The Origins of City-States in Southern Mesopotamia

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Abstract. The origins of the state are of interest to economists, political scientists, archaeologists, and anthropologists. We consider a leading example, the city-states of southern Mesopotamia. Starting around 8000 years ago, this region was organized into simple chiefdoms, with a few scattered towns of 1000 to 2000 people and many smaller villages. City-states with tens of thousands of people emerged between 5500 and 5000 years ago. These city-states had substantial inequality between elites and commoners. This transition was triggered by diminished rainfall, which shifted the labor supply curve facing the elites in southern Mesopotamia. As a result, the elites used additional labor for farming with river-based irrigation, and also started to use labor for urban manufacturing. Tax revenues from the urban sector were critical to financing large city-states. Similar mechanisms may have led to city-state formation in other regions of the world.

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1.   Introduction

        Early states involved government of, by, and for elites. The elites achieved better standards of living than commoners in many ways. The specific mechanisms varied from one society to another, and included taxation; the ownership of agricultural land or other natural resources; the monopolization of trade, mining, or manufacturing; the plunder of neighboring societies; corvée labor; and slavery. But early states may also have offered benefits to commoners such as public order, suppression of local warfare, infrastructure, and insurance against natural disasters. Early state formation influenced later economic growth in ways that have had persistent consequences for the modern world (Bockstette et al., 2002; Putterman, 2008; Borcan et al., 2018).

        We propose an economic explanation for the emergence of city-states in southern Mesopotamia around 5200 BP (before present). This case is of interest for a number of reasons: these are often regarded as the first known states, they have been the subject of much archaeological study, and they had a major historical impact. Even so, debates on their origins continue, and economic reasoning may shed new light on the issues at stake. An understanding of the Mesopotamian case may also yield insights into pristine states in Egypt, China, Mesoamerica, South America, and other regions of the world.

         Our working definition of a state is that it is an organized elite with the power to tax. This definition is consistent with a widely accepted view among archaeologists and anthropologists that early state societies were stratified into elite and commoner classes (Feinman and Marcus, 1998). We are agnostic about how decisions are made within the elite. For example, this may involve a council of elders, religious authorities, or a king.

We follow most economists in treating taxation as integral to a state. Economic historians often highlight the need for fiscal centralization in a coherent state (Acemoglu and Robinson, 2016), and this seems vital if the state is to function as a collective actor. As we will explain in more detail later, we define taxation broadly to include any sort of collective resource confiscation by the elite, whether this involves food, manufactured goods, raw materials, or labor services. Our emphasis on the power of the state to collect taxes is consistent with the broader idea from political science that states monopolize the use of force within a geographic area (Boix, 2015). However, taxation may be backed up by threats of ostracism or supernatural punishments from deities, not just brute coercion.

We begin with a brief sketch of the transition we want to explain. During the 'Ubaid period, from about 8000 BP to 6000 BP, a few towns having 1000 - 2000 people emerged in southern Mesopotamia, alongside many small villages. Social organization involved simple chiefdoms, with larger settlements having temples and elite residences. Food was obtained through hunting, gathering, fishing, and farming. Favorable climate, geography, and ecosystems supported a relatively high population density.

In the Uruk period, from about 6000 to 5000 BP, urbanization occurred. This culminated in a population estimated at 20,000 - 50,000 for the city of Uruk (modern Warka) and populations in the tens of thousands for nearby cities. Many authorities believe the urbanization process was triggered by adverse climatic changes, especially diminished rainfall. This encouraged migration toward southern Mesopotamia, where wetlands and irrigation made food production less vulnerable to increasing aridity.

Urbanization was associated with the emergence of manufacturing organized by elites, especially textiles, but also pottery, metalwork, and stonework. These activities

had previously been carried out in smaller settlements, but became more specialized and larger-scale in the new centers like Uruk. Manufacturing probably had scale economies external to individual workshops but internal to the city. There is a broad archaeological consensus that Uruk satisfied standard criteria for the existence of a state by 5200 BP.

Our economic model for the rise of Mesopotamian city-states has the following structure. First, consider an agricultural economy prior to urbanization. Food can be obtained in two areas: an open-access commons and a closed site controlled by a local elite. The commons includes many small sites with varying land areas. There is a fixed population of commoners who can move anywhere in the commons. Alternatively, they may choose to work on elite-controlled agricultural land. Due to open access, all agents in the commons have the same food income, which is what individual elite agents must pay in order to attract commoners to work on their estates. We call this the wage. It is convenient to think of elite-commoner relationships in terms of a labor market, but our conclusions would be unaffected if commoners instead rented land from elite owners.

Due to the fixed commoner population, the region-wide supply curve for labor is vertical. The demand for labor comes from two sources: a standard demand curve from profit-maximizing individual landlords at the closed site, and a 'demand curve' for labor in the commons. The latter is derived by computing the number of commoners who will work in the commons at any given level of food income. In each case, the demand curve is downward sloping due to diminishing returns to labor for fixed land. Summing the two demand curves and equating demand with supply yields an equilibrium wage.

Now suppose some or all sites in the commons are vulnerable to aridity, so when rainfall declines, output falls at any given level of labor input. The demand for labor on

elite estates is unaffected by aridity, or less affected, due to local irrigation opportunities involving river water. When rainfall diminishes, the 'demand' for labor in the commons drops. This lowers the region-wide wage and causes a substitution effect where labor is reallocated toward elite estates. To put it a bit more dramatically: climate refugees flee the commons and seek sanctuary at production centers under elite control.

In addition to food production, the regional economy has a latent manufacturing sector involving textiles and similar goods. When manufacturing becomes active, it has aggregate increasing returns, as long as individual workshops are in close proximity to each other. Within the formal model, we attribute increasing returns to static Smithian specialization, although learning by doing was probably more important in the long run.

Manufactured goods are sold on a competitive regional market to all agents (elite and commoner) at all sites (both the closed site and the commons). Manufacturing starts when the wage becomes low enough relative to consumer demand and the productivity of manufacturing. Climate deterioration reduces the wage, and if this effect is large enough, it can give rise to a manufacturing sector at the elite-controlled site.

As a benchmark, we consider a free-entry equilibrium where any elite agent can establish an urban workshop when it is profitable to do so. The demand for labor now has three sources: the commons, elite agricultural estates, and manufacturing. The wage is determined by labor market clearing, the price of manufactured goods is determined by product market clearing, and the scale of urban manufacturing is determined by a zero-profit condition. We derive a threshold value for our climate parameter such that when commons productivity drops below this level, the manufacturing sector becomes active and urbanization occurs.

We next consider a situation where the elite at the closed site is organized enough to collect taxes from the individual workshops based on the number of commoners they employ. Although individual elite entrepreneurs are price takers, the elite as a whole has monopoly and monopsony power. Specifically, the elite can use the tax rate to limit the size of the urban sector, driving up the price of output and driving down the wage. The resulting profit is captured through the tax system and rebated to individual elite agents. In short, the elite taxes its own members in order to enforce a cartel agreement. The elite could instead tax the wages of urban commoners, which would yield identical results. In our model, tax revenue is used for private consumption, but in reality it was also used for public goods such as monumental architecture.

In this framework, the elite faces a tradeoff between land rent and manufacturing profit. For moderate climate deterioration, yielding a moderate decline in the commoner wage, the elite prefers to enjoy higher land rent and suppresses manufacturing. But with more severe climate deterioration, the elite sets a tax rate low enough for manufacturing to become viable. This leads to a city-state with both urbanization and taxation.

Section 2 discusses some conceptual issues and section 3 reviews the economic literature on early state formation. We summarize evidence from archaeology in section 4. The formal model is in sections 5, 6, and 7, which address stratification, urbanization, and taxation respectively. Section 8 provides a verbal discussion of the implications of the model for inequality, while section 9 discusses an extension of the model to include Malthusian population dynamics. Section 10 closes with some comments about pristine states in other parts of the world and alternative explanations for state formation. Proofs of all formal propositions are available from the authors.

2.   Conceptual Issues

Our concern in this paper is only with 'pristine' or 'primary' states. We ignore cases in which states emerged in response to influences from other pre-existing states or through cycles of collapse and re-integration.   Pristine states emerged independently, or nearly so, in several areas of the world. The standard list includes Mesopotamia, Egypt, China, Mesoamerica, and South America. Other more debatable cases include the Indus River valley and Hawaii.

In section 1, we defined a state as an organized elite with the power to tax. Most economists also take it for granted that states supply public goods such as law and order. This is certainly plausible, but we do not require it here. Indeed, one point of our formal model is to show that a pristine state can emerge simply because it enhances private elite consumption. Accordingly we treat taxation but not public goods supply as a definitional feature of the state. Of course, in practice most early states did make large investments in temples, monuments, and other public goods of interest to the elite.

We draw an important distinction between land rent and taxation. Simply put, land rents result from a technology of exclusion, while taxes result from a technology of confiscation. These are different things. Elsewhere (Dow and Reed, 2013), we show that a local elite can use an exclusion technology to prevent outsiders from accessing land at a given site. Once such property rights exist, markets for labor or land enable elite agents to collect land rents from commoners who are endowed only with labor. This can yield the class stratification often found in pre-state societies.

By contrast, most economists concerned with state origins focus on a technology of confiscation, where bandits, predators, gangs, or the state can appropriate a fraction of

the output generated by producers (see section 3). The question is whether unorganized predators will be replaced by an organized state. While this is an interesting question, it is distinct from the question of whether an elite can collect land rent. For example, in an agricultural setting it might be easy for a local elite to punish trespassers (technology of exclusion), but difficult to seize the output produced by commoners because food is easy to hide (technology of confiscation). Conversely, it might be easy for roving bandits to seize stored food (confiscation), but hard for them to defend ownership rights over fixed parcels of land (exclusion).

We define confiscation technologies broadly to include not just appropriation of food output, but also confiscation of labor time, urban outputs, raw materials, and so on. In particular, we think of corvée labor as a form of taxation, as well as slavery in cases where slaves are owned by the state. Of course, there are important differences between the confiscation of material goods and the confiscation of labor. But both differ from the technology of exclusion, which involves the closure of land areas previously open to all.

These distinctions are significant here because our formal model begins with an agricultural economy where the elite controls land and therefore collects land rent, but does not engage in taxation (perhaps because it is easy to hide food or monitoring is too costly). We assume urban manufacturing is readily taxed once it exists (perhaps because workshops are highly visible and cities are physically compact). We will show that the elite faces a tradeoff between preserving land rent from agriculture versus collecting tax revenue from urban manufacturing. It is only when the balance tilts toward the latter that the elite will collectively prefer city-state formation.

Many writers distinguish chiefdoms from states (see, for example, Johnson and Earle, 2000). In some societies conventionally labeled as chiefdoms, the chiefs (or more generally, elites) may receive both land rent and tax revenue, because they can use both technologies of exclusion and confiscation. Thus one might say that such chiefdoms are small-scale states. If one wants to reserve the term 'state' for societies like those in early Egypt or Mesopotamia, further definitional restrictions will be needed. Such matters are not crucial here. Our goal is simply to explain the development of urban agglomerations controlled by elites who collect taxes.

3.   Literature Review

There are more theories of pristine state formation than there are pristine states. We cannot survey this enormous literature in a comprehensive way. Instead we focus on several contributions from economists, along with one economic hypothesis advanced by an archaeologist. Related comments on state formation will be provided in section 10.

A key strand of the economic literature portrays the state as defending producers against raiders or attackers. Grossman (2002) assumes that individual agents can choose whether to produce output or steal from others. Producers devote resources to guarding output. If the technology of predation is highly effective, banditry is a serious threat. In this case, everyone (including potential bandits) can be made better off by creating a state that taxes producers and deters banditry. Though the state maximizes elite consumption, excessive taxation is restrained by the possibility that producers could choose to become (untaxed) bandits. The main empirical prediction from the model is that states typically arise when it is easy for bandits to appropriate the output of producers.

Baker et al. (2010) use a similar theoretical framework. They assume there is a government only if food producers benefit from it. Unlike Grossman (2002), technology and population are endogenous, where the former evolves through learning by doing and the latter through Malthusian dynamics. A premise running through the paper is that as food technology advances, storage becomes more important, output becomes easier to steal, and the demand for a state intensifies. In their empirical section, Baker et al. use the Standard Cross Cultural Sample. The dependent variable is either a five-point scale from no political authority to a multi-layered state, or a binary variable for no political authority versus chiefdoms and states treated as a group. After taking the endogeneity issues into account, population has no significant effect; some technological variables such as specialization and writing have positive and significant effects (though these may be results of the state rather than causes); the share of agriculture in the food supply has no effect; and the availability of food storage technology has a positive effect but is only weakly significant.

By contrast with Grossman (2002), who assumes that a king has a monopoly on the sale of protection, Konrad and Skaperdas (2012) allow free entry of rival lords who all sell protection and fight for control over peasants. Competition among the lords will dissipate the potential gains from the sale of protection, leaving people no better off (and possibly worse off) than under anarchy. They are also pessimistic about the viability of self-government, in the sense of small groups that provide their own security as a local public good, in a world where such groups must compete against predatory states.

Two specific cases of pristine state formation have received serious attention from economists: Egypt and Mesopotamia. Allen (1997) argues that because the Nile valley

was circumscribed by desert, commoners were unable to flee from surplus appropriation by the elite. According to Allen, the trigger for state formation in Egypt was the arrival of agricultural technology from southwest Asia, which created storable grain stocks. At the same time, agriculture made labor more seasonal, leaving commoners available for elite public works projects such as pyramid construction.

According to Mayshar et al. (2011), early states were most likely to emerge in regions where food stores were readily appropriable (e.g., cereals but not tubers; see also Scott, 2017), and where technology was transparent in the sense that elites could readily measure or estimate the amount of food produced by commoners. Mayshar et al. (2017) argue that the rise of Mesopotamian city-states was largely driven by technical advances in irrigation and water control. The fact that local elites had specialized human capital regarding the operation of complex irrigation systems, and had good information about agricultural productivity, led to city-states run by coalitions of land-owning families.

One prominent archaeological expert on southern Mesopotamia has also proposed an economic hypothesis about the origins of city-states. Algaze (2001, 2008, 2013, 2018) argues that Smithian growth involving greater labor specialization increased productivity, and may have temporarily outrun Malthusian population growth, leading to growing per capita income. However, population responded positively to increased productivity over time. The rising population encouraged greater specialization, yielding a virtuous circle. According to Algaze, this dynamic supported several related trends: increasing imports of raw materials to southern Mesopotamia for processing; more exports of finished textiles to pay for imports; a general expansion in the scale of the economy together with import substitution; and a flow of captive labor to the south, both skilled and unskilled. We will

return to Algaze's hypothesis below, but first we discuss how our framework is related to the ideas of economists.

We depart from Grossman (2002), Baker et al. (2010), and Konrad and Skaperdas (2012) by abandoning the notion that elites protect commoners from predation. There is little archaeological evidence that this mechanism played an important role in the rise of the Mesopotamian city-states. Our story is closer to that of Allen (1997) in the sense that geographical circumscription does play a role: commoners decide whether to live under elite control or in less productive areas without an elite. We rely on increasing aridity to push commoners from the periphery to the center. In this sense, city-states arise because circumscription becomes more binding.

We differ from Allen (1997) and Mayshar et al. (2011, 2017) in downplaying the technological characteristics of agriculture. We are specifically interested in city-states, and thus we have to explain why urbanization occurred. Purely agricultural societies do not benefit from having large numbers of people congregate in cities. This imposes costs in the form of travel time to fields and herds. We therefore need to identify activities for which cities are a benefit rather than a cost, and the most likely suspect is manufacturing.

We have other reservations about the arguments of Mayshar et al. First, cereal crops were available in Mesopotamia long before city-states arose, so it is unclear why they did not arise much sooner. Second, if a state arose because cereal output was easily appropriated by the elite, why couldn't the elite have done this in a rural context without cities? Our theory deals with the timing issue by invoking climate change as the trigger. We deal with the appropriation question by arguing that manufacturing inputs or outputs were more readily taxed than agricultural inputs or outputs. However, we do not regard

Mayshar et al.'s story and our own as mutually exclusive, and we see the ability of elites to monitor agricultural output as an important factor in determining when taxation would occur in an agrarian economy.

Algaze's emphasis on manufacturing provides a reason for urbanization, which tends to be lacking in most other stories. We also agree with Algaze that the division of labor probably led to increasing returns in the urban sector. However, Algaze's account leaves some puzzles. We briefly mention two of them here. The first involves timing: in Algaze's approach, there is no trigger that explains the development of city-states during 5500 - 5000 BP rather than a millennium earlier or later. We handle the timing question by treating climate change as the prime mover, but Algaze does not mention this variable. A second problem is that Algaze attempts to explain the expansion of cities and trade, but he does not say why this process led to the formation of a state. By our definition, a state arises when taxation begins, and we provide an economic analysis of the conditions under which an elite will find it profitable to tax manufacturing.

4.   Archaeological Background

Our central question is straightforward: why did Uruk (modern Warka), located in the wetlands of southern Mesopotamia, become a city-state during 5500 – 5000 BP? The markers typically used to identify Uruk as a city-state include multi-level administration, a four-tiered settlement pattern (cities, towns, villages, and hamlets), significant colonial expansion, a large population, and monumental architecture in the form of temples and perhaps palaces. All of these markers are widely asserted to have been in place by 5200 BP. However, precise dates of this sort are problematic. Radiocarbon methods cannot be employed because carbon samples such as seeds and bones were not gathered in southern

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Mesopotamia. Instead, dating has been done by means of pottery styles (Ur, 2013), and this makes absolute dates somewhat tentative (Brisch, 2013).

Organizational complexity is inferred from the lists of specialized administrative positions inscribed on clay tablets (Brisch, 2013). However, Ur (2012, 538) questions the dating of the tablets to the interval from 5500 to 5000 BP. Use of a four-tiered settlement pattern as an indicator for a state is widespread. For example, it is the criterion for a state used in the Standard Cross Cultural Sample (Murdock and White, 1969, 2006). Algaze (2013, 82-85) gives particular weight to the colonial expansion in the late Uruk period. He argues that such "massive, quickly erected and well planned enclaves . . . could only have been built by state institutions capable of levying, commanding, and deploying substantial resources and labor."

The size of the population at Uruk has recently become controversial. By 5200 BP, Uruk reached a geographical size of around 250 hectares (10 times the size of other urban settlements), with an estimated total population of 20,000 – 50,000 (Nissen, 1988; Nissen and Heine, 2009; Yoffee, 2005; Algaze, 2008, 2013, 2018). The geographic size estimate appears well accepted, but the population estimate depends on density, which is more difficult to measure. Steinkeller (2018, 47), in comments on Algaze (2018), argues that large unoccupied spaces existed within Uruk, reducing the total population estimate considerably. In response, Algaze (2018, 49) uses textual evidence as well as population estimates for later Mesopotamian cities (the same kinds of evidence used by Steinkeller) to argue that there is little reason to doubt the higher population estimates.

As discussed in sections 1 and 2, we view the state through the lens of public finance. We regard the empirical markers discussed above as likely indicators of an

organized elite that could use tax revenues to maintain order in a settlement with a high population density, build large monuments, support a complex bureaucracy, and engage in large-scale colonial expansion.

Settlement chronology. Our chronology of southern Mesopotamia starts with the first evidence of sedentary occupation at the beginning of the 'Ubaid period (Stein, 1994; Van de Mieroop, 1997; Kennett and Kennett, 2006). Throughout the 'Ubaid period, from 8000 BP until around 6000 BP, human populations increased and aggregated into villages and towns. These communities were relatively small, averaging about one hectare in size with estimated populations seldom beyond 1000 people. The distribution of wealth items at 'Ubaid sites suggests economic inequality (Stein, 1994). There was mild inequality in housing but without any dramatic differences in grave goods, and depictions of rulers are rare (Stein, 1994; Pollock, 1999, 86-92, 176-77, 199-204). Food sources included wheat, barley, lentil, flax, sheep, goats, cattle, pigs, fish, and hunting (Pollock, 1999, 78-84).

A hierarchical distribution of settlements becomes visible in the middle 'Ubaid (Wright, 1981; Kennett and Kennett, 2006). Stein (1994) characterizes these societies as simple chiefdoms with a two-tier settlement structure, where larger sites had temples. He asserts that high-quality agricultural land with convenient irrigation was a scarce resource to which access could be denied, and that this provided the basis for chiefly power.

During the 'Ubaid, southern Mesopotamia was linked to the surrounding region by social networks, and similarities in artifacts indicate widespread exchange of goods and knowledge. For example, 'Ubaid ceramics from the south appear in settlements in northern Mesopotamia and the east coast of the Arabian Peninsula (Kennett and Kennett,

2006, 81). Our reading suggests that there were regional markets for utilitarian goods, but without political unification beyond a town and its associated villages or hamlets.

Kennett and Kennett (2006) also report that there is little evidence of warfare in southern Mesopotamia until near the end of the 'Ubaid. Settlements were unfortified and 'Ubaid seals do not depict warfare. This is consistent with the views expressed by Stein (1994) and Pollock (1999).

Settlement data for the Uruk period (about 6000 to 5000 BP) are severely limited. Nissen and Heine (2009, 21) refer to this period as "among the worst documented times in the history of the ancient Near East." Ur (2014, 14) remarks that "not a single non-monumental Uruk structure has been excavated on the southern Mesopotamian plain." Algaze (2013, 71-73) summarizes the data problems with excavations at the Uruk site as follows. First, excavations have focused only on elite quarters of the city, not commoner residences or industrial areas. Except for a few deep soundings, most of the materials and buildings uncovered date to the very end of the Uruk period, after the city-state had already formed. There has been no systematic exploration of second tier regional centers, villages, or hamlets. Texts and tablets are available starting around 5200 BP, but "shed no light whatsoever on the beginnings of the urban revolution."

Despite these data issues, there is broad agreement that there were high levels of in-migration to southern Mesopotamia during the Uruk period (see Kennett and Kennett, 2006; Algaze, 2008, 2013, 2018; Nissen and Heine, 2009). Algaze supplies evidence of declining populations in northern Mesopotamia and other nearby regions to support the assertion of in-migration (see also Nissen and Heine, 2009, 40). However, there is little agreement about the causes of this migration. Kennett and Kennett propose that it was

caused by a combination of resource-rich wetlands in the south and increasing aridity in nearby regions dependent on rain-fed agriculture. Algaze stresses the profits from urban manufacturing in a context of low transportation costs and expanding trade. Nissen and Heine (2009, 39) offer a land constraint argument. They attribute an observed dramatic increase in settlements after 5500 BP to cooler and drier conditions. This led to less river flow than in previous millennia, and fewer disastrous floods. They argue that the scarcity of settlements before 5500 BP can be explained by the prevalence of marshes and floods, while much larger land areas became inhabitable after the lessening of river flows.

Another unresolved issue is why the increased population became more urbanized in the Uruk period. Estimates of the share of regional population living in relatively large towns (10 or more hectares) are around 50-80% for the early Uruk period (Pollock, 2001; Algaze, 2013). Algaze (2013, 74) remarks that by the end of the Uruk period, the city of Uruk plus its hinterland and offshoots had a total population conservatively estimated at 80-90,000 people.

Algaze (2013, 75) offers several possible explanations: (a) increasing intra- and inter-regional trade was funneled through Uruk cities; (b) defensive flight from rural to urban areas was motivated by increasing conflict between urban centers; and (c) there was a widespread desire to live in centers where "the gods themselves were thought to reside." Kennett and Kennettt (2006, 89-90) mention the defensive flight story, but also stress the attractiveness, in a period of increasing aridity, of cities located near irrigation systems. In addition, they point to the possibility that social and economic opportunities may have been greater in urban environments. Ur (2012, 2013), like Algaze, suggests religious motivations for residing in cities, and he compiles a list of other archaeological

explanations for Mesopotamian urban agglomeration (2013, 139). Ur (2014) proposes an explanation based on an emergent household-based model of urban society.

Because burials disappear during the Uruk period, there is no evidence from this source about the degree of stratification. However, stratification with respect to housing becomes more pronounced (Pollock, 1999, 204-5), and elites apparently had better access to meat than commoners (Pollock, 1999, 112). Slave labor was clearly used (see Algaze, 2008, 128-31). This may have involved prisoners of war or farmers who became unfree when they were unable to pay off their debts. The shares of free and slave labor in the urban and rural sectors are unknown.

The Jemdet Nasr period starts around 5000 BP and is largely a continuation of the later Uruk. Wool supplanted linen in textile production, with linen comprising only 10% of total Sumerian output after 5000 BP (Wright, 2013, 397). Writing evolved in ways that allowed greater speed and complexity. There were also improvements in pottery technology that facilitated mass production (Nissen and Heine, 2009, 42-42). The latter authors cite evidence of a city wall around Uruk-Warka and the beginning of large-scale canal and irrigation systems (46-48). Pournelle (2007, 2013) raises questions about the existence of a city wall at this time, and contends that the observed straight alignment of watercourses indicates the existence of ancient transportation routes rather than canals. Wilkinson (2013, 36) remarks, "Because the channels in the lower plain have a tendency towards straightness rather than being meandering, it is difficult to distinguish between natural and artificial channels." Burials are archaeologically visible (in contrast to the Uruk period) and grave goods exhibit extensive inequality (Pollock, 1999, 206).

The Early Dynastic period runs from about 4800 BP to 4300 BP. There were written lists of kings, palaces gradually became architecturally distinct from temples and other large elite residences (Pollock, 1999, 48-51), and inequality of grave goods became even more extreme (Pollock, 1999, 213-17). The economy was dominated by large self-sufficient households centered around temples, palaces, and wealthy estates, where elite corporate groups owned both agricultural land and urban workshops (Pollock, 1999, 117-23, 147-8). The elites managed production directly, and workers received rations of food and clothing. Some workforces were kin-based but other large workforces involved non-kin. Women and children were the principal workers in large-scale cloth manufacturing. Slave labor was common and included prisoners of war.

During the Early Dynastic, the number of watercourses decreased with continued aridity. Agricultural areas evolved into a system of 'irrigation oases', each fed by a main canal that in turn was fed by river water. Populations from smaller settlements that were now without water tended to move into larger settlements, and by 4500 BP most people lived in cities (Nissen and Heine, 2009, 46-47).

Warfare between cities is well documented after 4600 BP, and was motivated by conflict over food-producing areas. The first political unification of multiple city-states occurred through a series of conquests by Sargon around 4300 BP. This brought the Early Dynastic period to an end. Uruk itself "remained occupied or was resettled at an urban scale for almost five thousand years" (Ur, 2013, 151).

Geography. At around 15,000 BP, the global sea level was 100 m below today's level. Marine transgression into the Persian Gulf, associated with deglaciation, was just beginning, creating productive wetland habitats (Kennett and Kennett, 2006). By 6000

BP, inundation by the Persian Gulf reached the hinterlands of the cities of Uruk and Ur (Ur, 2013, 132). Pournelle (2007, 2013) provides strong support for the abundance of wetland resources. Scott (2017) offers the following list: fish, dates, birds, and turtles; fodder for domesticated goats, sheep, and pigs; reeds for housing and watercraft; edible plants such as club rush, cattails, and bulrush; and small mammals as well as migrating gazelles. Pournelle (2013, 28) views early cities as "islands imbedded in a marshy plain, situated on the borders and in the heart of vast deltaic marshlands"

Another aspect of Mesopotamian geography was the timing of seasonal flooding in the Tigris and Euphrates rivers. Flooding peaked during April and May due to winter rainfall and the spring snowmelt in the mountains of northeastern Turkey, Iran, and Iraq. Cereal crops were at risk during the spring harvest. River levels were at their lowest in the fall when seedlings required plentiful water. These facts, together with insufficient rainfall, explain why cereal agriculture required investments in irrigation canals. But irrigation also had problems. Hydromorphic soils, common in flood basins and lower levee slopes of southern Mesopotamia, can become saline when the water table is high due to the use of irrigation canals and reservoirs, leading to crop losses (see Wilkerson, 2013, 38-42, for a discussion of these issues).

The rivers of southern Mesopotamia created an immense alluvial plain. As a result there was an absence of high quality timber, stone, and metals. Neighboring areas such as northern Mesopotamia were rich in these resources. At the same time, the rivers and the flatness of the plain allowed inexpensive transportation of both goods and people. Algaze (2013) believes Uruk had two key locational advantages: its proximity to wetland resources, especially food, and its access to easy transportation on the Euphrates River.

Climate. The climate phenomenon most relevant to the Uruk case is increasing aridity starting around 6000 BP. Our main source on this is Kennett and Kennett (2006). They report evidence from the Red Sea region indicating a marked trend toward greater aridity between 7000 and 5000 BP, which ultimately extended to Arabia and sub-Saharan Africa. After about 5500 BP, weakening monsoons led to more aridity over the Arabian Peninsula, with increasing dust transport in the Arabian Sea after 5300 BP. Aeolian deposits in deltaic sediments were most pronounced in southern Mesopotamia between 5000 and 4000 BP, and indicate severe aridity during this interval. Brooks (2006, 2013) links this overall climate trend to urbanization in southern Mesopotamia.

Of particular relevance here is Riehl et al. (2014), in which the authors use carbon 13 measurements from ancient barley seeds sampled from northern Mesopotamia and the Levant to infer drought stress. Their study covers the period from 7500 BP to 2900 BP. The results show that favorable conditions prevailed from 7500 BP to 6000 BP. Then a downward trend began that reached a level of severe drought stress around 5500 BP and maximum drought stress at 5200 BP.

Production technology. One of the fundamental questions regarding Uruk is how urban residents were fed. Food production in southern Mesopotamia came mainly from two sources: irrigated land used for cereal production, and wetland foraging. Received wisdom before the work of Pournelle (2007, 2013; see also Pournelle and Algaze, 2014) emphasized cereal production, and viewed increased investments in irrigation along with related technical advances as the key necessary conditions for the rise of city-states. But Pournelle argued for the primacy of food from the wetlands, and implied that irrigated cereal production was not necessary and therefore not important. Other archaeologists

argued in response that both sources of food were important (see for example Wilkinson, 2013, 35-40, and Gibson, 2014, 191-2).

Crawford (2004, chs. 8-9; 2013) provides a useful summary of manufacturing and trade. Urban manufacturing included textile production, pottery making, metalworking, and stoneworking. Metals and stone were not available locally and had to be imported, along with high quality timber and precious stones. Exports consisted of manufactured goods, primarily textiles. Cereals did not play a major role in trade. Most of the traded goods were transported by water. Trade flows increased significantly in the Uruk period. Algaze (2008, 2013, 2018) puts particular emphasis on the transition from linen to wool textiles, and regards textiles as the most important of the urban manufacturing industries in terms of economic growth.

Taxation. There is no direct archaeological evidence for any form of taxation before written documents. However, Steinkeller (2015a, 17) believes corvée labor was used in the late Uruk period for harvest work, major building construction, maintenance of irrigation systems, and military service. Such work was of limited duration and owed to the state by all free citizens. Elites could substitute a payment in place of labor (see Steinkeller, 2015b, 138-153, for a detailed discussion of corvée). In our terminology, mandatory labor contributions involve confiscatory technology and constitute a tax, as do mandatory payments by individual elite agents. Scott (2017) asserts that on the earliest tablets, the most frequent entry was for barley in the form of rations and taxes. Much later, in 4255 BP, a census in the city of Umma was used as the basis for assigning a head tax and corvée labor (Scott, 2017, 141-2).

We also infer the presence of taxation in city-states from the existence of massive public architecture and multi-level administration. However, apart from corvée labor it is difficult to determine which sectors were taxed (agriculture, manufacturing, local trade, or external trade), or how taxes were levied (on income, wealth, sales, profits, imports, or exports). Liverani (2006, ch. 3) gives examples of taxes on cereals, manufacturing, trade, and raw materials, but the time period of these taxes is unclear, especially with respect to the question of whether they apply to the period of city-state formation before 5200 BP.

Facts required by our story. As we have seen in this review, theories about the emergence of Uruk are not tightly constrained by data. Therefore, like all other writers on the subject, we are free to speculate. However, we adopt several premises that seem uncontroversial or have support from multiple well-informed archaeologists. These run as follows.

(a) There was pre-existing stratification in the 'Ubaid period involving mild inequality.

(b) There was increasing aridity in Mesopotamia and neighboring areas after 6000 BP.

(c) With increasing aridity, numerous migrants arrived in southern Mesopotamia from northern Mesopotamia and elsewhere.

(d) Irrigation-based agriculture was important in the south, while rainfall-based food production (farming and/or herding) was important in the north and other nearby areas.

(e) There was significant industrial production at Uruk (in addition to food production).

(f) Taxation existed at Uruk (where taxation is broadly defined to include all situations where an elite collectively takes resources from individuals).

These premises provide the foundations for our theory. Sections 5-7 present our formal model of stratification, urbanization, and taxation. Section 8 discusses the effects

of city-state formation on elite and commoner welfare, and section 9 shows how it would be possible to incorporate Malthusian population dynamics. Section 10 reviews markers for the existence of a state, briefly describes a few other examples of pristine states, and discusses the prospects for a general theory of state formation.

5.   Stratification

We begin with the 'Ubaid period prior to urbanization. The only consumption good is food, which is produced using inputs of labor and land. Food production takes place at two locations: an open-access commons and a special closed site called U. The commons includes many small sites with varying land areas. Production in the commons may involve rainfall farming, pastoralism, or foraging. Site U represents an 'Ubaid town and the future city of Uruk. It is simplest to have one site of this kind, but multiple sites would not affect our conclusions. Production at site U involves river-based irrigation, so production in the commons is vulnerable to drought while production at site U is not. A local elite controls access to land at site U, while the commons is beyond elite control.

Geographically, the commons may include areas of northern Mesopotamia, areas of southwestern Iran, or wetlands in the south not under elite control. These areas were not all equally exposed to drought, and the effects of aridity arrived at different times in different places. For example, wetland foraging was probably not initially vulnerable to reduced rainfall, but eventually the wetlands began to contract. We ignore these details and assume that aridity affected all sites in the commons simultaneously.

We refer to all food production generically as 'agriculture', although pastoralism and foraging may also have been important in the commons. For site U, we refer to elite-controlled land parcels with access to irrigation as 'estates' and to workers on these estates

as engaged in 'farming', although herding and related activities may also have occurred there. These terminological conventions do not affect the substance of our argument.

Each agent is endowed with one unit of time and maximizes food consumption. First consider the commons, which has a population C and a land area Z. Total output from the commons is

(1) $\qquad Y_c = \theta C^\alpha Z^{1-\alpha}$ $\qquad\qquad$ with $0 < \alpha < 1$

The resulting food per person is

(2) $\qquad w = \theta(Z/C)^{1-\alpha}$

The parameter θ captures the effect of rainfall on food output in the commons. As noted above, we picture the commons as consisting of many small sites with varying land areas. Migration equalizes the average product of labor across these sites. The equalization of marginal products of labor across sites follows automatically using (1). The total labor input C is therefore allocated efficiently within the commons.

Site U has a farming population F and one unit of land. Its food output is

(3) $\qquad Y_u = F^\alpha$ $\qquad\qquad$ with $0 < \alpha < 1$

Land at site U is irrigated using river water, so rainfall is irrelevant. We normalize the productivity of site U at unity and impose $0 \le \theta < 1$ so the commons is less productive.

To study inequality, we assume that if an organized group occupies a site, has the density $e > 0$ agents per unit of land, and devotes all of its time to excluding other agents, it enjoys collective property rights over the land at that site. Such a group will be called

an *elite*. When a non-elite agent threatens the property rights of an elite agent, the latter can call upon other nearby landlords for help in repelling the intruder. In principle, this could be done not only at site U but also at the smaller sites within the commons if these sites had enough elite agents per unit of land. The parameter e might vary as a function of geography (it may be easier to defend property rights over land on a flat alluvial plain than in wetlands or mountains), but here we treat this parameter as identical for all sites.

Non-elite agents will be called *commoners* regardless of whether they work at a site in the commons or on elite land at site U. Commoners are unorganized in the sense that landlords only need to repel or deter them one agent at a time to retain control over land. This framework resembles our previous model of early inequality (Dow and Reed, 2013), except that here we ignore farm labor supplied by the elite agents. We also ignore warfare, which involves conflict between two organized groups (Dow et al., 2017). The commoners at site U are free to exit to the commons if they wish (they are not slaves).

The regional population N is divided into three groups of size (C, F, e) such that

(4) $\qquad C + F + e = N$

N > e is assumed throughout, so there is a positive number of commoners C + F. Total population N is exogenous in sections 5-8 but will become endogenous in section 9.

In our model, landlords treat the food per person w from (2) as a parametric wage, because the standard of living in the commons determines what must be offered to attract and retain farm labor at site U. These wages are paid in the form of food. The rent to the landlord is the output of food net of such payments.

An elite agent at site U has land $1/e$ and hires n commoners to maximize $n^\alpha(1/e)^{1-\alpha}$ - wn. This results in the individual labor demand $n = (\alpha/w)^{1/(1-\alpha)}/e$. Multiplying by the number of elite agents gives the total demand for farm labor at site U:

(5) $\qquad F(w) = (\alpha/w)^{1/(1-\alpha)}$

Total land rent for the elite is

(6) $\qquad R(w) \quad = F(w)^\alpha - wF(w)$

$\qquad\qquad\qquad = (1-\alpha)(\alpha/w)^{\alpha/(1-\alpha)}$

and food per elite agent is $R(w)/e$.

It will often be convenient to aggregate agricultural output from the commons and site U. Let $Y_a = Y_c + Y_u$ be total food output and let $A = C + F$ be total agricultural labor. Using (1) and (3) and the fact that the marginal product of labor at site U is equal to the average product of labor in the commons, we obtain

(7) $\qquad C = AZ\theta^{1/(1-\alpha)}/\beta(\theta)$

$\qquad\qquad F = A\alpha^{1/(1-\alpha)}/\beta(\theta) \qquad\qquad$ where $\beta(\theta) \equiv \alpha^{1/(1-\alpha)} + Z\theta^{1/(1-\alpha)}$

Total food Y_a as a function of total agricultural labor A is

(8) $\qquad Y_a = Y(A, \theta) = \gamma(\theta)A^\alpha \qquad$ where $\gamma(\theta) \equiv [\alpha^{\alpha/(1-\alpha)} + Z\theta^{1/(1-\alpha)}]/\beta(\theta)^\alpha$

Because the marginal products of labor are not equated between the commons and site U, this aggregate output is below the theoretical maximum.

Equations (2) and (5) give a relationship between the wage and total demand for agricultural labor at all sites in the region (the commons and site U together):

(9) $A(w, \theta) = \beta(\theta)/w^{1/(1-\alpha)}$

In a purely agricultural economy, the equilibrium wage equates this total labor demand to the total supply of commoners N - e.

D1   The wage $w(\theta)$ is an *agricultural equilibrium* associated with the commons productivity θ when $A[w(\theta), \theta] = N - e$, or equivalently $w(\theta) = [\beta(\theta)/(N - e)]^{1-\alpha}$.

In an equilibrium of this kind, (7) gives $C = (N - e)Z\theta^{1/(1-\alpha)}/\beta$ and $F = (N - e)\alpha^{1/(1-\alpha)}/\beta$.

Two restrictions ensure open access in the commons and stratification at site U.

D2   An agricultural equilibrium satisfies the *stratification constraints* when

(a) $C/Z < e$ so population density in the commons is too low to support elites; and

(b) $R(w)/e \geq w$ so the elite agents at site U are at least as well off as commoners.

Proposition 1 (stratification). A necessary condition for an agricultural equilibrium to satisfy both stratification constraints is

(10) $\theta < \alpha^{\alpha}(1-\alpha)^{1-\alpha} \equiv \theta_{max}$

When (10) holds, both stratification constraints are satisfied if and only if

(11) $e\beta(\theta)/(1-\alpha)\alpha^{\alpha/(1-\alpha)} \leq N - e < e\beta(\theta)/\theta^{1/(1-\alpha)}$

where the set of N values from (11) is non-empty. The lower bound in (11) is an

increasing function of θ and the upper bound in (11) is a decreasing function of θ.

Condition (10) says that the productivity of the commons must be low enough

relative to the productivity of site U (normalized at unity). If the sites in the commons

are highly productive, two things happen. First, agents migrate into the commons, which

can propel the population density there beyond the threshold e, resulting in the formation

of elites. Second, a highly productive commons implies a high wage, which can make it

unprofitable to be a member of the elite at U. When (10) is violated, at least one of these

outcomes must occur. When (10) holds, there are commoner population levels N-e that

satisfy both stratification constraints. The set of (N-e, θ) points for which this is true is

shown in Figure 1.

When rainfall declines in the commons, θ falls but productivity at site U is left

unchanged. The wage from D1 decreases, yielding less food per capita in the commons.

Labor is reallocated away from the commons (C falls and F rises) because landlords hire

more commoners at the lower wage. As a result, total land rent R(w) rises. It is easy to

see from Figure 1 that for a fixed population N, if initially both stratification constraints

are satisfied, the same must be true after θ decreases.

6.   Urbanization

Here we build on the model of section 5 to show how urbanization could have

occurred in the Uruk period. Rather than having one consumption good, we will have

two: food (y) and manufactured goods (m). Prior to urbanization, manufactured goods

such as textiles and pottery were produced by local craft specialists or by farmers. We ignore these activities and treat the goods produced in cities as a distinct commodity.

We want to capture two aspects of the urbanization process. First, manufacturing activities were concentrated at Uruk rather than being dispersed throughout the commons. This suggests the presence of increasing returns in the manufacturing sector, likely due to Smithian division of labor. Second, scale economies probably operated at the level of the city as a whole rather than at the level of the individual workshop, and likely involved the usual suspects: a trained labor pool, industry-specific inputs, and technological spillovers. Uruk and other southern towns probably had additional advantages, including low export costs due to convenient river and coastal transportation, as well as the existence of elites who could enforce property rights over the inputs and outputs linked to manufacturing.

Now consider the demand for manufactured goods. Each agent has the identical quasi-linear utility function

$$(12) \qquad u(m, y) = b(m) + y \qquad \text{where } b(m) = 1 - e^{-qm} \qquad \text{with } q > 0$$

This functional form has $b(0) = 0$ with $b'(m) > 0$ and $b''(m) < 0$ for all $m \geq 0$. It also has finite marginal utility $b'(0) = q$ at zero consumption, so boundary equilibria without any manufacturing can occur. The price of the manufactured good is p, the price of food is unity, and income is x, so the budget constraint associated with (12) is $pm + y = x$. The non-negativity constraint $y \geq 0$ is ignored because this requirement is satisfied for all of the equilibria studied in this section.

There is a regional market for the m good so the price p applies both at site U and in the commons. All agents are price-takers. Let M be the aggregate market demand for

the manufacturing sector. Because agents have identical preferences and the distribution

of income can be ignored due to quasi-linearity, M satisfies

(13) $\qquad$ $M = 0 \qquad$ for $p \geq b'(0) = q \qquad$ and

$\qquad$ $b'(M/N) = p \quad$ for $p \leq b'(0) = q$

$\qquad$ Next consider the supply side. Labor is the only input for manufacturing. Let L

be the workforce in this sector. The total output of the manufactured good at site U is

(14) $\qquad$ $M(L) = e^{rL} - 1 \qquad\qquad$ with $r > 0$

This functional form has $M(0) = 0$ with $M'(L) > 0$ and $M''(L) > 0$ for all $L \geq 0$. The sign

of the second derivative gives aggregate increasing returns. The marginal product $M'(0)$

$= r$ at zero input is positive and finite. As with our demand-side assumptions, this allows

the possibility of boundary equilibria with no manufacturing. Due to increasing returns,

we replace the standard supply curve with a zero-profit condition

(15) $\qquad$ $pM(L) = wL$

Zero profit is maintained through free entry and exit by manufacturing workshops.

$\qquad$ We now extend the definition of equilibrium in section 5 to allow manufacturing.

<u>D3</u> The array (p^0, w^0, A^0, L^0) is a *zero-profit equilibrium* associated with the commons

productivity θ when the following conditions hold.

(a) $\quad$ consumer optimization: $\qquad$ $p^0 = b'[M(L^0)/N] \qquad$ if $L^0 > 0 \qquad$ or

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad p^0 \geq b'(0) \qquad\qquad$ if $L^0 = 0$

(b) $\quad$ manufacturing equilibrium: $\quad w^0 = p^0 M(L^0)/L^0 \qquad$ if $L^0 > 0 \qquad$ or

$$w^0 \geq p^0 M'(0) \qquad \text{if } L^0 = 0$$

(c)   agricultural equilibrium: $A^0 = A(w^0, \theta)$

(d)   labor market equilibrium: $A^0 + L^0 + e = N.$

Condition (a) requires that consumer demand for manufactured goods at the price p^0 add up to the amount $M(L^0)$ produced by firms. If no manufactured goods are produced, we allow any price p^0 that is sufficiently high to choke off demand. Condition (b) requires that if the manufacturing sector is active, firms receive zero profit. When $L^0 = 0$, we set the average product of labor equal to the marginal product, and allow any wage w^0 at or above the value of this average product. Thus profit is non-positive and there is no entry into manufacturing. Condition (c) requires that farm labor in the commons and on elite estates add up to total agricultural labor at the wage w^0. This always implies that $A^0 > 0$. Finally, condition (d) requires that total labor by commoners add up to the supply N - e. The food market clears automatically due to Walras's Law.

An equilibrium with positive manufactured goods ($L^0 > 0$) requires

(16) $b'[M(L^0)/N]M(L^0)/L^0 = w^0$ and

$[\beta(\theta)/(N - e - L^0)]^{1-\alpha} = w^0$

where the first equation comes from (a) and (b) in D3 and the second equation comes from (c) and (d). Together these yield

(17) $\beta(\theta)^{1-\alpha} = (N - e - L^0)^{1-\alpha} b'[M(L^0)/N] M(L^0)/L^0$

where $\beta(\theta) \equiv \alpha^{1/(1-\alpha)} + Z\theta^{1/(1-\alpha)}$

To avoid complications involving multiple equilibria for a given value of θ, we want to guarantee that the right side of (17) is decreasing in L. The term involving the supply of agricultural labor $A = N - e - L$ is clearly decreasing in L. Thus it is sufficient for the average value product $b'[M(L)/N] M(L)/L$ to be non-increasing in L. Condition A1 ensures that this is true.

A1 $q/N \geq 1/2$

<u>Lemma 1</u>. Define $\phi(L) \equiv b'[M(L)/N] M(L)/L$. We have $\phi(0) = qr$ and $\phi(L) \to 0$ as $L \to \infty$. If A1 holds, $\phi(L)$ is decreasing for all $L > 0$. If A1 does not hold, there is some $L_c > 0$ such that $\phi(L)$ is increasing for $L < L_c$ and decreasing for $L > L_c$.

A1 does not involve r so this parameter is irrelevant. We only need enough concavity in the utility function relative to the population N. A zero-profit equilibrium as in D3 with $(A^0, L^0) > 0$ is stable in the sense that if the prices p and w adjust rapidly to a given labor allocation $(A, L) > 0$, profit will be positive when $L < L^0$ so new workshops enter, while profit will be negative when $L > L^0$ so some existing workshops exit.

Assuming A1 holds, the nature of zero-profit equilibrium is depicted in Figure 2. The horizontal axis shows manufacturing labor L from left to right and agricultural labor A from right to left. These must sum to N-e to clear the labor market. The vertical axis depicts the wage. At a high enough value θ' for the commons productivity, the demand curve for agricultural labor from (9) does not intersect $\phi(L)$ and we have an agricultural equilibrium where $L^0 = 0$, as in section 5. In this situation, the wage w' that clears the labor market is too high to make manufacturing attractive. At the productivity level θ_0

the wage is qr and again $L^0 = 0$. But if productivity falls to $\theta'' < \theta_0$, the system moves to

an interior equilibrium with $L^0 > 0$. This marks the start of urbanization. Under present

assumptions, manufacturing labor is a continuous function of θ so the transition does not

involve any abrupt jumps.

To formalize these ideas, we derive the boundary productivity θ_0 by setting $L^0 = 0$

in (17). This yields

$$(18) \qquad \beta(\theta_0)^{1-\alpha} = qr(N - e)^{1-\alpha} \qquad\qquad\qquad or$$

$$\theta_0 \equiv \{[(qr)^{1/(1-\alpha)}(N - e) - \alpha^{1/(1-\alpha)}]/Z\}^{1-\alpha}$$

Note that $\theta_0 > 0$ holds if and only if $N - e > (\alpha/qr)^{1/(1-\alpha)}$ so there is a large enough supply

of commoner labor. If there are too few commoners, then demand for agricultural labor

by elite estates always keeps the wage above the level needed to trigger manufacturing,

even if the commons has zero productivity.

Proposition 2 (zero-profit equilibrium). Assume A1 holds. If $\theta_0 \leq 0$, then only part (a)

below applies. If $\theta_0 > 0$, then both parts (a) and (b) apply.

(a)   A zero-profit equilibrium with $L^0 = 0$ exists if and only if $\theta_0 \leq \theta$. For any such θ,

the wage w^0 is the same as in the agricultural equilibrium from D1 in section 5.

(b)   A zero-profit equilibrium with $L^0 > 0$ exists if and only if $0 \leq \theta < \theta_0$. For any

such θ, the associated equilibrium is unique. On this interval

(i)   The equilibrium values (p^0, w^0, A^0, L^0) are differentiable functions of θ.

(ii)   The variables (p^0, w^0, A^0) move in the same direction as θ. The variable

L^0 moves in the opposite direction from θ.

(iii)   As $\theta \to \theta_0$ from below, we have $p^0 \to q$, $w^0 \to qr$, $A^0 \to N - e$, and $L^0 \to$

   0. Thus the equilibrium values are continuous at θ_0.

(iv)   For $\theta = 0$ we have $(p^0, w^0, A^0, L^0) > 0$.

These results show that a drop in commons productivity from the interval in (a) to the interval in (b) leads to positive manufacturing output. This can only occur when the boundary value θ_0 is strictly positive. Taking the commoner labor supply N-e as given, this requirement places a lower bound on qr (the average value product of manufacturing labor evaluated at zero input) through (18). When qr is too small, the elite's demand for farm labor always keeps the wage too high to make urban workshops profitable.

For an interesting model, we need $\theta_0 < \theta_{max}$ where the upper bound comes from (10). Otherwise, it would be impossible to have an agricultural equilibrium satisfying the stratification constraints from section 5. It can be shown that if these constraints hold in an agricultural equilibrium, they still hold after manufacturing begins. As a result, open access persists in the commons and elite control persists at site U.

7.   Taxation

The model in section 6 showed that climate change could lead to urbanization, but not why the resulting cities would also be states. Here we extend the model to show why emergence of a city would coincide with the development of a centralized fiscal system. We assume the elite at Uruk was organized enough to tax its own members. The task is to determine whether the elite as a whole would benefit from such taxation.

In our model, tax revenue is rebated to individual elite agents and used for private consumption. It is not important whether taxes nominally fell on elites or commoners, or

whether workshops were taxed based on their inputs or outputs. We use the convenient assumption that taxes were levied on elite-owned workshops per commoner employed.

It does matter that only manufacturing was taxed. If taxation of agriculture had been profitable, a state would have emerged prior to urbanization. This contradicts the idea that the Mesopotamian city-states were in fact pristine states. Most scholars date the earliest Mesopotamian states to the mid- or late-Uruk period, when cities were forming or had recently formed. We infer that agriculture by itself did not provide an adequate basis for centralized taxation, probably because its dispersed activities made rural output and/or workers costlier to monitor than urban output and/or workers.

The crucial question is whether the elite wants to tax manufacturing when doing so has no administrative cost in the form of hired tax collectors, fixed costs from setting up the tax system, and the like. Clearly a necessary condition for taxation to arise is that it must offer net benefits to the elite when it can be done costlessly. If this is true, it may also be profitable to create a tax system having fixed or variable administrative costs, as long as these costs are not too large.

Suppose the elite levies a tax $t \geq 0$ per manufacturing worker, where tax revenue is collected by a central agency that redistributes it equally among the elite agents. The previous zero profit condition from (15) now becomes

(19) $pM = (w + t)L$

Total tax revenue is $tL = pM - wL$, which is also the total profit from manufacturing.

Individual elite agents are wage takers in the labor market and price takers in the product market, because they are small relative to the size of each market. However, as a

group the elite confronts an upward sloping labor supply curve and a downward sloping product demand curve for manufacturing. The elite understands that if it can collectively restrict labor input (and thus output) in this sector, it can drive down the wage and drive up the output price. Starting from a zero-profit equilibrium, this yields positive profit.

Figure 3 illustrates these ideas. The average value product for manufacturing is given by the locus $\phi(L)$, which is downward sloping under condition A1 from section 6. The supply curve for manufacturing labor is given by $w(L, \theta)$ reading from left to right, which is identical to the demand curve for agricultural labor in Figure 2 reading from right to left. The supply curve is always upward sloping.

The equilibrium (L^0, w^0) with zero taxation $(t = 0)$ occurs at point A. When the tax rate on manufacturing labor is positive $(t > 0)$, tax revenue and manufacturing profit are given by the area of the rectangle in Figure 3 defined by the average value product at point B and the wage at point C. The gap between B and C is $w^B - w^C = t$, the tax rate per worker. A higher tax rate implies a lower manufacturing workforce L. For any tax rate $t \geq 0$ there is a unique equilibrium level of L and vice versa, as long as L lies between zero and its equilibrium level $L^0 > 0$ with zero tax. In what follows, it is simplest to have the elite choose L directly and collect the resulting manufacturing profit using whatever tax rate $t \geq 0$ is needed to induce the desired L.

It may seem counterintuitive that the elite could appropriate profit by taxing itself rather than taxing commoners. The latter approach also works but the profit to the elite is the same. If urban workers pay a tax $t > 0$ as in Figure 3, they must be offered the wage w^B by employers in order to be recruited into the manufacturing sector, because the net wage is w^C after the tax is paid and w^C is available in the commons. The wage w^B is the

average value product, which leaves zero profit for firm owners. Again the elite collects

its profit through the tax system, not directly in the goods market or the labor market.

A positive tax t > 0 has several effects relative to the zero-profit equilibrium with

no taxation. First, taxation decreases urban employment L and manufactured output M.

Second, the price p for manufactured goods rises. Third, the wage w falls. Finally, the

lower wage raises the land rent of the elite. A sophisticated elite will take these effects

into account in choosing L.

To characterize the elite's optimal tax rate, we need to express the elite's indirect

utility as a function of prices. The prices w and p are determined from (9) and (13) by

(20) $\qquad w(L, \theta) = [\beta(\theta)/(N - e - L)]^{1-\alpha}$

(21) $\qquad p(L) = b'[M(L)/N]$

The indirect utility function for an individual agent is written as $v(p, x) = s(p) + x$ where

$s(p)$ is consumer surplus and x is income. Letting $m(p)$ be consumption for an individual

agent, $s(p) = b[m(p)] - pm(p)$, where in market equilibrium $m(p) = M(L)/N$. Multiplying

$v(p, x)$ by e gives the total indirect elite utility $V^E(p, X^E) = es(p) + X^E$ or

(22) $\qquad V^E[p(L), X^E(L, \theta)] = es[p(L)] + p(L)M(L) - w(L, \theta)L + R[w(L, \theta)]$

Hence the elite is concerned with three things: consumer surplus for manufactured goods,

total profit, and total land rent.

We now define an equilibrium with optimal elite taxation, where the scale of the

manufacturing sector is chosen to maximize the total utility of the elite agents.

<u>D4</u> The array (p^E, w^E, A^E, L^E) is an *elite taxation equilibrium* associated with commons

productivity θ if

(a) L^E maximizes $V^E[p(L), X^E(L, \theta)]$ subject to $0 \leq L \leq L^0(\theta)$

(b) $p^E = p(L^E) = b'[M(L^E)/N]$ from (21)

(c) $w^E = w(L^E, \theta) = [\beta(\theta)/(N - e - L^E)]^{1-\alpha}$ from (20)

(d) $A^E + L^E + e = N$ from (4)

In condition (a) of the definition, L is constrained not to exceed $L^0(\theta)$ because this is the

labor input for manufacturing when the tax rate is zero, and we are only considering $t \geq 0$.

A solution to the optimization problem exists because V is continuous and the feasible set

is non-empty and compact. The other conditions are straightforward. The constraint that

commoners have non-negative food consumption is discussed in an appendix.

To characterize an elite taxation equilibrium, we need to differentiate the indirect

utility function $V^E[p(L), X^E(L, \theta)]$ from (22) with respect to L. The derivative can be

broken into two parts, corresponding to two channels through which L affects the other

components of the model. The first channel acts through the product market and affects

M, p, manufacturing revenue, and consumer surplus, where the key parameters are q and

r. The second channel acts through the labor market and affects w, A, manufacturing

cost, and land rent, where the key parameters are θ, Z, and α.

The derivative of elite utility with respect to manufacturing labor is

(23) $dV^E[p(L), X^E(L, \theta)]/dL = \mu(L) + \lambda(L, \beta)$ where

$\mu(L) = qre^{rL - qM/N}[1 - (1 - e/N)qM/N]$ with $M = M(L)$ from (14)

$$\lambda(L, \beta) = -(N - e - L)^{\alpha-2}[\beta^{1-\alpha}(N - e - \alpha L) + \beta^{-\alpha}(1-\alpha)\alpha^{1/(1-\alpha)}(N - e - L)]$$

with $\beta \equiv \alpha^{1/(1-\alpha)} + Z\theta^{1/(1-\alpha)}$ from (7)

The function $\mu(L)$ captures the product market channel and has an ambiguous sign. The function $\lambda(L, \beta)$ captures the labor market channel, and is strictly negative for all $L < N - e$ and all β. The elite will always choose $L < N - e$ because $L \rightarrow N - e$ implies $A \rightarrow 0$, so the marginal product of agricultural labor goes to infinity, as does the wage.

Define $L_{max} > 0$ by $\mu(L_{max}) \equiv 0$, or equivalently $M(L_{max}) = N/q(1 - e/N)$. No labor input with $L \geq L_{max}$ can be optimal because then $\mu(L) \leq 0$ and $\lambda(L, \beta) < 0$ imply $dV^E/dL < 0$. In a situation of this kind, the elite would reduce L. Therefore, the relevant interval in the optimization problem D4(a) is $0 \leq L < \min \{L_{max}, N - e\}$.

Because θ is non-negative, the minimum value of β is $\alpha^{1/(1-\alpha)}$. For β greater than or equal to this level, $\lambda(L, \beta)$ is strictly decreasing in β and thus strictly decreasing in θ. This implies that a higher θ makes $\lambda[L, \beta(\theta)]$ more negative at any fixed value of L, so the elite is less inclined to expand manufacturing when commons productivity is higher.

It can be shown that $\partial\lambda/\partial L < 0$ always holds. However, in general $\partial\mu/\partial L$ has an ambiguous sign. Condition A2 below ensures that $\partial\mu/\partial L < 0$ holds on the interval $0 \leq L < \min \{L_{max}, N - e\}$. Details are available from the authors.

A2 $q/N \geq 1$

A2 gives $d^2V^E/dL^2 < 0$ for $0 \leq L < \min \{L_{max}, N - e\}$, so the objective $V^E[p(L), X^E(L, \theta)]$ from (22) is strictly concave in L on this interval. This is true for any productivity $\theta \geq 0$. A2 guarantees the uniqueness of the solution to the elite's optimization problem in D4(a).

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In non-trivial situations where $L^0 > 0$ so some manufacturing is feasible in D4(a), there are three possible cases. First, there could be a boundary solution having $L^E = 0$ so the tax rate is high enough to prevent any manufacturing. This requires $\mu(0) + \lambda[0, \beta(\theta)] \leq 0$. Second, there could be an interior solution with $0 < L^E < L^0$ so manufacturing occurs but with a positive tax rate. This requires $\mu(L^E) + \lambda[L^E, \beta(\theta)] = 0$. Third, there could be a boundary solution with $L^E = L^0$ so the level of manufacturing is the same as in a zero-profit equilibrium and the tax rate is zero. This requires $\mu(L^0) + \lambda[L^0, \beta(\theta)] \geq 0$. Later we use a sufficient condition that rules out the last case, so a solution involves either no manufacturing or else positive manufacturing at a scale below the zero-profit level.

First we consider boundary solutions with $L^E = 0$ so manufacturing is absent.

<u>Lemma 2</u>. Define θ_e implicitly by $\mu(0) + \lambda[0, \beta(\theta_e)] \equiv 0$. There are two cases.

(a)   If $qr(N - e)^{1-\alpha} < \alpha(2-\alpha)$ there is no such $\theta_e \geq 0$. In this case, the derivative in (23) is negative at $L = 0$ for all $\theta \geq 0$. Thus the elite always chooses $L^E(\theta) = 0$.

(b)   If $\alpha(2-\alpha) \leq qr(N - e)^{1-\alpha}$ there is a unique $\theta_e \geq 0$. The equality implies $\theta_e = 0$ and the inequality implies $\theta_e > 0$. In this case, the derivative in (23) is positive at $L = 0$ for $0 \leq \theta < \theta_e$, zero at $L = 0$ for $\theta = \theta_e$, and negative at $L = 0$ for $\theta_e < \theta$. Thus the elite chooses $L^E(\theta) > 0$ when $0 \leq \theta < \theta_e$ and $L^E(\theta) = 0$ when $\theta_e \leq \theta$.

Part (a) shows that if qr and N-e are small enough, the elite never wants manufacturing ($L^E = 0$). Part (b) shows that when qr and N-e are large enough and θ is small enough, the elite wants positive manufacturing ($L^E > 0$).

Next we rule out boundary solutions of the form $0 < L^E = L^0(\theta)$. Condition A3 (together with A2) is sufficient for this purpose.

<u>A3</u> $e/N \le 1/2$

This condition says that commoners represent at least half of the total population, and limits the size of consumer surplus effects relative to income effects for the elite.

<u>Lemma 3</u>. Suppose $L^0(\theta) > 0$ in D4(a) so that a positive labor input is feasible. Assume A2 and A3 both hold. The derivative in (23) is always negative at $L = L^0(\theta)$. Therefore the elite always chooses $L^E(\theta) < L^0(\theta)$.

The last possibility is an interior solution with $0 < L^E < L^0(\theta)$. Suppose Lemma 2(b) applies and $0 \le \theta < \theta_e$ so the elite's optimal labor input is positive. Let $L(\theta)$ be the input level defined implicitly by the first order condition:

(24) $\mu[L(\theta)] + \lambda[L(\theta), \beta(\theta)] \equiv 0$

This yields

(25) $L'(\theta) = -\beta'(\theta)[\partial\lambda/\partial\beta] / [\partial\mu/\partial L + \partial\lambda/\partial L]$

Due to $\beta'(\theta) > 0$ and $\partial\lambda/\partial\beta < 0$ in the relevant range for β, the numerator is positive. As mentioned above, $\partial\lambda/\partial L < 0$ always holds, and $\partial\mu/\partial L < 0$ holds in the relevant interval if A2 holds. Under these conditions, $L'(\theta) < 0$ holds in (25), so a lower productivity in the commons leads to a larger manufacturing sector. We use $M^E(\theta) \equiv M[L^E(\theta)]$ to denote the elite's optimal output choice, and $M^0(\theta) \equiv M[L^0(\theta)]$ to denote output with free entry and zero taxation as in section 6.

Lemma 4. Suppose Lemma 2(b) applies, and A2 and A3 hold. Consider the interval $0 \leq \theta \leq \theta_e$ where θ_e is defined in Lemma 2. We have $\theta_e < \theta_0$ where the zero-profit boundary θ_0 is defined in (18). The elite's optimal output $M^E(\theta)$ is unique with $M^E(\theta_e) = 0$ and $0 < M^E(\theta) < M^0(\theta)$ for $0 \leq \theta < \theta_e$. $M^E(\theta)$ is decreasing on this interval and continuous at θ_e.

Lemma 4 shows that when $0 \leq \theta < \theta_e$ three things are true: (i) a zero-profit equilibrium of the kind described in section 6 would lead to a positive manufacturing sector; (ii) the elite imposes a positive tax on this sector; and (iii) the tax is not so high that manufacturing is suppressed entirely.

   We now state our main results on elite taxation and its relationship to the zero-profit equilibria studied in section 6.

Proposition 3 (elite taxation equilibrium). Let θ_0 be the zero-profit boundary in (18) and
   let θ_e be the elite taxation boundary in Lemma 2. Assume A2 and A3 hold.

(a)   If $qr(N - e)^{1-\alpha} \leq \alpha$ then $\theta_0 \leq 0$ and Lemma 2(a) applies so there is no solution for
       θ_e. For all $\theta \geq 0$, zero-profit equilibrium gives $M = 0$ without taxation.

(b)   If $\alpha < qr(N - e)^{1-\alpha} \leq \alpha(2-\alpha)$ then $0 < \theta_0$ and either Lemma 2(a) applies so there is
       no solution for θ_e or Lemma 2(b) applies with $\theta_e = 0$.

       (i)   For $0 \leq \theta < \theta_0$, zero-profit equilibrium would give $M > 0$ but the elite
              enforces $M = 0$ through high taxes.

       (ii)   For $\theta_0 \leq \theta$, zero-profit equilibrium gives $M = 0$ without taxation.

(c)   If $\alpha(2-\alpha) < qr(N - e)^{1-\alpha}$ then Lemma 2(b) applies and $0 < \theta_e < \theta_0$.

       (i)   For $0 \leq \theta < \theta_e$, the elite imposes positive taxes but allows $M > 0$.

(ii)   For $\theta_e \leq \theta < \theta_0$, zero-profit equilibrium would give $M > 0$ but the elite

enforces $M = 0$ through high taxes.

(iii)   For $\theta_0 \leq \theta$, zero-profit equilibrium gives $M = 0$ without taxation.

Proposition 3 shows that when qr, the average value product at $M = 0$, is small, as in (a) and (b), a manufacturing sector does not emerge for any commons productivity θ. This is true either because entry is unprofitable even without taxation, or because entry would occur but the elite prevents it in order to maintain land rents. The only situation where the elite allows manufacturing is (c), where this sector is profitable enough that the elite taxes it moderately. Even in this case, it is also necessary to have a low commons productivity θ as in (c)(i), which pushes the wage down to a point where the gains from manufacturing outweigh the losses in land rent. These results are illustrated in Figure 4, which depicts case (c) where manufacturing occurs when θ is sufficiently low.

In sum: an elite that can tax manufacturing at no administrative cost will allow a city-state if there is a high demand for manufactured goods, a high productivity of labor in manufacturing, a high supply of commoner labor, and a low productivity in outlying areas beyond elite control (or some combination of these factors, allowing for tradeoffs among them). If these requirements are met, taxation arises together with urbanization. The collection of taxes is motivated by the elite's desire to impose a monopolistic output restriction on urban workshops, which increases total elite utility.

8.   Welfare

This section develops some welfare implications of the model from sections 5-7. These results are of interest because archaeologists and others frequently debate whether

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state formation makes commoners better or worse off. For brevity, we summarize the implications of our model verbally (formal results are available from the authors). We consider the effects of a reduction in the productivity parameter θ due to growing aridity across the region. The effects are clear when manufacturing is absent: a drop in θ always makes the elite better off, the commoners worse off, and reduces total utility. Therefore, we focus attention on situations where there is positive manufacturing in equilibrium.

In this case, a reduction in commons productivity again makes the elite better off. This is a straightforward consequence of the envelope theorem. Matters are much more complex for commoners. When θ falls, the elite wants more manufacturing labor, which reduces the price of manufactured goods and enhances consumer surplus for commoners. There is also an indirect effect where an increased demand for labor pushes up the wage. On the other hand, the direct effect of lower commons productivity is to reduce the wage. It can be shown that in the early stages of urbanization when M is small, the consumer surplus effect is negligible and the direct effect on the wage dominates the indirect effect. Therefore commoners become worse off early in the transition to a city-state. The effect on total utility is ambiguous, and depends on parameter values in a complicated way.

It may seem odd that a reduction in a productivity parameter could ever increase total utility. However, there are distortions in the pricing of manufactured goods that can yield this result. Due to increasing returns, marginal cost must be less than average cost. A first best allocation requires marginal cost pricing, while a zero-profit equilibrium with no taxation requires average cost pricing, and an equilibrium with positive taxes requires a price above average cost. Because the elite restricts output, lower productivity in the

commons can yield a social gain through greater manufacturing, despite a loss in food output. This is not a Pareto improvement because the commoners become worse off.

As urbanization proceeds, commoner utility may eventually start to rise for two reasons: consumer surplus effects become more important, and rising demand for labor may drive up the wage. However, for some parameter values (when initial productivity in the commons is high enough), commoners can never fully regain the welfare level they enjoyed prior to climate deterioration, and total utility is lower in the city-state than in the agricultural equilibrium (the loss to the commoners outweighs the gain to the elite).

9.   Population

The model from sections 5-8 has an important limitation. Although we allowed migration from rural to urban areas, we held the total regional population N constant. In reality, the Uruk transition unfolded over centuries, and population would probably not have remained static through a large climate shift and a massive economic upheaval. To be specific, one might think that a decreased standard of living for commoners during this transition would lower fertility and raise mortality. In the long run, the resulting decrease in the supply of commoner labor might drive up the wage and choke off the development of a manufacturing sector.

This gap can be filled using a Malthusian approach to population dynamics we have employed in several earlier papers (Dow et al., 2009; Dow and Reed, 2011, 2013, 2015; Dow et al., 2017). Our goal is to show that endogenizing population in a simple way leads to results consistent with our argument that climate change was the trigger for city-state formation. For brevity we only provide a summary here, but a formal analysis is available from the authors.

The population model runs as follows. Time is discrete and a period is the length of a human generation (about twenty years). An individual adult who is alive in period t engages in economic activities and generates utility v^t. This adult has $n^{t+1} = \rho v^t$ surviving adult children in period t+1, where the period-t adults die at the start of period t+1. The coefficient $\rho > 0$ captures the idea that a higher parental utility level raises fertility and lowers child mortality. These effects involve utility from both manufactured goods and food, not just food alone. For example, a child is more likely to survive when a parent acquires clothing from the urban sector.

Our model reflects the Darwinian viewpoint that an adult ultimately derives utility solely from their number of surviving offspring (there is no tradeoff between the quantity and quality of children here). The utility an adult receives from food and clothing is an intermediate input to the production of adult children. The demographic parameter ρ is identical for all agents and constant over time. Events occurring within a single period constitute the *short run*, while events spanning multiple periods constitute the *long run*.

Aggregating utility across agents (both elite and commoner) generates a time path for aggregate population. For a given level of productivity in the commons, we define a long run equilibrium (LRE) as a population N and a level of manufacturing labor L such that (a) L arises from an optimal tax rate for the elite at the population level N, and (b) the resulting total utility keeps the aggregate population N constant over time. In order for an LRE to be stable, the total population N must rise (fall) when N is slightly below (above) its equilibrium level. We assume these dynamics involve monotone convergence.

In equilibrium, elites and commoners will have different incomes and different utilities. As a result, they will have unequal numbers of surviving children. To keep the

populations of the two classes stationary, there must be downward mobility from the elite to the commoner class, perhaps based upon birth order (see Dow and Reed, 2013).

Here we focus on comparisons of LRE for alternative values of θ, and ignore the path along which N^t approaches a new long run equilibrium level when θ changes. The main result is that if the system starts from an initial LRE with an agricultural equilibrium ($L = 0$), a drop in the productivity parameter θ can lead to a new LRE with manufacturing ($L > 0$), even after all population adjustments have occurred. Our qualitative conclusions from sections 5-8 therefore survive when population is endogenized in a Malthusian way. The argument involves the following series of steps.

First, we consider a purely agricultural economy and show that there is a unique stable LRE for every commons productivity level $\theta \geq 0$ if and only if the size of the elite (e) is small enough relative to other parameters. An upper bound on elite size is needed because the elite produces no food but must be replaced demographically in each period. We then consider the general case where manufacturing can occur. There is a region of the parameter space such that, if a single-crossing condition is met, there is some $\theta^E \in (0, \theta_{max})$ such that

(a)   For $\theta \in [\theta^E, \theta_{max})$ there is an LRE with $L = 0$. This LRE is stable for $\theta > \theta^E$.

(b)   For $\theta \in [0, \theta^E)$ there is no LRE with $L = 0$, but there is an LRE with $L > 0$.

Case (a) involves a high level of commons productivity where there is no manufacturing in LRE, and case (b) involves a low level of commons productivity where manufacturing does occur. In case (b) there can be multiple equilibria with different levels of L for the same value of θ. In non-pathological cases, at least one of these equilibria will be stable. If the single-crossing condition mentioned above does not hold, it will still be true locally

that a decline in θ can lead to manufacturing when Malthusian population adjustments are taken into account. In this situation global results are difficult to obtain, but with suitable parameter restrictions a large enough drop in commons productivity must eventually lead to the formation of a permanent city-state.

Population in an agricultural economy tends to decline as climate deteriorates. Thus it would not be surprising if the expansion of the urban population were more than offset by a contraction in the number of farm laborers (either working in the commons or on elite estates). However, as mentioned in section 8, we cannot rule out the possibility that once manufacturing starts, it may be associated with increased total utility. This can lead to aggregate population growth despite declining productivity in the commons.

Even if regional population initially decreases due to a worsening climate regime, this negative population trend could eventually be reversed through learning by doing in the manufacturing sector. Such productivity growth likely occurred via experimentation with the division of labor, supervisory practices, and record keeping (including writing). These innovations would have had two effects: (a) a scale effect involving Malthusian population growth, and (b) a substitution effect that tended to reinforce agglomeration of the population in cities. Thus, a trajectory that started with worsening climate and falling population could ultimately have led to improving technology and rising population.

10.   Conclusion

Although data are scarce and archaeological interpretations of the data vary (see section 4), we believe the model in sections 5-7 accounts for several prominent stylized facts about city-state formation in ancient Mesopotamia. Our model also yields various hypotheses about climate, migration, manufacturing, inequality, and related matters that

could be tested in future archaeological research. We will conclude with some remarks about pristine state formation in other parts of the world.

Archaeologists have numerous ways of recognizing the presence of an early state. One popular approach involves the scale of the resources available to a ruling elite, which leads to a focus on the total population or geographic area of a polity. Another approach involves decision-making within the elite, which leads to a focus on specialization, more reliance on bureaucracy as compared with kinship ties, or the presence of a multi-tiered settlement hierarchy. A third approach involves expenditures often associated with state-level polities, such as for monumental architecture, large-scale infrastructure, or colonial expansion. An economist might also look for evidence of in-kind taxation, such as large central facilities for crop storage or animal herds, or a reliance on corvée labor. Another economic indicator might be a level of inequality beyond what was previously generated from land rent alone.

All of these indicators have limitations, and archaeologists frequently debate their interpretation in particular cases. Moreover, no early state has all of these features, so the absence of some does not imply that a state was absent. We skim lightly over such issues here and focus on the traditional list of regions with pristine states: Mesopotamia, Egypt, the Indus Valley, northern China, Mesoamerica, and the Andes (Service, 1975; Adams, 2001, 346; Spencer and Redmond, 2004, 174). We ignore pristine state formation in sub-Saharan Africa and other regions, except for a few remarks on Hawaii. Our main interest is in whether our theoretical framework could apply to regions other than Mesopotamia. A few alternative explanations for early state formation will also be discussed.

Our model ties state formation tightly to urbanization: it is a theory of city-states. Pre-dynastic Egypt apparently did have fortified city-states (Trigger, 2003, 104; Yoffee 2005, 47; Mayshar et al., 2011, 3-4 and references cited there). After the creation of the central state, such fortifications disappeared. Dynastic Egypt had some cities, but they were not large, and mainly served administrative and ceremonial purposes (Kemp, 2006; Yoffee, 2005, 48). They were not production centers for goods, although they dealt with other economic matters such as taxation and perhaps trade. Our model of manufacturing-driven urbanization clearly does not fit the Egyptian case. Brooks (2006) argues that the Egyptian state formed in response to increasing aridity in North Africa, which triggered large-scale migration toward the Nile Valley. Thus, our story about climate change and migration may be relevant for Egypt, even if our manufacturing story is not.

It has been claimed that Harappan civilization in the Indus Valley is an example of cities without a state (Possehl, 1998). The Mature phase for this region is dated to between 2500 and 1900 BCE, and included at least two major cities: Mohenjo-daro and Harappa. The transition between the Early and Mature phases (about 2600 - 2500 BCE) shows signs of burning, which may have involved violence, and was associated with new settlement locations. Urbanization occurred rapidly, within about a century.

The Mature phase exhibited social stratification, craft specialization, sophisticated technologies, writing, and the use of distant resources. Stratification is indicated mainly by residential patterns rather than burials. There is no evidence of warfare in the Mature period. The cities were "large, multifunctional, internally differentiated settlements" (Possehl, 1998, 276), but lacked temples or palaces. In Possehl's view, the Indus Valley had no bureaucracy, no state religion, and no supreme political authority. On this basis,

he rejects claims that it had a state. On the other hand, he cites archaeological specialists who do assert the existence of an archaic state, and it is not obvious why bureaucracy, a state religion, or a king would be necessary conditions for such a state.

We cannot resolve disputes about the status of the Indus Valley case. However, our model is consistent with the idea that cities can arise in the absence of a state. If the elite was too weak to tax the urban sector effectively, urbanization could have followed the path described by our model of zero-profit equilibrium in section 6. Conversely, if the elite had the power to tax, the model in section 7 would provide a better description. Either way, it is unclear whether Indus Valley urbanization can be attributed to climate deterioration. Brooks (2006) makes such an argument, but the climate changes he cites occur well before the early Harappan and seem unrelated to the mature Harappan phase.

For China, there is substantial support for the idea that the first state was centered at Erlitou in the Yiluo basin, from about 1900 to 1500 BCE. However, some experts are skeptical about claims that Erlitou was a state and award this distinction to the subsequent Shang dynasty (Shelach-Lavi, 2015, 184-190). Our description is based upon Liu (2006) except where noted (see also Liu and Chen, 2003).

The Erlitou region is a large fertile alluvial basin surrounded by hills, mountain ranges, and the Yellow River to the north. Good land quality provided high yields for grains and domesticated animals, and permitted a high population density. After earlier Neolithic settlement, the site was abandoned for 500 years before renewed settlement in Phase I, starting around 1900 BCE. The population of the site in this phase is estimated at 3500 - 5800. It is unclear where the initial migrants came from, what caused them to move to the site, or whether existing villages in the region were amalgamated.

Liu (2004, 235) observes that the Yellow River changed its course around 2000 BCE, that this was a time of flooding in many parts of the Yellow River valley, and that the floods may have been caused by climatic fluctuation. Thus, natural catastrophes may be part of the explanation for the Erlitou transition. Brooks (2006) suggests that climate change could have played a role but proposes a different mechanism, asserting that peak aridity in the area occurred between 4500 - 3500 BP, a time that fits the emergence of the Erlitou state beginning around 3900 BP. It is unclear how a story about increased aridity can be reconciled with Liu's story about increased flooding of the Yellow River.

Craft specializations in Phase I included bronze casting, bone carving, and pottery, and mainly involved non-elite goods, although Liu and Chen (2012, 266) report "many elite items" such as white pottery, ivory and turquoise artifacts, and bronze tools. The population engaged in both craft and agricultural activities. No elite residences or administrative buildings had been found for Phase I as of Liu's writing in 2006. There is little evidence of violence and the town was not walled, although geography may have made the area militarily defensible. In Phase II, population is estimated to have risen to 8300 - 13,900. Palace compounds have been found. The number of arrowheads grew at a rate similar to other tools, indicating that their primary function was hunting rather than warfare. This phase had a four-tier settlement hierarchy for the Yiluo region as a whole.

Phase III was the peak period for Erlitou. The urban center probably had about 18,000 - 30,000 people. New palaces were constructed, likely requiring large-scale earth moving. Craft workshops became even more numerous and produced both utilitarian and elite goods. The city population relied heavily on food from the hinterland, and the total population of the Yiluo region may have reached 54,000 - 82,000 people. It is not clear

whether market systems had developed for utilitarian goods, or to what degree the supply of agricultural output to the center reflected a tribute system. The number of arrowheads increased rapidly, suggesting military expansion motivated by a desire to control outlying sources of salt and metals. In Phase IV, population diminished, craft output became less important relative to food output and residential construction, arrowhead production rose, and fortifications were built nearby. During the Erligang period, the site was eventually abandoned, as people moved to settlements linked with the new and larger Shang state.

Our model may have some application to the Chinese case. The possible role of a climate trigger for the initial migration into the Erlitou region is suggestive. Evidence for stratification in Phase I includes luxury goods but not elite burials or residences. There is pronounced stratification by Phase II. It is unclear whether the early migration to Erlitou occurred at a time of pre-existing elite property rights over land (as in our present model), or whether rising population density fueled by migration led to elite-commoner inequality in the transition from Phase I to Phase II (as in the model from Dow and Reed, 2013). In any event, the central role of urban manufacturing seems indisputable, and the absence of violence in the early phases argues against theories of state formation based on warfare.

Spencer and Redmond (2004) provide a useful survey of the evidence on primary state formation for Mesoamerica. Their archaeological markers for states include a four-tiered settlement hierarchy, royal palaces and specialized temples, and the conquest or subjugation of distant territories. They describe Olmec society as involving chiefdoms, while Oaxaca, the Basin of Mexico, and the Lowland Mayan area gave rise to states.

The earliest case is the Zapotec state in the region of Oaxaca. It had a capital city at Monte Albán, arose around 300 BCE, and appears to have formed through aggressive

territorial expansion. By 250-100 BCE, the Basin of Mexico had one location with about 20,000 - 40,000 people (Teotihuacan) and a second with about 20,000 (Cuicuilco). The latter was focal for a cluster of sites exhibiting a four-tiered hierarchy, and had several monumental buildings. It is less certain whether Teotihuacan was focal for a four-tiered hierarchy or whether it had similar large structures in the relevant period. Some authors argue that the site locations in the Basin of Mexico reflected a concern with defense, but there is no sign of fortifications, warfare, or extension of control to distant areas. In the Lowland Mayan area, the first unambiguous states appeared around 250-500 CE. The evidence includes palaces, temples, and a four-tier hierarchy. Spencer and Redmond do not cite evidence of warfare or conquest for this period. Our sense is that while warfare was evidently important for Oaxaca, other processes of city-state formation were likely more relevant for the Basin of Mexico and the Lowland Maya.

Stanish (2001) provides a similar survey of archaeological evidence for pristine state formation in South America. The key areas are the central Andean highlands and the nearby central Pacific coast. Stanish downplays the role of monumental architecture as an indicator of early states, arguing that non-state societies like chiefdoms are capable of mobilizing the required labor. According to Stanish, the first clear states were Moche, Tiwanaku, and Wari, all of which arose during the first millennium CE. However, some experts on the region reject the claim that Moche was a state (Quilter and Koons, 2012), so we limit attention to Tiwanaku and Wari. These arose essentially simultaneously and had similar site sizes, with state formation occurring in unusually productive zones where agriculture could be intensified relatively easily, including by irrigation. Both societies had elites, palaces, large urban capitals, settlement hierarchies with four tiers, economic

specialization, and populations for each polity from 50,000 to 200,000. Both also had strong evidence of warfare based upon iconography, physical remains, and defensive architecture, as well as evidence for colonization of distant locations. Although Stanish highlights the prevalence of warfare, Jennings and Earle (2016, 478-482) appear to place little weight on this factor as a driver of state formation in the case of Tiwanaku. We are not aware of any persuasive climate story about state formation in the central Andes, but it is conceivable that El Nino cycles played a role.

This review suggests that pristine states can be grouped into three categories:

(a) Cases with urbanization and little or no evidence of warfare at the formation stage;

(b) Cases with urbanization and substantial evidence of warfare at the formation stage;

(c) Cases with little or no urbanization at the formation stage.

Category (a) includes Mesopotamia, China, and more tentatively the Basin of Mexico and Mayan Lowlands. Category (b) includes the Zapotec state in Oaxaca and the two South American states. The status of the Indus River valley in this scheme is uncertain because it may not have involved a pristine state at all. If it did, it may fit into category (b) if one accepts the claim of violence between the Early and Mature phases. Egypt might fit into category (b) if one puts significant weight on the role of fortified pre-dynastic cities, and category (c) otherwise.

A substantial number of archaeologists stress warfare among rival chiefdoms as a causal factor in pristine state formation (Carneiro, 1970; Marcus, 1998). This factor may well have been a proximate cause for the cases in category (b) above. Furthermore, there is no real doubt that this factor was central for Hawaii, assuming that Hawaii is accepted as a pristine state (Earle, 1997; Kirch, 2010). Among the hypotheses that appear to have

some explanatory power across a number of different regions, we see warfare as the most viable competitor to hypotheses based on climate change.

One way of thinking about the role of warfare involves a minor reinterpretation of our model. Suppose that rather than calling our parameter theta "agricultural productivity in the commons", we call it "agricultural productivity in the commons net of economic losses due to warfare". With this new interpretation, consider an increase in warfare in thinly settled areas. Let there be a few refuge sites that are relatively secure from warfare due to easily defended locations, easy fortification, or large pre-existing populations that would be difficult to attack. Increased regional warfare would have the same effects as climate deterioration in our previous model: starting from a stratified farming society, it would trigger a process of migration, urbanization, and elite taxation of urban activities.

There is, however, one central difference with our Mesopotamian model. While climate change is exogenous, warfare is not. In the scenario of the preceding paragraph, one would have to explain the transition from peace to war. One candidate to function as a trigger for more frequent or intense warfare is climate change itself, perhaps in the form of more frequent natural disasters (see Dow et al., 2017). Warfare could therefore be the proximate cause of state formation while climate change would be the ultimate cause.

Another possible ultimate cause is a change in technology that makes agricultural output a more tempting target for predation. This could involve increased storage (Allen, 1997; Baker et al., 2010) or enhanced transparency in production (Mayshar et al., 2017). In either case, elites might have stronger incentives to engage in conflict over land rents, leading to the intensification of warfare in agricultural areas.

Thus, the pristine states in both categories (a) and (b) could have arisen through a process of implosion where changes in climate or warfare conditions made life worse in rural areas, at least in relative terms, pushing population toward refuge sites. We doubt that pristine states arose due to a magnetic pull from the center, because productivity in manufacturing or urban administration would not have increased via learning by doing before urban centers existed. This leaves category (c), where state formation occurred with little or no urbanization. These might best be interpreted as examples of rapid state formation through warfare among rival elites over land rent or tax revenue, with only a minimal amount of migration by commoners toward refuge sites.

We close with a few thoughts on the role of the elite in pristine state formation. Many authors have argued that early states arose because they served a broad social goal. As discussed in section 3, economists have a tradition of explaining early states in terms of protection against banditry or predation. Other writers have argued that archaic states provided insurance, facilitated trade, or managed large irrigation systems. Although it is certainly possible that elites provided such services after the state existed, and that these activities may have offered benefits to commoners, we are skeptical that states emerged *because* they were needed to provide such services for the population as a whole. Given that pristine states appear to have been universally dominated by elites, it is much more plausible that the state formation process itself was driven by the interests of elites.

In our framework, the elite serves no social purpose. It does not produce output or supply any public good. In the agricultural sector, the elite enjoys land rent because it defends property rights through force. In the manufacturing sector, the elite appropriates profit through taxation, where taxes serve to enforce monopolistic restrictions on output.

Commoners have the usual sort of economic rationality but respond to market forces in an uncoordinated way and have no significant political power. In sum, the pristine state represents a victory of the organized over the unorganized. In this paper we have offered some insight into how such victories were possible.

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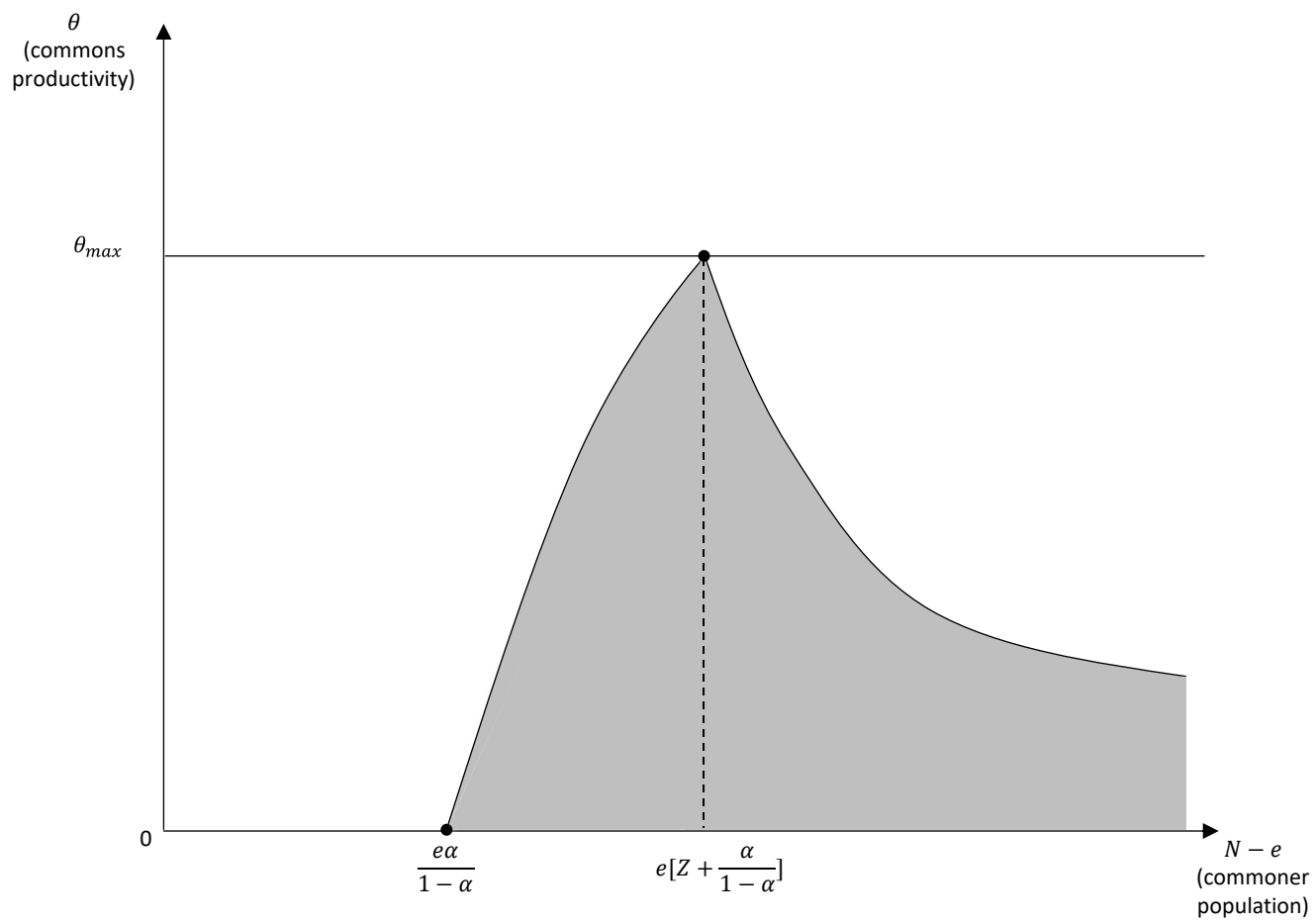
Figure 1

Stratification Constraints

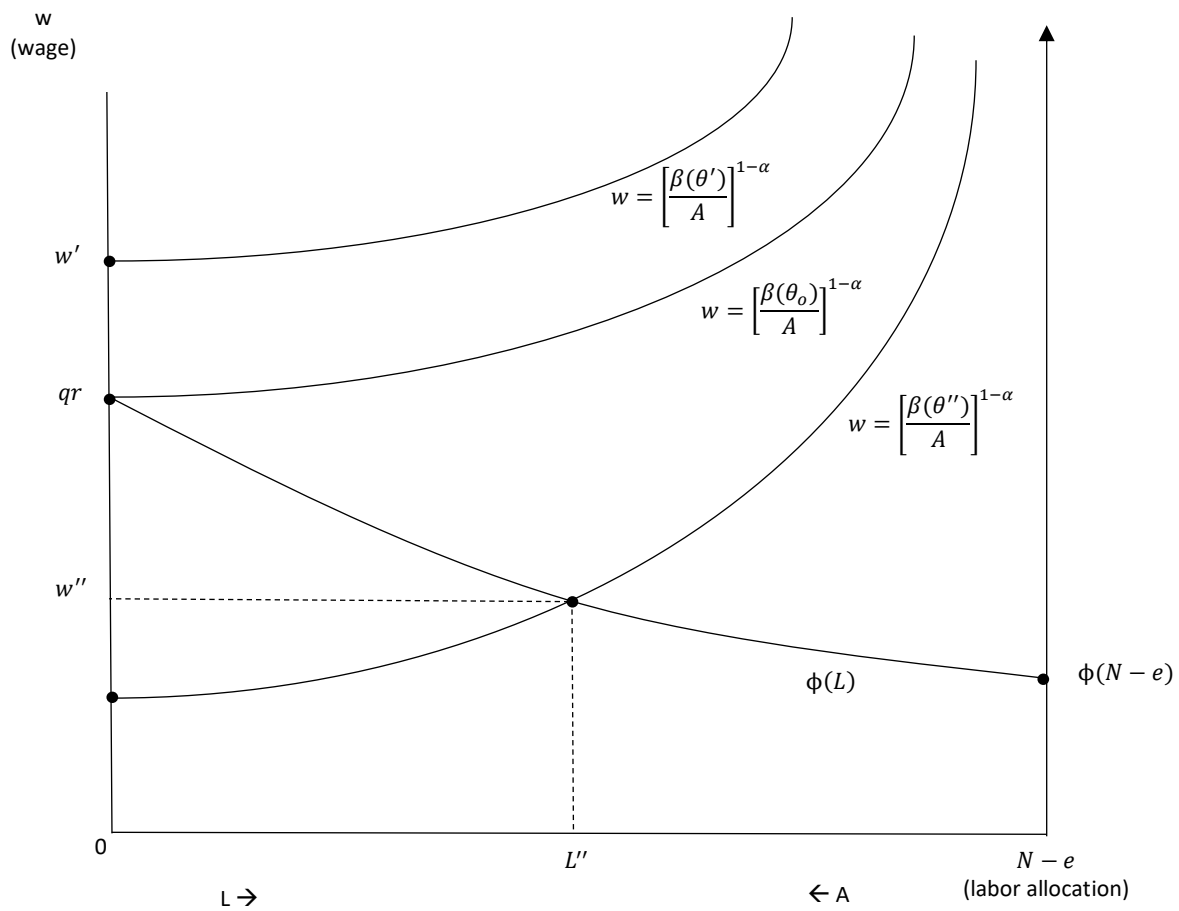(both constraints are satisfied in the shaded area)

w
(wage)

$$w = \left[\frac{\beta(\theta')}{A}\right]^{1-\alpha}$$

$$w = \left[\frac{\beta(\theta_o)}{A}\right]^{1-\alpha}$$

$$w = \left[\frac{\beta(\theta'')}{A}\right]^{1-\alpha}$$

w'

qr

w''

$\phi(L)$

$\phi(N-e)$

0

L''

$N-e$
(labor allocation)

L →

← A

Figure 2

Labor Allocation in Zero-Profit Equilibrium

$(\theta'' < \theta_o < \theta')$
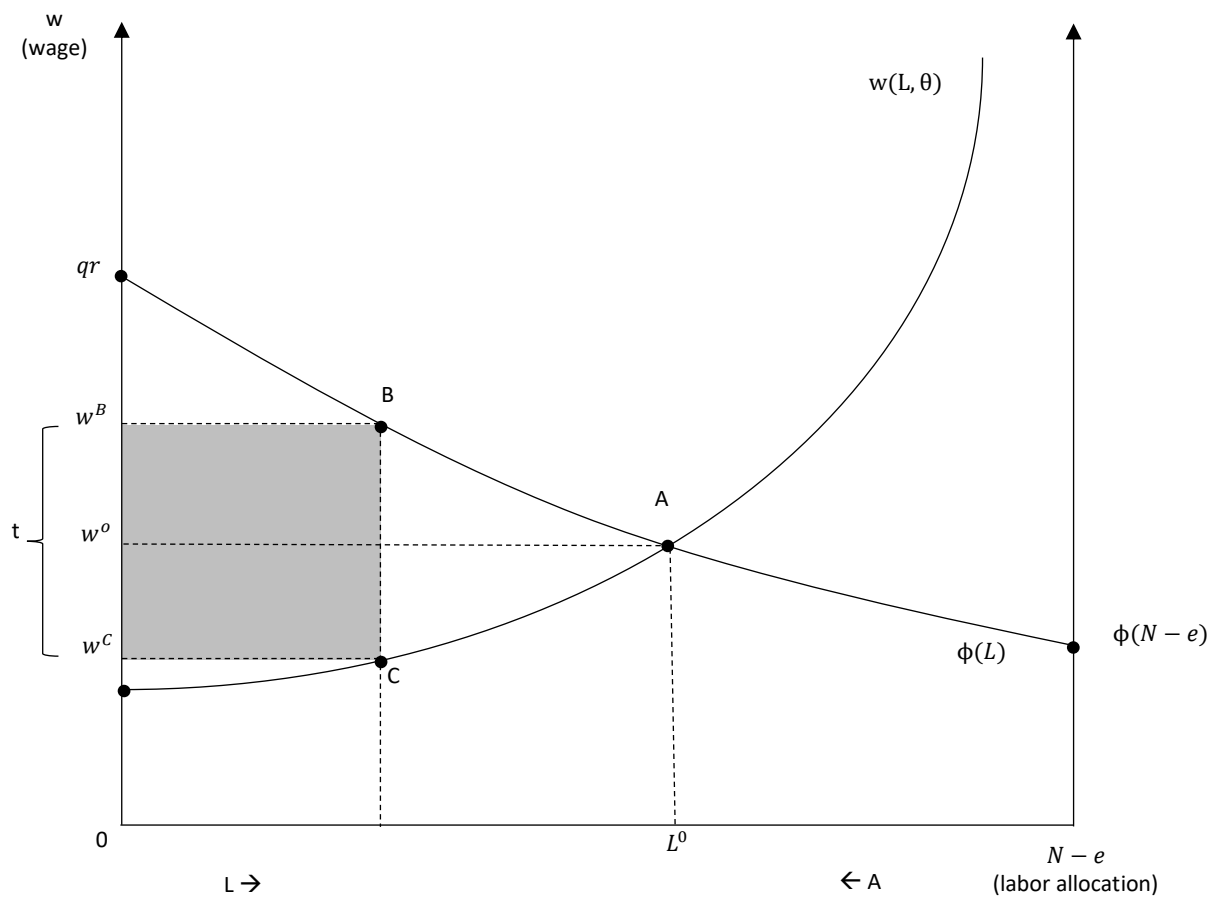
Figure 3

Taxation of Manufacturing Labor

(tax revenue and manufacturing profit shown by shaded area)

θ
(commons
productivity)

θ_s

θ_o

θ_e

$M^E(\theta)$

$M^o(\theta)$

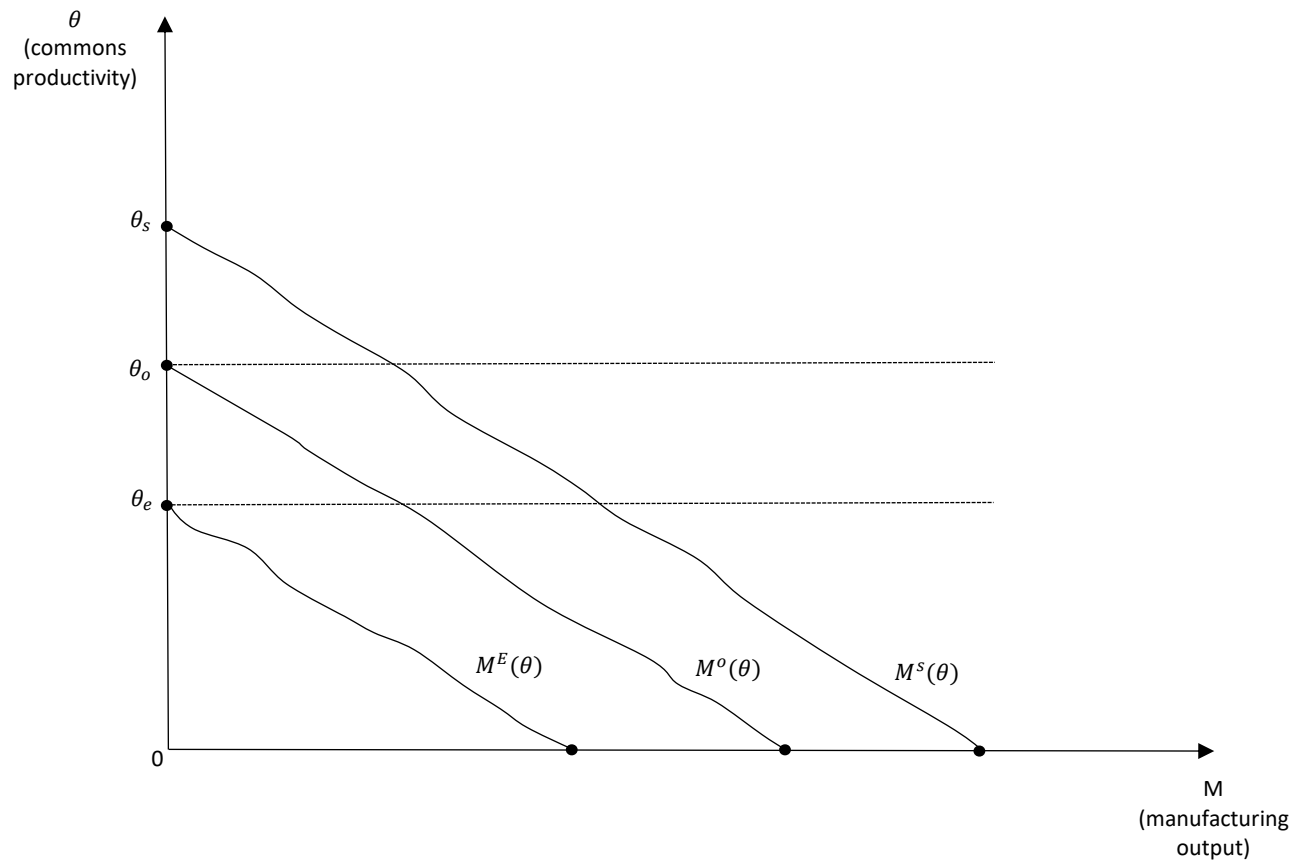$M^s(\theta)$

0

M
(manufacturing
output)

Figure 4

Manufacturing Output as a Function of Commons Productivity

$M^E(\theta)$ = elite taxation equilibrium

$M^o(\theta)$ = zero-profit equilibrium

$M^s(\theta)$ = social planner optimum