religious elites had strong incentives to adopt technology that would enable them to enforce social and commercial obligation against a background of impersonal bureaucratic relations.

In clarifying the magnitude and specifying the mechanisms whereby writing contributed to state capacity in Mesopotamia, we contribute to several literatures in anthropology and archaeology, as well as historical political economy, economic history and the economics of social organization and religion. We also contribute to the limited literature on the impact of information technology and information revolutions on the state - an increasingly important area of study, and an underappreciated one (Carugati, Loyle, and Steinberg 2023; 2024), in light of current debates on the role of digital ICTs on state development, stability, and survival (OECD, 2009; Diamond and Plattner 2012; Mazzuccato 2011; Farrell and Schneier 2018; Harari 2018).

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