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# The Economic Origins of Government[†]

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*We test between cooperative and extractive theories of the origins of government. We use river shifts in southern Iraq as a natural experiment, in a new archeological panel dataset. A shift away creates a local demand for a government to coordinate because private river irrigation needs to be replaced with public canals. It disincentivizes local extraction as land is no longer productive without irrigation. Consistent with a cooperative theory of government, a river shift away led to state formation, canal construction, and the payment of tribute. We argue that the first governments coordinated between extended households which implemented public good provision.* (*JEL* D72, H11, H41, N45, N55, Q15)

The main rationale for government intervention in the economy is the private underprovision of public goods and services. When studying such interventions, the existence of a government is oftentimes simply assumed. In this paper we examine this assumption and test the hypothesis that the demand for such goods and services matters for the *origin* of government as an organization as well. To do so, we combine data on the first states in Iraq with shifting rivers as a source of variation in the degree to which individuals stand to gain from government intervention.

Our "demand side" hypothesis builds on a long tradition in the social sciences and humanities that studies the formation of governments and states. As in this literature, we understand states to consist of several succeeding governments of a city or a territory. There are two main clusters of theories. The first views government as an organization with a comparative advantage in public good provision

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and dispute resolution, and is close to the standard view of government in welfare and public economics (Baumol 1952; Samuelson 1954). Individuals may be willing to give up resources and autonomy to such a government, as part of a "social contract" (Locke 1689). Their willingness fundamentally stems from problems of externalities (Pigou 1924; Bator 1958) and coordination failure (Olson 1965) in the private provision of public goods and services. Within this cluster, theories vary by what authors think the primary problem is that governments solve. In contrast, an influential "supply side" literature views government as an organization that is tasked with extraction on behalf of an elite. This idea is most prominently associated with Karl Marx and Friedrich Engels (e.g., Engels 1878) and has since been studied in archeology (Carneiro 1970), anthropology (Fried 1978), political science (Olson 1993), and economics (Sánchez De La Sierra 2020; Mayshar, Moav, and Pascali 2022). Within this cluster, theories vary by what authors think is the main incentive for elites to extract in a particular location, and public good provision is thought to result from the bargaining between social groups (Acemoglu and Robinson 2000; Persson, Roland, and Tabellini 2000). We review these two clusters in more detail in the next section.

The setting of our study is the formation of the first states in history in southern Iraq. Key to testing our hypothesis is the fact that between 5000BCE and today Iraq's main rivers, the Euphrates and the Tigris, shifted into their current course in six sudden shifts.[1] We study the first shift around 2850BCE as our main natural experiment. Figure 1 provides a map of our study area, and Figure 2 provides a timeline.

A river shifting away may have created a local demand for government because farming relied on irrigating the otherwise arid desert (Bagg 2012; Rost 2017). In response, individuals usually reverted to nomadism (Wilkinson 1977), but in our setting farmers could also re-irrigate the desert through canals (Adams 1981). Although small-scale canals had been provided privately, longer canals required to re-irrigate after a shift may have required cooperation by distinct communities. The inability to credibly coordinate between communities may, in turn, have led to demand for government to coordinate where the river shifted away. In contrast, as the tax base disappeared after a river shift, incentives to expropriate weakened where the river shifted away. Therefore, if governments are set up by an elite to organize extraction, they may be more likely to form where the river shifted to, or where the river did not shift at all. Crucially, rivers did not shift in parallel, but broke through their levees at specific points along their courses, creating variation in space in the incentives to form states.

Under our hypothesis, we expect a river shifting away to have three main effects. First, communities form states where the river shifted away. Second, we observe the provision of public goods and services. Third, we see resources flow to the government in return. To test these predictions, we construct a 5×5 kilometer grid cell panel covering southern Iraq. For each grid cell, we gather data for five

[1] Because river shifts result from a surge in water volume brought on by extreme upriver rainfall in Turkey and Syria, they happen in a matter of weeks.

archeological periods spanning 3900BCE–2700BCE.[2] We then reconstruct the first river shift in history which happened around 2850BCE. We combine these data in a panel difference-in-differences design, in which we compare grid cells directly next to a stretch of a river that shifted away, to grid cells whose access to water was unchanged, before and after the shift.

To study whether river shifts led to the formation of new states, we compile a new archeological dataset of all states that existed between 3900BCE and 2700BCE. We find that a river shift away led to a 14 percentage points increase in the probability of a grid cell being part of a state (relative to a mean of 6 percent). This effect is entirely driven by communities forming new states, rather than by the expansion of existing states into the countryside. Our second prediction is that a river shifting away led to public good provision. To test this prediction, we reconstruct the time-varying network of irrigation canals from archeological records. We find that the river shifting away is associated with a 12 percentage point increase in the probability that a grid cell is irrigated by a canal. We also observe, using data on all attested defensive walls, that the probability that the city nearest to a treated grid cell built a defensive wall increased by 11 percentage points (relative to a mean of 14 percent). Our third prediction is that the beneficiaries of public goods are willing to compensate the government. Historically, such compensation came in the form of tribute in kind. We collect a dataset of cuneiform tablets that indicate the presence of such tribute payment. We find that a river shift doubles the probability of tribute being recorded in the city nearest to where the river shifted away. As a corollary we find, using a new dataset of public buildings, that "state capacity" increases. The number of temples, palaces, and ziggurats in the nearest city increased by 0.6 relative to a mean of 0.75.

To establish a causal interpretation of these results we study the identifying assumption of our model (the parallel trends assumption) by estimating treatment effects in periods before treatment. We find parallel pretrends throughout. We then show that river shifts are uncorrelated with lagged settlement patterns. This is important because the presence of such correlations may indicate that farmers could have diverted or dammed a river. Finally, we provide evidence that river shifts occur as a consequence of changes in rainfall patterns in Turkey and Syria. This means that concurrent, local, correlated shocks are unlikely to explain the treatment effect of a river shift.[3]

The main attractive feature of studying this river shift as a local "demand shifter" for government is that cooperative and extractive theories of the origins of government map onto the main estimated regression coefficient. Our finding that states form where rivers shifted away is consistent with our demand side hypothesis: states formed where the returns to solving coordination failure, not expropriation, were higher.

A central challenge to our interpretation of our main results is that historically state formation is rare (Scott 2017), while (latent) opportunities for profitable coordination seem ubiquitous. To understand why this is the case, we split our sample by proxies for the costs and benefits of forming a government. We find that our

[2] These periods are classified by archeologists based on changes in styles of cultural artifacts, such as pottery. In our main study sample, the average period is 240 years.

[3] A remaining challenge to inference is spatial correlation. We report Conley (1999) standard errors and find that spatial correlation does not affect the interpretation of our results.

estimated effects are concentrated where the returns to cooperation were particularly high: our effects are confined to areas where population density is higher before the shift and where settlement was aligned with the gradient of the landscape, which increased the returns to cooperation. We also find that states are more likely to form where the potential productivity gains from irrigation are higher, and where the bed of the river allows for less costly water access. These results suggest that relative to the outside option of migration and nomadism, state formation may often be unappealing. A second important challenge to our interpretation comes from the observation that throughout history many states have been extractive. One way to reconcile this observation with our findings is that governments need to be endowed with some enforcement power, and after the initial formation of government this power may be used to repress or extract. To study the effect of river shifts after the initial formation of the state we expand our panel to include the full 7,000-year range of our data, 5000BCE–1950CE. We study the effect of subsequent river shifts that take place under well-known states and empires such as the Babylonian and Assyrian empires. We find that throughout the history of Iraq, public goods are more likely to be provided where rivers shifted away, indicating some degree of reciprocity between state and society throughout Iraqi history.

We then study what it is the first governments did, and find that their primary tasks were coordination and dispute resolution. Before the formation of the first states, extended kinship groups, called "lineages," would adjudicate disputes, coordinate through assemblies, and provide public goods locally (Ur 2014). These functions continued to be performed within individual lineages after the formation of states, but the newly formed governments extended these functions *between* lineages. The internal structure of the government mimicked lineage organization with a *lugal* acting as the lineage head of the state (Ur 2014; Garfinkle 2021). We find support for this characterization by analyzing the text from 5,885 publicly available cuneiform tablets. Two results stand out: we find increased mentions in government records of the lower level lineage leaders, indicating their involvement as implementors of collective decisions. When states formed, we also find the first mentions of "lugal," the term that indicated the head of a ruling lineage.

In sum, we find evidence for a cooperative theory of the origins of government. Our interpretation of our findings is that, faced with a coordination problem, lineages formed governments by scaling up their internal social structure to encompass multiple communities. These governments coordinated through the preexisting social structures to provide public services. The lineages' willingness to partially relinquish authority and to pay tribute originates in the inability of lineages to coordinate for the private provision of public goods. Our results are in line with standard economic arguments about the rationale of government intervention in the economy. Our results are inconsistent with Marxist theories of the origins of government that emphasize coercion.

The rest of this paper is organized as follows. The next section provides the context for our study, southern Iraq. In Section II we discuss related literature. Section III introduces our panel dataset and Section IV presents our estimation framework. Section V presents the main results of this paper. Sections VI and VII study heterogeneous effects and our evidence from cuneiform tablets. Section VIII concludes. Our online Appendix is comprised of three individual appendices, a Results Appendix, with additional results, a Data Appendix, describing data sources, and an online "Atlas of Long-Run Development in Iraq" which presents most of the raw data underlying this paper.

## I. Setting and Context

In this section we describe the setting of our study: southern Iraq. Our study area is the southernmost part of the Fertile Crescent and was part of ancient Mesopotamia. The inhabitants of southern Iraq were at various points in time known as Sumerians, Akkadians, Babylonians, Cassites, Assyrians, Aechemenids, Seleucids, Parthians, Sassanians, and under various names of Muslim empires and dynasties. We refer to them as Iraqis and to our study area as southern Iraq. The plain's area is about 30,000 square kilometers, which is roughly equivalent to Belgium, or Vermont. We map the location of the plain in Figure 1. In the remainder of this section, we first characterize society before the start of our study. We then discuss the change in global climate which resulted in the necessity to irrigate to farm away from the rivers. We document basic facts about the first states, their internal organization, and the organization of irrigation before discussing the literature on the origins of government.[4]

**Social Organization**, **and Climate Change after 3500BCE:** From around 6000BCE, the principal social unit in southern Iraq was the extended household, or "lineage."[5] Some lineages clustered together, forming the earliest cities that are in our sample, such as Nippur and Uruk (Dow and Reed 2013; Allen 2022). See Figure AA12 in our Atlas Appendix for the distribution of settlement in the first period we have data for. Habitation was constrained by the fact that rainfall has always been too low to sustain rainfed agriculture in southern Iraq (Brayshaw, Rambeau, and Smith 2011; Finné et al. 2011; Hewett et al. 2022). Before about 3500BCE much of the region was nevertheless underwater due to high river volumes and the high sea level in the Persian Gulf. In this environment, Iraqis lived on the resources of the marsh–fish, shellfish, reeds, water fowl as well as the milk and meat of animals pastured in the marshes. (Allen 2022; Gibson 1992; Dow and Reed 2013). There was little scope for agriculture. A key change from the perspective of our study happened around 3500BCE when southern Mesopotamia began to dry out (Benco 1992). This was due to a drop in the sea level of the Persian Gulf, progradation of the shoreline into the gulf as the rivers deposited sediment in the sea, reinforced by a sharp decline in rainfall shown in Figure 2 (Algaze 2008; Pournelle 2003; Rost 2017). Figures AA3 and AA4 in our Atlas Appendix map the location of rivers and marshes before and after this reduction in rainfall. Note that all marshes fully disappeared.[6]

The usefulness of shifting rivers as a natural experiment is motivated by these changes. From about 3000BCE farming was possible, but only close to rivers.

[4] The rest of the sections on social and political organization are based largely on Richardson (2012); Morony (1987); Ur (2014); van de Mieroop (1999); and Garfinkle (2021).

[5] A lineage traces its ancestry back to a shared common ancestor and can therefore be bigger than an extended household of relatives.

[6] In our dataset of settlement which we introduce in Section III we see six settlements around 5500BCE. About a millennium later, we see 54 settlements. Another millennium later, around when we start our study, there are 511 settlements in the plain. See our Atlas Appendix for maps of these settlements.

Because away from the large rivers irrigation required cooperation (Rost 2017; Bagg 2012), sudden shifts created incentives for state formation.

**How Was Early Government Organized?:** Within lineages, dispute resolution, family matters, and other issues within the community were solved "through mediation by kinship figures or groups" (Gibson 1992, p. 16). Government of groups larger than a lineage originated in cities. Most cities that existed from about 4000BCE were agglomerations of self-governing neighborhoods (Emberling 2015). The city neighborhoods, like every settlement outside the cities, were organized as lineages. Some cities, however, innovated some forms of government organization above these lineages/neighborhoods. We know, for example, that Uruk had several public or administrative buildings around 3900BCE (Heinrich 1984). After writing was invented around 3300BCE (Roaf 1990) we also have surviving clay tablets with government records (see Section III for more detail on these tablets).

The innovation that led to the formation of a government of a city or, eventually, a larger territory was the extension of lineage organization to encompass several lineages. Higher "levels" of government were organized internally like a lineage, with the head of, for example, a city performing the same functions as a head of an individual lineage. The key difference was that the component parts of a higher-level lineage were other lineages, represented by their group leaders, rather than individuals. The resultant social structure was pyramidal with each level repeating the structure of its lower constituent parts. After about 2900BCE in a period that archeologists term the "Early Dynastic I" period, some cities administer a larger area, potentially containing other cities and settlements (Postgate 2017; Nissen 1988). We discuss the key facts of the political history of each city in our sample in Section 5 of our Atlas Appendix. We map cities and states in Figure 3.

**The Governance of the State:** The government of a state was headed by the leader of the ruling household (Ur 2014). Decisions at every level were made between the heads of the relevant group, likely together with an assembly of community members (van de Mieroop 1999; Jacobsen 1943; Bailkey 1967). Higher level government officials, including the head of the ruling lineage, the *lugal*, had no enforceable direct authority over individuals but essentially co-opted the heads of the lineages into their enlarged households. The heads of lineages, in turn, ensured implementation of collective decisions within their communities. Within kinship groups, established norms of reciprocity ensured delivery of tribute to the head of their lineage, and, through the head, to the government as well.[7]

**The Role of the Government in Irrigation:** It is clear that throughout the Iraqi desert, individuals faced what we think of as standard coordination problems leading to socially inefficient provision and use of public resources. Even as late as 1948, "infringements of agreements about the quantity of water to be drawn from

[7] For Max Weber, such states would be called "patrimonial." His distinction between patrimonial states and bureaucratic states lies in the fact that government officials are appointed based on their person, and their reach within their communities. Once offices exist separately from the people occupying them, and selection into office is based on merit we can, according to Weber, speak of a bureaucratic state (Weber 1978).

the channels used in common are the cause of many feuds" (Gruber 1948, p. 73). For the first states in Iraq, "the cutting and maintaining of irrigation canals was an important royal duty" (Ur 2014, p. 9).[8] However, the available evidence suggests that government authorities only coordinated the implementation of maintenance between different groups in society (Schrakamp 2018).[9] The actual execution of tasks was fully decentralized, with the ruling family "co-opting local professional groups who were left on their own to handle the actual delivery of the labor" (Garfinkle 2021, p. 158; see also Ur 2014). Individuals who appeared to have been part of the government "would in fact have been heads of major lineages or groups of lineages, representing their constituencies" (Gibson 1992, p. 16). The consensus in the literature on the involvement of the government in irrigation then is that the government coordinated, leaving implementation to local lineages. We return to this insight in Section VII..

## II. The Literature

In this section we review existing theories of the origins of government, which form two broad clusters. One cluster emphasizes cooperation, and a "social contract." The idea of a social contract is that a group of people voluntarily cedes privileges to a subgroup of individuals. These people form a government and provide government services. The other cluster, what we termed the extractive theories of government, starts from an imbalance in coercive power between people. The more powerful "elite" form a state to manage taxation and other forms of extraction.[10] Public good provision results from subsequent negotiation between social groups (Acemoglu and Robinson 2000).

### A. *Two Clusters of Theories on the Origins of States and Government*

The government as a cooperative organization that provides public goods and services has its origins in the notion of a social contract advanced by Hobbes, Locke, and Rousseau.[11] For Hobbes the main public good is peace, and the social contract prevents conflict, which would prevail in the "state of nature." In exchange for the guarantee of peace, people give up authority to the government and treat "all the actions and judgments, of that man, or that assembly of men… as if they were his own" (Hobbes 1651, p. 54). For Locke, too, individuals "by their own consents, … make themselves members of some politic society" (Locke 1689, p. 62). In Locke's version of the social contract, the government is constrained by the social contract to a set of minimal tasks, most prominently dispute resolution. Disputes arise from the fact that, in the hypothetical state of nature, exercise of "free will" leads to

[8] For more background on the role of government in irrigation, see Postgate (2017).

[9] Rost and Selz (2011) provide a detailed case study for one particular canal close to Lagash. The state was involved in coordinating the maintenance work of various groups that benefited from the canal, such as a temple, various professional groups, as well as individuals.

[10] This distinction into two clusters is known as "contract" and "predatory or exploitation" in economic history (North 1979), "voluntaristic" and "coercive" in archeology (Carneiro 1970), and "integration" and "conflict" in anthropology (Service 1978).

[11] For a discussion of the intellectual precursors to these authors, as well as for a discussion of the philosophical critiques of social contract theory, see Lessnoff (1986).

opposing interests and a breakdown of cooperation.[12] Locke's version of the social contract is closest to the way economists have conceptualized the rationale for government (intervention). The government is an organization that has a comparative advantage in providing public goods (Baumol 1952; Samuelson 1954). The private underprovision of public goods goes fundamentally back to problems of externalities (Pigou 1924; Bator 1958) and cooperation (Olson 1965). We build on these authors' work by extending their rationales for government intervention to the origins of government.

Another cluster of theories takes as a starting point the existence of some imbalance in power between individuals or groups. Government is founded by and elite to manage "the glaring conflict in economic interests between the tiny ruling class, and the vast majority who were left with a bare subsistence" (Childe 1950, p. 4). In an already socially stratified society, the state is a "formal organisation of power [which] has as its central task the protection (and often extension) of the order of stratification" (Fried 1978, p. 36). The notion that the government is an organization used by an elite to repress society is most prominently associated with the work of Karl Marx and Friedrich Engels. Engels writes: "the state, that is, an organization of the exploiting class … for the maintenance of its external conditions of production … for the forcible holding down of the exploited class in the conditions of oppression … " (Engels 1878, pp. 314-15). In the more recent literature this idea is closely associated with the work of Mancur Olson, who envisioned "roving bandits" to form a state where the return to extraction was highest (Olson 1993).[13]

In sum, cooperative theories of government emphasize that individuals willingly form a government. Extractive theories of the state, on the other hand, emphasize extraction as a result of a power imbalance between groups in society. We now discuss the literature that has built on these ideas trying to understand when and where states form.

**Where Does the State Form?:** The literature that studies where the state forms has largely focused on variation in geography, and the resulting incentives for state formation. The most prominent explanation is that states form where agriculture has been innovated (Childe 1950; Diamond 1997). The argument typically is that agricultural surplus led to population growth, urbanization, and the emergence of a state.[14] Some authors de-emphasize agriculture, and claim that as population grows and social interactions get more complex, new forms of governance are required for productive coexistence (Boserup 2011; Wright and Johnson 1975). These theories are typically consistent with both a cooperative view of government as well as an extractive view. In the recent literature, Borcan, Olsson, and Putterman (2021) find empirical support for a correlation between the transition to agriculture and earlier state formation. Other authors emphasize parameters in the choice problem of forming a state as predictive for where states will form. Carneiro (1970) argued that

[12] Rousseau added a notion of political power to these theories. In his view, elites, after "signing" the contract along with everyone else, have more use of the state as they gain more by protecting property. By signing the contract, the disenfranchised ran "headlong into their chains" (Rousseau 1839, p. 79).

[13] In anthropology, this idea is most closely associated with Fried (1978).

[14] In anthropology, the idea of such "stages" of development is most closely associated with the proposed stages of societal progress from bands to tribes, chiefdoms, and states (Service 1962; Sahlins and Service 1960).

where productive land is surrounded, or "circumscribed," by less productive land, it is less attractive to run away. Similarly, Scott (2017) argues that the adoption of particular crops may facilitate taxation. These theories are more consistent with an extractive view of the origins of government. Recent empirical work finds support for these ideas. Mayshar, Moav, and Pascali (2022) show that where agricultural surplus is storable, and therefore taxable, rather than agricultural productivity, correlates with the historical location of states. Similarly, Allen (1997); Schönholzer (2017); and Mayoral and Olsson (2019) provide evidence find that states from where it is harder to run away.[15] Another strand of literature emphasizes irrigation per se. Most prominently, Wittfogel (1976) argued that the state is necessary to provide complex irrigation networks. Where these networks develop, Wittfogel argued, the state becomes repressive. Bentzen, Kaarsen, and Wingender (2017) provide evidence that historical dependence on irrigation correlates with autocracy today. However, since geography is fixed, these studies typically yield less sharp predictions on when the state will form. For example, the invention of agriculture preceded states by several millennia.[16] We now discuss the literature on the timing of the formation of the state.

**When Does the State Form?:** The most prominent explanation for the timing of state formation is war or conflict. Whereas social contract theorists argue that states form to mitigate conflict, a large number of authors across the social sciences and humanities see war and conflict as the prime mover. Typically, these authors take the viewpoint that the origins of the state are extractive. States form by conquest which is, in turn, motivated by repressive elites or "roving bandits" desire to expropriate (Oppenheimer 1922; Olson 1993).[17] A recent literature in economics has found empirical support for this idea. Sánchez De La Sierra (2020) estimates the effect of a change in attractiveness of taxation as a result of resource prices on the efforts of armed groups to start taxing in the Democratic Republic of the Congo. Mayoral and Olsson (2019) find that shocks to circumscription facilitate state formation.[18]

In sum, although cooperation-based theories are prominent in the theoretical literature, most empirical studies have focused on the relationship between the presence of the state and various measures of incentives for extraction. The contribution of our paper is to try to distinguish between the two clusters of theories.[19] We predict that states will form where the returns to cooperation are high enough. The returns

[15] Dal Bó, Hernández, and Mazzuca (2022) also emphasize geographical factors as important in predicting where surplus generation and the simultaneous protection of surplus will arise.

[16] Finally, our paper relates to a literature that studies economic development in the ancient past (Barjamovic et al. 2019; Chaney 2013; Bakker et al. 2021; Dow and Reed 2013). In particular, Benati and Guerriero (2022) study a model of granting of rights in early Mesopotamia, starting after the formation of the first states. The core prediction is that as temperature falls elites grant concessions to ensure sharing of food. In a half-century panel of 44 cities between 3050–1750BCE, the authors find a correlation between changes in temperature and the rights granted to nonelites. See also Benati, Guerriero, and Zaina (2022).

[17] Naturally, once a state exist, it may build up capacity to defend itself against others. This idea is most prominently associated with Tilly (1992) who, in the context of Europe, argued that interstate competition led to an expansion of state capacity.

[18] Others emphasize changing patterns of trade (Algaze 2008). There is empirical support for this idea in the context of Africa (Fenske 2014). See also Ang (2015).

[19] Some empirical evidence is consistent with both theories. For example, a correlation between population density and state formation could be consistent with both theories.

to cooperation may depend on many factors, and we use river shifts to exogenously increase them.

In the remainder of our paper we discuss our data, our empirical strategy to test our hypothesis, and our results.

## III. Data

In this section we describe the data we use. We rely on archeological micro data that has been collected over the last century by the Oriental Institute of the University of Chicago as the basis for our dataset. The core of these studies is a reconstruction of settlement and cities from about 5000BCE until 1950CE. We build on our digitized version of this data, and augment it with measures of state formation, state capacity, public good provision, and tribute payment. Naturally, using archeological data comes with its own challenges, which we discuss at length in our Data Appendix and in brief in the next paragraph. We also provide all raw data, either in map form or in list form, in our Atlas. Finally, Table 1 presents summary statistics.

**Using Archeological Data:** There are three main conceptual challenges to using archeological data: selection into sample, selection into treatment, and what we call selection into hypothesis. Selection into sample would occur if archeologists apply more search effort in some places than others, which seems natural. To alleviate this problem, we take advantage of the fact that southern Iraq has been covered by "sweep surveys." These are surveys designed to cover the full settlement history of contiguous areas and to record all known historical cities and villages. For example, all surveys of settlement and canals by the Chicago Oriental Institute were carried out with the explicit objective of recording the universe of settlements and canals. In other words, they document the full extent of human activity over an extended period. Through these surveys, we also know the location of each city that existed in southern Iraq.[20]

Selection into treatment would occur if archeologists were more likely to search—or it is easier to search—where rivers shifted. In Table 2 we provide balance checks that show that this is not the case. A more subtle variant of this selection problem occurs through artifact survival. If treatment led to permanent depopulation or instead to urbanization, it could be easier (or harder) for archeologists to find remains in treated areas. In Table RA1 of the Results Appendix, we show that economic activity in 1950 is balanced with respect to treatment suggesting that economic activity today does not differentially obscure potential historical finds around where the river shifted.

[20] Barjamovic et al. (2019) show how many cities are potentially missed if we could not rely on a systematic survey of southern Iraq. We locate virtually all cities, but not all cities have been excavated (most notably Akkad, the capital of the Akkadian empire). For such cities, we record building history from written sources, if these are available. For the city of Akkad, for example, we know that a royal palace and a ziggurat existed in the Akkadian period from Meyers (1997). If a city is neither excavated nor do we have textual records, we set all cells nearest to that city to missing. As explained in more detail in our Data Appendix, we have four cities that were never excavated: Akshak, Bad Tibira, Kesh, and Larak. In the Results Appendix, we provide a robustness check where we include these cities but with zero buildings.

Table 1—Summary Statistics

| | Observations | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| *Main study period sample* | | | | | |
| River shift (yes/no) | 6,870 | 0.15 | 0.35 | 0.00 | 1.00 |
| River shift closer (yes/no) | 6,870 | 0.13 | 0.33 | 0.00 | 1.00 |
| No. of settlements | 6,482 | 0.32 | 1.01 | 0.00 | 13.00 |
| City (yes/no) | 6,870 | 0.01 | 0.10 | 0.00 | 1.00 |
| Canal (yes/no) | 6,482 | 0.23 | 0.42 | 0.00 | 1.00 |
| Under city state (yes/no) | 6,830 | 0.06 | 0.24 | 0.00 | 1.00 |
| New state (yes/no) | 6,830 | 0.03 | 0.18 | 0.00 | 1.00 |
| Existing state (yes/no) | 6,830 | 0.03 | 0.16 | 0.00 | 1.00 |
| Admin. building (yes/no) | 6,411 | 0.11 | 0.32 | 0.00 | 0.00 |
| Wall (yes/no) | 6,411 | 0.13 | 0.34 | 0.00 | 1.00 |
| Tribute (yes/no) | 6,411 | 0.18 | 0.38 | 0.00 | 1.00 |
| No. admin. build. | 6,411 | 0.70 | 2.36 | 0.00 | 20.00 |
| *Extended study period sample* | | | | | |
| River shift (yes/no) | 42,594 | 0.02 | 0.13 | 0.00 | 1.00 |
| Canal (yes/no) | 36,970 | 0.33 | 0.47 | 0.00 | 1.00 |
| *Cross sectional data* | | | | | |
| Average rainfall (mm) | 1,374 | 11.93 | 2.55 | 8.08 | 20.08 |
| Average temperature (C) | 1,374 | 23.14 | 0.38 | 22.46 | 24.02 |
| Urban indicator period last pre-period | 1,374 | 0.01 | 0.11 | 0.00 | 1.00 |
| High economic returns to irrigation (yes/no) | 1,374 | 0.60 | 0.49 | 0.00 | 1.00 |
| Low water flow volume (yes/no) | 1,374 | 0.38 | 0.49 | 0.00 | 1.00 |
| High settlement density area (yes/no) | 1,374 | 0.40 | 0.49 | 0.00 | 1.00 |
| Settlement misaligned for canals (yes/no) | 1,374 | 0.50 | 0.50 | 0.00 | 1.00 |
| Surveyed (yes/no) | 1,374 | 0.80 | 0.40 | 0.00 | 1.00 |

Finally, by selection into hypothesis we mean that archeologists often search with a theme in mind, such as political history. If so, absence of evidence for, say, state formation could simply mean that archeologists did not look for evidence of state formation, rather than states being absent. We mitigate this concern through triangulation. To ensure that our conclusions do not rely on one source collected with a particular hypothesis in mind, we test our own hypotheses using data from different sources. For example, our data on state borders, administrative buildings, canals, and cuneiform tablets each come from a separate source. These were collected with a different research objective but we use them together to test our hypothesis.

## A. *Unit of Observation and Study Periods*

To situate our study, we provide four maps that successively zoom in from the Middle East to our study area in southern Iraq in Figure 1. Panels B–D show Baghdad and the modern courses of the Euphrates and Tigris rivers.

**Cross-Sectional Unit of Observation:** Our cross-sectional unit of observation is a 5×5 kilometer grid cell. We cover the union of the archeological surveys in our dataset, resulting in a dataset of 1,374 grid cells covering most of the area between the modern Euphrates and Tigris rivers between Baghdad and modern Basra. We provide more detail on the exact survey coverage of each survey in Section 1.2 of the

Data Appendix and we map this grid in panel D of Figure 1.[21] We refer to the area covered by these grid cells as our sample area.

**Periodization:** We observe each grid cell for each of 31 historical periods, covering 5000BCE until 1950CE, when the archeological surveys which form the basis of our dataset started. Table DA1 in our Data Appendix lists each period in our dataset. In this table, we also list the start and end years of each period in the Gregorian calendar. These periods are standard in the archeological literature. For example, the "Jemdet Nasr period" is the last pre-period in our main regressions and lasted from 3100BCE to 2900BCE. The Early Dynastic I period is our treatment period and spans between 2900BCE and 2700BCE. Following archeological conventions for periodization allows us to chronologically combine different archeological sources with the river shifts, which we date by calendar year.

**Main Study Period:** Within our panel, we mainly restrict our focus to the first recorded river shift in history. The first recorded shift is dated at 2850BCE.[22] This shift approximately coincides with the start of the Early Dynastic I period around 2900BCE. We consider four pre-periods which together cover 1,000 years of development before the first river shift. Archeologists refer to these pre-periods as the Early Uruk, Middle Uruk, Late Uruk, and Jemdet Nasr periods. Combined with the treatment period, our main estimation sample forms a five-period panel of $5 \times 5$ kilometer grid cells, covering the period 3900BCE–2700BCE. In this sample, an average period is about 240 years, and not all periods are equally long.[23] We refer to the timespan of this sample as our "main study period." In subsequent analyses we extend our sample period to cover the period 5000BCE–1950CE. In this "extended study period," an average period is 228 years. We indicate both the main study period and the extended study period in Figure 2.

### B. *Treatment: Measuring Shifting Rivers*

The treatment of interest in our study is a shifting river. Between 5000BCE and today, the Euphrates and Tigris shifted six times, and the first shift defines our main study period. Table DA3 in the Data Appendix provides detail on each shift. We graphically depict the timing of each shift in Figure 2, and our Atlas Appendix provides before-after maps in Section 2.

**How Do Rivers Shift?:** In 5000BCE the Euphrates and Tigris had not separated and formed one single river flowing down the center of our sample area (see Figure AA1 in our Atlas). Over time, sediment built up in its bed, and the Ur river, as it was called, was elevated above the plain, kept in place by natural levees formed by

[21] Historically, the Basra area was on the coast since the level of the Persian Gulf was higher. Our Atlas Appendix provides maps of the fluctuating coastline over time.

[22] Before the shift, some branches gained in relative importance to others, but no shifts occurred. See Table DA3 and its description in the Data Appendix for a discussion of the course of the rivers over time.

[23] A natural concern is that the archeological periodization depends on changes in an outcome variable of interest. We do not believe that this is a concern because we primarily identify off cross-sectional variation in the location of river shifts. Even if the timing of a period change would be correlated with, say, political events, where a river shift is, as we will show, not.

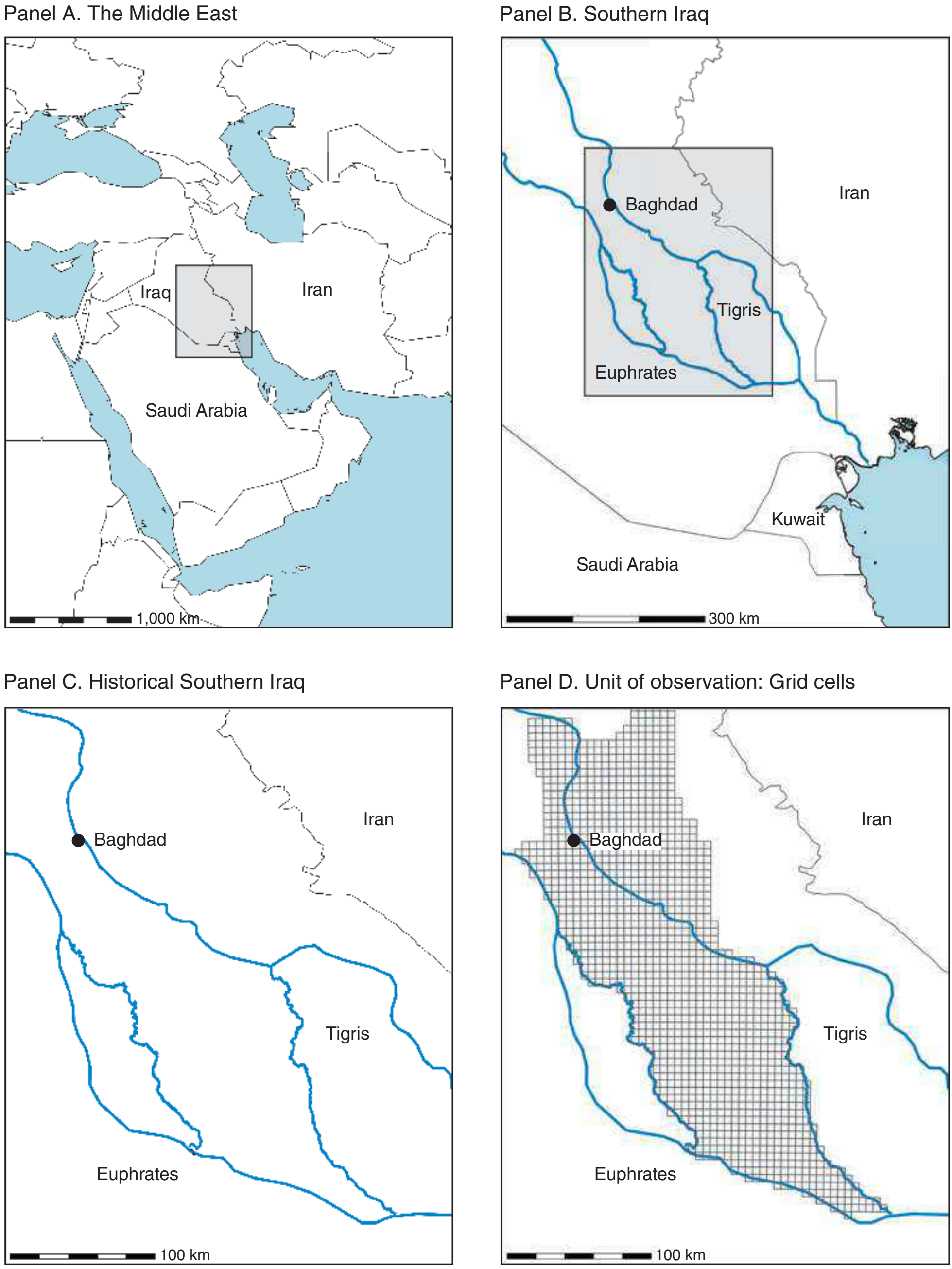


Figure 1. Sample Area

*Notes:* Panel A depicts the Middle East using current country borders. The bounding box in panel A is the full extent of B. Panel B also maps Baghdad and the current flow of the Euphrates and Tigris rivers. The bounding box in panel B is the extent of C. All further maps in this paper are zoomed in to the extent of panel C. The archeological surveys that form the core of our dataset focus on this area because historically the Persian Gulf reached the southern part of this map. The "Atlas of Long-Run Development in Iraq" (included in the online Appendix) shows the fluctuating coastline over time. Panel D shows our unit of observation, a 5×5 kilometer grid cell overlaid on the sample area.

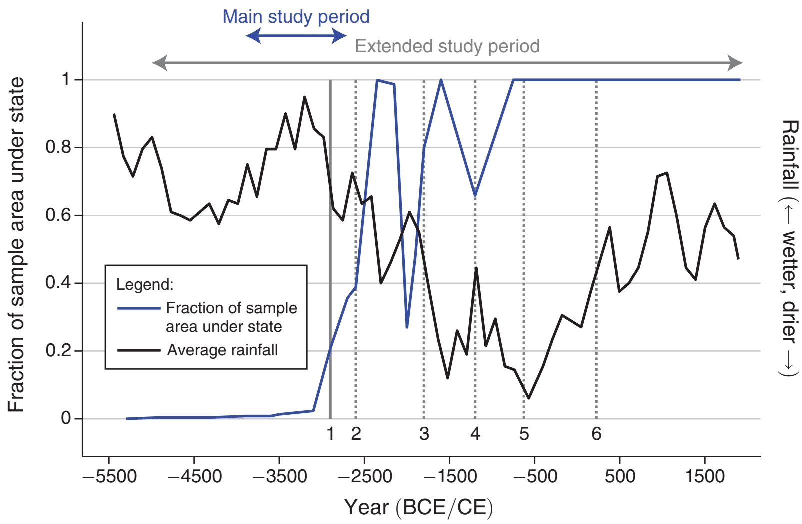


Figure 2. Rainfall, States, and River Shifts

*Notes:* This figure shows a time series of rainfall, and a time-series of the fraction of our sample that is part of a state. Around 3000BCE, rainfall declined precipitously. This coincided with a reduction in river flow volume and a retreat of the Persian Gulf, leaving Iraqis with irrigated agriculture as the main mode of subsistence. Subsequently, the first large river shift took place in our sample area, indicated as "1". After the river shift, new states formed. See Figure 3 for detailed maps of human activity before and after this shift. We also indicate the span of time covered by our main analyses as the "main study period," and the span of time covered by our full panel dataset as the "extended study period."

sediments from its floor pushed to the side by the weight of the water.[24] The Ur river, as well as the Euphrates and the Tigris later on, originate(d) in Turkey and Syria, and their flow volume is determined in part by rainfall there.[25] Due to surges in water flow upstream, the downstream flow volume of the Tigris can double in the span of two days, and the level in the river can rise by as much as six meters (Soroush and Mordechai 2018). When this happens, the increased pressure on the levees may cause a break and a river shift. Rivers did not shift in parallel, but found another bed in the almost level plain from the break point down.[26] Such river shifts can take place in the span of weeks or even days. We empirically validate the link between upstream rainfall and downstream shifts in two ways, directly and indirectly. As a direct test, we plot the time series of rainfall in Turkey and river shifts in our sample area in Figure RA1. We see that the first river shift in our sample coincides with a period of highly variable rainfall in the mountains where the river originated. Second, we show in Section IVB that our first river shift does not correlate with lagged human activity, suggesting an exogenous and geographical origin for this shift.

[24] The discussion in this section is based on chapter 1 in Adams (1981); Rost and Selz (2011); and Bagg (2012).
[25] For the Tigris, high water usually comes in April, for the Euphrates, early May.
[26] Levee breaks happen regularly, but large shifts are infrequent because often, when a levee broke, the resulting decrease in flow speed (as the water now covers more area) led to sediment deposit which would fill up the opened gap in the levee.

**Reconstructing River Shifts:** To measure the position of the rivers before and after each shift, we rely on reconstructions by archeologists and geographers (e.g., Cole and Gasche 1998). To measure the timing of each shift, we proceed in two steps. First, if a precise year of a shift is available in the secondary historical or geography literature, we record this. For example, this is the case for our main river shift. Second, if only an approximate window is available, we use our rainfall data to date the shift within a fifty-year window.[27] We elaborate on this dating method in the Data Appendix, Section 2. Importantly, a break in a levee may occur anywhere along the course of a river. Below the break point, the river will shift whereas above the break point, the course of the river is stable. Therefore, every shift creates cross-sectional variation.

**Measurement:** To measure a river shift at the level of the grid cell, we implement the following procedure. For each panel period $t$, a grid cell $c$ is "on a river" if its centroid is within five kilometers of the nearest river. We define grid cell $c$ as being treated in period $t$ if $c$ was on a river in period $t - 1$ and is no longer in period $t$. Measuring treatment this way captures the idea that settlements with their own independent water source can now only farm productively if water is brought in through a canal. When we average distance to the river before and after each shift across grid cells that were on a river before a shift, we find that rivers shift by 30 to 40 kilometers.[28]

## C. *Outcome Variables*

In this section, we describe the main outcome variables used in this paper. The main challenge our data collection effort overcomes is that written records on governments and states are typically produced and preserved by states. It is therefore challenging to learn about the origins of the state as an organization. Our solution is to collect archeological evidence for state formation, public good provision, and the functioning of government. As a basis for all our datasets, we reconstructed the full settlement history of southern Iraq.

**Villages and Cities:** We collect data on settlements from three large archeological projects by the Chicago Oriental Institute (Adams 1965, 1981; Adams and Nissen 1972). These projects aimed to reconstruct the full settlement history of southern Iraq. We map the areas covered by each project survey in Figure DA1 of the Data Appendix. The main advantage of using these surveys is that they were collected with the aim to capture all settlement over time in their study area. By starting from where we know settlements were located, we are more confident that we do not miss any states just because the cities they were based in have not been excavated. To achieve this, we record each settlement identified by the archeological teams as

[27] Note that above we used the rainfall data to *validate* the timing of the first river shift. We do this because we have an exact date for this shift from the secondary literature. Here we use the rainfall data to more precisely date subsequent river shifts.

[28] Through our use of shifting rivers as a source of identification, our paper is related to Hornbeck and Naidu (2014) who use a historical flood to identify the effect of the presence of low-skilled labor in the United States south, and Chaney (2013) who uses Nile floods to identify the effect of political power of religious leaders.

well as each archeological period in which it was settled.[29] We discuss the approach of the archeological teams and the advantages it offers us in more detail in the Data Appendix, Sections 1.1 and 4.[30] Larger settlements are often known by name, and we refer to these as cities.[31] In total we identify 62 cities as part of the archeological surveys or through secondary sources, which we map in Figure DA6 of our Data Appendix and we discuss each city individually in Section 5 of our Atlas.[32]

**States and Bureaucracy:** States over different periods were governed from administrative buildings, where the head of the ruling lineage of the state lived. These buildings were located in a city, and have been classified as either palaces, temples or ziggurats. A ziggurat was a large, elevated platform that was typically the center of a government area. Over our entire study period, we identify a total of 444 buildings (62 palaces, 423 temples , and 21 ziggurats) that existed at any point in a city from our sample. In our main study period, we record 64 administrative buildings.

To measure whether a grid cell was part of a state we use a two-step procedure. We describe the procedure in brief here and in full detail in Section 7 of our Data Appendix. We start with cities. We record whether there is a administrative building in a city in a particular period from Heinrich (1982, 1984); Meyers (1997); and Bryce (2009). We then record the outer borders of the territory administered from these buildings. This may be only the city itself and the immediate surrounding countryside—as is the case before our treatment period—or a larger area around the city, which is the case for some cities in our treatment period. We code a grid cell as being part of a state if it falls within the boundaries governed by a city with an administrative building, and we vary this definition in our Results Appendix.[33]

[29] Carrie Hritz generously shared her digitization of the originals with us.

[30] In total, 13,131 grid cell-periods are settled over our extended study period by 4,372 archeological sites. Of these 1,796 exist at any point during our main study period. Naturally, archeologists can not record every settlement. Adams (1981) discusses how settlements smaller than one hectare are not in the data.

[31] Most cities in our sample are part of the archeological surveys, but some fall just outside the reach of the surveyor teams. We therefore extend the archeological surveys in one key dimension. Using secondary sources on individual cities, we extend our sample of cities to record known cities around our sample area. We depict these in each map in this paper and, when recording outcomes in the nearest city to a grid cell, such cities can function as nearest cities for grid cells in the sample area.

[32] Since we have data going back to the earliest human occupation in the region around 5300BCE, we can use our settlement data to paint a unique picture of economic development in Iraq. We do so in the Atlas, where we show settlement patterns over time, and provide maps of settlement in each of our 31 archeological periods. For example, in the Early Uruk period (3900BCE–3600BCE), 202 out of 1,325 grid cells are settled. On average, a settled grid cell has 2.3 settlements, and the maximum number of settlements is 13. Aside from smaller settlements, we have identified eleven cities that were inhabited in this period. Uruk is the most important, but other well-known examples are Ur, Nippur, and Sippar. In the Middle Uruk period (3600BCE–3500BCE), 225 grid cells are inhabited, and the city of Esnunna (modern Tell Asmar) was founded. In the Late Uruk period (3500BCE–3100BCE), 228 grid cells were inhabited, and Khafagi was founded.

[33] Note that the presence of irrigation infrastructure made boundaries relatively well demarcated as the reach of the canal network that was maintained from a city led to a natural demarcation between the area watered by canals, and the area outside. Hans Nissen writes that after the founding of the city states "… the borderlines between canal-irrigated and unirrigated land, between land suitable for agriculture and land that could not be cultivated, became increasingly fixed." (Nissen 1988, p.141). In the periods preceding the Early Dynastic I period we only consider grid cells immediately adjacent a capital city (6 kilometer radius) as being within state boundaries. This definition of a city's hinterland is based on estimates of the supporting countryside from Nissen (1988) and Adams (1981). We vary the size of a city's hinterland in a robustness check. As discussed in Section I, from 3000BCE territorial states form, and we code a grid cell as being part of a state if it falls within the border of a state as defined by Lafont et al. (2017). We vary the definition of states in Table 3 and in the Results Appendix for robustness.

In Figure 3 we provide a graphical intuition for our historical reconstruction of states. We map the political situation in our sample area before and after the first river shift, shift 1 in Figure 2. In panel A we show the situation before the first river shift, around 2900BCE. We indicate cities without an administrative building and cities with at least one administrative building. For this pre-period, we observe five cities that have at least one administrative building: Esnunna, Khafagi, Tell Uqair, Tell Jemdet Nasr, and Uruk. In panel B we map states around 2700BCE. Esnunna has expanded its territory. Khafagi, Tell Uqair, and Tell Jemdet Nasr no longer govern. In the south, Uruk has expanded its territory and Abu Salabikh, Nippur, Adab, Umma, and Larsa have formed as new states.[34]

**Public Good Provision, and Public Administration:** We measure the presence of public goods mainly through a reconstruction of the full time-varying canal network. In addition, we measure defense through the presence of defensive walls. We reconstruct the canal network from the excavation reports by the Chicago Oriental Institute (Adams 1965, 1981; Adams and Nissen 1972). We measure the presence of irrigation canals by an indicator equal to one if a grid cell was within five kilometers of a canal. In total, we record 1,117 individual canals, of which 151 from our main study period. We describe the full coding procedure for the canals in Section 4 of the Data Appendix. We measure the presence of defensive walls using data from Bryce (2009) and Meyers (1997). We code an indicator variable equal to one if the city nearest to grid cell $c$ had a defensive wall in period $t$. We observe a total of 35 cities with a wall over our extended study period and 10 in the main study period. We describe the full coding procedure and additional city-specific sources for city walls in Section 6.4 of the Data Appendix.

**Cuneiform Tablets:** We study the internal organization of the early states using data from 6,573 cuneiform tablets that survive from our main study period, are published, and were made available by the Cuneiform Digital Library Initiative (CDLI). Texts were recorded in cuneiform script by impressing a stylus in a soft clay tablet. The consensus opinion among scholars is that the vast majority of these tablets are records of economic transactions (Englund 2011; Nissen 1993; Nissen, Damerow, and Englund 1993; Nissen 1986). Since in our main study period tablets were exclusively used by the government, these transactions are thought to be records of collection or redistribution of tribute payments (Pollock 1999; Bramanti 2020; Lafont et al. 2017). In Section 8 of our Data Appendix, we discuss the historical context of these tablets, and their subject matter, in more detail. For our analyses, we code several variables from these tablets.[35] As a first outcome, we code, for each grid-cell, an indicator equal to one if a cuneiform tablet was found for a period in the nearest city. For the subset of 5,885 tablets for which transliterations are available, we code

[34] Ur and Girsu were the centers of states as well, but these fall largely outside our sample area, and we therefore have not mapped them here. We map them in our Atlas Appendix. We code any grid cells that fall within their borders as being part of a state.

[35] As most tablets have not been translated we rely on the transliteration of the cuneiform signs into their Latin alphabet and Arab numeral equivalents. We conduct a keyword search to code several indicators for administrative activities. We discuss our methodology in Section VII and the list of Sumerian keywords we use in detail in Section 8.2 of the Data Appendix. We are indebted to John Melling of the department of Oriental Studies at the University of Oxford for expert help in preparing our list of keywords.

Panel A. Settlement, cities, and states before the river shift in 2850BCE

Panel B. Settlement, cities, and states after the river shift in 2850BCE

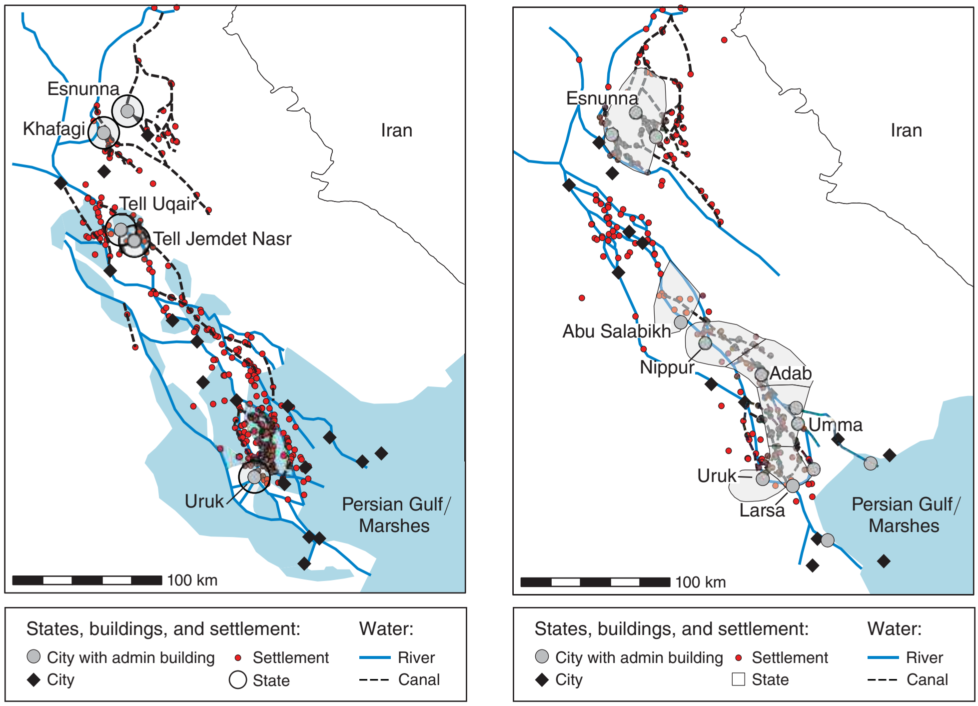


Figure 3. Before and after the River Shift

*Notes:* The panel A maps settlements, cities, cities with administrative buildings, and states in the last pre-period before the first river shift, indicated as shift 1 in Figure 2. Settlements are indicated as small diamonds. Cities, large settlements known by name, are large diamonds. Cities with administrative buildings are indicated with large circles. We indicate their hinterlands with circles. We also indicate rivers with solid lines, and canals with dashed lines. Note that in the south of our sample area there are no canals. The canals in the north divert water from the Diyala river valley, which comes down from the mountains. In panel B we map the situation about 150 years after the river shift. Note that the course of the rivers has changed. Most importantly, several states have formed. We indicate these by the name of their main city.

several indicators for more specific government functions which we introduce in Section VII.

The richness of our data is extraordinary compared to other parts of the world. This has two reasons. First, being known as the cradle of civilization, southern Iraq has been extensively studied. Second, since the desert is flat, and uninhabited remains of settlements and canals are easily visible in the desert.[36]

[36] Sir Austen Layard, one of the first archeologists to excavate, wrote in 1853:

> The plains between Khan-i-Zad and the Euphrates are covered with a perfect network of ancient canals and watercourses; … The face of the country, too, is dotted with mounds and shapeless heaps, the remains of ancient towns and villages. (Postgate 2017, p.17).

On the causes of the depopulation of the southern Iraqi plain, see Allen and Heldring (2022).

## IV. Estimation Framework

Our dataset of grid cells and archeological periods forms a balanced panel covering southern Iraq in our main study period: 3900BCE to 2700BCE. In this section we introduce our estimation framework to estimate the treatment effect of a large river shift around 2850BCE. Because we study a single river shift that generates cross-sectional variation within our panel dataset, we estimate a standard panel difference-in-differences model. This model allows a simple way to test its main identification assumptions by estimating pretreatment period treatment effects. We present this estimation framework before discussing challenges to identification.

### A. *Difference-in-Differences Model*

We estimate a panel difference-in-differences model, using ordinary least squares. Our main regression equation has the following form:

$$(1) \qquad Y_{ct} = \sum_{k=0}^{-4} \beta_k^{treatment} \times \mathbf{1}\{period_k\} \times treated_c + \rho_c + \gamma_t + \upsilon_{ct} + \varepsilon_{ct}.$$

Here $Y_{ct}$ is an outcome of interest for grid cell $c$ in period $t$. $k$ indexes periods relative to treatment with $\sum_{k=-4}^{0} \beta_k^{treatment} \times \mathbf{1}\{period_k\} \times treated_c$ being a vector of period-relative-to-treatment fixed effects multiplied with an indicator $treated_c$ which is equal to one if grid cell $c$ is treated in period $k = 0$. This indicator is time-invariant, and the $\beta_k^{treatment}$ coefficients capture the time-varying effect of being treated in $k = 0$ through their multiplication with the period-relative-to-treatment fixed effects. We express these coefficients relative to the last pre-period, $k = -1$. In the archeological periodization, our treatment period is the Early Dynastic I period, which spanned 2900BCE–2700BCE. Our coefficient of interest is $\beta_0^{treatment}$, the treatment effect in the treatment period. The pre-period coefficients (e.g., $\beta_{-2}^{treatment}$), capture pretrends.

This model neither assumes that there are no average differences between treatment and control, nor that there are no average differences between periods. These differences are absorbed by the unit fixed effects $\rho_c$ and period fixed effects $\gamma_t$. Rather, we study grid cells over time, comparing the average difference in the outcome of interest posttreatment relative to pretreatment, across treatment and control.[37]

$\upsilon_{ct}$ is a vector of period fixed effects interacted with time-invariant covariates. We include three indicator variables for the three large archeological survey areas covered by the Chicago Oriental Institute.[38] We also include rainfall, temperature, and urban status, defined as having a city in a grid cell in the last pretreatment period. If, for example, average rainfall decreases before a river shift, then period fixed

[37] We employ two simple sample restrictions throughout all analyses. First, we drop grid cells that saw a new river branch move closer to them, rather than further away. Treatment effects are similar with and without this restriction. Second, we drop grid cells that are within the nominal area of the survey but that were skipped by the survey teams. We provide a robustness check that varies all these restrictions in our Results Appendix, in Tables RA8–RA11. The Data Appendix also reports that some outcome variables are not available for all periods. We provide an overview of the data availability of our main variables in Table DA4 in the Data Appendix. The fact that some outcomes are unavailable for some periods results in small fluctuations in the number of observations in our results.

[38] We describe these surveys in detail in our Data Appendix section.

effects interacted with rainfall will capture these trends. Similarly, grid cells containing cities may be on different trends than grid cells in the countryside. Finally, $\varepsilon_{ct}$ is a standard error, clustered at the grid cell level. We provide two more ways to conduct inference. First, to account for arbitrary spatial correlation, we also report Conley (1999) standard errors using a cutoff of 484 kilometers (or 4.4 decimal degrees, covering our entire sample area). We find that Conley standard errors are similar to clustered standard errors or slightly higher, but nowhere high enough to threaten inference. Second, for outcomes that vary at the nearest city level we provide additional results in which we double cluster standard errors at the level of the grid cell and the nearest-city-by-period, to capture nearest city level unobserved heterogeneity.

Since all grid cells are treated in the same period, and we study the first treatment in our panel, we have a static panel without staggered treatment timing. In such data structures, heterogeneous treatment effects that affect the interpretation of estimated coefficients in more complex models are unlikely to be a major concern. Indeed, all weights on treated grid cells in the treatment period computed by the OLS estimator are positive (see De Chaisemartin and d'Haultfoeuille 2020 on this test). To ensure that we do not re-weight individual treatment effects in such a way to generate a spurious average treatment effect, we reestimate our results using De Chaisemartin and d'Haultfoeuille (2020)'s estimator in the Results Appendix Table RA6. We find virtually identical results.

Before presenting results in Section V, we discuss potential challenges associated with estimating the model introduced in this section.

## B. *Identification Assumptions*

The key identification assumption in this model is that absent treatment, treated grid cells would have evolved similarly to untreated grid cells, conditional on covariates. This assumption is untestable but can be studied using pretrends. In all tables, we report the *p*-value on the estimated coefficient in $k = -2$, and we report all pre-period coefficients in our Results Appendix. We find no evidence for pretrends: grid cells that are going to be treated in $k = 0$ look similar in $k = -2$ and in earlier pre-periods. In addition to parallel trends another important requirement for credible difference-in-differences estimation is that a river shift does not coincide with other shocks. Prima facie, we expect river shifts to be exogenous because flow volume and breaks in the levees in Iraq were determined by rainfall shocks in Turkey and Syria where the rivers originated.

We study the exogeneity of river shifts in two ways. First, we estimate equation (1) using lagged outcomes. If treatment in $k = 0$ correlates with outcomes in $k = -1$ or $k = -2$ this implies that grid cells that are going to be treated in the future look different before treatment. This could indicate, for example, that river flow was manipulable. We implement this exercise in Table 2. Columns vary outcome variables, and the first row provides estimates of $\beta_0^{treatment}$, the measured effect of a river moving away from grid cell $c$. We focus on the lagged values of the number of settlements in a grid cell, an indicator for the presence of a city, or an indicator for the presence of a canal. We find small and insignificant coefficients. In other words, these results are inconsistent with the idea that people

TABLE 2—BALANCE: RIVER SHIFTS AND LAGGED OUTCOMES

| Dependent variable: | No. of settlements | | City (yes/no) | | Canal (yes/no) | |
|---|---|---|---|---|---|---|
| | lag 1<br>(1) | lag 2<br>(2) | lag 1<br>(3) | lag 2<br>(4) | lag 1<br>(5) | lag 2<br>(6) |
| *River shift (yes/no)* | −0.15 | 0.05 | −0.00 | 0.00 | 0.02 | 0.03 |
| | (0.13) | (0.08) | (0.00) | (0.00) | (0.03) | (0.03) |
| | [0.13] | [0.08] | [0.00] | [0.00] | [0.02] | [0.04] |
| Mean dependent variable | 0.37 | 0.29 | 0.01 | 0.01 | 0.21 | 0.17 |
| Observations | 4,320 | 4,660 | 4,660 | 4,660 | 4,320 | 4,660 |
| Clusters | 932 | 932 | 932 | 932 | 932 | 932 |
| Period × archeological excavation | Y | Y | Y | Y | Y | Y |
| Period × rainfall | Y | Y | Y | Y | Y | Y |
| Period × temperature | Y | Y | Y | Y | Y | Y |
| Period × urban | Y | Y | Y | Y | Y | Y |

*Notes:* All regressions are estimated using OLS. The cross-sectional unit of observation is a 5×5 kilometer grid cell. The time series period is an archeological period. We describe periodization in our Data Appendix Section 1.3. No. of settlements is the count of settlements. City (yes/no) is an indicator equal to one if a city is contained within a grid cell. Canal (yes/no) is an indicator variable equal to one if there is a canal within five kilometers (distances measured from the cell centroid). River shift (yes/no) is an indicator equal to one if the nearest river was within five kilometers in period $t - 1$ and is further than five kilometers away in period $t$ (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period × archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix Sections 1.2 and 4. Period × rainfall is a vector of period fixed effects interacted with average rainfall. Period × temperature is a vector of period fixed effects interacted with average temperature. Period × urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. Conley (1999) standard errors are in square brackets.

manipulated river flow. Second, in Section 1.1 of our Results Appendix, we plot a time series of rainfall shocks identified from data collected in the proximity of the source of the Euphrates and the Tigris rivers. As sudden increases in river flow volume are ultimately determined by rainfall there, we want to verify that the first river shift downstream happened in a period of high volatility in rainfall where the rivers originated. This is what we find. This is not a conclusive test, but is in line with a literature in geography that points to the sudden swelling of river flow volumes as the sources of breaks in levees discussed in Section III. In the next section, we use our model to estimate the treatment effects of the first river shift in our panel.

## V. Results

In this section, we present the main results of the paper. We find that in response to a river shifting away, Iraqis formed some of the first states and governments in history. We also find that they constructed canals and built defensive walls. Finally, we find that where the rivers shift away tribute receipts are recorded, and the government set up the administrative infrastructure to support public good provision. We start by estimating the effect of a river shifting away on state formation.

## A. *Result: State Formation*

**Graphical Intuition, State Formation:** Before showing regression evidence, we build intuition for our main result graphically using Figure 4. Panels A and B depict rivers and states before the river has shifted. In panel A we plot the river system before the shift, which is the same river system as in Figure 3, panel A. We indicate the first point where the river will break in black. In gray we indicate the subset of grid cells that will be treated. Note that these are all directly adjacent to the river and can irrigate from the river directly. In panel B we replicate this map but add two features. First, we map the cities that had at least one administrative building with their immediate hinterland. Uruk in the south is the most well-known city, but there were several other cities that had administrative buildings, such as Esnunna in the north. In maroon diamonds we indicate which cells that will be treated were inhabited before the shift.[39]

In panels C and D we plot the river system after the shift. River courses changed throughout the plain as a consequence of a surge in river water which broke through the levees at the location indicated by the black dot. From there, the river found a new path. Panel C is identical to panel A with the only change being the new courses of the river. Note that all treated cells are now away from the rivers. In panel D we repeat panel B, but we map the states that had formed by the end of the treatment period. First, states overlap with treated grid cells. Second, the formation of states is concentrated where grid cells were inhabited before the river shifted away. We formally estimate the average effect of the river shift on state formation in column 1 of Table 3, and we study heterogeneous effect by pre-shift population in columns 2 and 3 of Table 5.[40]

**Main Result, State Formation:** We report results from estimating equation (1) in Table 3. In column 1 we use as the dependent variable our indicator equal to one if grid cell $c$ is part of a state. Row 1 contains the estimated effect of a river shifting away measured in the treatment period, or the Early Dynastic I period. We find a positive and significant treatment effect relative to the last pretreatment period. A river shifting away is associated with a 14 percentage point increase in the probability of being part of a city state (clustered SE $= 0.04$). Over the five-period panel, the mean of this variable is 0.06, and in the treatment period it is 0.24. We study pretrends in Figure 5. The $x$-axis plots periods in our five period panel. Treatment happens at the start of period 0, and we measure outcomes at the end of period 0. We normalize estimated treatment effects to zero at the end of the last pre-period and indicate treatment with a red vertical line. In black we plot treatment effects and confidence intervals. At the end of period 0 we see the same estimated treatment effect, 0.14. When we study pretrends, we see that estimated treatment effects before

[39] Note that we do not map settlement outside treated cells. Refer to Figure 3 for settlement in both treated and untreated cells.

[40] In Figure 2 we provide another piece of graphical evidence. Instead of mapping cross-sectional difference before and after the shift, we plot a time series of rainfall, with higher rainfall indicating more favorable climatic condition, and we graph the fraction of our sample area that is part of a state. We provide details on the coding of this variable for subsequent periods in our panel in Section 7 of our Data Appendix. We also indicate each river shift. This graph reveals an inverse correlation between favorable climate and state formation.

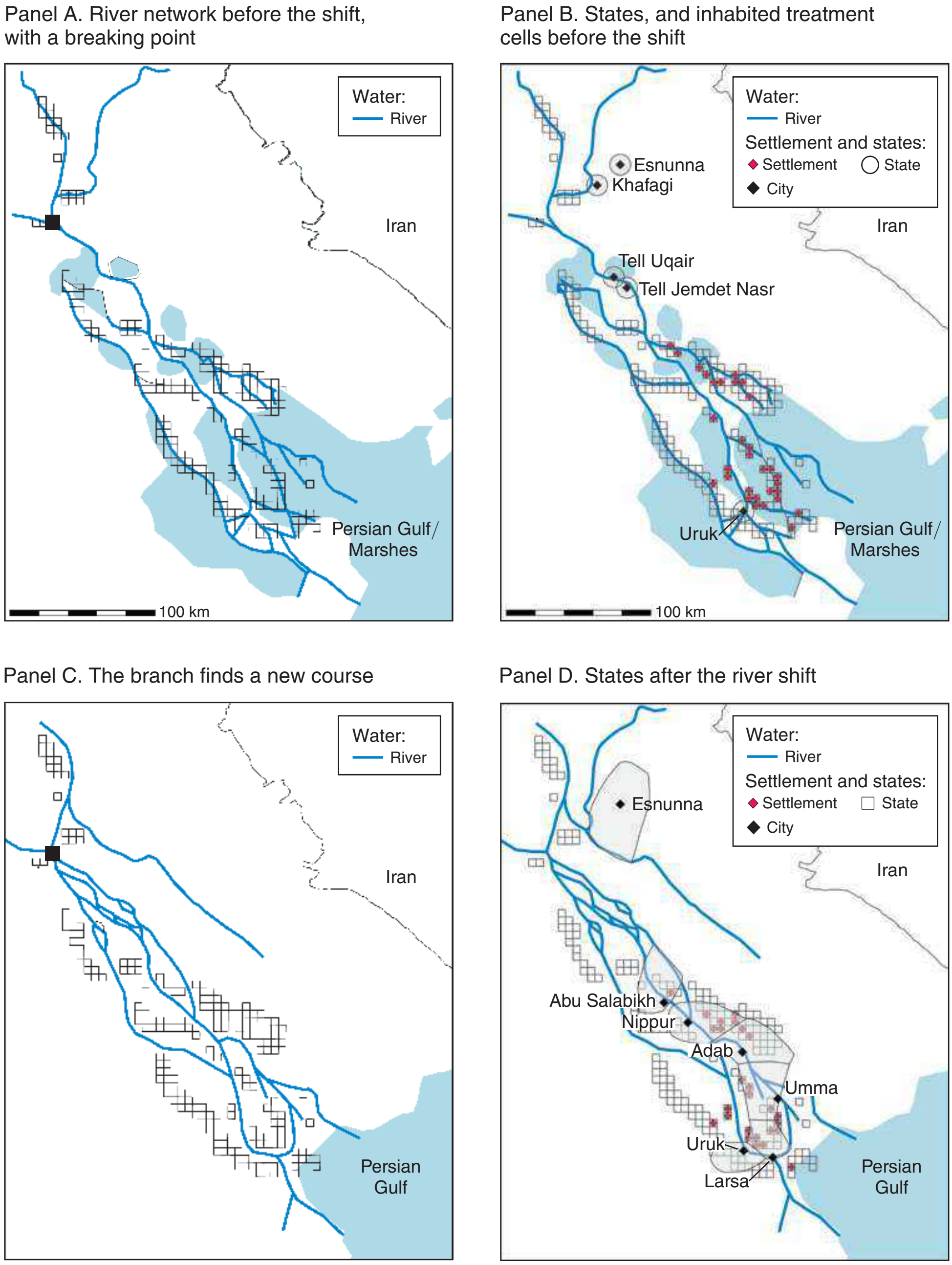


Figure 4. The Effect of a River Shift on State Formation: Intuition

*Notes:* These four maps provide intuition for the treatment effect of a river shifting away. Panel A maps the river network before the first river shift, indicated as shift 1 in Figure 2. Gray squares indicate grid cells that will be treated after the shift (see Figure 1 for the full grid). Panel B also contains the river network before the shift but now indicates states, like in Figure 3. We also indicate, by small diamonds, the grid cells that are inhabited before the shift. In panel C we map the river network post-shift, indicating the breaking point of the rivers as well as the treated grid cells, like in panel A. In panel D we map the states that form after the river shift. We also indicate settlement pre-shift, like in panel B. We observe that states form where the river shifted. This effect is concentrated in inhabited grid cells. We provide formal tests of this conclusion in Figure 5 and Tables 3 and 5.

Table 3—Main Result: A River Shift Leads to the Formation of New States

| Dependent variable: | Under city state (yes/no) | | New state (yes/no) | Existing state (yes/no) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *River shift* (*yes/no*) | 0.14 | 0.16 | 0.11 | 0.02 |
| | (0.04) | (0.05) | (0.04) | (0.02) |
| | [0.03] | [0.04] | [0.03] | [0.01] |
| *p*-value pretrend | 0.23 | 0.26 | 0.24 | 0.84 |
| Mean dependent variable | 0.06 | 0.12 | 0.03 | 0.03 |
| Observations | 4,631 | 4,424 | 4,631 | 4,631 |
| Clusters | 932 | 932 | 932 | 932 |
| Using reconstructed borders | Y | N | Y | Y |
| Period × archeological excavation | Y | Y | Y | Y |
| Period × rainfall | Y | Y | Y | Y |
| Period × temperature | Y | Y | Y | Y |
| Period × urban | Y | Y | Y | Y |

*Notes:* All regressions are estimated using OLS. The cross-sectional unit of observation is a 5×5 kilometer grid cell. The time series period is an archeological period. We describe periodization in our Data Appendix Section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within five kilometers in period $t-1$ and is further than five kilometers away in period $t$ (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period × archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix Sections 1.2 and 4. Period × rainfall is a vector of period fixed effects interacted with average rainfall. Period × temperature is a vector of period fixed effects interacted with average temperature. Period × urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. Conley (1999) standard errors are in square brackets.

treatment are all small and indistinguishable from zero (as well as each other). The fact that we do not observe pretrends, and our previous evidence on the plausible exogeneity of river shifts lends credence to our claim that we identify the causal effect of river shifts on state formation.[41]

**Interpretation in Relation to Theories of the State:** Our main result shows that relative to untreated grid cells, treated grid cells were significantly more likely to be part of a state. One of the attractive features of our setting is that we can interpret this treatment effect as providing evidence that separates cooperative, or "demand," and extractive, or "supply" theories of state formation we discussed in Section I.[42]

[41] Because in the pre-periods states consist of cities with an administrative buildings and their small hinterlands, the absence of pretrends shows that cities with administrative buildings were not more likely to be located along stretches of the rivers that would shift.

[42] On average, the center of the plain is more productive, further increasing the incentives to try to maintain agriculture through irrigation. In Results Appendix Table RA2 we show that the center of the sample area, where rivers flow earlier on in history is more productive, as measured by temperature, rainfall, and geographical suitability for growing barley, the main staple crop of the area.

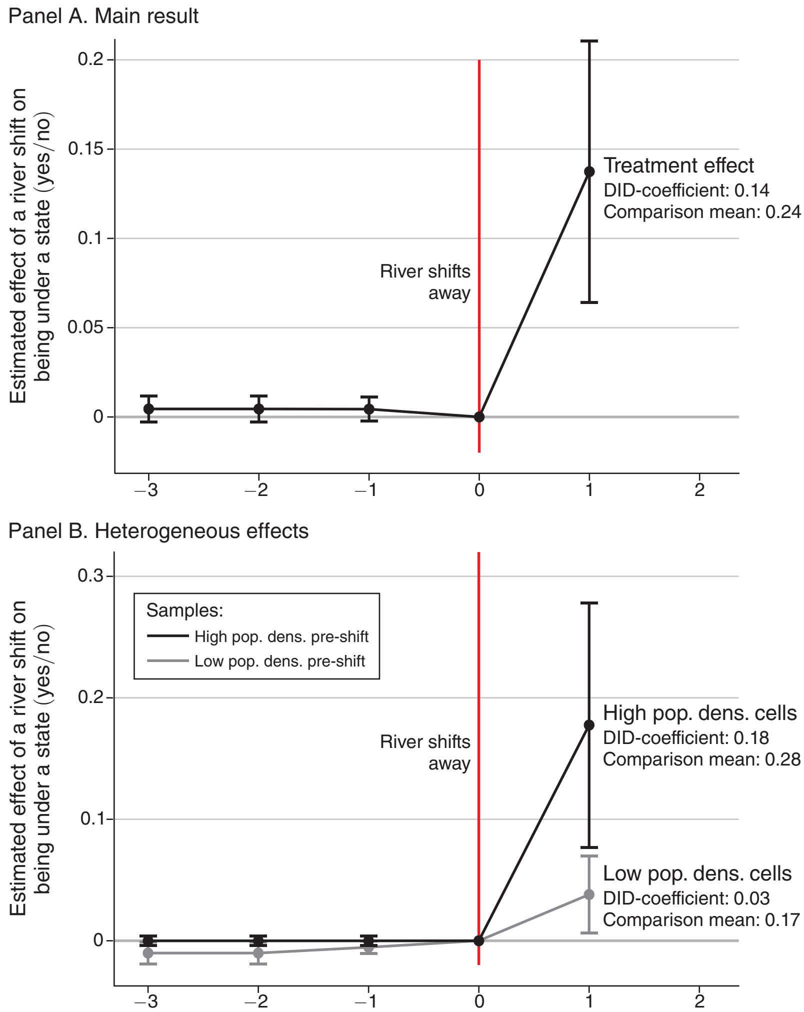


Figure 5. The Effect of a River Shift on State Formation

*Notes:* This figure provides two event-study graphs corresponding to our main result (panel A) and our main heterogeneous effect (panel B). In panel A we show treatment effects of a river shifting away. Where rivers shift away, states are 14 percentage points more likely to form after the river has shifted. We report the comparison mean for the treatment period. The panel-wide mean of the outcome variable is 0.06. This figure corresponds to Table 3, column 1. In panel B, we split the sample by the median of population density. Density is defined by the spatial lag of population before the river shifted, which we discuss in Section V. In high population density cells, the treatment effect of the river shifting away is positive, and equal to 18 percentage points. In low population density cells, the treatment effect is 0.04 percentage points. We report treatment period comparison means. Full sample comparison means are 0.07 and 0.04. This figure corresponds to Table 5, columns 2 and 3.

If state formation is fundamentally due to greater incentives for expropriation, we expect state formation to be less likely where rivers shifted away and more likely along the rivers. Along the rivers, the tax base is intact, and no canals need to be provided. If, instead, states form to address the coordination problems that arise from collective irrigation, we would expect states to form where the river has shifted away. Because we observe a sizable positive and significant treatment effect of a river shifting away on state formation, and the assumptions for identification have plausibly been met, we interpret our main result as evidence consistent with cooperative theories of the origins of the state.

This result relies on the credibility of our reconstruction of rivers and states over time. In our Data Appendix, we discuss this issue in detail, Sections 1.1, 2, and 7 in particular. We construct our indicator for whether a grid cell is part of a state from our data on administrative buildings and boundaries of states. We are confident in the archeological record on buildings.[43] The reconstruction of boundaries is more speculative. In column 2 we therefore recode our indicator for whether a grid cell is part of a state using only archeological information. We code an indicator that is equal to one if there is a building in the city nearest to a grid cell.[44] We find a similarly large, significant, and positive effect of a river shifting away on the probability of there being a building in the nearest city, showing that our main result in column 1 does not depend on our use of the reconstructed borders.

**New States or Expanding States?:** In columns 3 and 4 we study whether our main result is driven by cities that had developed some form of governance before 2900BCE, such as Uruk and Esnunna, expanding into the countryside or whether the states that form after 2900BCE were new states. We start again by studying Figure 4. We saw in panel B and D that although both Esnunna and Uruk extended their territory, where the river shifted, new states, such as Nippur, Adab, and Umma, formed. In column 3 of Table 3 we use as the outcome variable an indicator equal to one if a grid cell is part of a newly formed state. In our treatment period, this means that we capture new states, but not Uruk and Esnunna. In earlier periods we capture cities that built administrative buildings but did not have one in the previous period. In column 4 we reverse this coding and record an indicator equal to one if a grid cell is part of a state that existed before treatment. The sample means of the presence of new and expanding states are equal showing that we have both in our sample. However, the main effect in column 1 is entirely driven by new states. This result is consistent with communities forming states to solve the coordination problems created by a river shifting away.[45]

**Robustness:** In Results Appendix Section 2.2, we implement several robustness checks, which we briefly introduce here. We establish the robustness of our results to excluding fixed effects and trends in covariates, to varying our unit of observation and sample inclusion criteria. We also vary our definition of treatment and of what it means to be part of a state. We then show that our inference is robust to our choice

[43] Virtually all cities have been excavated, and the stratigraphy of these excavations gives a clear indication of which buildings were active in which archeological periods. Stratigraphy refers to the fact that subsequent periods of occupation leave "layers" of debris on top of each other. Excavating down therefore gives a time series of occupation for each point of excavation.

[44] Note that the mean of this variable is about double that of our main outcome in column 1 reflecting the fact that not using boundaries associates more cells with an administrative building.

[45] The most obvious alternative interpretation of our main result is that a river shift does not shock the returns to cooperation but instead shocks patterns of comparative advantage. For example, Algaze (2008) points out that rivers and canals were used for transportation. Similarly, no longer being able to engage in agriculture may induce farmers to switch to nomadism. Trade patterns, in turn, have been pointed to as having fueled the rise of Uruk and other city states (Algaze 2008). In the Results Appendix, we test for trade as an alternative interpretation of the effect of a river shift, Table RA26. We fail to reject the hypothesis that river shifts have no effect on trade patterns.

of estimator and standard errors. We also estimate a spatial lag model. Results are very similar throughout these exercises, showing that our findings are not driven by particular choices we made in setting up our empirical strategy. We then perform a placebo exercise, aimed at bolstering the interpretation of our main result. Rather than studying a river shifting away, we study a river shifting closer. We find a consistently negative effect of a river shifting closer.[46]

Although our results in this section are consistent with a cooperative theory of the origins of the state, we have not yet provided direct evidence for public good provision and public administration. In the next section, we use data on public good provision and tribute payments to the government to substantiate our interpretation of our main results.

### B. *Result: Public Good Provision, Tribute, and State Capacity*

In this section we study public good provision, tribute payment to the government, and "state capacity." We find that a river shift is associated with a higher likelihood of the construction of canals and defensive walls, a higher likelihood of tribute payment to the government, and a larger number of administrative buildings.

**Public Good Provision:** At the core of our natural experiment lies cooperation for irrigation. We now directly study this form of public good provision through our full reconstruction of the time-varying canal network. In column 1 of Table 4 we use as our outcome variable an indicator equal to one if a grid cell was irrigated by a canal. As before, the first row contains estimates of the treatment effect of a river shifting away in our main estimating model, equation (1). The estimated effect in column 1 is equal to 0.12 (clustered SE 0.03) which means that a river shifting away increases the probability of being on a canal by about 12 percentage points, or slightly less than one-half of its mean. These statistical results are clearly visible in our maps. Consider panel D of Figure 3. Note that the area east of Nippur and Adab is irrigated by canals. Compare the same area in panel B. Before the shift, this area was irrigated by the rivers.[47]

It stands to reason that governments may not only have coordinated to provide canals but would also supply other public goods. We study defensive walls as one public good that is measurable in the archeological record. We record, for each city in our panel, whether it had a defensive wall in the periods of our main study period. From this dataset, we code an indicator equal to one if the nearest city to grid cell $c$ had a defensive wall. Using this indicator as our outcome variable in column 2 of Table 4 we find that a river shift is associated with an 11 percentage point increase in the probability of having a city wall, relative to a mean of 14 percent.[48]

[46] This result is driven by the absence of states before and after treatment where rivers shift to, and our previous result that showed that states form where the river shifted away. Since cells that are part of a state that formed because of a river shifting away are more likely to be in the control group of a river shifting closer, we find a negative treatment effect.

[47] Following Ur (2014), we argued that in practice governments played a coordinating role between various stakeholders in the canal projects. We return to this interpretation in our mechanisms section.

[48] In the last pretreatment period, only Abu Salabikh had a defensive wall. In our treatment period Abu Salabikh, Adab, Esnunna, Khafaji, Nippur, Tell Aqrab, Umma, Ur, and Uruk had defensive walls.

Table 4—A River Shift Leads to Public Good Provision and Tribute

| | Public good provision (yes/no) | | Administration | |
|---|---|---|---|---|
| Dependent variable: | Canal (1) | Wall (2) | Tribute (yes/no) (3) | N. admin. build. (4) |
| *River shift (yes/no)* | 0.12 | 0.11 | 0.21 | 0.44 |
| | (0.03) | (0.04) | (0.06) | (0.15) |
| | [0.02] | [0.03] | [0.10] | [0.17] |
| $p$-value pretrend | 0.81 | 0.57 | 0.20 | 0.69 |
| Mean dependent variable | 0.28 | 0.14 | 0.19 | 0.70 |
| Observations | 4,320 | 4,424 | 4,424 | 4,424 |
| Clusters | 932 | 932 | 932 | 932 |
| Period × archeological excavation | Y | Y | Y | Y |
| Period × rainfall | Y | Y | Y | Y |
| Period × temperature | Y | Y | Y | Y |
| Period × urban | Y | Y | Y | Y |

*Notes:* All regressions are estimated using OLS. The cross-sectional unit of observation is a 5×5 kilometer grid cell. The time series period is an archeological period. We describe periodization in our Data Appendix Section 1.3. Canal (yes/no) is an indicator variable equal to one if there is a canal within five kilometers (distances measured from the cell centroid). Wall (yes/no) is an indicator variable equal to one if there is a defensive wall in the nearest city. Tribute (yes/no) is an indicator variable equal to one if a cuneiform tablet was excavated in the nearest city. No. of admin buildings is the sum of the number of palaces, the number of temples, and the number of ziggurats in the nearest city. River shift (yes/no) is an indicator equal to one if the nearest river was within five kilometers in period $t-1$ and is further than five kilometers away in period $t$ (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period × archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix Sections 1.2 and 4. Period × rainfall is a vector of period fixed effects interacted with average rainfall. Period × temperature is a vector of period fixed effects interacted with average temperature. Period × urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. Conley (1999) standard errors are in square brackets.

**Tribute and Government Organization:** We have argued that part of a cooperative explanation for the origins of the state is that individuals are willing to exchange resources for government services. The simplest way to measure tribute payment is an indicator equal to one if we have surviving cuneiform tablets in the nearest city to a grid cell. We do this because we discussed in Section III that most surviving cuneiform tablets are records of tribute payment or redistribution. We validate this conclusion in Table RA29 of the Results Appendix, where we use the text of the tablets to validate that our indicator does indeed primarily measure tribute. We provide full details on how we processed the tablets data in Section 8 of the Data Appendix. We find that a river shift away leads to a 21 percentage point increase in the probability of tribute payment taking place, relative to a sample mean of 19 percent.

In Section I we discussed the organization of public good provision. One aspect of public good provision we highlight here is the central role of administrative buildings. Government activity was concentrated in palaces, temples and ziggurats. In Table 3 we used administrative buildings as part of our reconstruction of states. Here we use the total number of palaces, temples, and ziggurats in the city nearest to a grid cell as a measure of "state capacity." We find that where a river shifts away the number of administrative buildings in the nearest city increases by 0.44, relative to a mean of 0.7.[49]

The fact that we observe states form, and these states both receive tribute and provide public goods from administrative buildings supports our claim that state form as a consequence of rivers shifting. The fact that states form where the river shifted away, rather than where the river shifted to, is consistent with public goods and taxes being cooperatively exchanged rather than taxes being extracted coercively. Before discussing the internal organization of the first states we discuss the generalizability of our findings beyond the Iraqi context.

## VI. Generalizability

In this section we study generalizability of our findings so far, both over space and over time. We start from the observation that historically, state formation is rare (Scott 2017). This poses a problem for any theory of state formation because purported favorable conditions for state formation were ubiquitous.[50] In this section, we study conditions under which our main results hold. We show that relative to an outside option like migration to the rivers or nomadism, state formation may not be sufficiently appealing. It is important to emphasize that the results in this paper are about the formation of the first states. Once states have formed, naturally there are incentives to both facilitate cooperation and predate or extract. To study how our results extend over time we study subsequent river shifts that happen within the territory of existing states. We find that in response to later river shifts, public goods continue to be provided locally.

**The Costs and Benefits of State Formation:** We start by splitting our sample by cross-sectional costs and benefits of state formation and estimating heterogeneous treatment effects. Throughout, we use our indicator variable for whether a grid cell is under a state in our main study period as our outcome variable. Results are in Table 5. We provide the average effect in column 1 and pairs of subsequent columns report treated effects estimated in subsamples of our main dataset.

In panel A we focus on the social costs and benefits of state formation. In columns 2 and 3 we split the sample by the median of the spatial lag of settlement density in the last pre-period before treatment (Anselin 2013).[51] We compute the spatial lag of settlement of grid cell $c$ by summing settlement density in surrounding cells, down-weighting cells that are further away.[52] We visualize these regressions in columns 2 and 3 in panel B of Figure 5. The effect of river shifts on state formation

[49] For example, in the treatment period a new palace is built in Umma, Nippur, and Adab. Uruk had a palace and a ziggurat, and Ur had a ziggurat in the last pre-period which survived into our treatment period. Tell Jemdet Nasr and Tell Uqair had a palace in the pre-period which is no longer in use in the treatment period.

[50] For example, conflict occurs far more frequently than state formation and some states form without any evidence of conflict (Lowie 1927). Opportunities for productive cooperation to alleviate issues arising from opposing interests seem ubiquitous too.

[51] The number of observations in each subsample are not exactly equal because we split before imposing the sample restrictions introduced in Section IVA.

[52] We include the entire sample area in this calculation. Since grid cells further away are heavily down-weighted, results are virtually the same if we instead impose a fixed distance cut-off.

Table 5—Heterogeneous Effects: Costs and Benefits of State Formation

| Dependent variable: | Under city state (yes/no) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| *Panel A. Social returns and costs of canal building* | | | | | |
| | | Social returns | | Social costs | |
| | | Population density | | Settl. aligned for canals | |
| Sample: | Full sample | High | Low | Aligned | Misaligned |
| *River shift (yes/no)* | 0.14 | 0.18 | 0.03 | 0.22 | −0.01 |
| | (0.04) | (0.05) | (0.02) | (0.06) | (0.03) |
| | [0.03] | [0.03] | [0.03] | [0.04] | [0.02] |
| $p$-value Chow test coefficient equality | | 0.06 | 0.06 | 0.00 | 0.00 |
| $p$-value pretrend | 0.23 | 0.98 | 0.12 | 0.42 | 0.49 |
| Mean dependent variable | 0.06 | 0.07 | 0.04 | 0.08 | 0.03 |
| Observations | 4,631 | 2,323 | 2,308 | 2,365 | 2,266 |
| Clusters | 932 | 465 | 467 | 477 | 455 |
| *Panel B. Geographic returns and costs of canal building* | | | | | |
| | | Geographic returns | | Geographic costs | |
| | | Δ potential productivity | | Water flow nearest river | |
| Sample: | Full sample | High Δ | Low Δ | Slow flow | Fast flow |
| *River shift (yes/no)* | 0.14 | 0.16 | −0.05 | 0.10 | 0.03 |
| | (0.04) | (0.05) | (0.02) | (0.05) | (0.06) |
| $p$-value Chow test coefficient equality | | 0.00 | 0.00 | 0.14 | 0.14 |
| $p$-value pretrend | 0.23 | 0.88 | 0.62 | 0.27 | 0.32 |
| Mean dependent variable | 0.06 | 0.07 | 0.04 | 0.08 | 0.02 |
| Observations | 4,631 | 2,319 | 2,311 | 2,775 | 1,856 |
| Clusters | 932 | 465 | 467 | 555 | 377 |
| *Covariates (all regressions):* | | | | | |
| Period × archeological excavation | Y | Y | Y | Y | Y |
| Period × rainfall | Y | Y | Y | Y | Y |
| Period × temperature | Y | Y | Y | Y | Y |
| Period × urban | Y | Y | Y | Y | Y |

*Notes:* All regressions are estimated using OLS. All estimated coefficients are standardized. The cross-sectional unit of observation is a 5×5 kilometer grid cell. The time series period is an archeological period. We describe periodization in our Data Appendix Section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. We split the sample by four indicator variables, measuring social returns, social costs, geographical returns, and geographic costs. Change in potential productivity returns to irrigation is an indicator equal to one if the difference between the suitability of the soil for irrigated and rainfed cultivation of barley is above its median. Slow water flow is an indicator equal to one if the nearest river is the slow-flowing Euphrates, or the smaller Diyala river, and zero if the nearest river is the fast-flowing Tigris. Slower flowing rivers are easier to irrigate from as they cut less deep into the landscape. High settlement density area is an indicator equal to one if the spatial lag of the number of settlements in period $t-1$ is above its median. Settlement misaligned for canals is an indicator equal to one if the number of settlements aligned suitably for canal construction is lower than the number of settlements that are misaligned in period $t-1$. River shift (yes/no) is an indicator equal to one if the nearest river was within five kilometers in period $t-1$ and is further than five kilometers away in period $t$ (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period × archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in Data Appendix Sections 1.2 and 4. Period × rainfall is a vector of period fixed effects interacted with average rainfall. Period × temperature is a vector of period fixed effects interacted with average temperature. Period × urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. Conley (1999) standard errors are in square brackets.

is concentrated where–before the shift–population density was higher. This is the same conclusion as we reached when we discussed our maps in Figure 4. In columns 4 and 5 we instead measure whether settlement was aligned with the landscape gradient *before* the river shifted. The gradient of the southern Iraqi plain slopes gently downward from northwest-west to southeast-east. This means a single canal irrigates several settlements if they are aligned north-south and these settlements will need to coordinate. If, instead, settlements are aligned east-west, each settlement will require a separate canal. For each grid cell, we compute an indicator equal to one if the count of settlements in cells to the north or south of a grid cell is smaller than the count of settlements to the east or west. If equal to one, then a grid cell is "misaligned." We find that states form where villages are aligned for irrigation, and where there are, therefore, benefits to coordination. For misaligned villages, we find no treatment effect of a river shift.

In panel B of Table 5 we focus on the geographical costs and benefits of forming a state. We split the sample in two ways. First, we split by the potential agricultural return to canal irrigation: the difference of irrigated to rainfed potential productivity of the soil.[53] A larger difference can be interpreted as a rate of return on canal investment for fixed inputs. We split the sample by its median, and report results in columns 2 and 3. Columns 4 and 5 instead split by whether a grid cell is closest to the Euphrates or the Tigris.[54] The Tigris is fast flowing and cuts deep into the desert making it relatively difficult to irrigate from. The Euphrates is slow moving, cuts less deep, and is therefore easier to irrigate from (Adams 1981). We find that the probability that a state is formed is higher if potential productivity is higher and where water for irrigation is easier to access.

These results, combined with the observation that river shifts are large shocks, provide insight into why, despite abundant collective opportunities for coordination, state formation is relatively rare in history. The simplest response to a river shifting away is to move away. If people are well positioned to coordinate, they may form a state.

**Results Using a Longer Panel:** Our main results show that states form where rivers shift away. Importantly, our main results pertain to the formation of the first states in history. It is clear however that once a government is in place, there are incentives to coordinate as well as predate.[55] This is especially the case since typically some enforcement power will have to be ceded to the state. In this section we extend our panel to cover all six river shifts that take place within our sample area. The objective of this section is to provide tentative evidence whether our results so far extend over time. To study the effect of river shifts under the later states and empires, we extend our panel to cover 5000BCE until 1950CE. After the formation of the first states five more river shifts take place within our sample area. We discuss the historical context for each shift in Section 2 of our Data Appendix, and we visualize each shift in our Atlas Appendix, Figures AA5 to AA11.[56]

All river shifts after our main study period take place within the territory of several smaller states or one large, consolidated state. This means that we can study

[53] These data come from the Food and Agricultural Organization, and we describe the data in detail in Section 3 of the Data Appendix.

[54] We group the smaller Diyala river that comes down from the Zagros mountains with the Euphrates.

[55] Historians do indeed point to the disappearance of assemblies as consensual organs of decision making (Bailkey 1967) and the a more central role of slavery (Scott 2017) from about 2000BCE.

[56] River shift 2 in Figure 2, happened around 2450BCE in the middle of the Early Dynastic III period. This period was characterized by military competition between city states and, towards the end of the period, by the first attempts of political centralization across the sample area. We visualize this shift in Figure AA5 of our Atlas Appendix. Especially in the north, the Euphrates and Tigris separated more clearly in two distinct watercourses

the responsiveness of governments in Iraq to increased returns to coordination. It also means we can for subsequent river shifts no longer study whether a grid cell is part of a state. Instead, we study the effects of a river shifting away on canal construction.[57]

We indicate the longer period that this exercise covers as our "extended study period" in Figure 2. We estimate the effect of all six river shifts that take place within our sample area in a standard panel difference-in-differences model, which we estimate using OLS.[58]

We report results in Table 6. In column 1 we use our full panel, covering 5000BCE–1950CE. In the first row we report the estimated effect of a river shifting away, across all six shifts. We find that when a river shifts away, the probability of having a canal increases by 11 percentage points, or about one-quarter of the full sample mean. The first two river shifts occurred when there were either no states that projected authority beyond a city and its immediate surroundings (this is our main study period, indicated by "1" in Figure 2), or when there were states and stateless areas (indicated by "2" in Figure 2). Each subsequent shift took place after our sample area was mostly or entirely governed by states. We indicate all subsequent shifts as well as the fraction of our sample area that is governed by a state in Figure 2. In columns 2 and 3 we break up our panel in two sub-panels, the first covering the first two shifts and the second covering the four subsequent shifts. In both subsamples

starting their slow movement towards the fringes of the plain. River shift 3 in Figure 2 took place during Hammurabi's reign, around 1750BCE, a period that marked a more stable transition from the coexistence of regional powers to firmer centralization across the sample area. The Euphrates further shifted from the center of the plain westward. We visualize this shift in the Atlas Appendix, Figure AA6. River shift 4 in Figure 2 took place around 1000BCE, at the beginning of the Middle Babylonian period, which was characterized by continuous foreign invasions and political instability across the sample area. Although formally under the centralized control of Babylon, southern Iraq was again split into different areas of political influence. The shift marked the definitive separation of the courses of the Tigris and the Euphrates in the sample area, which moved further to the east and west, respectively. We visualize the new river equilibrium in Figure AA7 of the Atlas Appendix. River shift 5 in Figure 2 happened around 700BCE between the end of the neo-Assyrian and the beginning of the neo-Babylonian period. The transition between the two periods marked the end of a period characterized by foreign occupation and instability to a new era of strong political centralization in southern Iraq. The shift, which we visualize in Figure AA8 of the Atlas Appendix led to the movement of the Euphrates roughly to its current bed. After the 700BCE shift, the riverine system substantially stabilized, with only smaller adjustments to the network. The last shift we record, number (6) in Figure 2, only led to the disappearance of a secondary branch of the Euphrates and to the adjustment of the course of the Diyala river. These adjustments happened around 450CE, in the middle of the Sassanian period, which was characterized by low state presence that followed the military confrontation of the Parthian and Sassanian empires in the area. We visualize the shift in Figure AA9 of our Atlas Appendix.

[57] We map settlement, cities, rivers, canals, for each archeological period spanning 5000BCE until 1950CE in our Atlas Appendix.

[58] The regression equation takes the following form:

$$Y_{ct} = \beta treated_{ct} + \rho_c + \gamma_t + \upsilon_{ct} + \varepsilon_{ct}. \tag{2}$$

Here $Y_{ct}$ is an indicator equal to one if grid cell $c$ in period $t$ was on a canal. $treated_{ct}$ is an indicator equal to one if grid cell $c$ in period $t$ is treated. We define treatment as before: a grid cell is treated if the nearest river was within five kilometers in $t-1$, and the nearest river is more than five kilometers away in period $t$. Our coefficient of interest is $\beta$. We include grid cell fixed effects $\rho_c$, and period fixed effects $\gamma_t$. As before, $\upsilon_{ct}$ is a vector of period fixed effects interacted with time-invariant covariates. We include covariates for the three large archeological survey areas covered by the Chicago Oriental Institute which we describe in our Data Appendix Section 1.2, rainfall, temperature, and an indicator equal to one if a grid cell was urban in the last pre-period before the first river shift. $\varepsilon_{ct}$ is a standard error, clustered at the grid cell level. As before, we report Conley standard errors throughout. In the Results Appendix, Tables RA33 and RA34, we show results using a stacked panel model, and using De Chaisemartin and d'Haultfoeuille (2020)'s estimator. Results are very similar.

Table 6—Heterogeneous Effects: Canal Construction over Time

| Dependent variable: | Canal (yes/no) | | |
|---|---|---|---|
| Period: | 5000BCE–1950CE | 5000BCE–2350BCE | 2350BCE–1950CE |
| State: | All | First states | Subsequent states |
| | (1) | (2) | (3) |
| *River shift (yes/no)* | 0.11 | 0.15 | 0.10 |
| | (0.02) | (0.03) | (0.02) |
| | [0.02] | [0.02] | [0.02] |
| Mean dependent variable | 0.40 | 0.20 | 0.51 |
| Observations | 27,106 | 9,718 | 17,388 |
| Clusters | 1,094 | 1,094 | 1,094 |
| Period × archeological excavation | Y | Y | Y |
| Period × rainfall | Y | Y | Y |
| Period × temperature | Y | Y | Y |
| Period × urban | Y | Y | Y |

*Notes:* All regressions are estimated using OLS. The cross-sectional unit of observation is a 5×5 kilometer grid cell. The time series period is an archeological period. We describe periodization in our Data Appendix Section 1.3. Canal (yes/no) is an indicator variable equal to one if there is a canal within five kilometers (distances measured from the cell centroid). River shift (yes/no) is an indicator equal to one if the nearest river was within five kilometers in period $t-1$ and is further than five kilometers away in period $t$ (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period × archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix Sections 1.2 and 4. Period × rainfall is a vector of period fixed effects interacted with average rainfall. Period × temperature is a vector of period fixed effects interacted with average temperature. Period × urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before the first river shift. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. Conley (1999) standard errors are in square brackets.

we find that a river shifting away leads to public good provision, indicating some degree of reciprocity between state and society throughout Iraqi history.

Our main results show that when a river shifts away, new states form. In Section I we argued the formation of states was a social adaptation to the larger scale at which coordination was now necessary. In response, existing social arrangements that operated within lineages were scaled up to operate across lineages. The government was essentially a ruling lineage that coordinated activities. In the next section, we substantiate this interpretation using evidence from surviving government records.

## VII. The Internal Organization of the State

In this section, we revisit our dataset of 5,885 transliterated cuneiform tablets to study the internal organization of the first states. For our main study period, these tablets are written in Sumerian. Sumerian has been deciphered, and we can therefore use a standard Sumerian dictionary to track the frequency of the use of terms in these tablets. Key to this exercise is that the view among Assyriologists is that most, if not all, surviving tablets from our main study period were produced by government scribes and were state administrative records (Englund 2011; Nissen 1993; Nissen, Damerow, and Englund 1993; Nissen 1986). Since we know where each tablet was found, and all tablets have been dated, we can subset to tablets within our sample area and study period.

We start with the word for lineage head, *lugal*. It literally translates as "big" (*gal*) "man" (*lu*) and indicated the head of a household and a lineage. As the first states appeared, the term came to define the head of the ruling lineage of a (city) state (Ur 2014; Emberling 2015).[59] Second, we also focus on the term *gal*, which translated literally means "great, senior," and by extension "chief"—both as an adjective and a noun (Garfinkle 2021). The *gal* designated a generic lineage leader (or chief) although likely of inferior rank compared to the *lugal*. For both *lugal* and *gal* we record the fraction of tablets that mention either. In addition, we record the fraction of tablets that mention canals and tribute, both to validate our approach to using these tablets as well as an additional way to measure cooperation. A complication for this approach is that Sumerian uses many variations of individual terms in different contexts. In Section 8.2 of the Data Appendix, we discuss how we use Sumerian keywords to search for these terms in more detail.

We present results in two ways. In Figure 6 we plot the fraction of tablets containing a particular term before and after the river shift that took place in our main study period. Panel A plots *lugal* and then *gal*, and panel B plots canal and then tribute. We observe that "lugal" appears after treatment and does not appear at all before the formation of the new states we found in Section V. The more general "gal" or "chief" appears in tablets both before and after the shift. However, the fraction of tablets that mentions "gal" increases by about 40 percent after the river shift. Canals are mentioned at low rates before the river shift and increase after. Tribute is not mentioned at all before the river shift and is mentioned after, albeit at low rates as well.

Because we assigned each tablet to the city where it was found, we can use the fraction of tablets in a regression framework too. We reestimate equation (1) using the fraction of tablets mentioning a particular term in the city nearest to a grid cell in a period. Results are reported in Tables RA31 and RA32 in the Results Appendix. We prefer the bar graphs because most of the variation in the fraction of tablets mentioning a term comes from having a tablet, rather than from the intensive margin of the fraction of tablets mentioning a certain term. Nevertheless, we can compare point estimates across columns, and find that, relative to the sample mean, the effects for "lugal" and canals are the strongest.

Taken together, the evidence from our cuneiform tablets is in line with the interpretation of the organization of the state we documented in Section I. The formation of the state was an extension of preexisting social structures to take on new tasks.

## VIII. Conclusion

In this paper we test between cooperative and extractive theories of the origins of states and governments. To test between these theories, we focus on river shifts in southern Iraq as natural experiments.

We hypothesized that such shifts create a coordination problem because private irrigation from the river now needs to be replaced by public canals. Importantly, because rivers do not shift in parallel, but break through their levees at a point and

[59] As such, *lugal* is somewhat anachronistically translated as "king." While anachronistic, the term had a secular connotation compared to other traditional religious titles, such as *en* and *ensi*. These have at times been interpreted as "ruler," but these titles had a stronger religious connotation (Marchesi and Marchetti 2011).

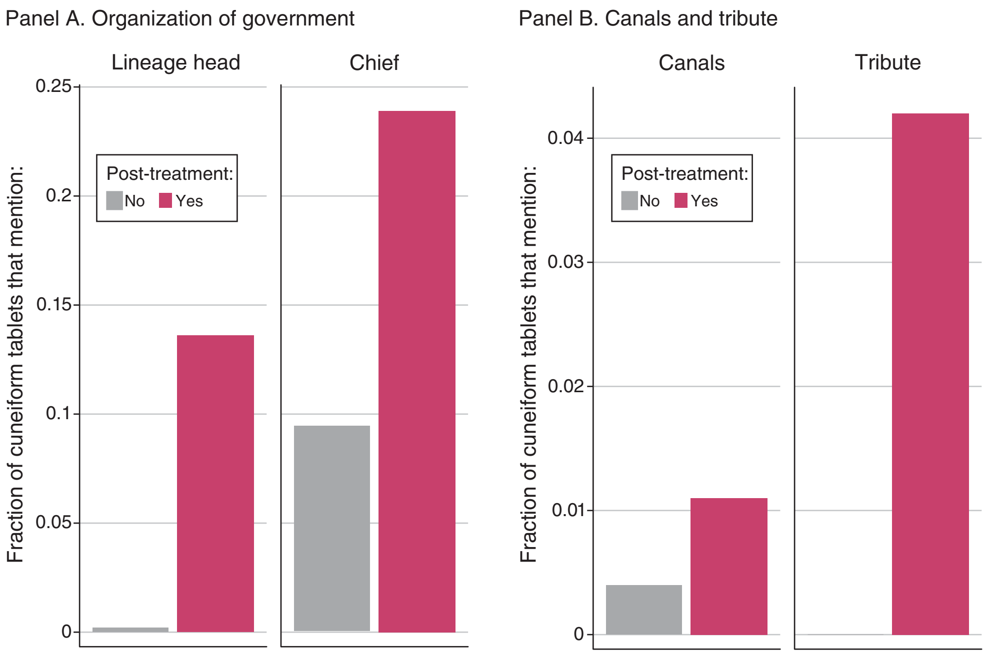


FIGURE 6. TEXT ANALYSIS OF CUNEIFORM TABLETS

*Notes:* This figure provides four comparisons of the fraction of cuneiform tablets that contain specific terms, before and after the first river shift, indicated as shift 1 in Figure 2. In panel A we plot the fraction of tablets that contain the word *lugal*, which translates as "lineage head" and was used for the leader of the ruling lineage. *gal* which designated a generic lineage leader (or chief) although likely of inferior rank compared to the *lugal*. Since cuneiform tablets are largely government records, we observe that both mentions of state leaders and local leaders increase as states form. We interpret this finding in Section VII. In panel B we provide additional evidence for the development of a social contract. We plot the fraction of tablets that mention canals and tribute. We provide the list of Sumerian terms we use to code these categories in the Data Appendix Section 8.2. We observe that both the frequency of mentions of canals and tribute go up as states form.

find a new course in the otherwise almost flat southern Iraqi plain, some farmers can still irrigate from the river whereas others cannot. This natural experiment maps onto cooperative and extractive theories of the state in the following way. If it was the case that states form to manage extraction (see e.g., Engels 1878), then we expect states to form where the rivers are. If, instead, states form to manage problems that individuals cannot solve privately (see, e.g., Locke 1689 and Baumol 1952) then we expect to see states form where the river shifted away.

We constructed a panel of shifting rivers, states, public good provision, and records of tribute payments for southern Iraq spanning 3900BCE–2700BCE. Our main results estimate the effect the first river shift which occurred around 2850BCE. Where rivers shift away states form, public goods—and in particular canals—are provided, and tribute is paid. We then use evidence from cuneiform tablets to bolster our interpretation of the internal organization of these first states. The first states were in essence scaled-up versions of the social structure that existed within extended kinship groups, called lineages.

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