Why Was It Europeans Who Conquered the World?
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The attached paper can stand alone, but it is part of a larger, book length project. The book seeks to explain why it was Europeans who conquered the world, and not someone else, such as the Chinese, the Japanese, the Ottomans, or South Asians. The book also analyzes what the consequences were–particularly the economic ones.

Part of the argument turns on the simple static tournament model that is the focus of the paper. The next question is then explaining why the key exogenous parameters in the model (in particular, the political costs that rulers faced in mobilizing resources for war) happened to be different in major Europe countries, and different at precisely the time when gunpowder weapons were militarily useful and had enormous potential to be improved via learning by doing. Those conditions meant that European rulers would push the gunpowder technology further than rulers elsewhere in the world, and the resulting technological gap would allow Europeans to plant colonies and fortresses in far away parts of the world.

Why were these key parameters so different in Europe? That question goes beyond the scope of the paper, but the answer turns out not to be geography or culture. Rather, it was the unintended consequence of Europe's history since the collapse of the Roman Empire. That history could have been very different, and so could the histories of the other major Eurasian civilizations. It is in fact easy to imagine at least two plausible counterfactuals in which someone else would have conquered the world. The issues involved in such counterfactuals go well beyond mobilizing resources for war or the size of states, for they also hinge on matters of economic and social policy. European governments, for instance, let civilians carry and use arms and placed relatively few limits on their ability to create organizations to trade or colonize abroad. Policy elsewhere in Eurasia was not so permissive. The unintended consequence was that it was much easier for civilians in Europeans to create colonies, and much harder for civilians in East Asia or the Middle East to do the same.

Why Was It Europeans Who Conquered the World?

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By the eighteenth century, Europeans dominated the military technology of gunpowder weapons, which had enormous advantages for fighting war at a distance and conquering other parts of the world. Their dominance, however, was surprising, because the technology had originated in China and been used with expertise in Asia and the Middle East. To account for their prowess with gunpowder weapons, historians have often invoked competition, but it cannot explain why they pushed this technology further than anyone else. The answer lies in the peculiar form that military competition took in western Europe: it was a winner take all tournament, and a simple model of the tournament shows why it led European rulers to spend heavily on the gunpowder technology, and why the technology was advanced as a result. Political incentives and military conditions kept such a tournament from developing in other parts of Eurasia, and they therefore fell behind in this particular technology, despite the fact that they used it to fight wars. The consequences were huge, from colonialism to the slave trade and even the Industrial Revolution.

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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?[1]

In this debate, one area in which Western Europe possessed an undeniable comparative and absolute advantage well before 1800 seems to have been overlooked–namely, violence, or at least violence with gunpowder weapons.[2] 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 this gunpowder technology to wage war at home and to establish outposts abroad. The result was that by 1800 Europeans had conquered some 35 percent of the globe and were preying upon lucrative trade routes as far away as Asia. They took control of even more territory in the nineteenth century.[3] There were certainly other forces that worked in their favor as well (among them, the diseases that they introduced into vulnerable populations) and there were limits to what firearms could do. Nonetheless, the gunpowder technology clearly played a large role in European conquest.[4] Why then was it the Europeans who came to dominate this technology, and not the Chinese, the Japanese, or the Indians?

Patterns of trade support the claim that Europeans had a comparative advantage in the gunpowder technology, for from the sixteenth century on they were exporting handguns and artillery to the rest of the world, and European experts were being hired through Asia and the Middle East to help with gun making and with the tactics of fighting with gunpowder weapons. In seventeenth-century China, even Jesuit missionaries were pressed into service to help the Chinese Emperor make better cannons.[5]

It is nonetheless surprising that western Europe became the leaders in the technology of gunpowder weapons. Firearms and gunpowder, after all, had originated in China and spread throughout Eurasia, and for at least a while, states outside western Europe did become proficient at manufacturing or exploiting the new military technology. The Ottomans, for instance, made high quality artillery in the early sixteenth century.[6] 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.[7] 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.[8]

Why did these other powerful states fall behind? This question has attracted a number of gifted military historians, but most simply substantiate 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 has been formulated most cogently by Paul Kennedy, who points to Europe's competitive markets and persistent military rivalries. In his view, while military rivalry created an arms race, competitive markets fostered military innovation and kept one country from establishing an empire.[9]

The military sector in early modern Europe (in other words, Europe before 1800) did experience rapid and sustained productivity growth; prolonged innovation of that sort was unknown in the rest of the economy.[10] But Kennedy's competition is not the final answer, for it leaves far too much unexplained. To begin with, 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.[11] What kept early modern European farmers from reaping the productivity gains of soldiers and sailors? What, in short, other than competition alone, was different in the military sector?

Nor do ongoing military rivalries always promote 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 lies with the peculiar form of competition that European rulers were engaged in. It was a winner take all tournament that spurred rulers to spend enormous sums on using the gunpowder technology in the continent's incessant wars. In the process, the technology was advanced—chiefly via learning by doing—even though the civilian economies likely suffered. Elsewhere, however, political and military conditions were not conducive to improving the gunpowder technology, and that is why the Europeans pushed the technology further than anyone else and why the rest of the world had trouble catching up.

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 an analysis of the costs and benefits of other military technologies besides gunpowder. We will start with Europe before 1800 and use it to motivate a simple tournament model, which will then be applied to the rest of the world and then to Europe after 1800. The model's predictions are born out by quantitative and qualitative evidence; other explanations—including the argument about competition—fail such a test. The model thus gives us a deeper understanding of why Europeans came to dominate a technology that made world conquest possible. The consequences were huge—from colonialism to the slave trade and even the Industrial Revolution.[12]

1. Rulers and their incentives in Europe before 1800

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 (Table 1). 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.[13]

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 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 ultimately up to the king.[14]

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, and they typically offered their subjects protection from foreign enemies, in return for tax revenue. In modern terms, 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. They went on the offensive too, and not just to protect their kingdoms.

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. For them, fighting had gone beyond the needs of defense and become, in the words of Galileo, a "royal sport."[15]

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.[16]

For the major monarchs of early modern Europe, victory was thus a source of glory or a way to enhance their reputation. Grabbing territory from small neighbors did augment their resources and help strategically, but the thirst for glory and the drive to bolster their standing could push them to spend large sums even on small bits of terrain. (Their goals may seem bizarre, but there are certainly modern analogues—the race to get a man on the moon, or, to take a non governmental example, college athletics.) And although the kings might lose small amounts territory themselves, they faced no major downside risk to their thrones, at least in the larger states, for loss in battle in anything but a civil war never toppled a major monarch from his throne, at least in the years 1500-1790.[17] They survived defeat, and as a result, Europe was never unified by one monarch who conquered the entire continent and thereby brought an end to the ongoing hostilities.

It now becomes clearer why the early modern rulers fought so much. What impels states do engage in hostilities is something of a mystery, at least to many economists and political scientists, who rightly ask why leaders do not simply agree to give the likely victor what he would win in a war and then spare themselves the lives and resources wasted in battle. The literature offers several reasons why such agreements prove unattainable, and why leaders go to war instead, despite all the devastation it causes.[18] Although all of these reasons apply to early modern Europe, two of them seem to fit the continent's history like a glove.

The first was that the leaders making decisions about war—early modern Europe's kings and princes—stood to win a disproportionate share of the spoils from victory but avoided a full share of the costs. They—not their subjects—were the ones who basked in glory or who burnished their military reputations when their armies were victorious. But they faced no down side risk and bore few of the costs, which fell disproportionately on their subjects. When the leaders' incentives are that biased, it can be impossible to reach any sort of bargain to avoid war, even if the leaders trade resources to compensate one another.[19]

There was a second obstacle to peaceful agreement as well—the difficulty of dividing the spoils of war that the early modern princes and kings were fighting over. Glory could not be divvied up. In fact, it simply vanished if there was no fighting, making the peaceful exchange of resources potentially more expensive than fighting. The same held for reputation; it too could only be earned on the battlefield. Commercial advantage would not be easy to share either, if, as was often the case, it involved a trade monopoly. And territory posed similar problems, when it offered a strategic advantage or if sovereignty or religious differences were at stake. Then even trading other resources might not work. In negotiations to end the Great Northern War between Russia and Sweden, for example, the Tsar Peter the Great told his envoy in 1715 that he would not consider giving back Riga and Swedish Livonia (which he had won from the Swedes) because that would threaten nearby Petersburg and all his other conquests in the war, and thus potentially cost him more than the Swedes could ever conceivably given him in return.[20]

These obstacles to peace were not unique to early modern Europe, so they cannot be the reason why Europe came to dominate the gunpowder technology. They were at work elsewhere too, because foreign policy in other parts of Eurasia was often in the hands of kings, emperors, or warlords who could could be as obsessed with glory as their European counterparts.[21] But the biased incentives facing the European princes and the indivisible spoils in their wars do at least explain why early modern Europe was wracked by virtually constant hostilities. Not that all rulers would take up arms. 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 conflict.[22]

2. A simple tournament model

A model inspired by the conflicts in early modern Europe can help explain why Europe's kings and princes advanced the gunpowder technology and why rulers elsewhere in Eurasia lagged behind. We will sketch the model first, and then show that it fits the evidence both in early modern Europe and in other parts of Eurasia.

The requisite model has to explain decisions about going to war and military spending. Otherwise it cannot make sense of all the fighting in Europe and all the effort that went into it. It also has to account for improvements in military technology, so that we can isolate differences between Europe and Asia.

A simple model drawn from the economic literature on conflict and tournaments provides a tractable starting point.[23] Although more complex models do a better job of accounting for the patterns of war and peace and of military spending that we see in the modern world, they have less to say about military technology, or about the virtually constant war that ravaged early modern Europe and parts of Asia as well.[24]

Consider then two (risk neutral) early modern rulers who are considering whether or not to go to war. Winning the war earns the victor a prize P, which might be glory or territory or a commercial advantage. The loser, by contrast, gets nothing.

To have a chance of getting the prize, the rulers have to take the steps that many early modern rulers did if they wanted to win wars. First of all, they have to establish an army or a navy and set up a fiscal system to pay the military's bills. We can interpret that as paying a fixed cost b, which we will assume is the same for both rulers. They also have to devote resources ($z_i \geq 0$ for ruler i) to winning, which we can think of as the taxes raised to pay for supplies, weapons, ships, fortifications, and military personnel. Revenues from the rulers' personal possessions, though usually less significant, would count too, and so would conscription and commandeered resources, although they too were typically less important, at least in early modern Europe. We will adopt a common functional form from the conflict literature and assume that the probability of ruler i winning the war if both decide to fight is $z_i/(z_1 + z_2)$. The odds of winning are then proportional to the ratio of the resources they each mobilize.[25]

Resources, however, are not free. They carry a cost c_i which may be different for the two rulers; we will assume that $c_1 \leq c_2$. These costs are political and include opposition to conscription and higher taxes, and resistance by elites when taxes revenues they controlled were shifted to the central government.[26] If these costs are too high or the expected gains from victory too low, a ruler may simply decide that it is not worth fighting. He can then sit on the sideline, as the Netherlands did in the eighteenth century. A ruler who opts out in this way expends no resources z_i and avoids paying the fixed cost b as well, but he has no chance of winning the prize.

We assume that the rulers first decide, simultaneously, whether or not to go to war. They then choose the resources to expend, z_i. If only one ruler is willing to go to war, he has to pay the fixed cost b involved in setting up an army, navy, and fiscal system, but he is certain to win the prize because he faces no opposition. He therefore devotes no resources z_i to the military and wins $P - b$. If both go to war, then ruler i can expect to win:

$$\frac{P z_i}{\sum_{1}^{2} z_j} - c_i z_i - b \qquad (1)$$

The first term in the expression is simply the probability that ruler i wins times the value of the prize P, and the next two terms are just the cost of resources z_i that he mobilizes and the fixed cost b.

The resulting game has a subgame perfect equilibrium. In it, only ruler 1 (the ruler with the lower political costs) goes to war if $P > b$ and $P < b(1 + c_2 / c_1)^2$. Ruler 2 sits on the sidelines, because with his higher political costs, his expected winnings would not be enough to defray the fixed cost. Ruler 1 and obviously ruler 2 as well spend nothing on the military, and so there is no actual fighting. We will consider that an outcome to be peace, even though ruler 1 has set up a military and a fiscal system to fund it.

Both rulers go to war if

$$P \geq b(1 + c_2 / c_1)^2 \qquad (2)$$

A valuable prize, low entry cost, and similar political costs will therefore entice both rulers to fight, and in equilibrium ruler *i* will then spend

$$z_i = \frac{P}{C}\left[1 - \frac{c_i}{C}\right]$$

on the military, where $C = c_1 + c_2$, while total military spending will be

$$Z = z_1 + z_2 = P/C$$

So if if there is actual warfare, low political costs and a big prize will drive up total military spending. The probability that ruler *i* wins the war will be $(1 - c_i /C)$, which will be higher for a ruler with a low cost c_i.

We will also suppose that the two rulers do not repeat this game. They play it once, at the outset of their reigns, and we interpret the decision to go to war as a choice not about a single conflict, but rather about being bellicose or not for their entire time on the throne. Other rulers may play the game too, including their successors, and one might therefore worry about dynastic considerations creating a repeated game. Foreign policy, however, changed enough from ruler to ruler to make this a reasonable assumption.

We thus have a model with war, military spending, and peace as well—namely, when one ruler wins the prize without any opposition and no resources are actually spent on fighting. How do improvements to military technology fit in? The technology used will be determined by a ruler's opponents. In western Europe, that was the gunpowder technology, but as we shall see, it was not the only military technology, and it was not effective against some enemies.

Whatever the military technology is, we will suppose (at least for now) that it progressed via learning doing—in other words by fighting wars and then using what worked against the enemy. That was typically how military technology advanced in the early modern world, whether it was weapons, organization, or tactics. The learning could take place during a war, or afterwords, when losers could copy winners and revise what they did. Conflicts in the late fifteenth century, for example, gave rise to lighter and more mobile artillery that could be mounted in and fired from gun carriages. The learning extended to organization as well. French and English commanders who battled against Spain in the sixteenth century, for example, learned to appreciate the Spanish infantry's training, discipline, and small group cohesion. They urged their own countries to adopt the same organization.[27] It is true that there were also conscious attempts to improve early modern military technology. King Philip II of Spain, for example, rewarded military inventors.[28] But such efforts themselves were often triggered by successes and failures on the battlefield, such as when the French sought to make lighter and more mobile field artillery after a defeat in the Seven Years War.[29] Learning by doing dominated, at least until the eighteenth century, although we will relax that assumption when we turn to the nineteenth century.

One reasonable way to conceive of the learning is to assume that it depends on the resources spent on war. Greater military spending gives a ruler more of a chance to learn, and rulers anywhere can do it—it is not peculiar to one corner of the world. We can model the relationship by assuming that each unit of resources z spent gives a ruler an independent chance at a random military innovation x, where x has an absolutely continuous cumulative distribution function $F(x)$ with support $[0, a]$.[30] If we ignore the fact that z is not an integer, then spending z is like taking z draws from the distribution, and the ruler who spends z will have an innovation with distribution $F^{z}(x)$. If both rulers draw from the same distribution (as would be reasonable to suppose if they are fighting one another and using the same military technology), then the highest realized value of x in their war will have a distribution $F^{Z}(x)$, where $Z = z_1 + z_2 = P/C$ is total military spending. We will interpret this best innovation as an advance in the military technology. As Z increases, the expected value of this best innovation will therefore rise, and x will converge in probability to a, which can be interpreted as the limit of available knowledge. Greater knowledge will therefore make for more innovation, like more military spending. Finally, if there is no war, there is no spending or learning, so in that case we can assume that $x = 0$.

Innovation is then an inadvertent byproduct of fighting wars, but what if the rulers intentionally seek to improve the military technology? If the innovation proceeds via learning by doing through same the process of spending on war, then the probability of having the best innovation will be exactly the same as the probability of winning the war, given by expression (1) above.[31] Winning the tournament for the best innovation will be the same as winning the war, with identical incentives, so there will be no difference, provided innovation comes from learning by doing.

So far this tournament is not repeated, but what happens if successive pairs of different rulers from the same two countries play the game over time, say once per reign? Let us assume that each pair of rulers can copy the best innovation from the previous round, which seems reasonable if they learn from experience. It also fits what happened in early modern Europe, where military innovations spread through espionage, efforts to copy what was successful, and Europe's longstanding market for weapons and military skills, in which professional soldiers had every incentive to adopt the most effective tactics, hardware and organization. In such a situation, no ruler will have any technological lead over his rival at the start of a new round of the tournament. If the limits of available knowledge do not change and if the successive pairs of rulers continue to draw from the same distribution and fight each round*,* then after n rounds the military technology will have a distribution $F^Z(x)$, where Z is now the total amount expended over the n rounds of the tournament. If the technology is ancient, then x will be so close to a that innovation slow to a halt, as typically happens with learning by doing.[32] It will also stop if wars are not fought. But if the technology is relatively new, then there will still be room for continued innovation, and the tournament will work like an idealized prize system that puts winning ideas into the public domain.

In that case, military innovation will be sustained and accumulate across reigns. Eventually, it will slow down as the limits to knowledge begin to bind. But that will not happen if these limits change, either through the learning by doing or (although this is more a matter for the nineteenth century) through advances in engineering and science.

Suppose, for instance, that learning in each round of the tournament shifts the support of the distribution F for the rulers in the next round to $[w, w + a]$, where w is value of the best innovation in the round that has just been played. Suppose too that the successive pairs of rulers confront the same costs and prize. They will continue fighting, and if x has expected value $E(x)$ after one round, then after k rounds of fighting, its expected value will be $k\,E(x)$. If F is the uniform distribution, then $k\,E(x) = kPa/(P + C)$. The rate of technical change in the military sector ($E(x)$ per round, or ruler's reign) will not slow, nor will there be any limit to improvements. On the other hand, if the fighting stops—say because the fixed costs b increase—then even this sort of technical change will screech to a halt.

Fixed limits to knowledge are more realistic for the early modern world, at least up until the eighteenth century. By the nineteenth century, however, they were clearly moving, although it would be debatable whether they shifted by as much w each round.[33] If we assume fixed limits as a reasonable approximation throughout early modern Eurasia, then what matters for sustained improvements to military technology are continued war with large military expenditures, and a new military technology, such as the gunpowder technology, which was ripe for improvement via learning by doing. A large prize P, low entry cost b, and costs c_i of mobilizing resources that are similar will guarantee continued war, and the expenditures will be big if, in addition, the costs c_i are low for both rulers. (If costs are high for both rulers, rulers will fight but spend little, and innovation will be minimal.) Eventually, however, the innovation will slow as learning by doing diminishes and the technology grows old.[34] The technology may still be used, because it can still win wars, but it will not become more effective. The only way to ward off this eventual slow down (at least in this model) is for the limits of knowledge to move. If that happens, innovation can continue unabated, provided that war persists and that the cost c_i of mobilizing resources remain low.

The assumption here is that the winning technology spreads after every round of the tournament. If it does not and if some rulers therefore lack the latest military advances, then they will fall behind and stand a greater chance of losing against rulers who possess the cutting edge technology. Having the winning technology, though, does not make the playing field perfectly even. Even with it, a ruler with high costs c_i will stand less of chance of winning against a low cost opponent, and if the difference in costs is big enough, he will simply avoid conflict.

Suppose now there are two technologies that are effective against different enemies. Gunpowder weapons, for example, worked well in early modern European warfare, whether on land or at sea. But until at least the seventeenth century they were relatively ineffective against the nomads who threatened China, portions of south Asia and Middle East, and even parts of eastern Europe that bordered the Eurasian steppe. The mounted nomads had no cities to besiege, and they were too mobile to be targets for artillery, except when it was fired from behind the walls of fortifications. Sending the infantry chasing after them would demand too many provisions, since they could simply ride off into the steppe 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 the nomads, the best option, at least for a long time, was simply to dispatch cavalry of mounted archers—essentially the same weapons the nomads themselves utilized. That was an ancient technology, which dated back to roughly 800

BC. In the early modern world, with fixed limits to knowledge, it could no longer be improved, although it would still be useful in war.[35]

Suppose then that a ruler fights only nomads. He will use primarily mounted archers, and only a little of the gunpowder technology, and because he spends practically nothing on it, he will not advance it. If one of his successors finds himself confronting an enemy against whom gunpowder weapons are useful, then he will try to acquire the latest gunpowder weapons from abroad because his realm will lag behind. The story will be similar for a ruler who fights on two fronts, spending a fraction g of his resources on the gunpowder technology and $1 - g$ on mounted archers. He will improve the gunpowder technology, but at a lower rate because he spends only gz_i on it, not z_i, and his successors too may want to import the latest gunpowder weapons because they lag behind.

This simple tournament model is certainly open to criticism. To begin with, the rulers are either bellicose, or they do not fight at all, either because they face no opposition or because they sit on the sidelines. The model does not generate more complex patterns of arming and fighting, as a repeated game might.[36] But that simple pattern does describe many rulers in the early modern world. Second, because rulers can opt out of conflicts, the model rules out defensive wars—wars that a ruler might want to avoid but cannot escape because his country has been invaded. But rulers did often sit out conflicts in the early modern world, and in any case, the behavior to explain is not whether a monarch must fight a particular invader, but whether he is bellicose or peaceful during his entire reign. Third, because the model has only two rulers, it glosses over what might happen if there were more than two political leaders battling for the prize, and in particular the problem of alliances. Yet that too is not as great a problem as it might seem. The underlying tournament model can be extended to more than 2 rulers, and when it is, the insights remain the same. What in fact matters is that there are two who are willing to fight rather than just one; having more than two is unimportant.[37] As for alliances, the early modern rulers we will consider typically had a chief enemy. For the Kings of France, for example, it was the Habsburgs in the sixteenth and seventeenth centuries, and the British in the eighteenth century. And while they did have allies, the alliances were typically decided in advance and often confirmed by a marriage of the rulers or their relatives. It thus reasonable to treat them as exogenous, with the dominant ruler making the decisions for the alliance. The game then reduces to our tournament between two rulers.

One final problem concerns the costs c_i. Throughout Eurasia, early modern rulers did sometimes confront political costs such as rebellions or elite opposition when they mobilized resources z_i for war. The costs c_i could differ from ruler to ruler, as in the model, although making them independent of z_i is a simplification, since they might well rise as z_i increases. The simplification, though, only amounts to supposing that the costs are constant during each monarch's reign and could possibly change thereafter. What then determines how the costs c_i differ from one ruler to another? One might assume that the king of a large and wealthy state would have smaller costs c_i because he could impose a low tax rate on a broad tax base. Even a small levy, however, might provoke opposition in peripheral provinces, which could evade payment or even secede. So the king's political costs at the margin (which is what c_i is measuring) might actually be high. Furthermore, small states might have certain advantages. They might have less trouble collecting taxes or preventing tax evasion. Furthermore, at least in early modern

Europe they were more likely to have representative institutions that would lower the political costs of levying taxes.[38] So c_i could vary in a complex way.

We cannot measure c_i directly, but fiscal and military histories should give us a qualitative gauge of whether c_i was low or high. If tax rebellions were rampant and elites were defecting to the enemy camp, then c_i would clearly be big. Per-capita tax rates would give us a rough quantitative measure of c_i.[39] If they are high, then presumably the political costs that rulers face must be low, for otherwise resistance would have likely broken out. That assumes that conscription and revenue from the ruler's property are relatively unimportant and that rulers spend money on war alone, and not on public goods that their subjects want. In much of the early modern world, both assumptions are reasonable.

Despite its simplicity, the tournament model does make useful predictions about when there will be war and when there will be advances in military technology, in particular the gunpowder technology. We will have war when rulers value the prize, when opponents' costs c_i are similar, and when fixed costs b are small. Opponents' costs will be similar if rival countries are of roughly the same size and face similar resistance to tax levies or conscription. The fixed costs will be small if setting up an army, a navy, or a fiscal system does not entail heavy expenses. That would certainly be the case for if some of the fixed costs are sunk: if, say, a tax bureaucracy was already in place, if naval dockyards had already been built, or a if system had already been established for drafting soldiers, commandeering ships, or supplying provisions. The fixed costs would likely be modest too if the two rulers' realms lay near one another, for fighting a distant country would entail setting up a big invasion force. War will persist if these conditions hold for successive generations of rulers.

Without war, there will be no learning by doing and no improvement in military technology. If the fighting halts, so will advances in military technology, and the resources mobilized z_i will decline too. War will be likely to stop if the fixed costs rise, or if a ruler annihilates his opponents and conquers their realms. His successors will then have no nearby rivals, and their only potential adversaries will be further away and so entail larger fixed costs. It will simply not be worth fighting them.

Continued war, though, is only a necessary condition for sustained productivity growth in the military sector. It is not sufficient. For that, the costs c_i must both be low. If they are both high, wars will be fought, but few resources will be mobilized, and technology advances via learning by doing will remain minimal. In addition, the technology has to a relatively new one, unless the limits to knowledge shift (as they may have, particularly after the eighteenth century). The gunpowder technology would qualify as new in the early modern period, but the mounted archers deployed against nomads would not. Rulers who do not employ the gunpowder technology (because it is ineffective against their enemies) will not advance it, and those who adopt it only part of the time will improve it only modestly. They will both fall behind rulers who use it constantly and extensively, and the same will be true of rulers who do not fight at all.

The technological gap between the leaders and the laggards will widen over time if successive rulers spurn the gunpowder technology or warfare in general. If one of them suddenly goes to war and faces an enemy against whom the gunpowder technology is effective, then he will try to import it from the technological leaders. If he can import it quickly, he will catch up, and if his political costs c_i are low, he will stand a good chance of defeating his opponent. But if there are obstacles to acquiring the gunpowder technology, then the gap between the leaders and laggards will persist, and it will grow even larger if the limits to knowledge shift.

3. Where in early modern Eurasia will the gunpowder technology be advanced?

The tournament model tells us where we can expect the gunpowder technology to be advanced in early-modern Eurasia. It also predicts where innovation will accelerate or come to a halt, and when gaps will open up between the laggards and the leaders, and it does so without any assumption that learning by doing is unique to a particular region. In addition, the model has implications for what will happen with taxes, the frequency of wars, and the likelihood of winning them.

For sustained improvements to the gunpowder technology, four conditions are sufficient and also necessary. First, over a long period of time, P must remain greater than $b(1 + c_2 / c_1)^2$, which will happen if P is always large, b always low and the c_i's always similar. That will guarantee continued war. If the condition fails to hold, war and any innovation will stop. Second, the c_i's must both be low so that $Z = P/C$ is high. Otherwise, war will continue, but there will be few advances. Third, all rulers must employ the gunpowder technology heavily. If not, learning by doing will be minimal, at least as far as the gunpowder technology is concerned. Fourth, rulers must have little trouble acquiring the latest military innovations. If not, they will lag behind leaders who have or can get cutting edge technology.

As for taxes and the likelihood of winning wars, the first and second conditions will boost military spending and (so long as non military expenditures remain low) taxes as well. The fourth condition and a low c_i will give a ruler a good chance of winning a war if he and his adversary both use the gunpowder technology.

We know what one of the other military technologies was—the age old technology of mounted archers, which was effective against nomads. But there were others as well. Against nomads, one alternative was simply to avoid war altogether and offer a truce with the lure of selective access to trade. It would appeal to the nomads since they lacked the agricultural and manufactured goods produced by sedentary people, and it might be cheaper than fighting. The Chinese adopted such a strategy repeatedly; so did the Spanish in their dealings with the Comanches on the fringes of their American Empire.[40] Similarly, in the Mediterranean there galley warfare, which dated back to classical times and was ideally suited to amphibious warfare in the light winds of the Mediterranean. It was also important in the Black Sea and the Baltic. Galleys grew more effective in the Middle Ages, and in the early sixteenth century they acquired ordnance that made it possible smash ship hulls. But then the limits to what learning by doing could do to improve this ancient technology were reached. Only a few guns could be added without taxing the oarsmen, and with little room to store water for the oarsmen, the galleys' range was severely restricted too. And they were vulnerable to heavily armed sailing ships.[41]

It is also clear what some of the barriers to acquiring the latest military technology would be. In the early modern world, embargos would not be the major obstacle, since enforcement was difficult. But distance alone would hamper the diffusion of the latest skills, weapons, and tactical innovations, even if mercenaries and weapons makers were willing to work for foreign masters. Technological gaps could then increase if learning by doing persisted in one part of Eurasia and stopped in another. All rulers could potentially advance the gunpowder technology, but if they fell behind, catching up would be slow.

And some parts of the technology were just hard to transfer, which would only widen the gaps between laggards and leaders. The reason was that they involved a number of complementary skills or changes, and rulers had to acquire the whole package if they wanted the innovation. One of the improvements to French artillery in the eighteenth century, for instance, was a shift to manufacturing them by boring a solid casting instead of using a mould with a hollow core. Boring made cannons more accurate and cut the number rejected in initial testing. But adopting the technique required careful training and supervision of whole teams of skilled workers. The Swiss cannon founder who perfected the process complained that if business declined and some of his employees departed he would have a hard time finding and training replacements when demand picked up again. And so, when he was asked to export the process to France's ally, Spain, he contracted to import a whole group of skilled workers and even got the right to impose heavy penalties on any of them who quit.[42]

Hiring the cannon founder alone was thus insufficient. The king of Spain needed all the supporting skills, or else he had to wait until a skilled team could be assembled and whipped into shape. Other advances required organizational changes—the small groups in the sixteenth-century Spanish infantry, for example, or the system of rewards on British ships that incited officers and men to victory at sea. Putting such changes into practice could easily provoke opposition and so take time. Transferring the innovations would be even slower if they depended on complementary skills (such as navigation or metal working) that were scarce in the civilian economy.

Which parts of Eurasia would be most likely to advance the gunpowder technology? Western Europe is an obvious choice. It had continual war, with all sides deploying the gunpowder technology, and the rival states were close enough so that rulers would not have too much difficulty acquiring latest military innovations through espionage, copying what worked, or Europe's large market for military goods and services. They could even hire a whole team, as Spain did with the boring technology.

That leaves only one more condition to check—the second one, that the c_i's were all low. Evidence that they were comes from per-capita tax revenues, which were high in western Europe. They exceeded per-capita taxes in the Ottoman Empire from the seventeenth century on, and they seem to have been higher than in China too, back as far as the sixteenth century (Table 2), if we can trust a claim based on French and English evidence and just two years of Chinese data.[43] Taxes were also high relative to GDP in western Europe, at least in the eighteenth century, when we can make such comparisons for France and England. By then France was spending 5 to 10 percent of its GDP on military, and Great Britain even more—perhaps as much as 28 percent.[44] 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.[45]

Western Europe should then have been a leader in improving the gunpowder technology. What parts of Eurasia would lag behind? The model predicts that if only one ruler is willing to fight, then he will spend nothing on the military and there will be no innovation and no war either, regardless of what technology he uses or what his costs are. That would apply to rulers in two places: Japan under the Tokugawa Shogunate, and China during much of the Ming and Ching dynasties.

Japan had suffered through generations of devastating civil war until three victorious warlords finally unified the fragmented country under what became the rule of the Tokugawa Shoguns (1603-1867). Peace made the populace better off, but it left the warlords and then the Tokugawa Shoguns with no one else to fight. In terms of our model, it was as though Japan's rulers were in a tournament with no other contestants. They would then have no reason to devote resources to war or to advance the gunpowder technology, which had been heavily used in Japan ever since firearms were introduced in 1543. One might of course wonder why the 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 a large fixed cost, including the expense of building a powerful navy. That fixed cost—the b in the tournament model—ruled out the possibility of foreign war and thus halted improvements to the gunpowder technology.[46]

We would therefore expect Japan to fall behind western Europe during the Tokugawa Shogunate. Before the Shogunate, by contrast, we would expect improvements to the gunpowder technology. The combattants were all using it in uninterupted warfare and they were close to one another enough to copy what worked. Furthermore, they managed to mobilize armies that by European or Asian standards were large relative to the population, a sign that their costs c_i were low.[47] One might fear that this prediction simply repeats the story of how the Tokugawa Shoguns banished guns. But in fact the shoguns did not ban firearms. Although they disarmed the population, they kept their own guns and required them for lords too.[48]

The model leads to a similar prediction for China. Under the Ming and Qing dynasties, as for much of its history, China was a large empire and much bigger than neighboring states. The emperors (and the officials who advised them) would therefore find themselves in a situation akin to that of the Tokugawa Shoguns: warfare abroad would require building an effective navy or fighting distant land battles and thus mean paying a prohibitive fixed cost b, which would discourage the emperors from fighting. Now it is true that the emperors did wage war (Table 3). But most of the hostilities were the sort of defensive conflicts that the tournament model does not take into account, which is at least consistent with the prediction that the emperors had little incentive to fight.[49] Furthermore, nearly all of these wars involved nomads at least to some degree, which meant that they made less use of the gunpowder technology. The contrast with western Europe was striking (Table 3), and it meant that there would be much less learning by doing with gunpowder weapons in China even when it was at war.

Not that China shunned the gunpowder technology altogether. It in fact gained in appeal in the early seventeenth century, when 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 when the Ming dynasty collapsed and China was unified under the Qing dynasty, the emperors once again found themselves facing big fixed costs if they wanted to fight abroad. And the gunpowder technology was still not effective against the Qing dynasty's major remaining enemy—nomads—for the simple reason that it continued to strain supply lines to the breaking point.[50]

The model would also predict that India would lag behind, particularly in the eighteenth century, when the subcontinent was convulsed by virtually constant warfare among the leaders and states that arose as the Mughal Empire disintegrated. The unremitting hostilities would suggest that the first condition of the model would hold, and the second and third would apply too, since the armies fought with gunpowder weapons and could easily acquire leading innovations from one another in what was an active market for military goods and services.[51] But the fourth condition—that all the c_i's be low—failed to hold, and without it we would not expect Indian leaders to advance the gunpowder technology. They might adopt it from abroad, but they would not improve it on their own.

The problem in India was that it was easy for Indian military leaders and other members of the elite to defect and join the enemy camp. (Behavior of that sort was less common in Europe, particularly after the early seventeenth century.) Indian rulers would hesitate before raising or centralizing taxes out of fear that elites would jump ship.[52] As a result, total resources $Z = P/C$ spent on the military were low, and so was military innovation. It was pushed even lower by conflict within powerful Indian families over succession to a throne or rights to rule.[53] Strife of this sort, which had grown rare in Europe after the late Middle Ages, reduced the value of the prize P for victors in India, by raising the odds that a prince or other ruler would be unable to enjoy fruits of winning. The prize was large enough to get the rulers to fight, but not big enough to get them to mobilize a large amount of resources $Z = P/C$ and innovate via learning by doing.

The argument about competition would lead to exactly the opposite prediction, for if unending warfare and highly developed markets for military goods are enough to advance the gunpowder technology, then eighteenth-century India should have been a leader, not a laggard. And if the model is correct, then it also helps explain why the East India Company became a dominant military power India: it simply had a lower c_i. Not only could it draw on its own financial system to fund its military ventures, but it had also gotten control of the wealthy Ganges plain in northwestern India and won support for higher taxes there by offering elites a land market in return for higher levies. Elite cooperation and more wealth to tax would mean a lower c_i, and it would be no surprise then that the Company conquered much of the subcontinent, simply by hiring away the best officers and their troops.[54]

The model predicts that India, China, and Japan should lag behind western Europe by the eighteenth century. It also suggests that the gap should grow, since India, China, and Japan were all far away from western Europe, where rulers would be developing cutting edge gunpowder technology. Distance would simply slow the diffusion of the latest weapons, tactics, and methods of organization and mean that although they would import military technology from western Europe, they would not quickly catch up.

What about Russia or the Ottoman Empire, which were much closer to western Europe? Both powers employed the gunpowder technology, but unlike the western Europeans, neither could focus on it. They both built galley fleets, for fighting on the Mediterranean, the Black Sea, or the Baltic. In addition, the Russians' major land enemy, until the middle of the seventeenth century, were nomadic Tatars. Firearms were of some use against them, particularly if deployed from behind fortified lines, but cavalry armed with bows and sabers was the major weapon, as in China. The Ottomans emphasized cavalry too, because much of their conflict involved frontier skirmishes and raiding. Even in the eighteenth century over 77 percent of their army was cavalry, versus under 27 percent in France.[55]

The tournament model would predict that Russia and the Ottoman Empire would be less likely to advance the gunpowder technology than the western Europeans and that they would both import western military technology if gunpowder weapons proved useful. The Ottoman Emperors faced another and even greater obstacle as well, at least by the eighteenth century, when political difficulties severely constricted their tax revenues. By then they were collecting considerably much less in per capita and gross tax revenues than the major western monarchs, and by the end of the century they had fallen behind the Russian czars.[56] In terms of the model, their c_i was high, which would make them even less likely to innovate and more likely to import technology. In addition, the high c_i would give the Ottomans little chance of winning when they fought against western Europeans or the Russians in the eighteenth century.

The Russians, by contrast, likely had a low c_i by the eighteenth century. Although the Russia's per-capita tax revenus were still lower than in the western European powers, the czars—thanks to the reforms of Peter the Great (1682-1725)—could draft serfs.[57] Western leaders had to wait for the wars of the French Revolution to conscript troops on that scale, which cut the cost of mobilizing resources. Furthermore, the Tatars had ceased posing much a threat, so that the Russians could devote more of their resources to the gunpowder technology. We would therefore expect them to do well in battles against western powers in the eighteenth century, and they might even begin to advance the gunpowder technology.

4. Testing the model's implications in early modern Eurasia

We can test the tournament model's implications for early modern Eurasia. If we begin with western Europe, we would expect to see innovation and productivity growth in the military sector. That certainly fits the literature on the military revolution (hardly a surprise, since it inspired the model), but there is also quantitative evidence supporting this prediction too, for we can measure the rate at which the productivity of the technology was increasing.[58] The yardsticks used underestimate the productivity growth, because they 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 the focus of much early modern naval warfare.[59]

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 (measure by the weight of the shot) as our sole yardstick of naval output, which we can divide by shipboard labor and capital to get an index of total factor productivity. In the English navy, this index was rising at a rate of 0.4 percent per year between 1650 and 1680, a period when firepower was gaining in importance.[60] 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.[61]

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.[62]

Productivity in the English navy increased in other ways as well. Captains, for instance, learned how to became much more effective fighters—a clear instance of learning by doing—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.[63]

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. 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.[64]

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. Using the dual, we can estimate productivity for weapons manufacturing in early modern France and England, and the median total factor productivity growth rate (over periods ranging from the late fourteenth century to the late eighteenth century) turns out to have been 0.6 percent—a rapid pace even at the outset of the Industrial Revolution.[65] 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 in Frankfurt who cast them reduced the price drastically. They did so by cutting the amount of copper they used, so that the weight of the miniature cannons plummeted. That may seem obvious to us, but in an era when artillery regularly exploded, it marked real progress. The resulting total factor productivity for these handgun makers (3.0 percent per year between 1399 and 1431) was impressive by modern standards and astounding for the end of the Middle Ages.[66]

What about the model's implications for the rest of early modern Eurasia? Although we lack similar figures for productivity, we can can test the predictions against the historical record. If we begin with Japan, the model predicts improvements to the gunpowder technology until the Tokugawa Shogunate, when innovation and warfare should stop. Taxes should diminish too.

Those predictions match the historical record. The warlords and other combattants fighting in Japan did innovate, and became, as we know, the first to use volley fire. But the military innovations ground to a halt, however, once the country was unified under the Shogunate.[67] Furthermore, not only did the Tokugawa Shoguns avoid foreign war, but their tax revenues declined as fraction of agricultural output.[68] A cultural explanation, it is worth noting, cannot account for this sudden change, for Japanese continued to have a strong attachment to martial values.

Historical evidence also confirms the model's implications for China and eighteenth-century India. Both would be expected to lag behind western Europe in developing the gunpowder technology, even though China was the birthplace of firearms and India should have been fertile ground for advances in gunpowder technology if the traditional argument about competition were correct. And both should have tried to import weapons and expertise from Europe when the gunpowder technology proved useful.

That is exactly what happened. In China, officials recognized that European weapons were superior, and they sought designs and expertise from the Portuguese or the Jesuits in both the Ming and the Qing dynasties. The imported weapons affected tactics, and defenses too, since Chinese towns were less heavily fortified than European cities.[69] And relative prices suggest that relative to the Chinese, the Europeans had a comparative advantage in manufacturing handguns.[70]

Military leaders in eighteenth-century India did much the same. They readily adopted new weapons and tactics in their unending wars, but they did not break new ground in their use. The innovations, by and large, came from western Europe with renegade experts, mercenary officers, and imports of weapons. And relative prices imply that western Europe had a comparative advantage relative to India as well when it came to manufacturing handguns.[71]

The model implies that Russia and the Ottoman Empire would also be less likely to advance the gunpowder technology and that both would import weapons and military expertise from western Europe, up until the eighteenth century. Then their paths would diverge. High political costs c_i would make the Ottomans drop further back and cut their odds of winning wars, particularly against western powers. The reverse would happen for the Russians.

That is what happened. Military historians argue that the Ottomans fell behind western Europe in the late seventeenth century, particularly in field warfare, and although the Ottomans had a large artillery industry, they imported expertise from western Europe. And by the eighteenth century, they dropped from the ranks of the great powers in Europe and were more likely to lose wars.[72] Russia, by contrast, joined the great powers in the eighteenth century, after importing western officers, shipwrights, cannon founders, and military architects. And increasingly, it won wars, against western European powers in particular.[73]

The divergence between Russia and the Ottoman Empire is difficult to square with the argument about competition, because both were frequently at war. That argument also fails to explain why all the wars in war-torn eighteenth-century India failed to advance the gunpowder technology. The tournament model can. It can also account for why China lagged behind, even though it was the birthplace of the gunpowder technology, and why Japan suddenly stopped improving the gunpowder technology, a shift that a cultural argument cannot make sense of. Although the model rules out the sort of defensive wars early modern China was engaged in, it does fit the rest of the Eurasian evidence about military victories, trends in taxation, and the flow of military goods and services. And with a simple modification, it can help us understand why the gap in military technology between Europe and the rest of Eurasia grew even wider in the nineteenth century.

5. Nineteenth century Europe

After 1815, the incessant warfare that had bedeviled Europe virtually disappeared. Diplomats at the Congress of Vienna had fashioned a coalition that discouraged wars within Europe (the rest of the world—including colonies—was another matter), and the coalition endured until late in the century. Some battles were fought, but by the standards of the past, they were short and relatively bloodless, allowing the continent to bask in peace until the onset of World War I (Table 1).[74]

With warfare subsiding, did the tournament fade away too? It might seem so. Nonetheless, military technology continued to evolve, as rifled handguns and artillery replaced smooth bore muskets and cannons, and steam powered gunboats and armored battleships took the place of sailing ships.

An extension of our model can explain why, one that takes into account three critical changes. First of all, glory had receded as a goal rulers pursued, having succumbed to Enlightenment attacks and the devasting experience of the Napoleonic era.[75] Since glory no longer offset any damage war did, peace was more attractive, and rulers had an easier time dividing up the expected gains from war. In addition, if foreign policy came under control of statesmen who stood to lose more from war than an Old-Regime monarch, then they would have even more reason to bargain for a peaceful settlement.[76]

To incorporate that possibility into the model, have two rulers or statesmen who have paid the fixed cost b and are willing to go to war go ahead and mobilize their resources z_i. But then allow to negotiate over dividing the prize P before they actually begin fighting.[77] If they can both agree to a division, they can split the prize P accordingly, but if not, they have to fight as in the original model, with the winner receiving a prize dP $(0 < d < 1)$ that is reduced by the damage done by war. If such their agreement can enforced by the resources they have mobilized, then they will reach a settlement. The tournament will have the same equilibrium as before, but with this difference: the rulers will act as if prize is reduced to dP, and they will no longer actually fight, even when they both arm and pay the fixed cost b. Instead, they will mobilize a total $Z = dP/C$ and live out an armed peace. War may still break out, because of other obstacles to a settlement, but it should be less frequent. That fits nineteenth-century history fairly closely.

The second major change in the nineteenth century were political and administrative reforms that cut the political cost c_i of mobilizing resources. During the Napoleonic Wars, states pushed centralization of their fiscal systems further than ever before, 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 c_i and the total cost C.[78] Patriotism and conscription had the same effect.

There was one final critical difference in the nineteenth century: it was now clear that military technology could be advanced not just via learning by doing, but by research. Although some research had always been was done, it grew more common in the eighteenth century, as the Enlightenment encouraged the collection of useful knowledge. That made it possible to improve military technology without actually fighting. The task became even easier in the nineteenth century, with the growth of engineering know how during the Industrial Revolution.[79]

When, for instance, the French navy added steam warships in the early 1840s, British leaders grew fearful of a possible invasion and quickly jumped into a naval shipbuilding race with France. In a short time, the arms race and the research it triggered led both the British and French navies to adopt the latest in steam technology—the screw propeller—which was less vulnerable to gunfire than the initial method of steam propulsion, paddle wheels. Yet Britain and France did not go to war to begin the process. They relied on research, including an 1845 tug of war in Britain between a steamship with a screw propeller and another one with paddle wheels.[80] Similar research, spurred by fear of potential enemies, led (along with advances in useful knowledge during the Industrial Revolution) to better handguns, artillery, and fortifications, all in the midst of what was, for Europe, a time of peace.[81]

More useful knowledge would relax the limit a to what learning by doing could do, but the model also has to incorporate decisions about research, which made it possible to innovate even in peace time. Let us consider then our two nineteenth-century rulers or statesmen who mobilize military resources z_i to use in either fighting or enforcing a peaceful settlement. Instead of equating z_i directly with taxes, assume that $z_i = f(x_i, y_i)$ is produced by spending tax revenues on x_i units of the existing military technology (each at a cost w_i) and y_i units of research on an improved technology (each at a cost r_i), with w_i and r_i reflecting both their relative scarcity in the economy and the political costs of raising revenue. Suppose, for the sake of simplicity, that the production function f is common to all rulers and constant returns to scale, and that each ruler takes his w_i and r_i (which may vary from country to country) as given. Then a ruler who decides to pay the fixed cost b in our modified tournament will choose x_i and y_i to maximize his expected payoff, given the possibility of a peaceful settlement and the actions of his adversary. It is easy to show that he will minimize the cost of producing the resources z_i that he mobilizes, that this cost will equal $c_i (w_i , r_i) z_i$ where is $c_i (w_i , r_i)$ is the cost of one unit of z_i , and that he will choose the same level of z_i as in the original model, except that the prize will now be reduced to dP and c_i will now be an increasing function of w_i and r_i . The equilibrium conditions of the model will remain the same, and if the two rulers do agree to a peaceful settlement, then they will still mobilize $Z = dP/C$ for the military. That is the same amount they would mobilize in war, and although the reduced prize dP will diminish Z, conscription and tax reforms will increase it by cutting the political portion of C.

How will innovation be affected? In the original model, innovation was only possible with war, and but research should make it feasible under the sort of armed peace that prevailed in the 1800s. One might assume, though, that research in peacetime would be less effective than the learning by doing that takes place with war. Let us suppose then that research works like military expenditure divided between two different military technologies so that in an armed peace it is the share $s = r_i y_i / c_i (w_i , r_i) z_i$ of research spending in the military budget that drives innovation. In such an armed peace, a leader who mobilizes z in military resources will then have an innovation x distributed as $F^{sz}(x)$, while if he is at war, the distribution is $F^{z} (x)$. If two rulers with the same share s are in an armed peace, then the best innovation to emerge from their research will have a distribution $F^{sZ}(x)$, where $Z = dP/C$. As in the original model, the incentives to improve military technology via research will be no different from the incentives to win a potential war.

With this modification, what would the model lead us to expect for innovation in the nineteenth century? Since leaders were no longer obsessed with glory, the prize dP

would be smaller, but C would be reduced by political reforms, and it would drop even more if the cost of research fell, as it likely did thanks to the advances in knowledge during the Industrial Revolution. Z, as a result, much be just as big as it was during early modern wars, or even larger, which could offset the effect of s on the distribution of innovations during an armed peace. The advances in science and engineering would also shift the support of the distribution F and relax the constraint imposed by the old limits to knowledge a. The armed peace would then generate as much innovation as in the past, or even more.

Thus, despite less time spent at war, the major European military powers were still competing in a tournament in the nineteenth century. Their effort were now devoted more to research and to building up the potential of their armed forces than to actual fighting, at least within Europe itself. Imperial wars, however, were not ruled out by nineteenth century diplomacy, and thanks to the military innovations that the ongoing tournament produced (rifles and steam gunboats are prime examples) it was now much easier to acquire colonies.[82]

7. Conclusion

The tournament model of Europe's wars yields a deeper understanding of why Europeans pushed the gunpowder technology of firearms, fortifications, and armed ships further than anyone else. Exogenous political and military conditions drove the rulers of western Europe's major powers to raise taxes and to spend heavily on this technology in fighting unending wars. The result was sustained innovation via learning by doing, all before the Industrial Revolution. When leaders' incentives shifted in the nineteenth century, the equilibrium outcome was armed peace, but when coupled with political changes and the advances in knowledge during the Industrial Revolution, that was enough to drive even more innovation.

Elsewhere, political and military conditions blocked such an outcome. In Japan, unification under the Tokugawa Shogunate snuffed out a similar tournament and removed incentives to funnel resources into the gunpowder techology. The story was similar in China, for it too, most of the time, was a large, unified empire. Furthermore, the gunpowder technology was not effective against its major enemy, nomads from the north. The technology was of little use either in Russia's early wars, or against some of the Ottoman Empire's adversaries. In addition, by the eighteenth century, the Ottoman Emperors faced heavy political obstacles to raising taxes. So did the leaders whose forces battled in unending wars in eighteenth-century India.

The implication, according to the model, is that all of these parts of Eurasia would fall behind western Europe in developing the gunpowder technology, and that the gap would grow over time, particularly in countries far from the leaders in western Europe, because distance would slow the transfer of innovations, particularly if packages of complementary skills were involved. Both quantitative and qualitative evidence bears out this and the other predictions the model makes and argues against alternative explanations for Europe's dominance of the gunpowder technology. The argument about competition, for example, cannot explain why all the wars in eighteenth-century India failed to make it a center of military innovation, nor why Russia rose to become a major power. And the model has the added advantage of raising new questions that go well beyond the model of competition: why, for example, the major powers in early modern Europe had such low cost of mobilizing resources, and why the same costs were so much higher in, say, eighteenth-century India.

Europe's lead was not forordained. Learning by doing would have been possible anywhere before the Industrial Revolution, provided that the exogenous political and military conditions were right. If, for example, the Mughal Empire had disintegrated earlier, then the rulers and leaders who arose in its place might have had time to develop fiscal systems and stable dynasties before the British conquest. They might then have been at the forefront of gunpowder technology, and India might even have remained independent. Similarly, if the Mongols had not conquered China, then it might have remained divided, and the successors to the southern Song emperors might have more of an incentive to funnel resources into the gunpowder technology. China, the birthplace of gunpowder, might not have fallen behind.

But Europeans ended up dominating this technology, which allowed them to wage war at a distance. Not that they were posting huge infantry armies abroad, at least before the nineteenth century. But they could dispatch ships armed with cannons to prey upon trade in places as far away as Southeast Asia, and for protection, ship maintenance, 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 posts 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 further technological innovation in the nineteenth century made it possible to extend the conquests and create colonial empires.[83]

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: 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 the French revenue and population figures, see Hoffman and Norberg 1994, 238-239 and the sources listed there. For England, 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 A3.1. 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 are 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. China was at war in 1578 and 1776, which might have raised tax levels. For the sake of comparison, England was at war throughout the 1570s and 7 years out of 10 in the 1770s; France fought 3 years of 10 in the 1570s and 5 years of out 10 in the 1770s.

Table 3: 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	0.56	0.03
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; and James Kung (personal communication of the figures for China).

Note: For the precise definition of the Austrian dominions and Spain, see Hoffman 2011b Table 2. The data for this table were collected by Margaret Chen, except for those for China, which were kindly furnished by James Kung. Chen also collected figures for China from the Chinese sources above, and her numbers were similar. Excluding wars against nomads does not change the figures for the western European countries because they did not fight wars against nomads.

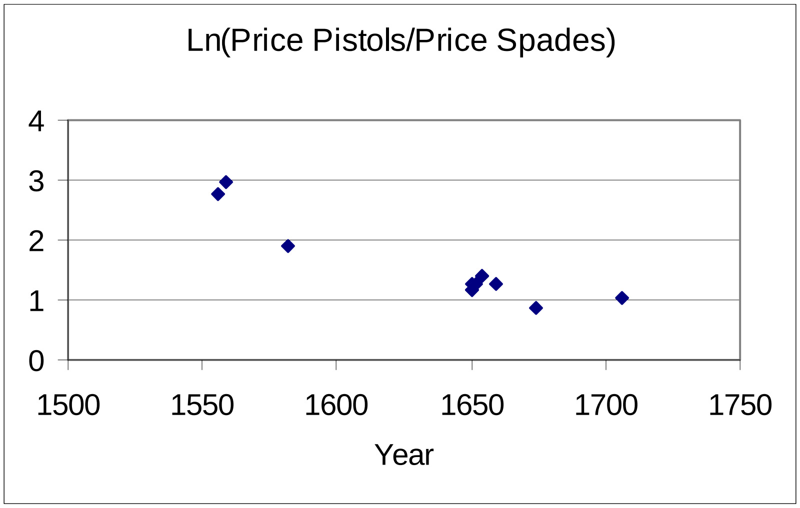

Figure 1: The logarithm of the price of pistols over the price of spades in England.
Source: Hoffman 2006

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1 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 .

2 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.

3 Headrick 1981 ; Parker 1996, 5; Headrick 2010 . Headrick is particular good on the limits to the technology.

4 As Black 1998 shows, luck had an enormous role to play, as did rivalries among people and powers outside Europe. 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 Lee and Temin 2004 .

5 See Parry 1970 ; Inalcik 1975 ; Parker 1996, 129-136; Black 1998, 30-32, 83-84; Heywood 2002 ; Agoston 2005, 10-12, 193-194, and Hoffman 2010 who shows that in the seventeenth and eighteenth centuries, the relative price of handguns was lower in Europe than in Asia. The Jesuits: Josson and Willaert 1938, 361-364, 580; Needham 1954, 5, part 7: 392-398; Spence 1969, 6-9, 14-15, 26; Waley-Cohen 1993

6 Guilmartin 1974, 255-263; Agoston 2005

7 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: Parker 1996, 18-19, 140-141.

8 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."

9 Kennedy 1987, 16-24

10 Hoffman 2010 and Carlo Cipolla's pioneering study Cipolla 1965 .

11 Hoffman 1996 ; Clark 2007 . Whether competitive markets do stimulate innovation will depend on property rights and other factors.

12For arguments that the Industrial Revolution was at least in part caused by Britain's naval spending and the by the share of international trade that its military victories won, see O'Brien 2006 ; Allen 2009 .

13 For money spent on the military, see Hoffman and Rosenthal 1997, Table III.1. For war and state formation, see Tilly 1990

14 Harding 1991, 28-30; Lynn 2000 . Rodger makes it clear that the cabinet had enormous influence over the way Britain fought wars in the eighteenth century, and Parliament often interfered in foreign affairs. Nonetheless, "foreign policy was still the king's prerogative" (Rodger 2004, 242). For Renaissance Italy, see Mallett 1974, 88. In Elizabethan England (Pettegree 1988), 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.

15 Louis-XIV and Sonnino 1970, 124; Machiavelli 1977, 247; Hale 1985, 29-32.

16 Lynn 2000 ; Bell 2007, 29-35 (the source of the quotation).

17 For the data, see Hoffman 2011b, Table 2. Losses in war did cost ministers their position.

18 Brito and Intriligator 1985 ; Powell 1993 ; Fearon 1995 ; Jackson and Morelli 2011 . The other reasons, according to Jackson and Morelli's summary, are asymmetric information, difficulties enforcing or getting credible commitments to agreements, and multilateral interactions in which coalitions can block potential accord.

19 Jackson and Morelli 2007

20 Anisimov 1993, 244-245

21 For an example from Japan, see Berry 1982, 215-216. It is conveivable that incentives were less biased in imperial China, because the pivotal decision maker may have been a member of the bureaucracy. Glory may have excercised less of a hold there as well.

22 The cost of wars in the late seventeenth and early eighteenth century and the political difficulties of changing the Dutch fiscal system forced the Netherlands to remain neutral for much of the eighteenth

century. The Dutch did not stop fighting altogether, but they ceased being an innovator in land and naval military technology: indeed, by the 1720s the Dutch navy was hiring British shipwrights. See Levy 1983, 37-38; Glete 1993, 411; de Vries and van der Woude 1997, 117, 122-123. Small countries relied on alliances to keep from being swallowed up; the complicated topic of the alliances is one that I leave aside.

23 The model below is adapted from Fullerton and McAfee 1999 with insights from Garfinkel and Skaperdas 2007 .

24 For an excellent overview of the conflict literature, see Garfinkel and Skaperdas 2007 . The insightful model of Jackson and Morelli 2009 takes into account both spending and the decision to go to war, and it can explain more complex patterns of war and peace and military spending. But it says relatively little about the effect of changes in the cost of war, which will be important in what follows. See also the works on the obstacles to peaceful bargains referenced above.

25 Garfinkel and Skaperdas 2007

26 An alternative interpretation would be to consider c_i as the marginal cost of transforming civilian goods and services into military resources z_i . Military resources z_i would then be harder to measure (it would be an index of the number of guns, soldiers, battleships, and fortifications), but a low c_i would imply a low relative price of producing military resources, and hence a comparative advantage in exporting them, which we could observe. Europe did have such a comparative advantage.

27 La Noue 1587, 320-322, 352-357; Bonaparte and Favé 1846-72, 1: 65, 72; Williams 1972, c-civ; Hall 1997, 121-122; Parrot 2001, 42-43

28 Goodman 1988, 123-141.

29 Alder 1997

30 This interpretation of spending is taken from Fullerton and McAfee 1999

31 Fullerton and McAfee 1999 .

32 Lucas 1993

33 Mokyr 2002

34 For examples of the same eventual slow down, see Lucas 1993

35 McNeill 1964 ; Esper 1969 ; Hellie 1971 ; Barfield 1989 ; Rossabi 1998 ; Chase 2003 ; Gommans 2003 ; Agoston 2005, 58-59, 191; Lorge 2005 ; Perdue 2005 . In the nineteenth century, firearms became much more effective against against nomads Headrick 2010, 281-284.

36 See, for example, Jackson and Morelli 2009 .

37 Under some technical assumptions, Fullerton and McAfee show that 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.

38 Dincecco 2009 ; Stasavage 2011 ; Dincecco forthcoming . High transportation costs (so David Stasavage has demonstrated) made it difficult to hold assemblies in large states. When delegates in the assembly were merchants who lent to the government (as in many European city states), then the assembly would also make it easier for states to borrow and so smooth their expenditures over time.

39 I am not assuming that c_i is exactly proportional to the reciprocal of per capital taxes but rather that higher per capital taxes imply (other things being equal) a lower c_i.

40 Hämäläinen 2008, 131-133. Early modern Europeans made strategic use of trade and diplomacy too. But diplomacy was often a means of winning allies for war, not a way to prevent it. As for trade, it too was usually something to be fought over or a strategy used during a war, and not a step toward a truce.

41 Pryor 1988 ; Glete 1993, 114-115, 139-146, 310, 706-712; Guilmartin 2002, 106-125

42 Alder 1997, 39-46; Minost 2005

43 For the Ottoman Empire, see Pamuk and Karaman 2010

44 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.

45 Brzoska 1995 , Table 3.

46 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 ; Parker 1996, 140-143; Guilmartin 2002, 182-190; Chase 2003, 175-196; Berry 2005 .

47 Finer 1997, 3: 1088

48 For the source of the story (Noel Perrin's *Giving up the Gun*) and a review that sets the facts straight, see

Totman 1980 .

[49] Using the Chinese sources listed in Table 3, Margaret Chen classified only 6 percent of China's wars as offensive, in the sense that China was the first to attack, and only 3 percent if the wars are weighted by their duration. The emperors could certainly go on the offensive, as when they wiped out the last major nomadic threat, the Zunghars, in the eighteenth century Perdue 2005 .

50 Here I am relying on Needham 1954, 5, part 7: 398-407; Franke 1974 ; Atwell 1988 ; Lorge 2005 ; Perdue 2005 and ongoing research by Bozhong Li and Guanglin Liu.

[51] Kolff 1990 ; Gommans and Kolff 2001 ; Gommans 2003 . Although the Mughal Empire did use gunpowder weapons, it was more reliant on cavalry than the Europeans.

[52] Gommans and Kolff 2001 ; Gommans 2003

[53] Gommans 2003 .

[54] Alavi 1995 ; Gommans and Kolff 2001 ; Cooper 2003 ; Gommans 2003 . The argument about the Ganges plain is due to Roy 2010 .

[55] McNeill 1964 ; Esper 1969 ; Hellie 1971 ; Parry and Yapp 1975 ; Guilmartin 1988 ; Glete 1993 ; Lynn 1997, 528-529; Paul 2004 ; Agoston 2005, 191, 202-203. The figures for cavalry are from Agoston and Lynn.

[56] Pamuk and Karaman 2010

[57] Hellie 1971 ; Pintner 1984

58 For military revolution, see Parker 1996

59 Guilmartin 1974, 253-254; Guilmartin 1983 ; Glete 1993, 58-61.

60 Capital here is computed from displacement, and labor from 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 and Berti 1994, 146-152. For the growing importance of firepower in this period, see Glete 1993 ; Guilmartin 2002 .

61 For examples, see Hoffman 1996 ; Clark 2007 .

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

63 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.

[64] Hoffman 2011a, Table 3

65 For evidence and the economics of the argument, see Hoffman 2010 . An alternative calculation yields an even higher median rate of total factor productivity growth, 1.1 percent.

66 Hoffman 2010

67 Parker 1996, 140-143; Chase 2003, 175-196; Berry 2005 . Philip Brown (personal communication) has pointed out to me that Japanese efforts focused on handguns. They made less use of artillery and did not do as much to improve it or to develop the trace italienne fortifications that proliferated in Europe. The obstacle, in his view, was the poor transportation in Japan, which made it difficult to deploy artillery.

68 Smith 1958 Increasing revenues from the mint could provide an alternative explanation for why taxes were not raised, an explanation that might not have any direct connection to the tournament. According to Philip Brown (personal communication), the central government's stagnating tax revenues in the early Tokugawa Shogunate may have reflected how vulnerable the immediate successors to the first shogun (Tokugawa Iyeasu) were after his death 1616. Stagnating tax revenues did not mean, however, that the central government lost control of the warlords—far from it.

69Josson and Willaert 1938 ; Needham 1954, 5, part 6; Spence 1969, 15, 29; Franke 1974 ; Väth 1991, 111-115; Waley-Cohen 1993 ; Lorge 2005, 125-128 and Li Bozhong, personal communication.

70 Hoffman 2011a . Cheaper capital may have also contributed to Europe's comparative advantage in the gunpowder technology (particularly with capital intensive naval warfare), 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.

71 Kolff 1990 ; Gommans and Kolff 2001 ; Gommans 2003 ; Hoffman 2011a . 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.

72 Levy 1983, (who the great powers were); Murphey 1983 ; Agoston 2005, 10-12, 193-194, 201. The

Ottomans lost 30 percent of 23 wars in the years 1500-1699 and 56 percent of 9 wars in 1700-99 (p = 0.09, one sided). For the sources and assumptions involved, see Hoffman 2011b, Table 2

[73] Cipolla 1965 ; Hellie 1971 ; Levy 1983 ; Pintner 1984 ; Anisimov 1993 ; Paul 2004 . The imports continued up to the 1780s. Russia lost 36 percent of 11 wars in 1500-1699 and 12 percent of 17 wars in 1700-1799 (p = 0.06, one sided); for the sources and assumptions involved, see Hoffman 2011b, Table 2. Russian continued to import western military technology into the 1780s.

74 Schroeder 1994, vii, 574-575, 581, 799-803. In Table 1, most of the wars in the years 1800-1850 were fought before 1815. If they are removed, the number of years at war drops sharply.

[75] Schroeder 1994 ; Bell 2007 . Annualized troop losses during the Napoleonic wars were higher than than in any other European conflicts during the period 1650-1913, according to data in Dincecco 2009, appendix, table 1; total troop losses were also bigger than in other wars before 1914, including the US Civil War: Clodfelter 2002, 159; Landers 2003, 337. One sign of glory's waning hold was the diminishing frequency with which the word appeared in books, according to a search (conducted on August 5, 2011 with ngrams.googlelabs.com) of books scanned by Google. Both "glory" in English and its French equivalent "gloire" peaked in frequency in the seventeenth century. Thereafter, the rate at which they appeared declined and it dropped even more in the nineteenth century. A more complex search (conducted on the same date on the French literature search engine artflx.ucchicago.edu) showed a similar pattern for the frequency of "gloire" in the same sentence with the French word for war, "guerre".

[76]Jackson and Morelli 2007 . In addition, after 1789, monarchs in the major powers also began to run the risk of being dethroned if they lost a war (Hoffman 2011b, Table 2); that had not been a danger before, except during civil wars. In terms of the tournament model, it would be as if both P and b were larger, which might lead some of them to sit out the war and others to fight harder. If, however, they were risk averse, they would have an even greater reason to find a peaceful settlement.

[77] The extension to the model here is adapted from Garfinkel and Skaperdas 2007 , which contains more realistic variations; see also McBride and Skaperdas 2007 .

78 Dincecco 2009 .

79 For the Enlightenment and the growth of useful knowledge, see Mokyr 2002 . Military examples would include experiments improved the quality of British gunpowder during after the American War of Independence, and late eighteenth-century trials of copper sheathing that protected wooden hulls against shipworms and increased ships' speed British navy. The effect was huge: warships were up to 20 percent faster, and since they spent less time being careened, the number of vessels available increased one third. For details, see Rodger 2004, 344-345, 378 . Improvements to French artillery after the Seven Years War provide yet another example.

80 Lavery 1983-1984, 1: 155; Glete 1993, 443-446, 450, 455; Corvisier and al 1997, 2: 490-497. Working screw propellers, which emerged in the 1830s, were not invented by the navies. The passage to steam powered warships with propellers was not immediate, and the results of the Crimean War (1853-1856), in which both France and England were allied, did play a role in winning over decision makers.

[81] See, for example, Corvisier and al 1997, 2: 476-477, 483-499.

82 Headrick 1981 .

[83] Headrick 1981 ; Headrick 2010