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RESEARCH ARTICLE

Learning like a state organizational learning and state capacity in ancient Greece

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Abstract
State capacity is critical for development. Yet, the question of how states learn – that is, how they acquire and incorporate information to improve performance over time – has received little attention. In this paper, we draw from organizational theory and the political economy of knowledge and innovation to study the components of effective learning in states as organizations. We focus on three functionally simple, but well-documented early states in ancient Greece: Sparta, Athens, and Macedon. We argue that Macedon's superior performance relied on a learning model capable of integrating both experiential and experimental knowledge within existing structures. By directing our attention away from the early modern period, where much work in economic history and historical political economy is concentrated, our account challenges the focus of the existing literature on processes of centralization. Instead, we highlight organizational factors that may promote capacity-enhancing learning even in the context of weak centralization.

Keywords: ancient Greece; organizational learning; state capacity

Introduction

How do states learn? The literature on state capacity focuses on the functions crucial to the rise and evolution of states, such as waging war, extracting revenue, and administering people and land (Acemoglu et al., 2015; Besley and Persson, 2009, 2011; Tilly, 1990; cf. Dincecco and Wang, 2022; Grzymala-Busse, 2020). But it pays little attention to the question of how states gather and process the information needed to perform such functions. This gap is particularly striking when considering the emphasis placed on knowledge and information management in the theoretical literature on the state (Foucault, 1977; Scott, 1998) and in literatures that study organizations other than states, such as firms (Argote and Levine, 2017).

A recent 'informational turn' in the study of the state grapples with the need to conceptualize and measure information capacity as an independent function. Existing work analyses the effects of increases in information capacity on core state functions, including administration and taxation (Bowles, 2023; Brambor et al., 2020; Christensen and Garfias, 2021; D'Arcy and Nistotskaya, 2017; Lee and Zhang, 2021; Rogowski et al., 2022).

Building on this literature, we focus on the related question of how states learn – that is, how they acquire and incorporate information to improve performance over time. Learning processes have received little attention in political economy. A notable but lone exception is Hoffman's (2012) work on the dynamics of learning by doing in the development of gunpowder technology in early modern

Europe (cf. section 'Alternative explanations'). But, although Hoffman talks about learning, neither epistemic nor organizational considerations inform the model, which takes knowledge and the ability to deploy it on the battlefield as given.

In this paper, we explore learning processes in states as organizations. We draw from two traditions of scholarship that rarely speak to one another: organizational theory (henceforth, OT) and the political economy of knowledge and innovation. We use OT to identify the variables influencing states' learning models. We use the political economy of knowledge and innovation to articulate how different models may affect state performance.

OT focuses on organizational structures and their context: learning takes place in competitive environments where organizations have access to human and material resources and through institutions (including cultures) that can harness new knowledge to spur innovation and integrate it within existing structures. Two sources of variation make up different learning models: variations in symmetry and clustering. Symmetry concerns whether individuals in the learning organization have the same influence or are structured hierarchically (in which case influence is asymmetric). Clustering concerns whether individuals in the learning organization are equally likely to be connected with others (in which case influence is non-clustered) or if there are instead clusters that need connecting to ensure the flow of information.

To understand how different learning models affect performance, we turn to the political economy of knowledge and innovation, which focuses on epistemic factors: effective organizations are able to manipulate and apply theoretical knowledge to practical uses through (quasi-)experimental methods. Indeed, the application of experimental knowledge in the development of technological innovation has been viewed as an important factor in Europe's takeoff, contributing to the divergence between Europe and China (Lin, 1995; Mokyr, 2002, 2005). In combining these frameworks, then, we begin to articulate how different combinations of (a)symmetry and (non)clustering may shape the development and integration of differing types of knowledge in ways that affect organizational performance.

We apply these insights to ancient Greece, particularly Sparta, Athens, and Macedon in the 4th-century BCE.[1] Ancient Greek states offer several advantages for such a study:[2] first, because they are smaller and simpler than contemporary ones, they afford a clearer look into complex institutional dynamics; second, the political histories of the Greek states are well-documented compared to other pre-modern societies; third, these states shared a coherent ecology in terms of geography, climate, and natural resources, allowing us to keep these variables constant; fourth, ancient Greek states coexisted in the kind of resource-rich competitive environment that, according to OT, is suitable for learning.

We focus on Sparta, Athens, and Macedon because they are high performing, among the best documented, and emblematic of different approaches to learning, which manifests in different outcomes for state capacity. We study the 4th century because this period saw critical changes in the nature of knowledge and the technology of knowledge transmission – changes comparable to those that occurred in Europe around the time of the scientific revolution. Before the 4th century, knowledge was 'sticky' – that is, tightly bound to professional families or dedicated social institutions – and informal, lacking explicit handbooks or other literature (Roochnik, 1996). By the 4th century, however, experts not only travelled widely, but also recorded domain knowledge explicitly and taught it vocationally; they operated largely outside of thickly embedded structures like family, religious, or cultural associations; and their knowledge could be defined, codified, and shared in schools, workshops, and other impersonal organizations (Pyzyk, 2015, 2024).

This new epistemic environment created opportunities for states to acquire and incorporate novel fiscal, administrative, and coercive practices. We argue that different learning models shaped the ability of states to take advantage of these opportunities.

Sparta's learning model – asymmetric and non-clustered – suffered from several bottlenecks well known to the organizational literature, contributing to the state's decline: to protect itself from enemies

[1]All dates referring to Greece are BCE unless otherwise noted.

[2]On the Greek city-state (*polis*) as a state: Hansen (2002).

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at home and abroad, Sparta overinvested in one area of learning – hoplite warfare – to the detriment of others, and refused to incorporate innovation that might upset the rigid social order on which defence relied.

Athens' model – symmetric and clustered – fostered effective incremental learning, but discouraged risky experimental endeavours. Athens made significant changes to its extractive, administrative, and coercive practices in the 4th century, but these changes are best seen as gradual evolutions produced through the manipulation of experiential knowledge. Experimental knowledge, like the experts themselves (Hanssen and Fleck, 2012), was shunned in a political system that privileged gradual shifts from the status quo, consistent with median voter expectations. As in Sparta, so in Athens, political survival and the preservation of social order produced a learning model that made it difficult to take full advantage of the new epistemic environment.

Macedon's model, instead, proved capable of developing and integrating experiential and experimental knowledge within existing structures. Asymmetry and clustering combined in Macedon to enable a gifted leader – Philip – to shape and control learning organizations to enhance state performance. Macedon's asymmetry differed from Sparta's, in that Philip, unlike the Spartan elite, faced little opposition from potential competitors, especially insofar as change strengthened his position of power. Macedon's clustering, moreover, differed from Athens' in that, whereas in Athens clusters were independent and connected only serendipitously through decision-making institutions, Macedon's clusters were connected through the person of the monarch.

Our analysis thus suggests that learning processes contributed to the differential performance of the Greek states and that a core mechanism that distinguished successful from unsuccessful (or less successful) states was the ability to integrate the results of experimental research within existing institutions.[3] But our question, and the evidence on which we rely, do not lend themselves to clean identification. In the section 'Alternative explanations', therefore, we consider other factors shaping the performance of the Greek states: these include processes of centralization, as well as the presence of resources, pre-existing levels of development, and the role of leadership. We provide evidence that allows us to put pressure on some of these factors, and acknowledge the possibility that others might also be at play. Our goal is not to provide a statistically robust causal explanation of the effects of learning on performance. Instead, we explore how learning occurred in the three states, focusing on the organizational and epistemic factors promoting or thwarting it.

The paper makes several contributions to existing literatures: first, we add to the literature on state capacity by analysing states – not just firms and individuals – as epistemic agents to understand how states build capacity over time. Second, we add to the literature on organizational learning by articulating some of the mechanisms whereby different learning models may lead to divergent performance. Third, we add to the literature on the political economy of ancient Greece by offering a comparative perspective on the role of knowledge for development – a topic already explored by others in the context of Athens (Hanssen and Fleck, 2012; Ober, 2008). Finally, we contribute to the literature on political development: by directing our attention away from Europe in the early modern period, where much work in economic history and historical political economy is concentrated, we explore how organizational factors within states may promote capacity-enhancing learning.

How do organizations learn?

Drawing from OT, we define learning as *the acquisition and incorporation of knowledge into an organizational structure* (cf. Argote and Levine, 2017).

[3]We lack data to measure the performance of the Greek states comparatively based on commonly used proxies like economic growth (we have data for Athens and Sparta, but not for Macedon). Our basic intuition about comparative performance in the 4th century relies on the fact that Macedon conquered Athens and Sparta (and much more). As such, our ultimate proxy for state performance is military success, a common proxy to evaluate state performance in premodernity, subsuming a range of more difficult-to-observe indices of state capacity, such as administration and extraction (Tilly, 1992).

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	Asymmetric	**Symmetric**
Clustered	Macedon	Athens
Non-clustered	Sparta	[bad for org. learning]

Figure 1. Models of learning in ancient Greece.

OT suggests that the *acquisition* of knowledge is facilitated when several factors are present across three levels of organizational structure. First, at the level of the individual components of the organization, knowledge acquisition depends on cognitive capacity, diversity, and expertise (Page, 2007). Second, at the level of the organization, two factors are critical: availability of resources and the institutional environment, including formal decision-making structures as well as norms and culture (Gibbons and Henderson, 2012; Henderson and Cockburn, 1994). Finally, at the interorganizational level, competition fosters effective learning by creating incentives to innovate (Allen et al., 2019; Callander and Harstad, 2015).

Effective *incorporation* of knowledge requires structures to enable routinization and integration within existing epistemic domains and hierarchies (March, 1991; Nelson and Winter, 1982). The integration may be conflict-free but, more often, actors who stand to be weakened by new practices will hinder development (cf. Acemoglu, 2008; Bueno de Mesquita, 2003; Garfias and Sellars, 2023; North et al., 2009; see also Allen and Leeson, 2015).

OT also suggests the importance of two sources of variation in organizational structure: (a) symmetry and (non-)clustering. Organizations where influence is symmetric – that is, where group members have the same influence – and non-clustered – that is, where every individual is equally likely to be connected to every other individual – tend to thwart effective learning because 'shared information receives disproportionally more attention than unshared information' (Puranam and Maciejovsky, 2017: 526). Organizations where influence is asymmetric (they feature, for example, a leader or an advisor) can improve learning, but leadership can also make things worse: in some studies, leaders improve the flow of information, but in others they make mistakes, for example by overweighing their own opinions (ibid. 527). Because evidence is scarce, Puranam and Maciejovsky suggest that this is a 'priority area for research into the link between organizational structure and organizational learning' (ibid. 528). Similarly, in organizations where influence is clustered – where individuals are not all connected with one another – connections must be forged across nodes or units to facilitate the flow of information (Tsai, 2002). These connections can be formal or informal, and both their existence and their topology – where they are situated within the organization – matters. One example is the role of bridging ties in networks: as the seminal work of Granovetter (1973) on the strength of weak ties shows, individuals or units that 'bridge' two nodes are critical to the diffusion of information. But not all connections foster effective learning. In other words, for clustering, as for asymmetry, design matters – but the question of what designs may facilitate learning in different organizations remains underexplored in the literature.

These insights from OT shape our case selection and design: we focus on three high-performing states in a highly competitive environment; and we study the institutions and norms that make up their learning models. As illustrated in Figure 1, our states vary across the two dimensions discussed in the OT literature: Macedon presents an asymmetric, clustered model; Athens a symmetric, clustered model; and Sparta an asymmetric, non-clustered model.

To understand how these models may affect state performance, we turn to the political economy of knowledge and innovation. Focusing on epistemic factors, this literature highlights a distinction between experiential and experimental knowledge and the capacity-enhancing effects of applying experimental knowledge to technological innovation. Studying early modern Europe after the scientific revolution, Mokyr (2002, 2005) suggested that the expansion of 'useful knowledge' – applied knowledge produced through experimental tinkering – fostered the emergence of impersonal

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organizations that reduced access costs, spurring technological innovation critical to the industrial revolution (see also Greif and Tabellini, 2017; North et al., 2009). Similarly, for Lin (1995), the scientific revolution entailed a shift from experiential to experimental knowledge that led to the reversal of fortunes between Europe and China: as long as knowledge was experiential, China's large size gave it an advantage over Europe; but when experimental knowledge made China's size futile, the integration of science and technology that occurred in Europe enabled the 'continuous shift to the right of the invention distribution function' associated with the industrial revolution (1995: 281). Such integration, in turn, had been possible in Europe due to a political environment that did not disincentivize elites from pursuing scientific work, as was the case in China.[4]

We combine these frameworks to explore the epistemic and organizational bases of state learning, documenting how different combinations of (a)symmetry and (non)clustering shaped the ability of Sparta, Athens, and Macedon to manipulate experiential and/or experimental knowledge toward capacity-enhancing goals.

State learning in Sparta, Athens, and Macedon

The 4th century presents developmental dynamics in need of explanation: why, after winning the Peloponnesian War and inheriting the lucrative structure of the Athenian empire, did Sparta experience a period of severe decline? Why was Athens, barely spared from annihilation but able to quickly regain geopolitical prominence, eventually defeated and conquered? And how did Macedon, historically an isolated backwater, manage to conquer not just Greece but territories all the way to the Indus river in the span of a mere forty years?

This section articulates the three states' learning models and how these shaped institutional and technological evolution in coercion, extraction, and administration. To illustrate the organizational structures that enabled Macedon to produce and incorporate experimental knowledge, we discuss the development of the torsion catapult.[5]

Sparta

At the beginning of the 4th century, Sparta occupied an enviable position. Success in the Peloponnesian War had vaulted the city to the head of the Greek world. When the conflict ended in 404, Sparta took over the network of dependencies of the Athenian empire, along with their tribute. This provided new administrative capacity and a great deal of wealth. However, Sparta's tenure as imperial hegemon was brief, and the state's subsequent decline rapid. Sparta's failure, we suggest, depends at least in part on the state's inability to perform as a learning organization.

Sparta's learning model featured organizations that privileged one sector of state activity – coercion – over the others; taxation and administration were entirely built to serve the needs of a professional class of elite soldiers. Within the realm of coercion, learning was asymmetric and non-clustered: knowledge of military matters flowed across the class of professional soldiers through social institutions – like the agoge, the dining clubs, and the army itself – where rigid hierarchy in the chain of command coexisted with a strong egalitarian ideology. Indeed, Spartan males were known as *homoioi* or equals. Below the *homoioi* was a population of serfs – the *helots* and *perioikoi*, living in the neighbouring territories of Laconia and Messenia – on whose productive activities Spartan society depended. The levels – citizens and serfs – required only a minimal crossflow of information, as we will see. In the language of OT,

[4]Although Mokyr's and Lin's arguments reflect outcomes in terms of state performance, state behaviour is neglected in their accounts.

[5]We do not mean to suggest that the catapult led to Macedon's success. It is unknown whether torsion devices were deployed before the conquest of Asia. Instead, we use the relatively well-documented organizational context of catapult development to illustrate how Macedon's learning model made possible the incorporation of experimental knowledge.

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individuals did not have the same influence (i.e., influence is asymmetric), but within each level individuals were equally likely to be connected to the others (i.e., influence is non-clustered).

In what follows, we draw from the available empirical evidence to describe how such a model operated in practice. We then proceed to articulate the model's limitations.

In the heavily militarized Spartan state, the army was a primary site of learning. Greek infantry warfare required soldiers to fight at close quarters, in disciplined lines, heavily armoured, and wielding long spears (~eight feet long). This combat formation rewarded extensive drilling, keeping ranks, and following orders. The Spartans spent a lot of time practising their military skills, and the ideology was strongly reinforced through social institutions. Spartan boys were trained in warfare from an early age in an educational system called the *agoge*. From the age of seven, they were divided by age cohorts into 'herds' which were led by a 'herd leader' of their own age. From the age of thirteen, boys engaged in more complex tasks, which included various team-based wargames and espionage exercises, often conducted against the subservient populations of Laconia and Messenia (Kennell, 1995). Within these groups, as in the army itself, Spartan males were trained to follow orders from their leaders and to consider each other as equals. Equality was also reinforced in the dining clubs (*syssitia*), to which each citizen was required to furnish equal quotas of food and drink: even Sparta's kings were enrolled in dining clubs – and while they received double portions, at public expense, the second was meant to be given to another Spartiate, to honour them (Hodkinson, 2009: 193ff.).

These resource-intensive military institutions extended coercive functions not just into the administrative structure of the Spartan state but also deep into the social fabric, structuring the education and conduct of citizens. The sources are impressionistic, yet telling: much of what was reported about the Spartan system in antiquity describes strategies of surveillance and public shaming to ensure all citizens equally performed an extensive (and costly) series of duties that included military service, marriage, and the production of children (Hodkinson, 1986).[6]

In the realm of revenue extraction, as in other areas of state activity, non-clustering among the privileged class of Spartan citizens coexisted with strong asymmetry between Spartans and non-Spartans. In a state averse to commercial exchange, where coinage was shunned and iron bars preferred as currency, revenue extraction relied on the agricultural labour of the *helots* and *perioikoi*. The mechanisms for revenue extraction were quite simple – the subjects handed over a significant proportion of their harvest every year and that surplus went to support the Spartan state (Figueira, 1984).

Extracting revenue from serf-like populations solved the problem of surplus wealth creation, but it created new problems: *helots*' rebellions were a source of constant fear among the Spartans – and they did occur quite often, especially at times of state weakness (Thuc. 1.101-2). These occurrences, in turn, contributed to justify the Spartan military state.

Sparta's learning model was peculiar, but not necessarily ineffective. In the 6th and 5th centuries, Sparta was the leading power in Greece because its institutions had transformed Spartan citizens into fearsome quasi-professional soldiers (Cartledge and Spawforth, 2002: 137). But the model presents two major bottlenecks: overcommitment to one area of learning and inability to incorporate innovation.

First, Sparta learned too well in the area of infantry warfare to the detriment of others. Learning for military training, as we saw, was deeply embedded within a web of social practices that circumscribed its scope and left little room for other types of learning. Moreover, even within the realm of coercion, knowledge acquisition and integration beyond hoplite fighting was looked upon with suspicion: one example, which we discuss at greater length below, is the rise and rapid fall of naval commanders at the end of the Peloponnesian war.

[6]It is harder to establish how much the economy reflected these patterns of asymmetry and non-clustering: the nature of the sources has generated significant disagreements in the scholarship concerning the system of land ownership, how inheritance worked, or the extent to which the state interfered with private property (Cartledge, 2002 [1979]; David, 1981; Hodkinson, 1986; Hodkinson, 2009).

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Such overcommitment to one area of learning is a common risk in organizations. Because competitive equilibria often reward organizations that cultivate extensive core competencies in particular fields, such expertise may persist long past its shelf life (Levitt and March, 1988: 323). Although the Spartans' focus on hoplite warfare served the state well early on, as neighbours caught up, and as other tactics and technologies were introduced, the Spartans found themselves stuck. In other words, an early investment locked Sparta into a suboptimal long-term path (Levitt and March, 1988: 323, 332). Organizations can and do adapt to such circumstances. But often, finding their critical strengths outmatched, they instead obfuscate cause and effect, moralizing failure and ignoring historical lessons (Weick, 1995: 153). This was the case in Sparta, which would continue to cultivate strength in infantry warfare for another century and a half – only now by selling expertise to other powers (Cartledge, 1987).

Second, Sparta refused to incorporate innovation. This problem emerges clearly in Sparta's approach to the threat of population decline. Because of its extremely restrictive citizenship criteria, Sparta had a relatively small, ever-shrinking, population of citizen hoplites. Aristotle called it *oliganthropia* – literally, 'fewness of humans.' Sparta did, at times, supplement its citizen hoplites with men from subservient classes. For instance, during the Peloponnesian War, Sparta recruited soldiers from the *helots*: they were called *neodamodeis* – literally, new people. However, no regular process was ever created to enable them to join the citizen ranks, and the creation of new *neodamodeis* was discontinued after the Battle of Mantinea in 362, just when Sparta most needed manpower (Cartledge, 1987: 328).

The same resistance to opening access to new citizens applied to new leaders. Unorthodox leaders emerged during the Peloponnesian War, especially associated with naval warfare – itself an innovation that emerged during the conflict. But, like the navy itself, the commanders were immediately shunted aside when the conflict ended. Many of these upstarts came from families of uncertain or inferior status: the so-called *mothakes*, for example, whose families were Spartan, but required sponsorship to stay in good standing (Hodkinson, 2015). Like the *neodamodeis*, the *mothakes* never earned a permanent place in the Spartan state (Cartledge, 1987; Runciman, 1990).

In sum, Sparta presents an asymmetric, non-clustered learning model serving one specific purpose – to build and maintain a class of professional soldiers. Such a model worked well to preserve a rigid social order on which Spartan society relied for survival, but it proved vulnerable to several bottlenecks and ill-suited to develop and incorporate new knowledge, particularly in areas other than hoplite warfare.

Athens

Unlike Sparta, Athens was not in good shape at the beginning of the 4th century. Whereas, in the preceding period, Athens stood out as an Aegean power, by the end of the 5th century things had taken a turn for the worse: defeat in the Peloponnesian War deprived the state of its empire, walls, and fleet; twenty-seven years of war and a plague decimated the adult male population; after the defeat, Athens devolved into civil war. Nevertheless, the Athenians managed to rebuild both their democracy and their economy on new bases and to introduce significant innovations in both areas. Athens in the 4th century was an effective learning organization. But its learning model, shaped by political constraints, proved unable to incorporate disruptive innovation.

Athens' learning model differed radically from Sparta's. This model – articulated by Josiah Ober in the influential book *Democracy and Knowledge* (2008) – depicts Athenian citizens participating as epistemic equals in overlapping political, social, and economic institutions, which exposed them to numerous fields of expertise relevant to the running of the city. Ober focused especially on institutions such as the *Boule,* where 500 citizens appointed yearly by lot prepared the agenda for the main decision-making institution – the Assembly. Rotation and term limits in the *Boule* meant that a significant proportion of Athenian citizens participated in its activities within their lifetimes. This system of selection also meant that knowledge and expertise travelled from one year's councillors to

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subsequent ones via participation in social networks, especially at the level of the deme – the main local administrative unit. If a network model could be derived from Ober's account, it would be that of a flat, or non-hierarchical, organization where strong bonding ties at the level of the single administrative unit, association, or occupation were scaled up via bridging ties forged through participation in political institutions (Granovetter, 1973).

In the language of OT, the Athenian model is symmetric and clustered: within and across institutions, individuals had the same influence. Symmetry was reinforced through democratic ideology – the belief that every citizen had the same power and ability to rule and be ruled in turn, as Aristotle put it (*Pol.* 3) – which permeated the Athenians' political, as well as associational and occupational life. Athens' model was also clustered, in that every individual was not equally likely to be connected to every other individual; in fact, as Ober suggested, learning was the product of many interactions among diverse people coming together across various institutions to effectively share dispersed knowledge. We see examples of such effectiveness across the three core state functions.

Fiscal policy underwent substantial changes in the period under consideration.[7] Although in the 5th century revenue extraction relied on the empire, in the 4th century it relied on commercial exchange in the harbour of Piraeus and the exploitation of natural resources from the Laurion silver mines. But increasing revenue extraction in these sectors required substantial institutional innovation. To incentivize economic activity in maritime commerce and mining, the Athenian state progressively expanded forms of institutional access to non-citizens, including slaves, resident aliens, and foreigners (Carugati, 2019). These actors acquired rights previously reserved to citizens: to litigate, to own land, to lease access to natural resources, and to form and participate in cultic associations. They did not, however, obtain political inclusion.

We see a similar gradual and instrumental approach in the reform of the system of taxation for funding the navy: around the year 357, the Athenian state replaced the *ad hoc* system of *trierarchies* with a regular system of *symmoriai*. Before the reform, the burden of funding a warship and paying for crews and equipment fell upon individual elites (or pairs). After the reform, clubs of rich men were allowed to pull resources and split the cost: this reform put the city's single biggest line item – the navy – on a more secure footing (Gabrielsen, 1994). But it did not break with the traditional pattern of voluntary elite taxation.

Similarly, in administration, a notable reform of the period is the *merismos* – a system used to centrally distribute funds to various magistrates to increase transparency in public spending. This system was first used for one specific fund and later extended to others (Davies, 2004: 507).[8] Once again, we see the tendency to promote gradual change through the manipulation of experiential knowledge.

Finally, in the realm of coercion, the Athenians developed early on (soon after the Persian wars) a form of naval warfare that centred on a ship known as the trireme. But in Athens there was no naval equivalent of the *agoge* – rowers were not trained in a punishing, structured educational system. As the Old Oligarch tells us (Ps.-Xenophon, *Const. Ath.* 19), the Athenians did learn to row starting from an early age (not childhood, but probably as soon as they could row effectively), but usually working first on merchant vessels and then on military vessels: this practice stimulated the acquisition of tacit knowledge across overlapping, life-long activities at sea. Throughout the 5th and 4th centuries, the Athenians continued to maintain, and at times expand, their navy, but the adoption of new technology, or innovations in fields other than naval warfare, was limited (Garland, 1987: 100; cf. section 3d).

[7]On Athenian reforms in the financial sector (such as banking institutions, insurance, loans policy, interest rates, and currency protection): Bitros et al. (2020).

[8]Reforms like the *merismos* have been attributed to individuals, like Eubulus and Lycurgus, belonging to a class of "experts" that rose to prominence across Greek states in the second half of the 4th century. Athens was a prominent home for fiscal experts, and Sparta and Thebes were famous for their military experts. These people were hired abroad by non-Greek states, including Macedon, to help with reforms there. Callistratus, whom we will hear about in the next section, is a case in point.

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As in Sparta, so in Athens, the constraints on effective learning can be ultimately traced to questions of political survival. At the end of the Peloponnesian war, Athens experienced a severe and protracted constitutional crisis. In response to the crisis, the Athenians significantly reformed their political institutions Although in the 5th century the Assembly held the uncontested power to pass new legislation, in the 4th century, the decision-making process featured a complex system of checks and balances among several institutions (the assembly and *nomothesia*, coordinated via new procedures to pass and amend legislation). The new structure was created to limit the excesses of unchecked assembly power, which during the war led to many infelicitous decisions – first and foremost the disastrous invasion of Sicily.

The new institutions embodied principles that today we associate with the notion of rule of law (Canevaro, 2017; Fleck and Hanssen, 2019) and, like modern rule of law institutions, they were established to enable the state to commit to policy (Weingast, 1997). However, the costs of commitment rise during wartime or other crises: today, we see modern states suspending the rule of law in emergencies – declaring martial law, for example; similarly, Rome resorted to a *dictator* during crises, who would take over executive powers for a short period of time. The Athenians, having no formal executive branch, had no simple way to suspend the rule of law. So, in the aftermath of the defeat, the constitution was rebuilt to promote relatively conservative policy change: in the Assembly, as in the law courts, where legislation would be reviewed if challenged as unconstitutional (through the *graphe paranomon* and *graphe nomon me epitedeion theinai*), the new structure encouraged decisions that reflected the preferences of the median voter. This structure did not thwart change *per se*, but it did make it harder to pass reforms that significantly departed from the status quo (Carugati, 2019; Carugati et al., 2021; Halkos et al., 2022).

In sum, Athens presents a symmetric and clustered learning model that effectively harnessed dispersed knowledge toward capacity-enhancing goals in all areas of state activity. But the model also privileged reforms that resulted in gradual improvements upon existing practice. Disruptive innovation was likely to attract additional scrutiny, and failure to convince the demos of its potential benefits for the collectivity could lead to harsh punishment for the would-be reformers. It is then no surprise that those who pursued experimental research – including Plato, Aristotle, and their students – and the institutions in which they pursued it – the Academy and Lyceum – were regarded with suspicion and indeed considered antidemocratic by the demos (cf. section 'The torsion catapult').

Macedon

Like Athens, Macedon began the 4th century in bad shape. While resource-rich, the state had always been weak compared to its southern neighbours. Macedon's capacity began to increase when Philip took the throne in 359. Philip succeeded his brother, Perdiccas III (r. 365–360), killed in a disastrous invasion of Illyria. After the defeat, Philip was left with a state on the brink of collapse, with foes on every side. But, within four decades, Macedon grew from a regional power on the Greek periphery to one capable of toppling the mighty Persian empire. An important factor, we suggest, was the state's effectiveness as a learning organization.

Macedon's learning model combined elements of both Athens' and Sparta's. Like in Sparta, influence was asymmetric: a king sat at the top of the political hierarchy and a royal court of territorial barons controlled the regions outside of Pella, the capital. Moreover, like in Athens, influence was clustered: knowledge flowed through multiple institutions and organizations – such as the army or domain-specific research institutions – but the resulting network looked very different. As we saw, Athens' featured institutions in which people participated as epistemic equals in a flat organizational structure made up of bonding and bridging nodes. In Macedon, instead, the king played a pivotal role in shaping and controlling learning organizations.

This model fostered the development and integration of experiential and experimental knowledge without the blowback that sometimes accompanies reforms. Ober (2015) suggested that Philip's ability to avoid blowback depended on the alignment of interests between Philip himself and other social

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classes, including the elite and the masses. But there are reasons to put pressure on this view: as we will see, many of Philip's reforms were in fact detrimental to the interests of the Macedonian elite. The question of how Philip avoided blowback in response to his capacity-enhancing reforms, then, requires a more robust explanation.

To get there, we begin by articulating Macedon's learning model. As we did for Sparta and Athens, we focus on knowledge production and incorporation across three state functions: coercion, administration, and extraction. We then discuss the development of the torsion catapult, which helps us articulate Macedon's approach to developing and integrating experimental knowledge.

In the realm of coercion, Philip made substantial changes to the structure he inherited from his predecessors. Borrowing from, and innovating upon practices developed by Sparta and Thebes, Philip developed a new style of infantry warfare.[9] Like the Greek phalanx, the Macedonian version relied on long, deep lines of infantry, but Philip lengthened the spear (*sarissa*) to almost twenty feet and lightened soldiers' armour. A spear so long required two hands, so Macedonian soldiers carried only a small shield slung over the shoulder. These changes made soldiers more effective, but also rendered the formation vulnerable to missiles. As such, the Macedonian phalanx relied on tremendous discipline and a willingness to hold together in spite of losses. This, in turn, required professional drilling and significant experience. Such intensive training was expensive, and it demanded a considerable pool of disposable manpower, something that Macedon had and that other Greek states – with their smaller numbers of citizens – did not. Philip, then, took existing practices and improved upon them experientially, leveraging Macedon's strengths.

The new style of warfare depended, in turn, on changes in administrative and social structure. Philip rooted the phalanx not in the aristocratic stratum, but rather much more broadly: shepherds and other non-elites were incentivized to undertake military service (Arrian, *Anabasis* 7.9.2ff.) and the new soldiers were enfranchised as *Makedones* – citizens of the Macedonian kingdom.[10] For the next two centuries, the reformed phalanx was central to Macedonian warfare, alongside the aristocratic cavalry and other supporting units. As such, its elevation directly impinged on the prerogatives of other groups – a dynamic that hindered reforms in other states, as we saw in Sparta. But, as in Athens, so in Macedon, inclusion of previously marginalized groups was limited and instrumental: if the status of *Makedones* benefited the recipients, it was neither extended beyond the cadre of citizen soldiers, nor did it confer extensive rights.

A professional army requires not just manpower, but also money. Fiscal and financial reforms were therefore high on the agenda. In the first three years of his reign, Philip captured and began to exploit the gold mines of Mt. Pangaion and the 'hill of Dionysus' (Lane Fox, 2011: 367–368). Like other natural resources, including profitable forestry concessions, the mines were the direct domain of the crown and could thus be used at the king's discretion (Hatzopoulos, 2011: 48).

Philip also worked to make revenue collection more efficient. We have only a very small window onto these reforms, but what we see is significant. Once again, Philip relied on expertise already developed by his southern neighbours: he hired an Athenian named Callistratus – a prominent democratic politician who was exiled in 361 – to advise on tax collection practices. The clearest piece of evidence comes from the city of Methone, where Callistratus advised lowering the up-front cost of bidding on the right to collect the harbour tax from twenty talents to roughly a third of that amount (Aristotle *Economics*, 1350a16-22). This change had the effect of almost immediately doubling harbour revenues, since bidders from a wider circle, requiring less ready cash, were able to participate in the auction. Here, as for other reforms, the change impinged upon elite privileges – in this case, those of local magnates who dominated tax farming by keeping bids artificially high (Ober, 2015: 284–85).

In sum, Macedon's learning model enabled effective production (by borrowing wholesale and/or adapting) and integration of knowledge, and we have evidence of important reforms across all three

[9]Borrowing from Greek states continued in the Hellenistic period: Economou and Kyriazis (2019).

[10]Being a Makedones gave people the right to participate in citizen assemblies, but it remains unclear how influential such gatherings were (Hammond, 1994: 25–26; Hatzopoulos, 201: 72–73; Lane Fox, 2011: 360).

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state functions. Within this model, Philip played a prominent role in identifying domain expertise and deploying it toward capacity-enhancing goals. But in the examples discussed so far, integration depended, at least in part, on the fact that the reforms, while capacity-enhancing, were also gradual and incremental. We saw a similar strategy in Athens. But, unlike Athens, Macedon also proved capable of building and integrating new knowledge through (quasi-) experimental methods, leading to significant breakthroughs. These processes are nowhere as clear as in the development of the torsion catapult.

The torsion catapult

The torsion catapult was one of the most advanced technological innovations in Greek warfare in the period under consideration (Cuomo, 2007) – an example of the kind of risky and expensive endeavour that, if successful, could give early developers a significant advantage over their competitors. Catapult development offers a window into the learning processes that developing breakthrough innovation required – processes that neither Sparta, nor Athens, proved capable of pursuing.

The invention of the torsion catapult in Macedon centred upon a research institution that brought together trained Greek engineers. In Athens, as we saw, such research institutions were looked upon with suspicion, while in Sparta none developed outside the domain of infantry warfare. But in Macedon these institutions thrived. We highlight three reasons.

First, Philip proved particularly successful at securing the services of domain experts. In the porous and competitive environment of ancient Greece, experts were free to move around and work for the highest bidder (Ober, 2015). Philip had resources at his disposal, including revenue streams from mining and forestry concessions. These resources were probably on par with those of Athens, which, in this period, was the most prosperous state in Greece (Ober, 2015). But, unlike Athenian statesmen, Philip was able to spend considerable sums on these experts without having to ask for permission (Athen. 9.58; Cic. *Tusc.* 5.91).

Second, in Macedon, research institutions were closely integrated within existing institutions. The catapult workshop was run by a man named Polyides of Thessaly, who brought students with him and trained new ones in Pella (Marsden, 1977: 220). One of these was Posidonius the Macedonian, who went on to design the famous *helepolis* siege towers employed by Alexander and his successors (Marsden, 1971). Moreover, we know from Vitruvius (Vitr. 10) that one of Polyides' students, Diades, who eventually took over the role of lead engineer, went on campaign with Alexander (Murray, 2012: 903.4 99). In other words, soon after the technology was invented, the workshop and its engineers were integrated directly into the army, where Macedonians and non-Macedonians alike could make significant contributions (Cuomo, 2007: 47, 71; Marsden, 1977; Murray, 2012: 87ff.).

Finally, the workshop was likely to have been connected directly to Philip and the royal court, where it was shielded from scrutiny, popular or otherwise. Although we lack robust direct evidence from Macedon, the practice was common elsewhere, as the model was popular among Greek autocrats in the 4th century, and became widespread in the Hellenistic period (Diod. 14.41.3-14.43.4).[11] Like later monarchs, Philip probably established personal relations with his engineers, taking a direct interest in technological advancements (Vitr. 10.4).

As he had done in other fields, Philip could build and integrate these research institutions without creating blowback from existing social actors. Part of the explanation lies in the position of the monarch himself. As suggested above, unlike democratic Athenian politicians, or even the Spartan kings, Philip did not have to go through an assembly of his peers or complex constitutional checks and balances to use revenue to fund risky endeavours. This was true of other autocrats, but Philip may have further benefited from the strength of the Argead dynasty – which by the middle of the 4th century, had ruled Macedon for over 250 years – and from his own leadership capabilities (Davies, 1983). There were also contextual factors that weakened the Macedonian elite: first, as we saw, elites in Macedon did

[11]Notable examples are the Library of Alexandria, directly sponsored by the king starting with Ptolemy I, and the Library of Pergamum, sponsored by the Attalid dynasty.

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not control the bulk of the resources that were needed for state building; second, the defeat that preceded Philip's accession to the throne had contributed to unseat entrenched elites (Ober, 2015: 251). The lack of significant political rivals within the state meant that Philip's projects and priorities could be pursued without much resistance.

The second reason had to do with the type of institution created to support experimental learning. In Macedon, this was a delimited space funded by the state but not beholden to political imperatives outside of the functional domain of the experts themselves. Such research institutions pursued their learning and investigation independently of other special interests, be they those of the elites or the people. Other Greek states typically regarded these institutions with suspicion. This is evident, as we saw, in Athens' attitude toward the Platonic Academy or Aristotelian Lyceum whose illustrious predecessor – Socrates – was famously murdered by the democracy.

Neither in Sparta, nor in Athens, do we see an eagerness to develop, or improve upon, catapult technology. Sparta's reaction can be illustrated through a famous anecdote about King Archidamus III: having seen an early catapult while in Sicily, and horrified by its operation, the king is alleged to have cried out, 'By Herakles, they've destroyed manly valor!' (Plutarch *Sayings of Kings and Commanders*, 191e). This reaction, true or not, neatly captures the attitudes of Sparta's elite. Not only did catapults require a deviation from hoplite tactics – involving a set of skills Spartans had no interest in mastering or even understanding; they also replaced the valour and courage of battle with mechanical, cowardly, projectile weapons. And, in fact, we hear nothing about the use of catapults in Sparta until 204, almost two centuries after their adoption elsewhere (Marsden, 1969: 167). The Athenians proved much less hostile to catapult development: once the technology became available, they displayed an interest in acquiring and routinizing relevant knowledge and expertise. In fact, catapult training was incorporated in the ephebic curriculum essentially as soon as it became available (between the 360s and 330s: Cuomo, 2007: 63). But Athens remained a follower in the development of catapult technology, merely keeping up with innovations pioneered elsewhere.

Alternative explanations

The roots of Macedon's success have received some attention in historical scholarship. The most influential explanation centres on Macedon's 'cheap and scalable' centralized structure, which is contrasted with the more 'expensive' decentralized ones of Athens and Sparta (Davies, 1995; Ober, 2015; Runciman, 1990). In particular, for Ober (2015: 278–281), centralization fostered political control and ease of decision-making, enabling rulers to bypass the complex checks-and-balances structures common elsewhere in Greece.

This argument echoes the conclusions of a vast literature on the early modern period suggesting that 'the consolidation of power under a central authority lays the foundation for the construction of state capacity and longer-term institutional and economic development' (Sellars and Garfias, 2023: 1). Centralization fosters development by making revenue extraction more efficient (Besley and Persson, 2009, 2011; Dincecco and Wang, 2022; Tilly, 1990; *contra* De Vries and Van Der Woude, 1997; Economou and Kyriazis, 2019).

In both literatures, learning processes are sometimes considered, but they are viewed as a by-product of centralization. According to Ober (2015), centralization in Macedon favoured learning by enabling Philip to borrow and adapt foreign practices, particularly in the realms of taxation and coercion. In the early modern literature too, centralization favours effective learning: according to Hoffman (2012), among the European states involved in the winner-take-all tournament of gunpowder technology development, those that learned more effectively were also those in which the sovereign had more control over fiscal revenue.

The argument about the role of centralization for development, however, does not hold up to further scrutiny in the context of Greece. First, processes of centralization became common in 4th century Greece among several states on the periphery of the Greek world. These states were characterized by monarchic government, typically with large geographic footprints, and an eagerness to adopt successful

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institutions and technologies – especially fiscal and military practices – from places like Athens (Davies, 1993; Ober, 2015). Yet, among them, Macedon stood out. As a result, centralization alone appears as an insufficient explanation.

Moreover, if we define centralization as a process whereby core state functions – such as coercion, revenue extraction, and administration – become concentrated in the hands of a ruler or group that sits at the top of the political hierarchy (Tilly, 1990), then Athens, Sparta, and Macedon were all centralized in significant respects: in Athens, several central institutions – including a popular assembly, a council, magistrates, and courts – considered and executed all decisions concerning fiscal, administrative, and military matters; the same was true for Sparta, though the institutions differed (here, central institutions featured two kings, five ephors, thirty elders, and a popular assembly); in Macedon, the king and his Companions may have made the bulk of the decisions, but they also relied on local elites to obtain additional revenue and military contingents. Explanations that focus on variation in centralization, then, may be conflating centralization with autocracy.

The question of the causes of Macedon's success is otherwise understudied in ancient history because scholars rarely seek to adjudicate cause and effect (e.g., Hatzopoulos, 1996; Worthington, 2014). There are, however, other possible explanations. Political scientists will easily spot at least four from the discussion above.

First, it is possible that Macedon had more resources to spend on experts. As we suggested above, explanations based on resource endowments may go some way toward explaining Sparta's comparative decline, but they fail to account for the divergence between Athens and Macedon: after all, Athens was by far the richest state in Greece in the mid-4th century.

Second, unlike Sparta or Athens, Macedon was a 'latecomer' to development (Gerschenkron, 1952): by the time Philip took the throne, Macedon, which had never been a powerful state before, was nearly collapsing due to the military failures of his predecessor. Philip's reforms, which jumpstarted the process of centralization and development essentially from scratch, created the conditions for significant gains. But this account cannot quite explain how Macedon managed not just to match, but also to surpass its rivals – and go on to conquer a good chunk of the world.

Third, Macedon's success may have depended on its political geography (Redding and Venables, 2004): as we discussed earlier, without the expertise flowing in from its highly developed neighbours, Philip's fiscal and military reforms would have been unthinkable. Political geography may have played a role, but it can hardly account for Macedon's success on its own: simply stated, Macedon had great neighbours well before it became great itself.

Finally, Philip's leadership also played a role. The historical literature attributes to him (and to Alexander) extraordinary qualities – intelligence, perseverance, foresight (see Davies, 1983) – and leadership has been identified as an important ingredient in processes of political and economic development, historically and today (Alston et al., 2016; Alston, 2017). As we showed, asymmetric influence is one ingredient of Macedon's success, but asymmetry per se is an insufficient explanation: neither Sparta (whose symmetric structures arguably differed), nor other Greek states led by intelligent autocrats managed to achieve what Macedon did.

Conclusion

In this paper, we studied states as agents of knowledge production and management. Combining insights from organizational theory and the political economy of knowledge and innovation, we derived a framework to study learning processes in three high-performing and well-documented Greek states. We suggested that clustering and asymmetry combined in Macedon to enable the production and smooth integration of new knowledge, including risky and potentially disruptive new knowledge, which gave the state an advantage over its competitors.

As in early modern Europe, so in 4th century Greece, changes in the nature and technology of knowledge created opportunities for significant advances in state capacity. But the mechanisms differ. According to Lin and Mokyr, Europe's takeoff rested on the incentives for elites to pursue scientific

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work and on the evolution of impersonal organizations that lowered costs of accessing knowledge for the wider public. For others, decentralization and weak central power were key to stimulating innovation (Economou and Kyriazis, 2019; De Vries and Van Der Woude, 1997). In Greece, by contrast, capacity gains accrued to those states where the decision to pursue scientific work was made from the top down.

Our findings also contribute to the related debate on the role of the state in fostering innovation in a multipolar international context, as well as the relative advantages of autocracy and democracy (Farrell and Schneier, 2018; Harari, 2018; Mazzuccato, 2018). The analysis supports the conclusion that democratic regimes might find themselves at a disadvantage when it comes to harnessing technological innovation, but also that the 'autocratic advantage' some contemporary states are alleged to have should be evaluated in light of a particular state's learning model.

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