Why Was It that Europeans Conquered the World?

Philip T. Hoffman[1]
Caltech (pth@hss.caltech.edu)
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By the eighteenth century, Europeans dominated the military technology of gunpowder weapons. Their dominance was surprising, because the technology had originated in China and had been used with expertise in East and South Asia and the Ottoman Empire. Historians have often invoked competition to account for the Europeans' military prowess, but competition cannot explain why they forged ahead in developing this technology. The answer lies in the peculiar form that military competition took in western Europe: it was a tournament that induced European rulers to spend heavily on improving the technology of gunpowder weapons. Political incentives and military conditions kept such a tournament from developing in China, Japan, India, and the Ottoman Empire, and as a result rulers had much less reason to push the gunpowder technology, which had enormous advantages for fighting war at a distance.

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In recent years, historians, economists, and other social scientists have energetically debated when Western Europe first forged ahead of other parts of the world–in particular, advanced parts of Asia–in the race toward economic development. Was it only after 1800, with the Industrial Revolution well underway, that Western European per-capita incomes, labor productivity, or technology diverged? Or was it earlier, before the Industrial Revolution? And what was the cause of the divergence? Was it beneficial institutions, which stimulated investment and the accumulation of human and physical capital? The evolution of cultural practices that encouraged hard work and education? The Scientific Revolution and the Enlightenment, which spread useful knowledge and political reform? Or was it simply an accident that the Industrial Revolution started in Western Europe?[2]

In this debate, one area in which Western Europe possessed an undeniable comparative advantage well before 1800 seems to have been overlooked–namely, violence, or at least violence with gunpowder weapons.[3] The states of Western Europe were simply better at making and using artillery, firearms, fortifications, and armed ships than other advanced parts of the world and they had this advantage long before 1800. They used the gunpowder technology to wage war at home and establish outposts abroad. By 1800, the Europeans had conquered some 35 percent of the globe, and they controlled lucrative trade routes as far away as Asia.[4] Some of the land they subjugated had come into their hands because of new diseases that they introduced into vulnerable populations, and in these instances–in the Americas in particular–their advantage was not just military, but biological as well.[5] But other inhabitants of densely populated parts of Eurasia would

have had the same biological edge. Why was it therefore the Western Europeans who took over the Americas, and not the Chinese, the Japanese, or the Indians?

The history of conquest is not the only evidence for Western Europe's military advantage before 1800. States elsewhere–China, Japan, and the Ottoman Empire–certainly possessed firearms or ships equipped with artillery, but by the late seventeenth century, if not before, nearly all of them had fallen behind in using this technology, which we will label the "gunpowder technology." The case of the Ottoman Empire is illustrative. There the military gap may reach back as far as 1572, when Venetian cannon founders judged that guns captured during the naval battle at Lepanto were simply not worth reusing. The Ottoman cannons had to be melted down–and new metal had to be added to the mixture–because "the material is of such poor quality."[6] At a time when the high cost of manufactured goods meant everything was salvaged—even clothing from fallen comrades—that amounts to strong evidence from revealed preference about how much better Western European weapons had become. The history of trade and the migration of military experts points in the same direction. Although the Ottomans had a "robust ordnance industry" and could threaten Vienna as late as 1683, they did import weapons from western Europe and often relied on the expertise of European military specialists.[7]

The Ottoman Empire was hardly exceptional. From the Middle East to East Asia, experts from Western Europe were hired throughout Asia to provide needed help with gun making, tactics, and military organization. They ranged from renegade European gun founders in the sixteenth century to Napoleonic officers the early 1800s. In seventeenth-century China, even Jesuit missionaries were pressed into service to help the

Chinese Emperor make better cannons. The evidence for Western Europe's military prowess is so strong that it has even convinced some of the historians who argue against any divergence between Western Europe and prosperous parts of China before 1800. Although they argue that Western Europe was not wealthier or more developed than rich areas of China, they admit that its military technology was more advanced.[8]

The evidence is thus fairly clear, but it is nonetheless surprising that western Europe had come to dominate this technology of gunpowder weapons so early. Firearms and gunpowder, after all, had originated in China and spread throughout Eurasia. States outside Western Europe possessed the revolutionary weapons and did become, at least for a while, proficient at manufacturing or exploiting the new military technology. The Ottomans, for instance, made high quality artillery before Lepanto.[9] And the Japanese discovered—some twenty years earlier than Western Europeans—the key tactical innovation (volley fire) that allowed infantry soldiers with slow loading muskets to maintain a nearly continuous round of fire.[10] Yet by the late seventeenth century, if not before, Chinese, Japanese, and Ottoman military technology and tactics all lagged behind what one found in western Europe.[11]

Why did these other powerful states fall behind? This question has attracted a number of gifted military historians, but most simply describe the Europeans' proficiency, without unearthing its underlying causes. The closest they come to a deeper explanation is the claim that military competition in Europe gave the Europeans an edge. The argument, which dates back to Gibbon, has been formulated most cogently by Paul Kennedy, who points to Europe's competitive markets and persistent military rivalries. While military rivalry created an arms race, competitive markets encouraged military

innovation and kept one country from establishing an empire.[12] That would explain why the military sector in early modern Europe turns out to have experienced rapid and sustained productivity growth—an outcome unknown in other parts of the economy.[13]

Competition, however, is not the final answer. Although it is a first step in the right direction, there is more that needs to be explained. First of all, competitive markets do not always stimulate innovation. The clearest example comes from agriculture in early modern Europe, which had highly competitive markets but witnessed virtually no productivity growth.[14] What kept early modern European farmers from reaping the productivity gains of soldiers and sailors?

Nor do ongoing military rivalries always stimulate innovation. They in fact failed to do so in eighteenth-century India and southeast Asia. The case of India, as we shall see, is particularly illuminating, for like Europe it had markets and incessant warfare, and the combatants were quick to adopt the latest weapons and tactics. The innovations, however, by and large originated in the West.

The answer to this conundrum lies with the peculiar form of competition that European rulers were engaged in up until 1815. It was not the garden variety economic competition that prevails among small entrepreneurs who maximize profits and at least in theory pay no attention to other firms. Rather, it was political competition in what economists would call a winner take all tournament. Competitors in such a tournament—in contrast to the idealized small entrepreneurs—must pay attention to one another, because their relative standing determines who wins a single prize. And doing worse does not simply reduce their profits, as with entrepreneurs; rather, it means they win nothing at all.[15]

A tournament of this sort had long engaged the monarchs of Europe, and tournaments among rulers existed in other parts of the world as well. Under the right conditions, they spurred rulers to improve military technology in the broadest sense of the word, even at the expense of the rest of the economy. In early modern Europe, the conditions were conducive to advances in military productivity. Elsewhere, however, they were not. Understanding why requires a look at the political, military, and fiscal incentives rulers faced, both in Europe and in other parts of Eurasia. It also requires a glance at the costs and benefits of other military technologies.

1. The tournament in Europe and its consequences

The states that coalesced in Europe in the waning days of the Middle Ages by and large had a single purpose, at least if we judge by what they levied taxes and borrowed money for. That purpose was clearly warfare. True, funds were spent on justice and palaces, and there was a pittance for transportation and famine relief. But particularly in the major powers, some 40 to 80 percent of the budget went directly to the military, to defray the costs of armies and navies that fought almost without interruption (see Table 1 for the frequency of battles). The fraction of the budget devoted to war climbed even higher—to 95 percent in France during the 30 Years War—if we add sums spent subsidizing allies or paying of the debts of past wars.[16]

In early modern Europe, decisions about war typically lay in the hands of a ruler such as a king or a prince. He would of course be advised by councilors and influenced by elites, and an influential minister (a Richelieu or Olivares) might sometimes be

dictating most of the decisions. But the assumption that a king or prince made the decisions about war is not far from historical reality. Even in eighteenth-century Britain, where Parliament and the cabinet decided whether to commence hostilities, the choices about the conduct of the war once it had begun were up to the king.[17]

What then made European kings take up arms? That question has to be answered if we are to understand what the tournament was. In Europe's major powers, the rulers often won control of warfare in the process of assembling their states in the late Middle Ages or the sixteenth century. They might have constructed their states by defeating domestic and foreign rivals, but typically they offered even conquered provinces protection from foreign enemies, in return for tax revenue. In modern terms, one would say that they provided the public good of defense in return for taxes.

That public good was precious, as anyone who suffered through the horrors of the 100 Years War in France or the 30 Years War in central Europe could testify. But the rulers of early modern Europe likely provided far more defense than their average subject would have wanted. The reasons were not hard to understand. The kings and princes had been raised to fight one another, with toy soldiers, pikes, and firearms as children and actual training in their youth. Advisers like Machiavelli might tell them that princes "ought to have no object, thought, or profession but war." Their own fathers would teach them that war was a path to glory, a means to "distinguish [kings] . . . and to fulfill the great expectations ...inspired in the public," in the words of Louis XIV's instructions for his son. They took the lesson to heart and once enthroned often surrounded themselves with images exalting their role as military leaders or glorifying the martial exploits of their reigns, as Louis XIV himself did at Versailles. And they pursued war with gusto, at

least if they ruled over a major power. Fighting had gone beyond the needs of defense and become, in the words of Galileo, a "royal sport."[18]

Glory did recede as a motive for war in the eighteenth century, when the major powers might fight simply to preserve their reputation, to gain commercial advantage, or to snatch territory from weaker neighbors. But war was still "what rulers did," the normal target for their ambitions. It continued to appeal to them, just as it long had attracted much of the European aristocracy.[19]

For the major monarchs of early modern Europe, victory was thus a source of glory or a way to enhance their reputation. They could gain smaller amounts of prestige by fighting, or even by raising a large army. Grabbing territory from small neighbors would add to their standing and augment their resources. And although they might lose small amounts territory themselves, they faced no major downside risk to their thrones, at least in the larger states. Smaller principalities might be swallowed up if defeated, but for western Europe's bigger powers, loss in battle in anything but a civil war never toppled a monarch from his throne, at least in the years 1500-1799 (Table 2).[20] Nor did warfare threaten Europe's kings and princes with personal financial ruin, for the funds to pay for war by and large came from tax revenues, not from the rulers' own possessions. Although they might worry about tax revolts, the negotiations that went into to the construction of the larger European states insulated powerful elites from many of the tax increases. Without backing from the elites, the revolts were less of a threat.[21]

Europe's major monarchs thus had every reason to fight and even stronger reasons to outdo their neighbors and win victories. They would have an incentive to vie with one another for a prize that would go to the winner and they would really exert

themselves, because victory would depend on beating or outlasting their enemies. Of course not all rulers would participate. Some countries would be too small, and others (the Netherlands in the eighteenth century, for example), though big enough to fight, would bow out, or at least not enter a particular war.

Such a contest is an example of the economists' winner take all tournament. Potential contestants can choose whether or not to join in, and the reward that motivates them depends on their relative performance. To win the prize, they exert effort, which may be harder or more costly for some potential entrants than others. If the reward is large, the effort elicited can be huge, so long as there are at least two contestants.

This sort of tournament is what drives top notch athletes, such as a talented baseball player, to drastic measures in the quest for success. The prize the baseball player seeks is a professional career, and victory depends on whether he is better—even by only a tiny amount—than other players. He is therefore likely to go to extremes—such as taking steroids that may harm him later in life—just to get that slight margin of victory. A tournament, it has been argued, is also what justifies the pay of corporate CEOs. Their huge compensation packages are the prize that motivates lower level executives to push themselves in the hope of someday becoming CEO's themselves. Tournaments are also used to promote research and improve technology. The United States Defense Department has in fact run tournaments to choose whether Lockheed or Northrop would develop an improved jet fighter, and it has sponsored a recent one to support research on robotic vehicles.[22]

Here skeptics may complain that the notion of a tournament really adds little and that it seems little more than a complex label stuck on the older and altogether adequate

idea of competition. Yet a closer look at the features of winner take all tournaments should help put that objection to rest, particularly if we look more closely at the tournament in early modern Europe and compare it with military rivalries elsewhere in the world. (For a formal treatment of what follows, see the appendix and the brief description of the economic model in the next section.)

To begin with, there is one feature of tournaments that clearly distinguishes them from garden variety economic competition, as we can see by varying the number of entrants who compete. In a tournament, if only one competitor enters—one prince, for instance, in early modern Europe—he will exert no effort at all. He does not have to, because his prize is guaranteed. In a market, by contrast, a single entrant, such as the lone firm making a product, may well exert itself, because it can sell goods at a monopoly price. The monopoly rights may in fact give the firm a powerful incentive to do research that will make its monopoly even more valuable. A single competitor in a tournament would never behave that way.

Other differences emerge as the number of competitors grows. In a market, competition increases with the number of entrants, but that need not be so in a tournament. Indeed, under certain conditions, the total effort expended may even fall as the number of entrants rises above two, for the odds of winning fall, which reduces the expected value of any prize. Someone who designs a tournament can in fact usually achieve any desired level of effort at lowest cost in term of the prize that has to be offered simply by limiting entry to two competitors.[23] In a tournament, therefore, what matters is having more than one entrant. Two is enough; drawing in additional ones will not always increase effort and may even reduce it, in stark contrast to market competition.[24]

Two was the number of competitors the tournament in early modern Europe often attracted, particularly if we take into account the alliances between countries. The Hapsburgs battled the kings of France in the sixteenth and seventeenth centuries, and the English fought French in the eighteenth. Other sizeable powers—the Swedes and the Dutch—dropped out, while smaller countries simply did not participate, except perhaps as allies. Treating the alliances in this way is admittedly a simplification, for it assumes that they were decided in advance, before the tournament began, and that rulers had ways to ensure that their allies would exert effort too. But such an assumption is not unreasonable. Alliances were often concluded before hostilities started and then sealed by marriages, treaties, or agreements about division of the spoils from war. And they rarely broke down during wars, even in the eighteenth century when they seemed lose a bit of their stability.[25]

The prize in the European tournament was apparently valuable enough to get the rulers of Europe to expend effort. The value of the prize must of course be measured relative to the costs of joining the tournament, which would include the expenses involved in setting up armies, navies, and fiscal systems, and the political costs of raising taxes to fund the military. Those political costs could not have been too high.

What did all this effort go for? It went to pay for larger armies and navies and to improve tactics, logistics, and military technology. Gunpowder weapons required centralized revenue and expenditure, particularly when armies and navies swelled and the technology improved. In an era before nationalism motivated troops, armies had to be centralized, for if soldiers (many of whom were mercenaries) were scattered across a country, desertions would soar. The cost of shipping supplies to the infantry also

encouraged the centralization of armies, and it had a similar effect on navies. Countries that could organize more effective provisioning could prevent mutinies and desertions and retain the loyalty of veteran troops, who often provided the margin of victory.[26] As for navies, they needed suitable ports, meaning ones which could easily be defended and which, at least by the eighteenth century, would be deep enough for ships of the line. The scarcity of such harbors also favored centralization.[27] Fortifications had the same effect. It was extraordinarily expensive to build them large enough to house a defensive battery of cannons and strong enough to stand up under an siege, and their design required the expertise of skilled military architects. The cost put them out of reach for small principalities and limited the number that could be constructed. Even in large kingdoms the money devoted to fortifications had to be allocated carefully, so as to protect frontiers, key passes, and vulnerable cities or harbors.[28]

The clearest mark of all this effort was huge great increase in the tax revenues that central governments collected, at least among the major powers. For France and England, where fiscal records begin early, the per capita tax burden (measured in grams of silver) rose over 6-fold between the 1540s and the 1780s (Table 3). Picking other decades or measuring per-capita taxes in grain or days of a workman's labor would not change the results appreciably. By the eighteenth century, France may have been spending 5 to 10 percent of its GDP on military, and Great Britain even more—perhaps as much as 28 percent.[29] For countries that were still poor by modern standards, these figures are quite high. For comparison, at the end of the Cold War, the United States was devoting 5 percent of its GDP to the military, and the USSR perhaps 10 percent.[30]

Here one might object that raising taxes would take no effort at all, at least in absolute monarchies like France and Spain. But even under absolutism taxes were limited by the concessions made to elites when kingdoms were assembled. The kings of France and Spain could not simply raise taxes at will without provoking elite resistance, particularly in provinces that had joined the kingdom late. The monarchs had to negotiate, offer additional privileges and liberties, or simply go without added revenue. Outside of Britain, which was far ahead of the rest of western Europe, it would take the even greater efforts of centralization during the Napoleonic Wars (and the creation of national representative institutions in the nineteenth century) before the constraints on tax revenues were finally relaxed.[31]

Rulers also strived to improve military technology, in the broad sense of the term: not just the design and manufacture of ships and weapons, but tactics, logistics, and training too. In the sixteenth century, King Philip II of Spain hired away talented military architects from Italy and skilled gunners from Flanders, France, and Germany. He also rewarded military inventors and established academies to train military engineers. Two centuries later, the French were subsidizing the British iron master William Wilkinson in an effort to acquire British technology for manufacturing cannons.[32]

These efforts helped spread the best military technology. So did widespread espionage and states' efforts to copy what was successful.[33] Yet the technology would have spread even if states had not sought to imitate their rivals and hire away talent, via Europe's long standing market for military goods and skills. Officers and professional soldiers had long been able to hire themselves out and even switch sides, with Wilkinson being far from the first entrepreneur who helped spread new techniques of making

weapons.[34] Efforts to interfere with the market usually failed: the Habsburg Emperor Charles V, for example, could not stop gunsmiths in Nürnberg from selling handguns to his enemies the French. Assistance to allies was another major channel for the diffusion of technology. Sweden's King Gustavus Adolphus, for instance, trained with the Dutch and then improved upon the infantry tactics (such as volley fire) that they had pioneered.[35]

Better technology did not spread overnight—otherwise no ruler would have had an incentive to innovate—but it did eventually diffuse among the military powers and keep any one of them from gaining a monopoly on military strength. The effect was to make the European tournament work almost like an idealized prize system that put winning ideas into the public domain. The rulers of major powers had every reason to improve their militaries, because they wanted the glory, renown, or added territory and revenue that came with victory, but they would be less likely to pile triumph upon triumph and come to dominate the entire continent or even put an end to the tournament itself. Competitors would thus begin each new tournament with roughly the same improved technology and the same impetus to push it even further.[36]

We can actually measure the rate at which military technology was improving, in the same way that we can gauge the productivity of modern workers and industries. The yardsticks used are perhaps crude and fail to capture advances in tactics or provisioning that were an integral part of the gunpowder technology. They also have trouble with naval warfare, where western Europe's lead was perhaps greatest. The reason, beyond the scarcity of quantitative data for early navies, is simply that warships had variety of different goals, which varied over time. Firepower dominated the eighteenth century, but

speed, range, and an ability to fight in inclement weather were also important, particularly in wars of economic attrition that were focus of earlier warfare at sea.[37]

Yet despite all these difficulties, the evidence that military productivity was advancing in early modern Europe is clear. Suppose, for example, that we ignore the other goals navies pursued and take firepower as our sole yardstick of naval output, which we can measure relative to shipboard labor and capital to get a measure of total factor productivity. In the English navy, this measure was rising at a rate of 0.4 percent per year between 1650 and 1680, a period when firepower was gaining in importance.[38] Such a rapid growth was virtually unheard of in preindustrial economies, where total productivity was typically increasing at 0.1 percent per year or less (if it grew at all) in major sectors of the economy.[39]

One might argue that measure is misleading because the English navy was simply specializing in firepower at the expense of speed or range—in other words, that it was moving along a frontier of output possibilities while productivity remained constant. But we can control for that possibility by considering earlier ships that had specialized in firepower. One of the earliest examples comes from the English fleet that fought the Spanish Armada in 1588. The English navy had already begun to emphasize bombardment as an alternative to the boarding that had been the customary goal in naval battles, and as a result the English flotilla in 1588 was heavily armed. If we compare these specialized vessels which confronted the Armada with their counterparts in 1680 and repeat the same calculation, we again find total factor productivity growth rates of 0.4 percent per year, but now it is sustained over a full century.[40]

Productivity in the English navy increased in other ways as well. Captains, for instance, learned how to became much more effective fighters, which drastically cut their fatality rate. If one holds constant the intensity and amount of fighting the captains were exposed to, their odds of dying in typical five year period fell from 16 percent in 1670-90 to one in a thousand in 1790-1810.[41]

Nor was productivity growth limited to naval warfare. On land, for instance, the effective firing rate per French infantryman jumped by a factor of 6 or more between 1600 and 1750, as bayonets made it possible to replace pike men and matchlocks were supplanted by flintlocks with ramrods and paper cartridges (Table 4). The higher firing rate translated into labor productivity growth of 1.5 percent per year, which rivals what developed countries experienced in the late twentieth century and far exceeds what one would expect for preindustrial economies.

Still another sign of rapid productivity growth was the falling price of weapons, which dropped faster than the cost of other manufactured goods from the late Middle Ages onwards (see Figure 1 for an example). The price of weapons—cannons, muskets, and pistols—also tumbled relative to the cost of the relevant factors of production.[42] Like modern computer manufacturers, the gunsmiths of late medieval and early modern Europe were getting better at making weapons, and as in modern industries the productivity growth was particularly rapid when new weapons were first introduced. When the first handguns appeared on the scene circa 1400 (they were little more than tiny, hand held cannons that could be fired from atop a city's walls), the metal founders who cast them reduced the price drastically.[43] They did so by cutting the amount of copper they used, so that the weight of the miniature cannons plummetted (Figure 2).

That may seem obvious to us, but in an era when artillery regularly exploded (Figure 3), it marked real progress.

Rising productivity is what would be expected from a tournament, if the prize was large, if the number of contestants was greater than one, if the costs of exerting effort (particularly the political costs of raising taxes to fund the military) were not too high, and if the technology was such that innovation was feasible economically and technologically. Those four conditions were precisely the ones prevailing among the major powers in early modern Europe. The gunpowder technology did in fact allow for many improvements, not just to ships and weapons, but to tactics, organization, and provisioning. The prize for victory in war, including glory and an enhanced military reputation, had an enormous appeal to Europe's monarchs, and the political costs of raising taxes were not too high, at least for the major powers. Finally, the number of contestants fighting in Europe (essentially the major powers) always remained greater than one, since no one state conquered the others. Innovation and rising military productivity is what we would then anticipate, as a result of the enormous effort that such a tournament would elicit. Meanwhile, there was little or no productivity growth in the rest of the economy of early modern Europe, despite widespread competitive markets.

2. A model of the military tournament

The evidence thus seems consistent with a story of a tournament under conditions favorable to military innovation. But what about the rest of the world? Does the same story work elsewhere?

To answer those questions, let us make our four conditions more precise by writing down a simple model for the tournament. (For a more detailed treatment, see the appendix.) Suppose then that there are two rulers (or leaders who make decisions about foreign policy, such as a prime minister) and that they simultaneously decide whether to have their countries enter a tournament and compete for a prize P that will be awarded to the one with the best military innovation. Since the tournament is military, the prize may be glory, commercial advantage, revenue from conquered territory, or an enhanced reputation; as the appendix explains, adding more countries will not change things in any serious way, so long as we suppose that alliances are decided upon in advance. We will equate entering the tournament with going to war, and winning the tournament with military victory. We will also assume that the rulers play the tournament only once—say at the beginning of their reign or tenure. If the tournament is played again, it is with different rulers, who have all adopted the winning innovation from the previous round.[44]

A ruler who enters the tournament pays a fixed cost *b* and chooses to exert effort *z* to improve his innovation. The fixed cost may go for creating a navy or standing army, for establishing a fiscal bureaucracy to pay for military expenses, or for organizing a huge invasion force to fight an expensive land war in a distant country. A ruler who declines to join the tournament avoids the fixed cost but has no chance of winning the prize. For a ruler who does enter, the effort *z* gives him a random innovation *x,* where *x* has cumulative distribution $F^z(x)$ on the interval [*0, a*] and *a* represents the limits of available useful knowledge. More effort means a better chance at an innovation close to *a*; if a ruler exerts no effort, his innovation is a worthless 0. Effort is expensive, with a

cost (which we will think of as the political cost of raising and centralizing taxation) c_1 for one ruler and c_2 for the other ruler. We assume c_1 is less than or equal to c_2.

In the equilibrium of the resulting game, it may be that only the ruler with the lower cost c_1 enters the tournament. That will happen if the other potential contestant's expected winnings will not offset the entry fee b and the higher cost c_2 of his effort. If so, then ruler 1 will win the prize whether or not he exerts himself, and so he will not expend any effort. Graphically, the one entrant will be at the point *A* in Figure 4, because the prize P is not big enough to draw in the second ruler. To get the second ruler to join in, P has to exceed $b(1 + c_2 / c_1)^2$ but P is not that large. And with no effort exerted, there will be no innovation either, leaving effort and innovation at D in Figure 4, where both are zero.

If, however, the prize P is greater than the threshold $b(1 + c_2 / c_1)^2$, then both rulers will enter, creating a situation like the point *B* in Figure 4. Both will exert themselves by raising and centralizing taxes, and the total effort the two expend, Z, will equal P/C, where $C = c_1 + c_2$. More total effort Z will mean more military spending, and it will also mean a higher expected value $E(x)$ of the winning innovation, with $E(x)$ approaching the limit of available knowledge a as Z grows. In the preindustrial world that limit may be set by what can gleaned by experimentation, but if the technology is relatively new (as with gunpowder in early modern Europe) then effort may well yield many improvements.

The four conditions that encourage military innovation (a large prize, more than one contestant, low cost of effort, and a technology that effort could improve given available knowledge) are now clearer. The key is having more than one contestant,

which will happen if P exceeds $b(1 + c_2 / c_1)^2$, or in other words, if the prize P is big, the entry cost b is small, and there are not big differences in the political costs of effort, c_1 and c_2. If there is more than one contestant, then an enormous prize and low political costs will yield great effort. The effort will in turn translate into innovation if attempts to improve the technology are not hemmed in by severe limits to what can be done with available knowledge—or equivalently, if a is large.

With this simple model we can already gain deeper insight into what happened in nineteenth-century Europe and in early modern Asia. In Europe after 1800, losing a war began to carry the risk, even in the major states, that a ruler would be toppled from his throne or from power (Table 3). There was now a downside to war, but from the perspective of the tournament, the penalty for losing simply meant a larger fixed cost b and a bigger prize P.[45] The nineteenth century witnessed political and administrative reforms as well, which affected the cost of effort. States began centralized their tax systems during the Napoleonic Wars, and later in the century representative assemblies gained a voice in fiscal decisions. Cumulatively, the reforms made it easier to raise taxes and hence diminished the political cost of effort.[46] Patriotism and conscription likely had the same effect.

The higher fixed cost b would shift the threshold $b(1 + c_2 / c_1)^2$ at which both rulers enter over to the right, as in Figure 5. The prize P would be larger too, but if it was not big enough to attain the new threshold, only one ruler would join the tournament, leaving an equilibrium like A, with no effort. If, however, the prize did exceed the threshold and draw both rulers in, then the effort they would expend would rise above what it would have been earlier, for it would equal P/C, and the prize P would now be

higher, and the cost *C,* lower. The equilibrium would then shift from the point *B* to a point like *B** further up in the figure. At the same time, the correspondingly greater effort $Z^* = P/C$ would translate into even more expected innovation *E(x)**, because spillovers from the Industrial Revolution would have expanded the limit of available knowledge from *a* to *a*.*

Nineteenth-century Europe could thus be either at *A* in Figure 5, with no war and no effort, or at *B**, with military competition and more effort and innovation than ever before. That seems a fairly good portrait of the nineteenth century. Warfare diminished, particularly after 1815 (Table 1), but there were a number of innovations, which among other consequences made it easier to acquire colonies.[47]

What about Asia? There, as we shall see, rulers before 1800 often found themselves at equilibrium *A* in Figure 6, with no reason to exert any effort and improve the gunpowder technology. Either the prize was too low, or the entry costs loomed too large, leaving them to the left of the threshold. And if rulers did find themselves to the right of the threshold and vying against one another in a tournament, they often faced high costs of exerting effort and so end up at B* in Figure 6, with war but little innovation of their own. Only rarely did then end up at *B,* the equilibrium of war, effort, and advances in military technology that prevailed in Europe.

3. Comparison with the Rest of the World

If the tournament model is correct, then it should explain why Europe gained a comparative advantage in the technology of artillery, firearms, fortifications, and armed

ships. In particular, it should help explain why Japan, China, the Ottoman Empire, and India eventually fell behind in the use of the gunpowder technology. Presumably, either they did not have a tournament, or if they did, the conditions were not the same as in Europe and did not generate advances in the gunpowder technology.

War was a threat everywhere, but there were ways to defend a country without using gunpowder weapons or straining to improve military technology. Diplomacy could weaken enemies by pitting one against another. Strategic access to trade could pacify them. The Chinese employed both strategies against their major enemy—central Asian nomads on horseback—and Spanish proposed doing the same against the nomadic Comanches on the fringes of their American Empire.[48]

Much of Asia and the Middle East, it turns out, were threatened by nomads. Where they were a menace, diplomacy and strategic trade might be all the more attractive because the gunpowder technology was (for a long time at least) of relatively little use against them. Nomads, after all, had no cities to besiege, and they were too mobile to be targets for artillery. Sending the infantry chasing after them would demand too many provisions, since the nomads could simply ride off into the steppes and live off the land. Muskets gave no advantage, because they could not easily be fired from horseback, and while pistols could, their range was limited. When fighting them, the best option was usually dispatching cavalry armed with bows and swords, the same weapons the nomads themselves utilized. But that venerable technology had been around since perhaps 800 BC, leaving little room for improvement via pre-industrial experimentation, even if there were a tournament. In short, against nomads who galloped off the step, it often made little sense to engage in any military tournament, particularly one that involved

advancing the gunpowder technology. The rewards, or prize, would be minimal. It would be better to deploy the ancient technology of archers and swordsmen on horseback. Or better yet, use diplomacy and strategic access to trade and avoid any kind of tournament.

There were of course powers in Asia and the Middle East who were vulnerable to the gunpowder technology. But in potential war against them rulers may have been willing to enter any tournament, perhaps because the prize was too small or the entry costs too high. And even if other countries joined the fray and vied against one another, the political costs—particularly of centralizing taxation—may have loomed too large for any rulers to exert themselves very much and thereby improve the gunpowder technology. They might therefore use the gunpowder technology but they would not advance the cutting edge.

With these conditions in mind, let us consider the other major powers in Eurasia. The case of Japan is perhaps clearest. After firearms were introduced there in 1543, battling warlords and their opponents swiftly became experts in their manufacture and use, and they employed them with extraordinary skill in the virtually constant warfare that had wracked the fragmented country since the late fifteenth century. Just as in Europe, they innovated, at a furious pace. Not only were the Japanese the first to use volley fire, but they too devised fortifications that could resist artillery siege. And as in Europe, the ability to mobilize resources and to provision armies effectively proved critical with this technology. The military innovations ground to a halt, though, after the country was unified in the late sixteenth and early seventeenth centuries.[49]

It all seems to fit for the tournament model. As long as the civil war continued, the warlords and the other combatants would have powerful reasons to improve the gunpowder technology. They would be at point B in Figure 3. But once the country was unified, the tournament would be left with only one contestant, leaving the winner—the ruling Tokugawa Shogunate—at point A, with no incentive to advance the technology. Since there was no longer any reason to exert effort, the impetus to extract more resources for the central government would disappear too, and sure enough, its tax revenues declined as fraction of agricultural output.

One might of course wonder why the victorious warlords who united the country did not turn to foreign conquests once they had vanquished their domestic enemies. But one them—Toyotomi Hideyoshi—actually did, in vain attempts to invade Korea (and via Korea, China) in 1592 and 1597. He failed, however, because he "lacked the resources" needed to carry out such an operation—in particular, a large navy. Other Japanese leaders were "unenthusiastic" about the operation and "quickly" withdrew from Korea after Hideyoshi died. They seemed to realize that an invasion without adequate resources was unrealistic. They knew, in other words, that successful military competition against foreign powers entailed large entry costs, including the expense of building a powerful navy. Those entry fees—the *b* in the tournament model—ruled out the possibility of foreign war and were one more reason why Japan found itself at point A in figure 3. The Japanese themselves were certainly better off, because the Tokugawa Shogunate brought an end to over a century of devastating warfare. Advances in military technology, however, stopped in Japan, despite an enduring cultural attachment to martial values.[50]

What about China? Does it too fit the model of the tournament? It of course faced attacks by nomads, and against them, as we know, the gunpowder technology was (for a long time at least) of relatively little use. There would therefore be little reward for trying improve it, and there would be little reason either to centralize provisioning and tax collection, since it might simply be more effective to have soldiers settle near the frontier regions where the nomads were most likely to attack. They could make some of their own equipment and grow some of their own food. Such a tactic of partial military decentralization was in fact common during much of China's history and in other parts of the world where attacks by nomads posed a threat.

There were other possible defenses as well; none depended on the gunpowder technology. One could build fortifications such as the Great Wall to keep the nomads out, as happened repeatedly in China, and during the second half of the Ming dynasty in particular. Or honors and rights to trade could be bestowed upon the nomads in return for being peaceful (an example of the strategic use of trade), while diplomacy kept them from uniting into a major military menace. Policies of that sort paid off handsomely during the subsequent Qing dynasty.[51]

That does not mean the gunpowder technology was shunned altogether. It in fact gained in appeal in the early seventeenth century, when something like an arms race began to develop in East Asia. As the Ming dynasty, beset by rebellions and under attack by the Manchus, fell into decline, its troops fought and defended besieged cities with muskets and artillery. Their opponents replied in kind. But the gunpowder technology was still not terribly effective against nomads, and it remained ineffective even under the Qing dynasty, for the simple reason that it strained supply lines to the breaking point.

That is why the Qing dynasty continued to resort to diplomacy and the strategic use of honors and trade, at least until the middle of the eighteenth century, when its supply lines finally grew strong enough to allow it to wipe out the last major nomadic threat, the Zunghars.[52] In short, the military dangers facing China often made the gunpowder technology unappealing, and if there were a tournament to improve it, the prize would have little value, leaving China at a point like A in Figure 3. As for the military technology that for a long time seemed more effective—cavalry equipped with bows and swords—it may have been so old as to rule out any further innovation, even if there had been a tournament.

Efforts to advance military technology of any sort may have also been hampered by a belief that the emperors of China should focus on peace and use force as a "last resort." Such a political norm, which would have reduced the value of the tournament prize, might have been given political teeth by officials, who had to give their assent to imperial policy and who (unlike many European elites) had no reason to favor warfare.[53] To be sure, one should not naïvely exaggerate the importance of the norm or believe that it always restrained China's emperors. The Qing emperor Qianlong could not be dissuaded from massacring the Zunghars, despite reservations about the policy at court and among some military leaders.[54] Furthermore, Confucian officials were perfectly capable of organizing wars while speaking a language of moral persuasion. But the norm might have been particularly strong under the late Ming, and it too would have cut the value of the prize if the Chinese emperors were in fact engaged in a tournament, by deterring them from chasing conquests. Europeans who knew early modern China well would likely agree here. One of them–the Jesuit missionary Matteo Ricci, who died in

Peking in 1610 after spending 28 years in China–noted that although the China could easily conquer neighboring states neither the emperors nor Chinese officials had any interest in doing so. "Certainly, this is very different from our own countries [in Europe]," he noted, for European kings are "driven by the insatiable desire to extend their dominions."[55]

One other factor also worked against military innovation in China, no matter what the technology or norms of behavior might have been: the size and durable unity of the empire. For nearly three quarters of the two millennia between 221 BC and the nineteenth century, the Chinese Empire was intact; western Europe, by contrast, spent much more time fragmented into warring states. Indeed, after the fall of the Roman Empire, western Europe knew only two short lived empires (the Carolingian and the Napoleonic), and it thus lived through a millennium and a half of nearly uninterrupted disunity. More often than not China was thus in a situation like Japan after it was unified under the Tokugawa Shogunate: even if a Chinese emperor had wanted to compete in a military tournament, he would be the lone contestant and have no reason to exert any effort. Or he would have had to build an effective navy or fight distant land wars and thus pay prohibitive entry costs. The only exception would be when the empire happened to be under attack or was fragmented into hostile powers. The threshold for joining any tournament would then shift to the left, creating incentives for innovation. That is in fact when we would expect to see military advances, though not necessarily with the gunpowder technology.

There is one final condition that may have kept the Chinese from pushing the gunpowder technology. When this technology finally became appealing in the

seventeenth century, it may simply have been more advantageous to acquire it from the Europeans, by asking the Portuguese (or the Jesuits) to provide designs and expertise.[56] The European rulers, after all, had already been through a tournament, They had already spent heavily in improving the gunpowder technology and learned a great deal by working with it. They had become specialists in the technology, and rather than duplicating their efforts, a Chinese Emperor might find it much cheaper to buy the European innovations by hiring European experts, rather than trying to duplicate it or improve it on their own. The relative prices of weapons in China and the direction of trade in military expertise certainly point in that direction.[57]

Quantitative evidence bears out these claims about China. The Chinese did invent a large number of weapons—more than just gunpowder and firearms—and not surprisingly the discoveries tended to be made when emperors were at war.[58] But over the years 1500-1799, China was less likely than major European powers to be fighting foreign enemies against whom gunpowder weapons might prove useful. It was less likely to be battling foreign enemies overall, and most of the hostilities involved civil wars or nomads, which gave less of an impetus for innovation.[59] If these two sorts of strife are set aside, the contrast with major European powers is striking (Table 5). So at the very time when gunpowder technology was advancing, China's rulers had less reason to cultivate the new weapons, and the Chinese military had much less experience with them. Greater experience could of course translate into learning how to improve the technology, as with British naval captains.

The Chinese emperors also seem to have done less to raise and centralize taxation, as would be expected if they were not embroiled in a tournament involving the

gunpowder technology. The evidence we have for China is admittedly scanty, but suggests that the government's per capita tax receipts (in grams of silver) were in fact much lower than in European powers such as England or France (Table 6). The difference is particularly striking if we consider the fraction of the receipts that were under the central government's control. More data for China would obviously help here, but the Chinese figures, it is worth stressing, err on the side of overestimating both per-capita tax receipts and the fraction under the central government's control.[60] As for Europe, the higher tax burden there is a sign of the enormous effort the tournament elicited. Political conditions in China were different, for the emperors hesitated to squeeze taxpayers so hard, even when the Empire was at war. Fighting China's enemies had traditionally not hinged on high centralized taxes; raising and centralizing them could easily provoke rebellion or daunting political resistance. That was true in particular at the end of Ming dynasty, and it limited the dynasty's to acquire gunpowder weapons.[61]

A similar argument fits the Ottoman Empire, which had to confront both nomads and enemies who employed the gunpowder technology. The Ottomans could therefore not devote all their resources to gunpowder, as the Europeans could. That would raise the cost of any effort they exerted to improve the gunpowder technology if they joined a tournament against the Europeans. So too would the growing difficulty the Ottomans had in raising and centralizing taxation, particularly in eighteenth century, when the central government's tax receipts failed to keep up with collections in western Europe.[62] The high political cost of effort would put the Ottomans at a point like B* in Figure 6 when they tried to participate in the European military tournament. They would wage war; deploy musketeers, artillery, and armed naval ships when appropriate; and manufacture

cannons too. But they would do relatively little to improve the gunpowder technology. Instead, they would import cutting edge weapons and expertise from the Europeans, especially after 1700, which is precisely what happened.[63]

The final and most telling comparison, however, is between Europe and India, which should have been fertile ground for advances in gunpowder technology, if the traditional argument about competition were correct. India was ravaged by virtually constant warfare and had highly developed markets for military goods and services.[64] The claims about competition would predict that Indians would therefore push the gunpowder technology further, yet while they readily adopted new weapons and tactics, they did not break new ground in their use. The innovations, by and large, came from the West with renegade experts and officers and imports of weapons.[65] That runs counter to what the claims about competition would lead one to expect.

Part of the reason was that India, like the Ottoman Empire, had one foot in the nomadic zone. Armies were predominantly (though not exclusively) cavalry, particularly under the Mughal Empire, and for a long time the gunpowder technology was of little use. But when the Mughal Empire fell apart in the eighteenth century, the gunpowder technology became advantageous. Yet even at that point the Indians failed to innovate. Their highly developed military markets meant that they quickly embraced the latest that the gunpowder technology had to offer, but they did not push it further on their own.[66]

Our model can explain why. There was a military tournament in India, with more than one contestant entering the fray from among the leaders and states that arose as the Mughal Empire disintegrated. The conditions of the tournament, however, differed greatly from those in Europe and worked against improvements in the gunpowder

technology. One difference was that strife often broke out within powerful Indian families over succession to a throne or rights to rule.[67] Conflict of this sort, which had grown rare in Europe after the late Middle Ages, reduced the value of the prize in the Indian tournament, by raising the odds that a prince or other ruler would be unable to enjoy fruits of victory. As a result, Indian rulers would exert less effort to centralize provisioning and to upgrade weapons and tactics.

The political and economic costs of centralizing taxation and army funding were also major obstacles in India. It seems to have been easier for Indian military leaders and other members of the elite to defect and join the enemy. Behavior of this sort was less common in Europe, particularly after the early seventeenth century. Indian rulers might therefore have hesitated before raising or centralizing taxes out of fear that elites would jump ship.[68] In addition, grain markets in eighteenth and early nineteenth-century India were more fragmented than in Europe, which would make centralized provisioning and tax collection all the more difficult.[69] In a tournament, the higher political and economic costs would in turn mean less effort overall and less innovation, for Indian rulers would be at B* in Figure 6, and not the point B. They would import the latest gunpowder technology, but they would not improve it.

If we consider the most powerful successor states to the Mughal Empire, most of them did fail to develop to develop centralized tax and supply systems. That is a telltale sign that conditions in the Indian tournament were different, because advancing the gunpowder technology depended on centralizing the fisc and provisioning. In this situation, the British East India Company thus had an enormous advantage in India, even though it was only a private enterprise, because it could easily use its own financial

system, which was already in place, to centralize the funding of war. That advantage allowed it to conquer much of the subcontinent, simply by hiring away the best officers and their troops.[70]

4. Conclusion

The idea of the tournament yields a deeper understanding of why Europeans pushed the gunpowder technology so far and why therefore they were the ones to conquer the world. The rulers of western Europe's major powers were competing in a tournament, under conditions that drove them to improve the artillery, firearms, fortifications, and armed ships that they deployed in their wars. Since the gunpowder technology required it, they raised taxes and strove to centralize provisioning and the fiscal system. They overspent on the military and provided more defense than their subjects likely desired. But they had little reason not to. Victory in the tournament won them glory, enhanced reputations, and resources from territory snatched away from smaller neighbors. Before 1800, losses never cost them their throne, at least for the major powers and as long as they faced no civil war. Finally, the rulers did not bear the full costs of warfare, and neither did elites with political voice, who in any case often aspired to military careers.[71]

The economic and political costs of centralization were more favorable in Europe than they were in India or the Ottoman Empire, and the tournament prize was not diminished by frequent strife over succession. And in Europe, the market for weapons and military skills helped prevent one country from getting too far ahead, although there

was an important element of historical contingency involved. Had one power crushed the others—the Habsburgs in the sixteenth century, or Napoleon at the height of his power—then the tournament in Europe would have halted, as it did in early modern Japan. But that never happened in Europe. It never enjoyed the political unity that would have cut the incentives for military innovation, as in China, or in Japan under the Tokugawa Shogunate.

Other factors also worked to Europe's advantage, in particular the fact that western Europe faced no threat of attack by nomads. The rest of Eurasia did have to confront nomads, and against them, the gunpowder technology—and the centralized provisioning and tax collection that went with it—were of little use. The gunpowder technology therefore lost part of its appeal for the Ottomans, and it was even less attractive for the Chinese. But even here the tournament gives us insight. When the technology finally did become advantageous, as in eighteenth-century India and in seventeenth-century China too, it was cheaper to buy it from the Europeans. The experience the Europeans had gained in their tournament had given them a comparative advantage and they were perfect willing to export their expertise. Why should an Asian or Middle Eastern ruler exert himself to improve the technology on his own?

This expertise in turn allowed the Europeans to wage war at a distance. Not that they were posting huge infantry armies abroad. But they could dispatch ships armed with cannons to prey upon trade in places as far away as Southeast Asia, and for protection and essential supplies of water and fresh food, the ships could rely upon European style fortresses, which, when built in Asia or the Americas, could be defended with a relatively small force. The fortresses thus complemented the naval forces and allowed the

Europeans to hold critical trading points and to protect what land they conquered without sending large numbers of officers and men abroad—an expensive undertaking given the high mortality rates during long voyages. And the defense worked both against attacks by native powers and by other Europeans, who were always a threat.

To make this whole argument persuasive, there are still a number of questions that need to be answered. As far as Europe is concerned, did the actual operation of the tournament—with potential competitors having to pay the initial cost of establishing a standing army whether or not they later chose to fight—actually heighten the effort that they would later exert? A more elaborate model of the tournament suggests as much.[72] Was there a parallel tournament among the arms makers and suppliers of military goods and services who fed the European rulers' ravenous appetites for more effective armies and navies? And how did the military innovations generated by the tournament give an advantage to the early Portuguese naval explorers and Spanish conquistadores, who were themselves usually not military professionals? Was it because the tournament and the enormous effort it generated ended up familiarizing most Europeans with the gunpowder technology, even when they themselves were not veterans?

If we consider Eurasia as a whole, how do we explain the historical contingencies that brought the tournament to an end in Japan and kept one power from conquering the others in Europe? Were they purely accidental? Did they reflect norms of behavior that varied across Eurasia? Or were they simply different equilibria in some larger repeated game among rulers? All three possibilities are conceivable. Rulers in western Europe were related to one another, and from the time of Carolingians on, they were supposed to be merciful. They might therefore have reason not to annihilate one another, even though

their armies and navies were ruthless in combat. If such behavior were peculiar to western Europe, then a tournament with more than one competitor would have been more likely to endure there. The fate of the royal hostages Jean II after Poitiers and François I after Pavia might suggest such an argument, but proving it would require quantitative evidence from across Eurasia.

Finally, why did the rulers of early modern Europe face incentives that give them every reason to join the tournament and little reason to hold back? Napoleon and the wars of French Revolution did finally overturn the rules of the game: henceforth losing at war could cost the ruler of a major power his throne (Table 2). Where did these ancient incentives originate and why did they finally change? And what in turn were the political and economic consequences? Far back into the Middle Ages, Europe had overspent on warfare, with consequences for the economy that were at best mixed and at times disastrous, particularly when battles were fought on land. With a century of peace after 1815, did the continent reap any economic benefits? Is it any surprise that the continent swiftly followed the British example and industrialized?

Appendix

In Fullerton and McAfee's model of a tournament, n potential contestants (each with a cost c_i of exerting effort) simultaneously decide whether to enter the tournament and compete for a prize P that will be awarded to the one with the best innovation. A potential contestant who decides to enter pays a fixed cost b and chooses to exert effort $z \geq 0$ to improve his innovation. The effort z gives the contestant a random innovation x, where x has cumulative distribution function $F^z(x)$ and the function F has support $[0, a]$. (If a contestant enters and pays the fixed cost b but exerts no effort, then his innovation $x = 0$.) The highest realized value of x wins the prize, and a potential contestant who does not enter the tournament avoids the fixed cost but has no chance for winning the prize. The innovations are independently distributed across contestants with the same function F for all of them. If we ignore the fact that the effort z need not be an integer, then it would be as if each entrant were taking z independent draws from the underlying distribution F.

There is a subgame perfect equilibrium in the resulting game in which the potential contestants with the lowest costs c_i enter the tournament. (There may be other equilibria besides this low cost one, but they cannot involve firms whose costs are too high.) If the potential contestants are arranged according to their costs c_i from lowest (when $i = 1$) to highest (when $i = n$), then in this low cost equilibrium, only contestants 1 through m will enter, where m satisfies

$$P\left[1-\frac{c_m(m-1)}{\sum_1^m c_i}\right]^2 - b \geq 0 \qquad (1)$$

$$P\left[1-\frac{c_{m+1}m}{\sum_1^{m+1} c_i}\right]^2 - b < 0 \qquad (2)$$

If we let $(c_1 + c_2 + \ldots + c_m) = C$ and let Z denote the sum of the effort levels z_i exerted by each of the m entrants, then in this equilibrium,

$$z_i = \frac{P(m-1)}{C}\left[1-\frac{c_i(m-1)}{C}\right] \qquad (3)$$

and

$$Z = \frac{P(m-1)}{C} \qquad (4)$$

The resulting distribution of winning innovations is $F^Z(x)$. Greater effort therefore raises the expected value of the winning innovation x and the probability that x exceeds any given value. If, for instance, F is the uniform distribution on [0, a], then the probability that x is greater than $a/2$ is $1 - 2^{-Z}$ and the expected value of x is $Za/(Z+1)$, which approaches a as effort increases.

Several things are worth noting here. First, if only one contestant enters the tournament, he exerts no effort and there is no innovation. Second, if the potential entrants' costs c_i are all multiplied by $d > 1$, then (1) through (4) imply that the number of entrants remains the same but they exert less effort. As a result, there is less innovation. Third, a bigger prize P may draw more entrants into the tournament, but as long as their number remains the same, the bigger prize will increase effort by each entrant and therefore lead to more innovation. Fourth, under some mild technical assumptions, it is possible to achieve arbitrary high levels of effort with just two entrants. So long as $c_2/(c_1 + c_2) < 2\,c_3/(c_1 + c_2 + c_3)$, one can choose P to generate the desired level of total effort $Z = P/(c_1 + c_2)$ and then simply adjust the entry costs b so that (1) and (2) are satisfied for $m = 2$. Fullerton and McAfee in fact show that under similar technical assumptions someone designing such a tournament can attain any level of effort Z (and hence any expected value of innovation) at lowest cost by limiting the tournament to two contestants.

Having more than one contestant in a tournament is thus essential if there is to be innovation; having more than two is unimportant. It is also clear what conditions will encourage more than one participant to enter. If $n = 1$ (as under an empire), there can only be one competitor, but there may be only one entrant ($m = 1$) even if $n > 1$. Conditions (1) and (2) imply that $m = 1$ if P is low, b is high, or c_1 is much smaller than c_2 .

Since adding potential contestants beyond the second one is unimportant, it suffices to consider the case $n = 2$, which is the model used in the body of the paper. In that model, both rulers enter the tournament if P exceeds $b(1 + c_2 / c_1)^2$. That threshold condition is a simple transformation of (1) and (2). The effect of higher entry and effort costs for two rulers follows from the entry conditions and (4), and the impact of more useful knowledge (a higher value of a) is clear from the distribution of x. Figures 4, 5, and 6 simply graph these results for the two player tournament.

The only other issue for the simple $n = 2$ model is what happens when rulers faced a penalty $d > 0$ for losing wars they had entered, as in nineteenth century Europe. The game payoffs for the losing entrant will then change from $-b$ to $-b - d$, while the victor's payoff will remain $P - b = P + d - b - d$. But that is identical to what the payoffs would be if the rulers were playing the same game with a higher entry cost $b + d$ and a larger prize $P + d$.

Table 1
Frequency of War in Europe

Period	Average Percentage of Time Principal European Powers Were at War
1550-1600	71
1600-1650	66
1650-1700	54
1700-1750	43
1750-1800	29
1800-1850	36
1850-1900	23

Source: Wright 1942, 1: Tables 29, 45, 46; Levy 1983 leads to similar results.

Note: The principal European powers are defined as France, Austria, Great Britain, Russia, Prussia, Spain, Netherlands, Sweden, Denmark, Turkey, and Poland.

Table 2

Probability That a Major European Sovereign Was Deposed After Losing a Foreign War: Civil Wars Excluded

	Fraction Deposed Because of Defeat in Each Year of War or in Each Year of War Loss			
	Conditional on:			
	Being at War		Losing War	
Period:	1500-1799	1800-1919	1500-1799	1800-1919
Country				
Austrian Dominions	0.00	0.07	0.00	0.20
France	0.00	0.06	0.00	0.67
Great Britain	0.00	0.00	0.00	0.00
Hohenzollern Dominions	0.00	0.06	0.00	0.50
Spain	0.00	0.10	0.00	0.33

Source: Langer 1968 .

Note: The calculation of the conditional probabilities begins with a count of sovereigns who were deposed after losing a foreign war for the Austrian Dominions, France, Great Britain, the Hohenzollern lands, and Spain. The count includes any assassinations provoked by loss in a foreign war, but it excludes assassination or removal from office during civil wars and internal revolutions, unless the cause was the loss of a foreign war. In particular, the executions of king Charles I of England and Louis XVI of France are not counted, and the same holds for the removal of James II of England and the deposition of Ferdinand II in Bohemia in 1618. The calculations also exclude the simple downfall of ministries. The number of deposed monarchs is then divided by the number of years the country was at war; that yields the probability of deposition after losing a foreign war conditional on being at war. War here is defined as any class of armed conflict significant enough to be included in Langer; no formal declaration of war is necessary. It includes colonial fighting, but it excludes civil wars unless foreign powers are involved. The calculation of the probability of deposition conditional on losing a war is similar; the only difference is the number of deposed monarchs is divided by the number of years in which a war ended with a loss for the country concerned. Sovereigns included all monarchs, whether absolute or constitutional. For republics, the sovereign was the parliament or legislative assemblies; if the legislative assemblies shared sovereignty with a president or other executive, then the sovereign was the executive and the legislative assemblies together.

The Austrian dominions exclude Habsburg territory in the Iberian Peninsula, Italy, Low Countries, and Latin America. Bohemia is excluded before Habsburgs assume the crown in 1526, and Hungary is not counted until it was fully integrated into the Habsburg holdings in 1699. For France, the Convention is counted as a sovereign; Napoleon's abdication in 1814 is counted as a removal after a loss, but not his second abdication after Waterloo. For Great Britain, the calculation concerns England and Ireland alone up until 1603; during the Protectorate, the Lord Protector is counted as sovereign. For Spain, depositions do not include loss of Portugal or of non-Iberian possessions. All the probabilities are ex-post, and they clearly make more sense for monarchies than for republics. The table leaves out countries that were major powers at some point between 1500 and 1800—Sweden and the Netherlands in the seventeenth century, and Russia in the eighteenth.

Table 3
Central Government's Per-Capita Tax Revenue, 1540s-1780s

	Per-Capita Taxes (Grams of Silver)	
Country	England/Great Britain	France
1540s	27.52	9.13
1780s	171.69	68.86
Increase	6.24	7.54

Source: For the French revenue and population figures, see Hoffman and Norberg 1994, 238-239 and the sources listed there. For England (in the 1540s) and Great Britain (in the 1780s), the revenue figures come from data collected by P. K. O'Brien and P. A. Hunt and posted at the European State Finance Data Base that Richard Bonney has assembled (http://www.le.ac.uk/hi/bon/ESFDB/dir.html); and from evidence gathered by Mark Dincecco and made available at the Global Price and Income Group web site at http://gpih.ucdavis.edu/ and in Dincecco 2009 . The population figures are taken from Wrigley, Schofield et al. 1989, Table 7.8 for the 1540s and from Dincecco's data for the 1780s. The Global Price and Income web site is also the source of the silver conversions.

Note: Data are missing for some years in each decade. Silver conversions are based on mint prices.

Table 4

Military Labor Productivity in the French Army:
Rate of Successful Fire per Infantryman, 1600-1750

Approximate Date	Rate of Successful Fire per Handgun (shots/minute)	Handguns per Infantryman	Rate of Successful Fire per Infantryman (shots/minute)	Assumptions
1600 (1620 for handguns per infantryman)	0.50	0.40	0.20	1 shot per minute with matchlock; 0.50 misfire rate
1700	0.67	1.00	0.67	1 shot per minute with flintlock, 0.33 misfire rate; bayonets have led to replacement of pike men.
1750	2.00	1.00	2.00	3 shots per minute with flintlock, ramrod, and paper cartridge; 0.33 misfire rate.

Source: Lynn 1997, 454-472

Notes: The calculation considers only pike men and infantrymen with firearms; it ignores unarmed solders, such as drummers. The implied rate of labor productivity growth over the 150 year period from 1600 to 1750 is 1.5 percent per year.

Table 5: Frequency of Foreign War in China and Europe, 1500-1799

	Fraction of years at war against foreign enemies	
Country	With wars against nomads	Without wars against nomads
China	0.31	0.08
France	0.52	0.52
England/Great Britain	0.53	0.53
Spain	0.81	0.81
Austrian dominions	0.24	0.24

Source: Micheal Clodfelter, Warfare and Armed Conflicts: A Statistical Reference to Casualty and Other Figures,1500-2000 (McFarland &Company, 2002); Quincy Wright, A Study of War, 2 vols. (University of Chicago Press, 1942); Zhongguo Junshi Tongshi (Military History of China), vols. 15-17 (Junshi Kexue Press, 1998); Bai Shouyi, editor,vol.8-10, Zhongguo Tong Shi, vols. 8-10 (Shanghai People's Press, 1999); Peter N. Stearns, The Encyclopedia of World History, page 376-381.

Note: Austrian dominions and Spain as in Table 2. The data for this table were collected by Margaret Chen, a graduate student in economics at UC Davis. Excluding wars against nomads does not change the figures for the western European countries because they did not fight wars against nomads.

Table 6: Annual per-capita taxation in China, England, and France, 1578 and 1776 (in grams of silver)

		1578	1776
China	Total	6.09	8.08
China	Portion under central government control	3.56	7.03
England	Portion under central government control	10.47	180.06
France	Portion under central government control	16.65	61.11

Source: For England and France, the sources are as in Table 3, except that Wrigley and Schofield's Table A3.1 is used for population. For China the sources are Huang 1998 ; Myers and Wang 2002 ; Liu 2009 ; and the Global Price and Income History Group (gpih.ucdavis.edu) for units, silver equivalents, and prices of grain in China.

Note: The figures for England and France and decennial averages. For China, they are upper bound estimates that involve the following assumptions: the population is 175 million in 1578 and 259 million in 1776; the grain levy in 1578 is converted to silver at 1 shi equals 0.6 taels of silver; the service levy in 1578 is worth 10 million taels per year; the portion of taxes under central government control in 1578 includes taxes sent to Beijing or Nanjing, plus 25 percent of the service levy; 87 percent of the taxes are under central government control in 1776.

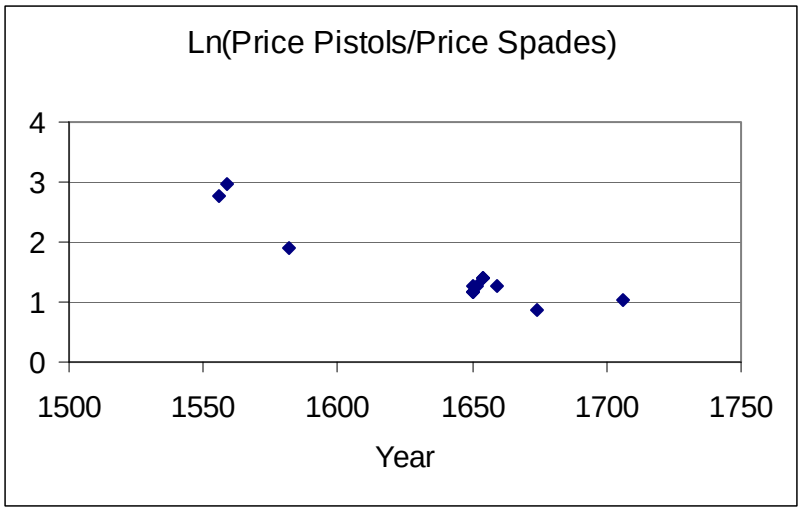


Figure 1: The logarithm of the price of pistols over the price of spades in England. Source: Hoffman 2006

Figure 2: Logarithm of the Price and Weight of Early Handguns in Frankfurt. Source: Rathgen 1928, 68-74

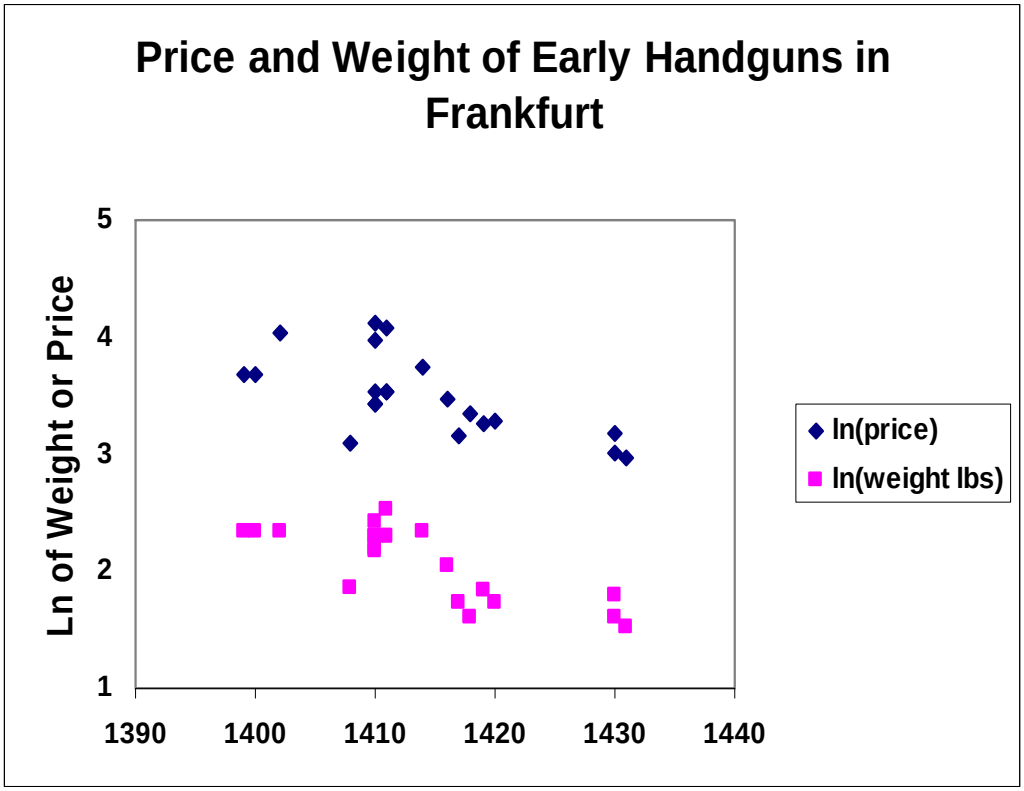


Figure 3: Warning of the danger that a cannon might explode, from an early fifteenth-century cannon maker's manuscript book. Source: Leng 2002, plate 4

Figure 4: The rulers' tournament with two potential entrants

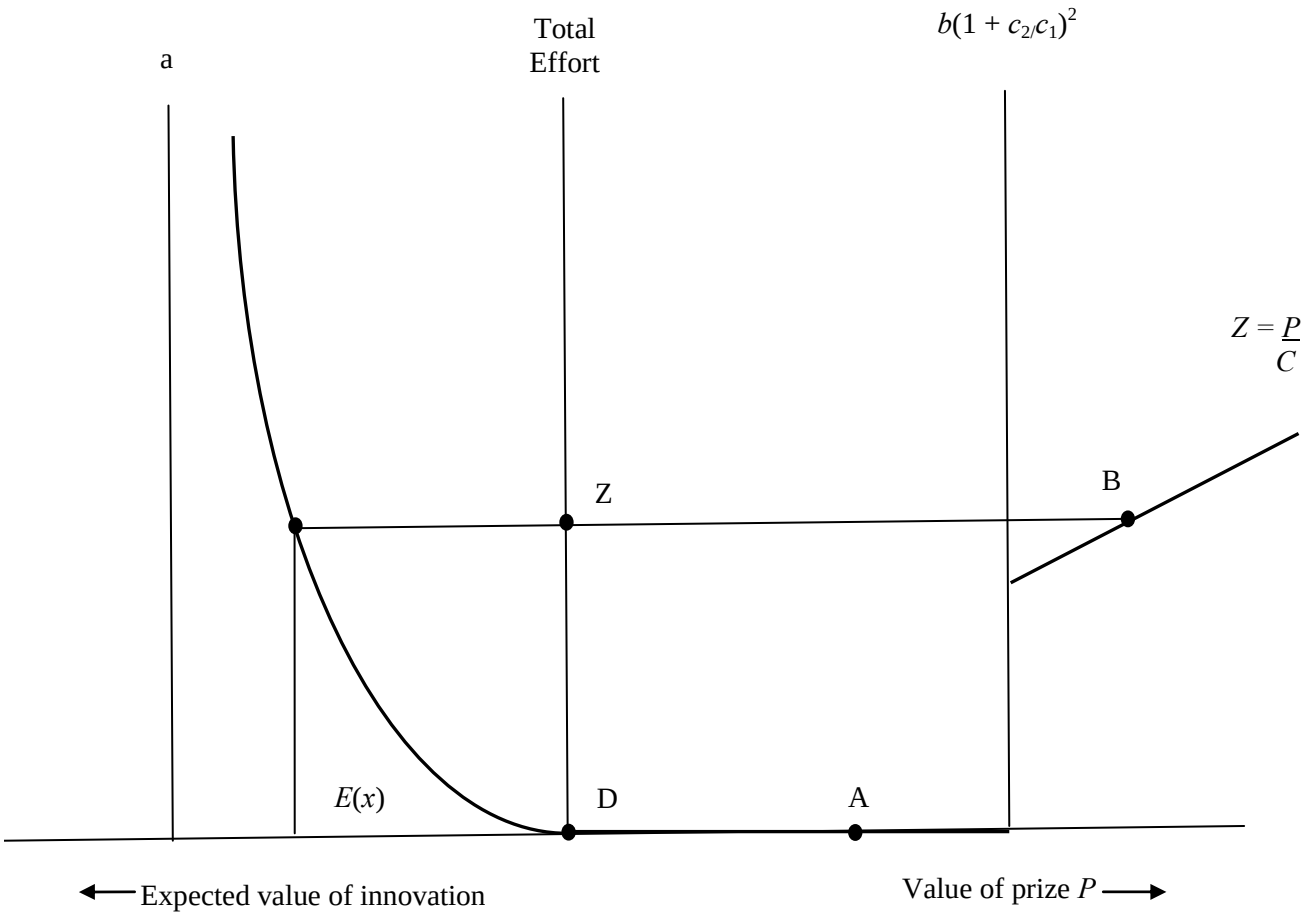


Figure 5: The tournament in nineteenth-century Europe

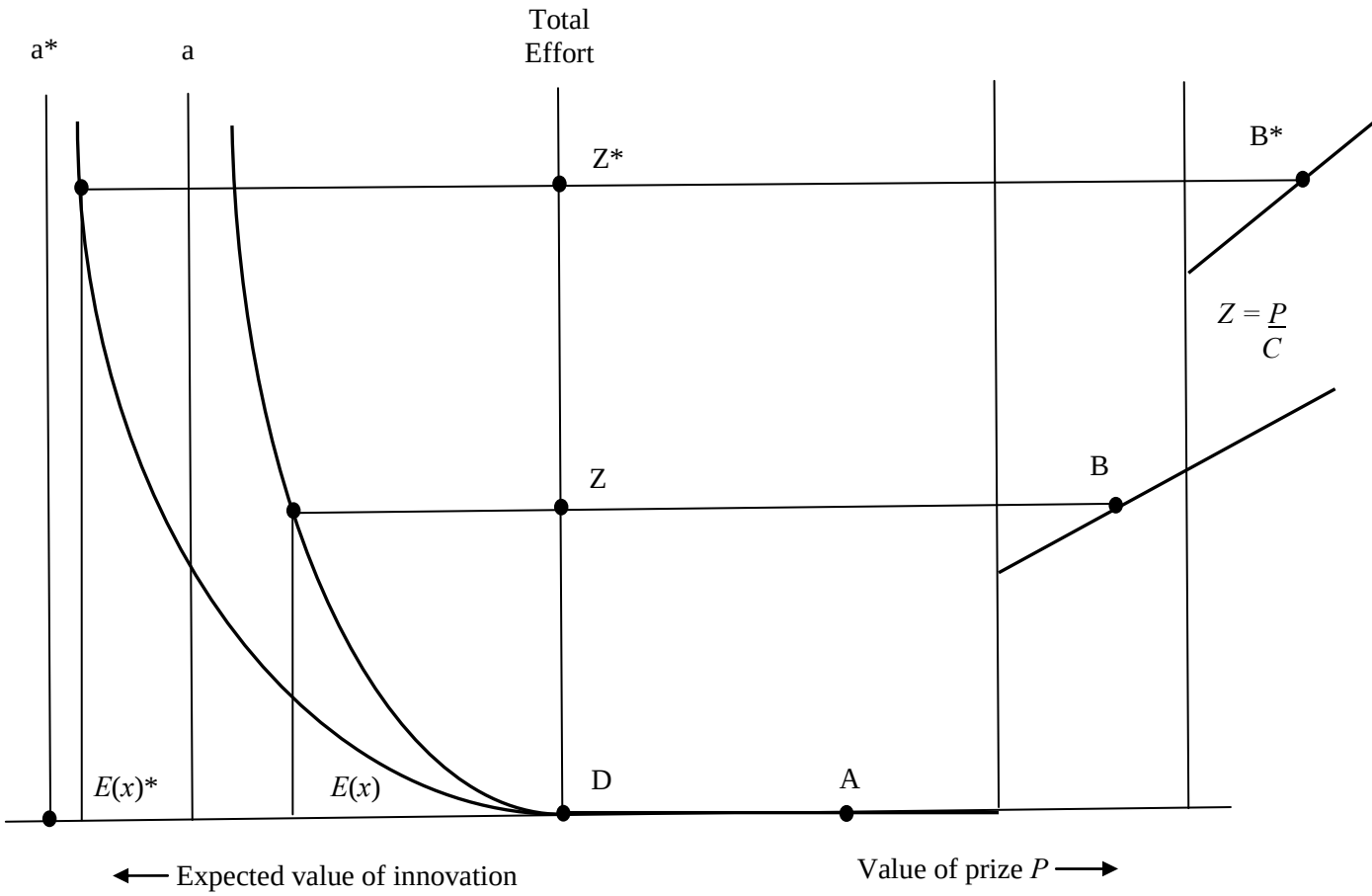
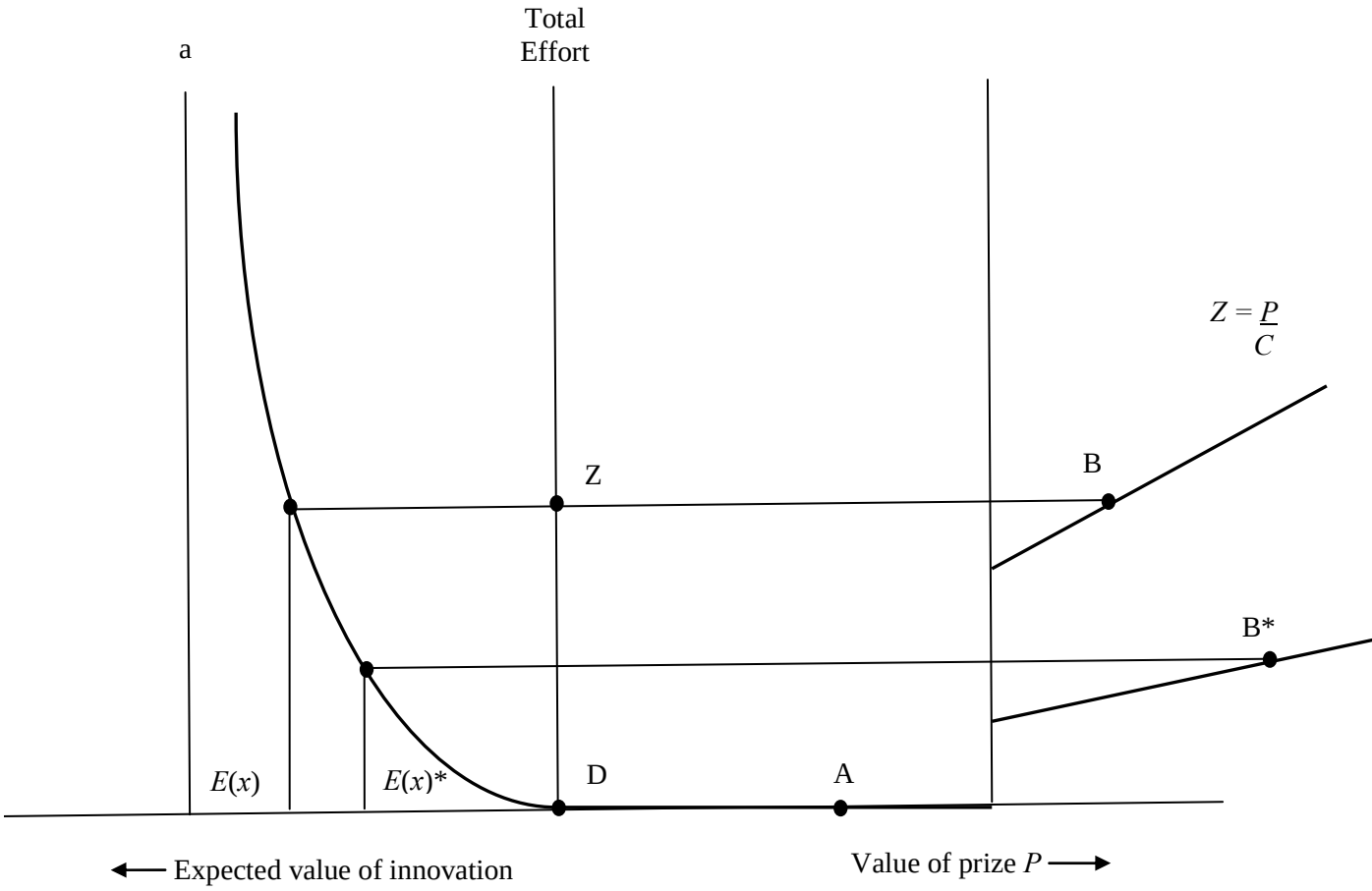


Figure 6: The tournament in Asia and the Middle East



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[2] For the divergence debate, see Wong 1997 ; Pomeranz 2000 ; van Zanden 2003 ; Goldstone forthcoming Allen 2005 ; Broadberry and Gupta 2005 . For arguments in favor of institutions, see North and Thomas 1973 ; North and Weingast 1989 ; Acemoglu, Johnson et al. 2002 . For the other explanations, see Cosandey 1997 ; Jacob 1997 ; Mokyr 2002 ; Clark 2003 ; Clark 2007 .

[3] If we measure violence simply by the number of people conquered, then the early modern Europeans would no doubt be surpassed by the Mongols and others. But it was the Europeans' proficiency with the gunpowder technology that made them stand out.

[4] Parker 1996, 5. The subsequent conquests after 1800 (when European empires covered some 84 percent of the globe) are, as Parker points out, easier to explain, for Europeans had the technology of the Industrial Revolution on their side. For a lucid analysis of the advantages Europeans therefore gained, see Headrick 1981 .

[5] Crosby 1967 ; Diamond 1997 ; and Crosby 2004 emphasizes disease, but Brooks 1993 suggests that its role may well have been exaggerated. Military technology was in any case important too, notably the horses and the small galleys that Cortes constructed for the conquest of Tenochtitlan (Gardiner 1956). Familiarity with this technology was widespread in Europe, even among people (such as the majority of the conquistadores) who were not professional men of arms. There was of course more to the story of European conquest than disease and military technology, even if technology is defined broadly so that it includes logistics, finance, and mobilization of resources. Luck and rivalries among people and powers outside Europe also had an enormous role to play, and perhaps the sailing conditions in the Atlantic had honed the skills of European navigators. Furthermore, rulers in Asia might have had more reason to restrict maritime trade, which would in turn discourage the development of naval technology and of the sort of private trading companies that spearheaded European expansion. For an insightful analysis of the incentives that rulers in Europe and Asia faced when fixing trade policy, see Lee and Temin 2004 .

[6] Mallett and Hale 1984, 400.

[7] See Parry 1970 ; Inalcik 1975 ; Parker 1996, 87-89, 126-129, 173-175; Black 1998, 60-64, 89-90; Heywood 2002 ; Heywood 2002 ; Chase 2003, 2, 97-98; and Agoston 2005 , especially pp. 10-12 (the source of the quotation about the ordnance industry), and 193-94. Agoston demonstrates that the Ottomans produced most of their own weapons in the early modern period, but he acknowledges that they did import arms and expertise from Europe. Chase considers the Ottomans a military threat to Europe until the late seventeenth century, and he quotes a 1644 Chinese opinion that Ottoman guns were better than European ones. But he also acknowledges that the Ottomans were not at the frontier of military technology and that they often depended on Christian "renegades" for help. As Parry points out, the western Europeans shipped weapons to the Ottomans despite a papal ban on military trade with the Muslims.

[8] Wong 1997, 89-90; Pomeranz 2000, 199-200.

[9] Guilmartin 1974, 255-263; Agoston 2005

[10] With volley fire, infantrymen were trained to line up in long rows. The first row would fire their muskets, and while they were reloading, the rows behind them would advance to the front and take their place on the firing line. For volley fire in Europe and Japan, see Parker 1996, 18-19, 140-141.

[11] Agoston, 10-12, 193-94, argues that the European technological superiority was minimal, at least until the late seventeenth century, but he does admit that it was "European military experts who sold their expertise to the Ottomans and not vice versa."

[12] Kennedy 1987, 16-24

[13] For quantitative evidence for the productivity growth in early modern Europe's military sector, see Hoffman 2006 . See also Carlo Cipolla's pioneering study Cipolla 1965 .

[14] Hoffman 1996 ; Clark 2007

[15] A single, all or nothing prize is, to be sure, a simplification. As a rough model of reality, though, it does shed light on what happened in early modern Eurasia.

[16] For money spent on the military, see Hoffman and Rosenthal 1997, Table III.1.

[17] Harding 1991, 28-30; Lynn 2000 . As Harding shows, public opinion could affect decisions to go to war, but it could in turn be influenced by propaganda. For decisions about war in Renaissance Italy, see Mallett 1974, 88. In Elizabethan England (as the review essay by Pettegree 1988 shows), foreign policy could be shaped by courtiers, soldiers, and merchants, but their interests often coincided with those of the queen and her councilors, who made the ultimate decisions.

[18] Louis-XIV and Sonnino 1970, 124; Machiavelli 1977, 247; Hale 1985, 29-32; Cornette 1993, 16-19, 23-64, 151-176.

[19] Lynn 2000 ; Bell 2007, 29-35.

[20] Civil wars are of course another matter; in Table 2 they include all hostilities that involve domestic enemies, even if foreign powers were also engaged. Table 2 also demonstrates that in the years 1500-1799 simply participating in a foreign war was never so unpopular that it toppled monarchs, at least in the great powers of western Europe.

[21] Hoffman and Norberg 1994 ; Hoffman and Rosenthal 1997 ; Hoffman and Rosenthal 2002

[22] See Fullerton and McAfee 1999 and www.darpa.mil.

[23] The model here comes from Fullerton and McAfee 1999 . See the appendix and the next section for more detail.

[24] Enticing more competitors into a tournament does requires changes in the exogenous variables (the entry fee, the size of the prize, or the cost of each competitor's effort) in the simple model we are using. See the appendix for details.

[25] If we leave out the wars of the French Revolution, which drastically changed European diplomacy, then the average war in eighteenth-century Europe involved 4.75 contestants. The contestants were always allied into two coalitions, but only 4 percent of them ever switched sides during a war, and only 14 percent of them dropped out and stopped fighting. The data here come from Clodfelter 2002 . The observed stability of alliances could of course be equilibrium behavior in a larger game that would include the tournament. Choosing allies would then be part of the game, and not something exogenous and settled in advance, as in my tournament model.

[26] Parker 1996 ; Landers 2003

[27] Guilmartin, Gallies, p. XXX; Corvisier 1997, 1: 490, 497-500. As Corvisier shows France lacked good ports, particularly ones deep enough for ships of the line, which could draw 7.5 meters of water.

[28] Guilmartin 1974, 262-263; Pepper and Adams 1986 ; Parker 1996 ; Corvisier 1997, 1: 449-484. Many of the best early modern military architects were Italian; their services were sought throughout Europe and in the Americas and Asia: Pepper and Adams 1986 ; Goodman 1988, 126-129.

[29] For Great Britain, the estimates come from Kennedy 1987 Table 2. They reach 27 percent during the Seven Years War and 28 percent during the wars of the French Revolution and Napoleon. For France, I assume that taxes are 12 percent of GDP and allow military expenditure to range from 45 to 85 percent of tax revenues. The 12 percent figure is derived from Mathias and O'Brien 1976 , Table 5.

[30] Brzoska 1995 , Table 3. Israel was allocating 8 percent of its GDP to the military.

[31] Hoffman and Norberg 1994 ; Epstein 2000 ; Hoffman and Rosenthal 2002 ; Dincecco 2009

[32] 1782 ; Goodman 1988, 123-141; Chaloner, Farnie et al. 1989, 19-32. The British technology including a cannon foundry with a boring mill and blast furnaces that smelted iron with coke. See also Cipolla 1965 on English efforts to encourage the manufacture of cast iron cannons.

[33] In the seventeenth century, for instance, the Dutch navy copied England's successful tactics, and French kept a close eye on the design of English ships: 1691-1759 ; Bruijn 1993, 88-89

[34] Mallett 1974 ; Hale 1985, 69, 141-146; Parker 1996, 50-52; Hanlon 1998 ; Bell 2007, 28 For an earlier example of how the technology of making weapons spread, see Cipolla 1965 for the role that the Dutch played in establishing the armaments industry in Sweden.

[35]Willers 1973, 220-308; Cornette 1993, 47-48; Parker 1996, 19-24.

[36] The argument here depends on the assumption that the European tournament was not a repeated game and that efforts to improve technology behave like independent draws from a common distribution. See the appendix for details.

[37] Guilmartin 1974, 253-254; Guilmartin 1983 ; Glete 1993, 58-61.

[38] Firepower is measured here by weight of the shot, capital by the displacement, and labor by the size of the crew for the English navy as a whole. The data are taken from Glete 1993, 186, 195, 205, except for the factor shares (0.496 for capital and 0.503 for labor), which are derived from 1744 construction and crew labor costs in Boudriot, Vaisseaux de 50 et 64 canons, pp. 146-152 [add to bibliography] For the growing

importance of firepower in this period, see Glete 1993 ; Guilmartin 2002 .

[39] For examples, see Hoffman 1996 ; Clark 2007 .

[40] The Armada data come from Martin and Parker 1999 , who discuss the shift to bombardment on pp. 33-36.

[41] Benjamin and Tifrea 2007, 981-984. As the authors argue, the lower death rates were not simply the result of Britain's naval dominance in the late eighteenth century, for they were already lower by 1710, before Britain's lead was overwhelming. The calculations are based on a hazard rate fractional logit regression and assume that the intensity and frequency of battle are held constant.

[42] For evidence and the economics of the argument, see Hoffman 2006

[43] The implied rate of total factor productivity growth is 3.0 percent per year, which is impressive by modern standards. See Hoffman 2006 for details.

[44] Although one might worry that dynastic interests would make the tournament a repeated game, foreign policy varied enough from ruler to ruler to make our assumption of one play per ruler seem reasonable.

[45] For details see the appendix.

[46] Dincecco 2009 .

[47] Headrick 1981 .

[48] For this and the following paragraph see Barfield 1989 ; Rossabi 1998 ; Chase 2003 ; Gommans 2003 ; Perdue 2005 ; Hämäläinen 2008, 131-133.

[49] Here I draw upon Parker 1996, 140-143; Chase 2003, 175-196; Berry 2005 , and forthcoming work by Thomas Conlan.

[50] The sources for this and the preceding paragraph are Smith 1958 ; Reischauer, Fairbank et al. 1960, 1:614-615; Berry 1982, 207-217 (the quotations are from 213); Berry 1986, 207-217; Brown 1993 ; Guilmartin 2002, 182-190; Chase 2003, 175-196; Berry 2005 .

[51] The previous two paragraphs are based on Barfield 1989 ; Chase 2003 ; Perdue 2005 ; [add citation to Fairbanks and Kierman].

[52] Here I am relying on Needham 1954, 5, part 7: 398-407; Atwell 1988 ; Perdue 2005 and ongoing research by Bozhong Li and Guanglin Liu. One additional factor worked against the development of the gunpowder technology in China: in contrast to Europe, the private production and ownership of guns was limited in China: Chase 2003, 151-154; Perdue 2005, 119.

[53] The quotation here is from Chase 2003, 30. The early Qing dynasty was quite different: Perdue 2005 The insight about Chinese officials I owe to Debin Ma, who points out that because the officials were chosen by examination from among the Chinese people, they would likely favor policies that would keep the people from being harmed. In Europe, by constrast, royal officials and advisers often had a military background or aspired to one.

[54] For the Qing campaign of extermination, see Perdue 2009, 283-287.

[55]Elia and Ricci 1942, 1: 66. Ricci's remarks cannot simply be dismissed as an instance of the sort of stereotyping that was common among westerners in China, because as this and other passages make clear, he admired the emperors' avoidance of war.

[56]Spence 1969, 15, 29; Chase 2003, 167-171. and Li Bozhong, personal communication. The issue was not the ability to cast metal, for Chinese craftsmen were likely as good or better than Europeans at doing that. Rather, it was the design and testing of the cannons.

[57] If the fragmentary data from the early seventeenth century are believable, the price of muskets in China (measured relative to food) was 3 to 9 times higher in China than it was in England or France. Large numbers of military advisers and experts in the gunpowder technology were also hired in East and South Asia, as early as the sixteenth century. For the evidence, see Philip T. Hoffman, "Prices, the Military Revolution, and Western Europe's Comparative Advantage in Violence" (*Economic History Review*, forthcoming, 2010) [add to bibliography]. Cheaper capital may have also contributed to Europe's comparative advantage in the gunpowder technology, but the tournament argument, which relies on learning by doing and the efforts spent on improving the technology, would hold even if the relative price of capital in China and Europe were the same.

[58] Margaret Chen, a graduate student in economics at UC Davis, has gathered data on Chinese military inventions over the past three millennia for a comparative paper on Europe and China that she and I are doing. Other things being equal, the military inventions were more common under dynasties that spent more than half their time at war.

[59] This is not to say that use of the gunpowder technology was pointless during rebellions and battles

against the nomads. It was no doubt useful, particularly when troops rebelled at the end of the Ming dynasty. But battles against rebels and nomads did not usually threaten the emperors with better technology.

[60] One could argue that the difference in 1578 reflected the relative price of silver in China, where silver was dear relative to gold, but converting to gold would multiply the Chinese figures by a factor of at most 2 relative to Europe (Von Glahn 1996, 128). That might erase the difference with England in 1578, but it would still leave China well behind France, and it would do nothing to the gap in 1776.

[61] Huang 1970 ; Huang 1998 .

[62] The argument about the Ottomans and nomads is taken from Chase, and the evidence about Ottoman tax receipts comes from forthcoming work by Sevket Pamuk. The differences in warfare also mattered at sea. In Power over Peoples [add to bibliography], Daniel Headrick notes that the speed and maneuverability of Ottoman galleys kept the Portuguese from dominating the Red Sea. Out on the ocean the story was different.

[63] Parry 1970 ; Agoston 2005, 10-12, 193-194.

[64] Kolff 1990 ; Gommans and Kolff 2001 ; Gommans 2003 .

[65] Even defenders of Indian military prowess admit that the advances with the gun powder technology by and large came from the West. See Subrahmanyam 1987 ; Barua 1994 ; Alavi 1995, 24-25; Cooper 2003, 31-32, 42-44, 289-294.

[66] Kolff 1990 ; Gommans and Kolff 2001 ; Gommans 2003 .

[67] Gommans 2003 .

[68] Gommans and Kolff 2001 ; Gommans 2003

[69] Studer 2008

[70] Alavi 1995 ; Gommans and Kolff 2001 ; Cooper 2003 ; Gommans 2003 The East India Company would of course still have to contend with fragmented grain markets.

[71] Hale 1985, 91-140; Cornette 1993, 294; Hanlon 1998, 241-267; Drevillon 2005 ; Bell 2007, 5-48.

[72] Fullerton and McAfee 1999 To design an efficient tournament when the competitors' costs are unknown, Fullerton and McAffee suggest holding an initial auction for the rights to enter a tournament; the designer then selects the two highest bidders in this auction to compete in the tournament. The initial action would have a nominal prize, and all competitors would have to pay what they bid whether or not they were subsequently selected for the tournament. Raising a standing army resembles paying a bid in an initial auction where the prize is prestige or reputation. War between the rulers with the two biggest armies would then be the tournament.