Why Did Europe Conquer the World

Philip T. Hoffman

California Institute of Technology

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Chapter 1: Introduction

Imagine that a time machine could carry you back to the year 900 and land you anywhere on earth for an extended stay. Where would you go live?

As you consider the possibilities, you might want a bit of useful advice—namely, avoid western Europe at all costs. Why reside there, when it was poor, violent, politically chaotic, and by almost any yardstick, hopelessly backward? There were no cities, apart from Cordoba, but it was part of the Muslim world. Luxuries (silks, perfume, and spices, which flavored an otherwise bland cuisine and served as the health food of the day) were scarce and extremely expensive. To get them, you had to trade with Middle Eastern merchants and sell the few western goods they deigned to purchase, such as furs or slaves. And if you were not careful—if, say, you wandered down to the beach in Italy—you yourself might be captured and delivered into slavery.[1]

Choosing Europe would, in short, be like opting to move to Afghanistan today. You would be far better off picking the Muslim Middle East, for back in 900 it was richer and more advanced, culturally and technologically, and would be a much more inviting destination. Or southern China, where political regimes would soon stabilize after a period of turmoil, allowing agriculture to advance and trade in tea, silk, and porcelain to flourish. Western Europeans, by contrast, had nothing like that on the horizon—only continued raids by marauding Vikings.[2]

Now let your time machine whisk you forward to 1914. How startled you would be to discover that the once pitiful Europeans had taken over the world. Their influence would be everywhere, no matter where you stop. Somehow, they had managed to

conquer 84 percent of the globe and they ruled colonies on every other inhabited continent.[3] While some of their possessions, such as the United States, had gained independence, they had spread their languages and ideas around the earth, and they wielded military power everywhere. If we set the United States aside as a European clone, there would in fact be only one non European power that would dare stand up to their armies and navies—Japan, which was busy borrowing their technology and military know how. No one would have expected that a thousand years ago.

Why were the Europeans the ones who—surprisingly—ended up subjugating the world? Why not someone else—the Chinese, the Japanese, or Ottomans from the Middle East or South Asians? All at one time or another could boast of powerful civilisations, and unlike Africans, Native Americans, and the inhabitants of the Pacific Islands, they all had access early on to the same weapons the Europeans used. And if you go back into the past, they would all seem to be stronger candidates than the Europeans. So why didn't they end up in control?

Finding out why is clearly important. After all, it determined who got colonial empires and who ran the slave trade. And it even helps explain who was the first to industrialize. But so far this question remains an unanswered riddle, and a particularly bedevilling one at that.

Now you might think that the answer is obvious: it was industrialization itself that paved the way for Europe's take over. The Industrial Revolution began in Europe and gave Europeans tools—from repeating rifles to steam powered gunboats—that assured their military supremacy. World conquest was then easy.

But things are not that simple, for if we step back a century, to 1800, the Industrial Revolution was scarcely underway in Britain and it had yet to touch the rest of Europe. Yet the Europeans already held sway over 35 percent of the globe, and their ships were preying on maritime traffic as far away as southeast Asia and had been doing so for three hundred years.[4] Why were they the ones with armed ships, foreign fortresses, and colonies, all well before the Industrial Revolution?

This question, once you begin pondering it, swiftly becomes one of those great intellectual riddles that you can't get out of your mind, not if you're the least bit curious. You simply can't stop thinking about it, because the standard answers do not get to the bottom of the issue. Or they just fall apart once you begin to scrutinize them.

One of those standard answers points to smallpox, measles, and the other crowd diseases that slaughtered Native Americans and inhabitants of the Pacific. The Europeans, by contrast, were unaffected because they had been exposed to these diseases and were therefore resistant. Their immunity was what let them conquer the Americas and the Aztec and Inca Empires in particular.[5]

The Europeans, however, were not the only people with this biological edge, for all the major Middle Eastern and Asian civilizations had the same advantage. Why had they too—and not just Europeans—been exposed to the crowd diseases? The reason (as Jared Diamond has explained) is simply that there were more easily domesticated plants and animals in Eurasia than in the Americas and fewer geographical and ecological barriers to the diffusion of crops, livestock, and agricultural technology. That meant earlier agriculture in Eurasia, and with agriculture came villages, herds of animals, and ultimately cities, all of which served as breeding grounds for disease, and also trade,

which spread epidemics.[6] So if Chinese, Japanese, South Asian, or Middle Eastern invaders had reached the Americas, they too would have survived, and Native Americans would still have perished. In short, even if disease is the crux of the matter, we still have to explain why it was the Europeans who were pursuing conquest, and not other Eurasians.

The claims about disease also fail to explain how the Portuguese could gain a foothold in South Asia at the turn of the sixteenth century and then successfully prey upon ocean going trade. The South Asians were immune too, so disease gave the Europeans no edge.

And there are other problems with the argument too, even we focus on the Aztec and Inca Empires. The assumption is that epidemics (of smallpox and measles in particular) were the single driving force behind the catastrophic collapse of the native populations of the two empires after the conquistadors arrived. If epidemics wiped out that many people (so the argument would go) then they must have destabilized Native American society and made conquest easy. There is evidence in favor of such an argument. Smallpox does seem to have struck the Aztec capital, Tenochtitlan, at the end of 1520, only months before Cortes captured the city. With the Aztec king among the many victims, the survivors had to confront Cortes under a new and inexperienced ruler, who had not yet had time to consolidate his authority. A similar claim case can be made for Pizarro's conquest of the Inca Empire, for an epidemic killed the Inca ruler and helped to touch off a debilitating civil war that ended just as Pizarro arrived.[7]

The trouble, though, is that the demographic catastrophe in Latin America had multiple causes—and not just smallpox and measles—for otherwise the native population

would have recovered after the initial epidemic. That at least is what a careful demographic analysis suggests. And what kept the population from recovering was the conquest itself, by wreaking havoc with Native American domestic life. Indians fled from warfare, and survivors were forced to work for the conquerers, often away from home, so that they could not provide their families with food. Indian women were also drawn into the conquerors households, often as their sexual partners. In short, it became much harder for the Native Americans to have children, making much of the population decline the result, not of disease, but of brutal conquest itself.[8] But then the argument that traces the conquest of the Inca and Aztec empires back to social dislocation brought on by epidemics is simply far too narrow, because there were other causes behind the plummetting population, including the devastation visited on the native population by the conquerors themselves.

There are also doubts that smallpox could have even triggered the Inca civil war, because it was unlikely to have reached the Incas before Pizarro arrived.[9] It does seem to have struck the Aztecs, but we have to keep in mind that it killed Cortes's Indian allies too, although he could then replace their leaders with individuals loyal to him. We have to remember as well that many Aztecs survived the epidemic. Warriors were particularly likely to make it through, and there were enough of them to force Cortes to fight a bitter three-month siege before he finally took Tenochtitlan. The same was true for the Incas, whatever the epidemic was that had afflicted them. Despite all the deaths from disease, the conquerers therefore had to confront enemy units that were far larger than their own, even if they had native allies. The forces Pizarro faced when he entered the Inca Empire in 1532 were particularly daunting. He had only 167 men and no native allies, yet he

managed to surprise the Inca imperial bodyguard of 5,000 to 6,000 men, crush them, and capture the emperor Atahuallpa. He then extorted a ransom of 13 tons of silver and over 6 tons of gold (most of it melted down native art work) before executing Atahualpa in 1533. For his brutal triumph against such odds, the rewards were gigantic—more than he and his men would earned if they toiled for 250 years as laborers back in Spain. Nor was that only victory against an overwhelming enemy. When the Incas rebelled in 1536, 190 conquistadors in the city of Cuzco successfully resisted a year-long siege by an Inca army of over 100,000.[10]

How could the Europeans triumph against such numbers? As an answer, disease alone fails. And how could the Europeans go on to conquer 35 percent the world by 1800, and even more by World War I, with much of the acquired territory in Asia, where the population was immune, or in Africa, where the Europeans themselves were vulnerable to tropical maladies?[11]

For some gifted military historians, the answer is clear: the Europeans simply had better technology. Epidemics and divisions among the natives helped, but technology gave them the edge, particularly against the centralized empires of the Aztecs and Incas. It helped even more when they sent armed ships to Indian Ocean and began to get a toehold in Asia.

What was the technology? It was, first and foremost, the weapons and defenses spawned by a military revolution that swept through early modern Europe (Europe between 1500 and 1800) as gunpowder transformed warfare: firearms, artillery, ships armed with guns, and fortifications that could resist bombardment. It also included older piercing and cutting weapons that had been honed during the Middle Ages and that

remained an essential part of fighting with gunpowder, through at least the sixteenth century and even beyond: swords, protective armour, lances for cavalry, and pikes for infantry to protect against charging horsemen. And it was the tactics and methods of organization that made it possible to squeeze more and more out of the weapons and defenses: how to turn crews and soldiers into an imposing fighting force, how to provide them with supplies efficiently, and how to get them to operate with speed and discipline even when under fire. The technology here encompasses a lot, and intentionally so, because it has to embrace everything that made victory more likely, from weapons to training and administration. All the various parts of the technology played a role in the European conquest, and they complemented one another and were continuously changing over time. Pikes, for example, defended musketeers against a cavalry charge, but they were eventually replaced by bayonets and disappeared by early eighteenth century. The reason for all the change was that from the late Middle Ages on Europeans were forever making the whole broad gunpowder technology more lethal and more effective, and they pushed it even further in the nineteenth century.[12]

The Portuguese deployed this technology when they sailed to South Asia at the turn of the sixteenth century. With it, they could use systematic violence (or the threat of violence) to shake down merchants, extract concessions from rulers, and draw allies to their side. Their armed ships could bombard cities and defeat larger fleets. And despite being outnumbered ten to one, they managed to capture the strategic port of Malacca (Figure 1.1) by staging an amphibious landing during which their troops turned back attacking war elephants with their pikes. Once Malacca was in their hands, they immediately built a European style fortress to protect it from attack. Such fortresses

(which eventually spread throughout the Portuguese Empire) could store food, merchants' goods, and supplies for Portuguese ships, and when they could be relieved by the sea, they were virtually impregnable. In 1568, for example, the fort in Malacca withstood a siege by a Muslim amphibious force that outnumbered the Portuguese and their allies 10 to 1.[13]

With elements of the same technology, Cortes and Pizarro could vanquish much bigger Native American armies. The cutting and piercing weapons—in particular, the swords and lances in the hands of horsemen—were Pizarro's greatest advantage, along with the discipline and experience of his forces, over half of whom had probably fought Native Americans before. His horsemen could scatter the Inca foot soldiers and then easily cut them down.[14]

Cutting weapons and discipline helped Cortes too, but so did other parts of the technology—in particular 13 small armed galleys—brigantines—that he constructed in order to take Tenochtitlan. He needed them because the Aztec capital lay on an island in the middle of a lake (Figure 1.2) and was connected to the shore by narrow causeways, making it difficult to take by force. Capturing the city was even harder than it seemed, for attackers on the causeways were vulnerable to Aztec archers in canoes and bridges in the causeways could easily be removed to block attackers or to keep them from getting back to the shore. Cortes immediately grasped the problem when he was first allowed into the city in 1519. Having taken Aztec emperor hostage, Cortes feared that he could easily be trapped away from shore and "starved . . . to death." He therefore "made great haste to build four brigantines," each with a cannon and able to carry 75 men. The brigantines could stop the Aztec canoes and transport Cortes's men and horses wherever

they were needed. To make their military superiority clear, Cortes brought the captive emperor aboard and fired the cannons.[15]

Eventually the Aztecs rebelled, drove Cortes out and destroyed his brigantines. But he vowed to return and one of the first things he did to retake the city was to build thirteen more of the galleys. They were important enough to have them constructed in safety, some fifty or so miles from the city, and then carried in pieces across rugged terrain so that they could be reassembled near the lake. And they were worth the effort. Besides defeating the Aztec canoes, ferrying men and supplies, and providing protection on the causeways, they cut off food to the city and, in the final battle for Tenochtitlan, shelled buildings from canals that led into the city.[16]

Although there was certainly more to Cortes's victory than just brigantines, they were clearly an important part of the gunpowder technology he had at his disposal. Some historians would nonetheless deny that the technology really mattered much at all. In their view, Cortes won not because of brigantines or other weapons, but because of divisions within the Aztec empire, which he could exploit to gain allies and eventually take the emperor's place at the top. A similar argument would apply to Pizarro and the Incas, and to the Portuguese in South Asia.[17]

Allies were clearly crucial, as were divisions in the Aztec and Inca empires. In the final campaign against Tenochtitlan, Cortes's 904 Europeans were vastly outnumbered by some 75,000 Native American on his side. They fought on land and in canoes on the lake, carried the brigantines and supplies to the lake side, and cut breaches in the causeways to let the brigantines through during battles.[18] But we must not forget that siding with Cortes was a strategic decision for his allies. They chose to join him for

a simple reason: defeat of the Aztecs was possible only if they fought alongside Cortes. By themselves, they could not beat the Aztec army or take over Tenochtitlan, but with Cortes they could, and the reason was his powerful technology, for it could open a breach in the Aztec lines that the huge numbers of allies could then exploit.[19] In short, his technology and their numbers were complementary; together they made Cortes look like a winner. Their decision to ally with him was in fact clear evidence of the power of his technology, not a sign that it was irrelevant.

The same holds for the Asian allies of the Portuguese.[20] The divisions the Europeans exploited were common to all early modern polities, not just those that were conquered. (They divided the European conquerers too. Pizarro, after all, was assassinated by fellow Europeans.) In theory, anyone could exploit such tensions; it was not a tactic reserved to the Europeans. But to do so, you had to attract allies, by appearing to be a winner. And with a small invasion force or tiny ship's crew that was possible only with better technology.

That is what this broad gunpowder technology allowed the Europeans to do. With it, handfuls of Portuguese could intimidate South Asia and then profit by muscling in on the spice trade and selling protection to Asian merchants. And it allowed small numbers of Europeans to seize the rulers of the Aztec and Inca Empires and eventually take their place at the top. From that apex of political power, the Europeans could extract resources from native tribute and forced labor, without ever having many colonists or any sort of an army of occupation. The technology did have limits. In Africa, the Spanish and Portuguese failed to conquer the Angolan kingdom of Ndongo, and tropical diseases kept most Europeans at bay until the nineteenth century. And in the Americas, the Europeans

had a much harder time with less hierarchical native groups such as nomadic plains Indians, who could adopt elements of European technology themselves and then successfully wage guerrila war into the nineteenth century.[21] But the Europeans continued to improve the technology and with it they eventually it vanquished the nomads too.

Military historians (Geoffrey Parker in particular) make it clear that Europeans were at the forefront of the gunpowder technology, well before the Industrial Revolution.[22] Patterns of trade tell the same story and demonstrate Europeans had a comparative advantage in the technology, for from the sixteenth century on they were exporting handguns and artillery to the rest of the world, while 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.[23]

But if the broad technology of gunpowder weapons is the answer, then we still have an immense amount to explain, for it is in fact astonishing that Europeans had come to dominate this technology at such an early date. After all, the piercing and cutting weapons were common throughout Eurasia, not just in Europe, and the Europeans themselves marveled at the quality of the swords and daggers in Japan.[24] As for firearms and gunpowder, they 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 arms. The Ottomans, for instance, made high quality artillery in the early sixteenth century.[25] And the Japanese discovered—some twenty years before

Europeans—the key tactical innovation (volley fire) that allowed infantry soldiers with slow loading muskets to maintain a nearly continuous round of fire.[26] 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.[27]

Why did these other powerful states fall behind, even before the Industrial Revolution began? And why did the Europeans continue to push the gunpowder technology further than anyone else on up through the nineteenth century? Those are the questions that must be answered if we want to understand why it was Europeans who conquered the world, and not someone else.

So far the best response is 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 any one country from taking over the continent and bringing the competition to a halt.[28] The ongoing innovation gave the Europeans early supremacy in the technology and eventually helped them conquer the world.

If competition was spurring continued military innovation, then the military sector in Europe should have experienced rapid and sustained productivity growth from an early date. It turns out that it did, and well before the Industrial Revolution.[29] But 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.[30] 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.

It seems then that our fundamental question still has no satisfactory answer. But there is a way to resolve this enigma. The resolution lies with the peculiar form of military competition that European states were engaged in. It was what economists would call a tournament—the sort of competition that, under the right conditions, can drive contestants to exert enormous effort in the hope of winning a prize. To take a modern example, think, for instance, of talented young baseball players in, say, the Dominican Republic, who are striving to make the big leagues. To get even a slight edge over other players, they foregoe education, spend all day working out, and take every steriod imaginable even if it damages their health, all for a miniscule chance of appearing in a major league uniform.

Between the late Middle Ages (1300-1500) and the nineteenth century, Europe witnessed a tournament with just as much intensity and commitment. The European one, however, was far more serious, for it repeatedly pitted the continent's rulers against against one another in warfare that affected the lives of people around the globe. The prize for the rulers engaged in this grim contest was financial gain, territorial expansion, defense of the faith, or the glory of victory. To snatch the prize, they raised taxes and

lavished resources on armies and navies that used the gunpowder technology and advanced it by learning from their mistakes or, especially in the nineteenth century, by doing research. The flood of resources channelled into warfare continued unabated up into the nineteenty century, even when it harmed the rest of the economy. In Europe, political conditions made it possible to mobilize gigantic sums for armies and navies, and military conditions favored the gunpowder technology, which, because it was new, had enormous potential for improvement by the sort of learning by doing that was going on in Europe before 1800. Elsewhere, political and military incentives worked against such an outcome, and that is why Europeans pushed the gunpowder technology further than anyone else. Europeans raced even further ahead in the nineteenth century, when political change and an expanding stock of useful knowledge made it easier to advance military technology via research, even though it was a time of relative peace within Europe itself. Meanwhile, despite sales of weapons and military services, the rest of the world fell way behind. Too many economic and political obstacles blocked the wholesale transfer of the gunpowder technology and the mobilization of resources on the same scale as in Europe.

Understanding why requires a look at the political, military, and fiscal incentives rulers faced, both in Europe and in China, India, Japan, the Ottoman Empire. It also requires an examination of other military technologies besides gunpowder. We will start with Europe before 1800 and use it to sketch a simple model of a repeated tournament, which will then be applied to Asia and the Middle East and to Europe after 1800. The model reveals the political and military conditions that distinguished Europe from the rest of the world and set the European tournament on its peculiar course, which only

came to an end after World War I. These exogenous conditions explain why Europeans came to dominate the gunpowder technology and why they—and not someone else--conquered the world, with consequences that ranged from colonialism to the slave trade and even to the Industrial Revolution.[31]

The question then becomes why political and military conditions were so different in Europe from what they were China, Japan, India, or the Ottoman Empire. A variety of answers—among them, geography and kinship ties—may at first glance seem plausible, but the only one that fits the evidence is history—in other words, the pecular train of past events that launched each part of Eurasia and a distinct path of political development. History unleashed the European tournament and kept it going, and it kept that from happening elsewhere in Eurasia. And it put the technology into the hands of European entrepreneurs, who could employ the technology to establish settlements or colonies or prey upon trade abroad. History is then the ultimate cause here, but that means that the outcome was contingent and (for a long time at least) not at all preordained. A different turn of events could easily have made another power the likely master of the world. If Charlemagne's descendants had not fallen to fighting with one another and the Mongols had not conquered the Chinese Empire, then we might be asking why China conquered the globe. And that is far from the only plausible scenario that would have fashioned a world totally unlike our own.

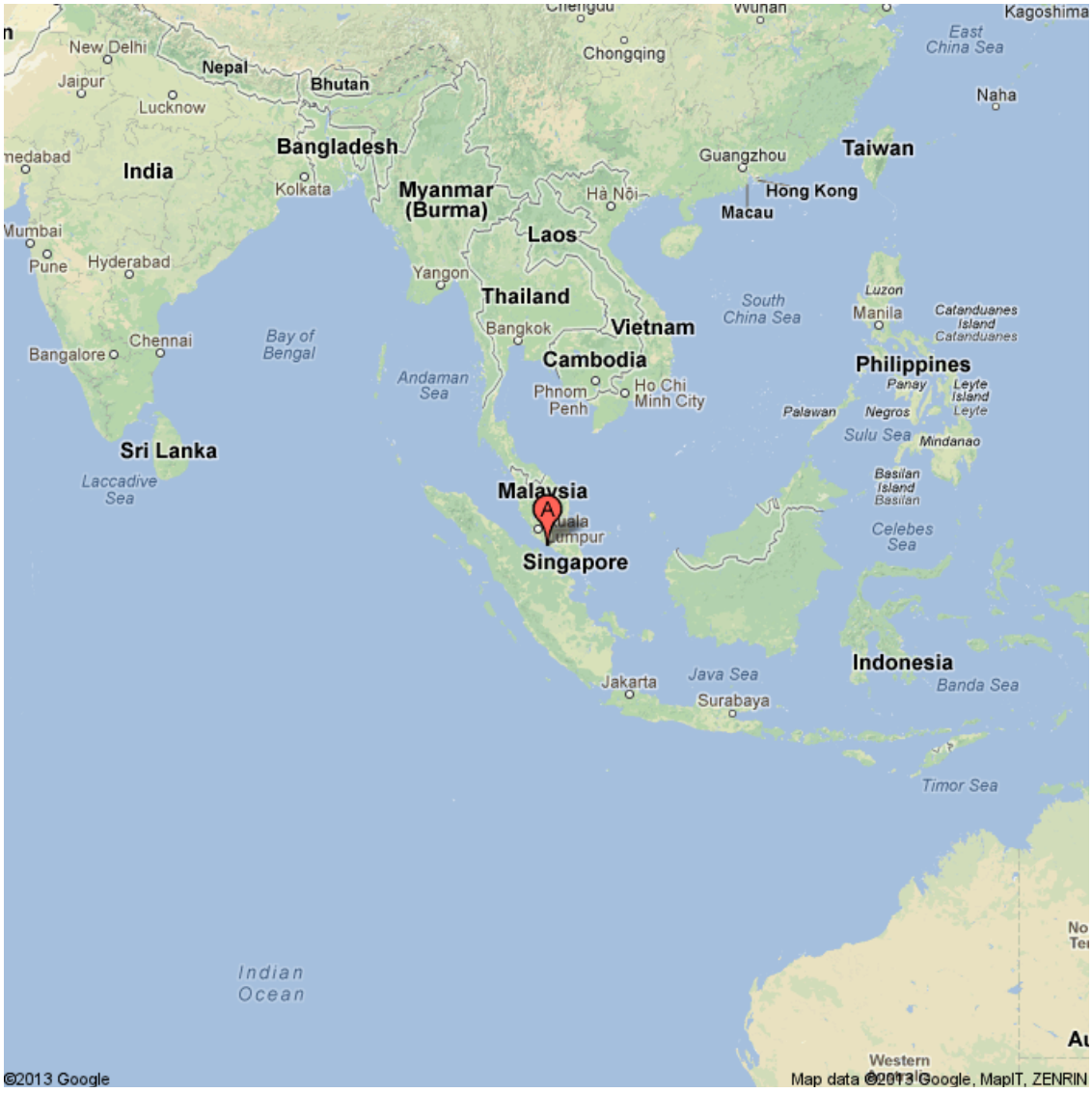


Figure 1.1 Malacca

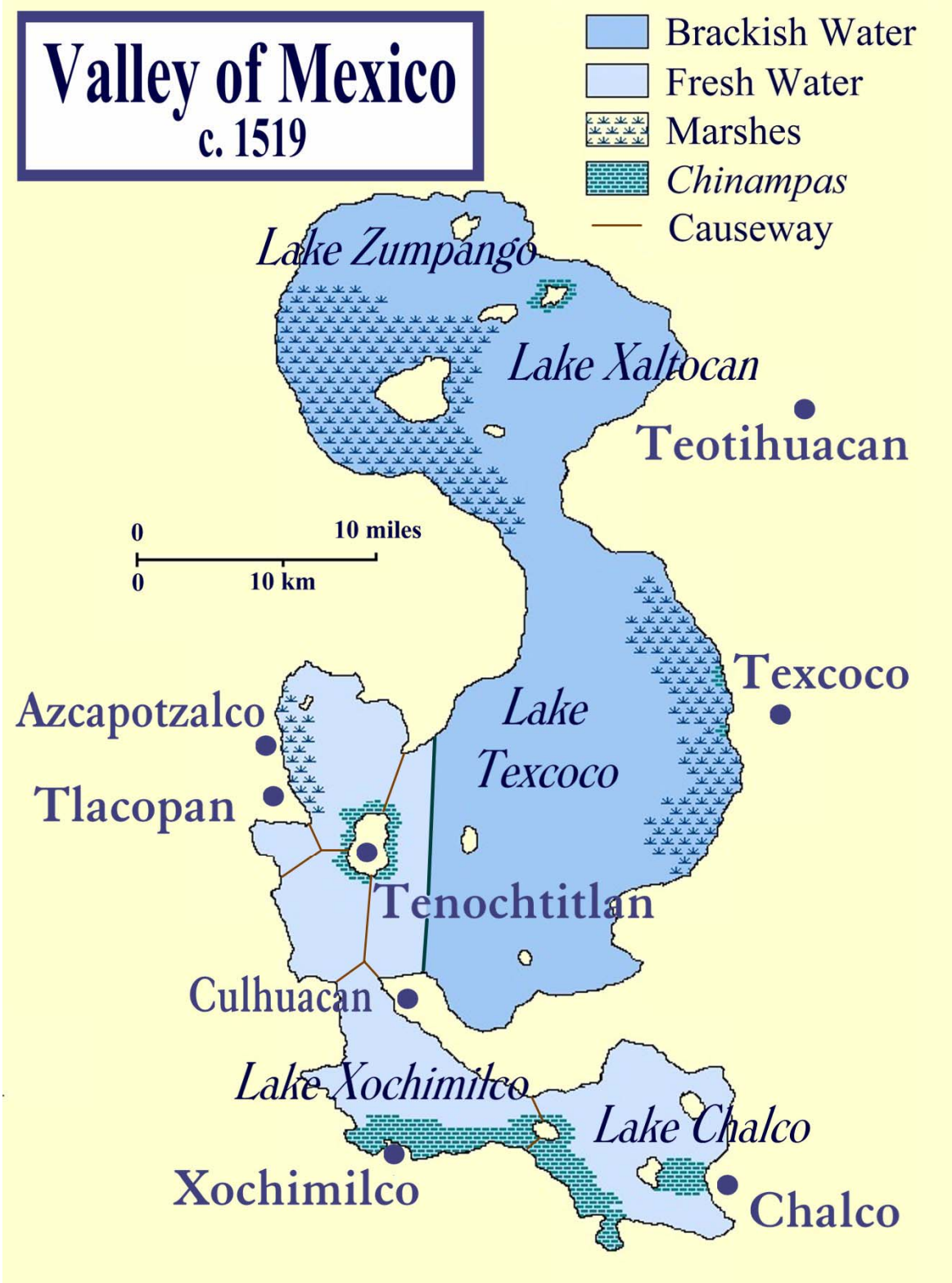


Figure 1.2 Tenochtitlan, the Aztec capital

Chapter 2: How the tournament in early modern Europe made conquest possible

Today political leaders are supposed to deliver prosperity, security, relief after catastrophes, and peace. But expectations were strikingly different for the monarchs who wielded power in early modern Europe. They "ought to have no object, thought, or profession but war." That was the single minded advice Machiavelli offered, and while the amoral realism of his other recommendations shocked the early sixteenth century, few of his contemporaries would have disagreed that the business of rulers was war. A rare thinker—an Erasmus or a Thomas More—might inveigh against all the fighting princes engaged in, but their lonely criticisms only underscored the harsh political reality. War was what monarchs did, at least in Europe.[32]

Sovereigns on the other side of the world, however, seemed far less bellicose. The Italian Jesuit Matteo Ricci concluded as much, roughly a century after Machiavelli, as he reflected on nearly three decades spent as a missionary in China, trying to convert the country's cultural and political elite. Although China in his view could easily conquer neighboring states, neither the emperors nor Chinese officials had any interest in doing so. "Certainly, this is very different from our own countries [in Europe]," he observed, for European kings are "driven by the insatiable desire to extend their dominions."[33]

The contrast was not mere rhetoric. Early modern states in western Europe lavished an immense amount on warfare—up to 12 percent of GDP in France and 28 percent in Britain in the eighteenth century, the earliest date when we can first make such calculations. For countries that were still poor by modern standards, these numbers are huge, and in all likelihood more than double what they were in China.[34] (For

comparison, at the end of the Cold War, the United States was devoting only 5 percent of its GDP to the military, and the USSR perhaps 10 percent.[35]) The money funded the first permanent navies in Europe and armies that at their peak mobilized more of the population than even the Roman Empire could.[36]

To understand what impelled rulers in early modern Europe to spend so much on war, the first step is to ask why they fought. We can then get a deeper understanding of what happened, by considering a simple tournament model of the political decisions involved in going to war and of their effect on military technology. The model will reveal the distinctive features of western Europe's politics and military rivalries, features that were the driving force behind European rulers' fiscal exertions and the continent's early supremacy in the gunpowder technology. The question then is how the gunpowder technology and the money expended on the military fed into world conquest. The answer, at least at first glance, may seem far from obvious, for most early conquerers were private adventurers, not generals leading a massive royal army of invasion. But the pecularities of western Europe's history will make it clear that there is in fact no contradiction at all.

1. Why rulers fought

Warfare was indeed the sole purpose of the states that coalesced in western Europe in the waning days of the Middle Ages, at least if we judge by what they levied taxes and borrowed money for. True, funds were spent on justice and palaces, and there was a pittance for transportation and famine relief. But the sums involved were

minimal—mere pocket change, at least for the major powers. Even the grandest of royal residences—the palace of Versailles—absorbed less than 2 percent of Louis XIV's tax revenues. Meanwhile, 40 to 80 percent of the countries' budgets went directly to the military, to defray the costs of armies and navies that fought almost without interruption (Table 2.1). The fraction of the annual spending devoted to war climbed even higher—to well over 90 percent in England, France, and Prussia—if we add sums spent subsidizing allies or paying of the debts of past wars (Figure 2.1). And it remained high for as long as we can chart the numbers.[37]

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—an Olivares in Spain or a Richelieu in France—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 the cabinet influenced the way wars were fought and Parliament could interfere in foreign affairs, "foreign policy was still the king's prerogative," and he could choose ministers to help him get Parliament to go along.[38]

To be sure, even an absolute monarch had to have some support, at least among the elites with a political voice, if he wanted to levy taxes or mobilize the resources needed to fight. Raising revenue or troops always came with a political cost that the king would have to take into account when deciding to go to war. That cost usually varied from province to province, for the fiscal systems of kingdoms such as France or Spain were far from homogeneous, and the same tax laws did not apply to every region until the nineteenth century. Impositions also varied across social groups, for the privileged often

escaped taxation. Nonetheless, the nobility, as we shall see, often favored war, and so did merchants, at least in maritime powers, where in age of mercantilism, military victory could bring commercial advantage or a share of monopoly profits. In short, Europe's rulers often had political support if they wanted to go to war.

What then made the European kings take up arms? That question has to be answered if we are to understand what the tournament was. In western 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. Whether they constructed their states by marriage and inheritance, or by defeating domestic and foreign rivals, they typically offered even conquered provinces 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.[39]

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. At the age of seven, the future King Philip IV of Spain could besiege a toy fortress with a model of the enormous army that his father maintained in the Spanish Netherlands. At age eight, his counterpart in France, the future Louis XIII, graduated from play weapons and warships to firing actual handguns. As the princes grew, 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. When they finally sat on their thrones, advisers like Machiavelli would then counsel them they should have no other thought but war, and their religious convictions would given them added reason to battle against Muslims, against heathens in distant parts of the world, and, after the Reformation, against Christians on the other side of confessional divide. It was hardly surprising then that for western Europe's monarchs, warfare had gone beyond the needs of defense and become, in the words of Galileo, a "royal sport."[40]

Religion did recede as a motive for war in the seventeenth century, and glory diminished in importance in the 1700s, 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 lure them on, just as it long had attracted much of the western European aristocracy. War, after all, had long been the traditional vocation of the European nobility, and through the eighteenth century most aristocratic families had sons under arms. Military service offered them honor, and it gave commoners who aspired to noble status a way to climb the social ladder.[41] In maritime powers such as England or the Netherlands it could also appeal to merchant elites, particularly if it could be combined a campaign for commercial advantage with attacks on political and religious enemies. In sum then, the political elite of the early modern European monarchies therefore had powerful reasons to support the king's military ventures, which meant less risk of significant political opposition when he opted to go to war.

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, particularly the non pecuniary ones, may perhaps 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 their ambitions did not seem strange at all to contemporaries. Thomas Hobbes invoked glory and reputation as one of the three causes of war in *Leviathan* (1651); other perceptive obververs said much the same, back to humanists in the fifteenth century.[42] Nor were the rulers of the major powers dissuaded by the downside risks of war. Although they might lose small amounts of territory, they faced no little chance of losing their thrones, for defeat in battle in anything but a civil war never toppled a major western European monarch from his throne, at least in the years 1500-1790 (Table 2.2).

It now becomes clearer why the early modern rulers fought so much. What impels states to 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. But such agreements often prove unattainable, and leaders go to war instead, despite all the devastation it causes.[43] As to why that happens, the literature offers several explanations. Although they all 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 bore few of the costs, which fell disproportionately on their subjects, particularly those outside the elite who were conscripted or paid taxes but had little political voice. 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.[44]

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. Territory posed similar problems, when it offered a strategic edge 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 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.[45] Finally, religious strife could make negotiation itself impossible if it meant dealing with enemies of the faith.[46]

These obstacles to peace were not unique to western Europe in the early modern period, 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 be as obsessed with glory as their European counterparts. 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 have taken up arms. Some countries were too small, and, others like the Netherlands in the eighteenth century, were big enough to fight but tended to bow out, or at least not enter a particular conflict.

2. A model of the tournament

We can now understand why rulers fought, but delving deeper requires a model, one that will explain why western Europe's rulers advanced the gunpowder technology and, ultimately, why their counterparts elsewhere in Eurasia lagged behind. A simple tournament model will do the trick, by isolating the peculiar features of the politics and military rivalries in early modern Europe. Readers who want to skip the reasoning involved (even though it is not at all complex and is always described in words) can simply leap ahead three sections to the verbal summary of the model's implications. That will be enough to to see how the model sheds light both on early modern Europe and the rest of the world.

The requisite model has to explain decisions about going to war and military spending. Otherwise it cannot make sense of all the fighting in weestern Europe and all the resources that went into it. It also has to account for improvements in military technology and apply not just to western Europe but to the rest of Eurasia as well. Otherwise it cannot help isolate the crucial differences between Europe and Asia.

An elementary model drawn from the economic literature on conflict and tournaments provides a tractable starting point.[47] 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.[48]

Consider two risk neutral early modern rulers who are considering whether or not to go to war. (The reasoning will be the same if decisions about foreign policy lie in the hands of ministers, officials, or elected representatives. We merely replace ruler by the leader who makes the decision—a prime minister, chief advisor, or pivotal member of a parliament or administration. For convenience, though, we will simply talk about rulers.) Winning the war earns the victor a prize P, which might be glory, territory, a commercial advantage, a victory over enemy of the faith. For the sake of simplicity, we assume the loser gets nothing, but the model will remain essentially the same if the ruler pays a penalty for losing or for failing to defend his kingdom against attack.[49]

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, 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 is assumed 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.[50]

Resources carry an average variable cost c_i, which may be different for the two rulers; assume therefore that $c_1 \leq c_2$. For now—we will relax this assumption later—let us suppose that the average variable cost c_i is constant for all levels of resources z_i. These costs are political: they include opposition to conscription and higher taxes, and resistance by elites when taxes revenues they control are shifted to the central government. 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. Making him pay a penalty for not defending himself against attack will only lower the fixed cost b and leave the model unchanged.

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 earn:

$$\frac{Pz_i}{\sum_1^2 z_j} - c_i z_i - b \qquad (1)$$

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. Only the ruler with the lower political costs (ruler 1) 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 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

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

Inequality (2) is necessary and sufficient for there to be war in equibrium; it will hold when the prize is valuable, the fixed cost is low, and the ratio of average variable costs c_2 / c_1 is near *1*. The ratio is always greater than or equal to *1* since $c_2 \geq c_1$ and it will be near 1 when both rulers face similar political costs for mobilizing resources.

Inequality 2 ensures that military spending will be positive, but it does not guarantee it will be large, which will turn out to be essential for advances in military

technology. To see when military spending will be big, consider the comparative statics of the equilibrium with war. In that equilibrium, ruler *i* will spend

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

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

$$Z = z_1 + z_2 = P/C \qquad (4)$$

So total military spending Z will only be large if, in addition to (2), P/C is big, or, in other words, if the prize is valuable and both rulers' political costs for mobilizing resources are low. Finally, the probability that ruler *i* wins the war will be

$$(1 - c_i/C) \qquad (5)$$

which will be higher for a ruler with a low average variable cost c_i.

We will also suppose that the two rulers play the game only 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 in power. If they are bellicose (if inequality 2 holds), they will fight one another throughout their time on the throne; if not, their reigns will be peaceful. Other pairs of rulers (from other countries or other periods of time) may play the game too, but to keep things simple, we will assume that they do not form alliances or take into account what happens after their own reigns are over. One might of course worry that two kings engaged in the tournament might change their behavior if, say, they knew that their sons would be pitted against one

another in the same game a generation later. Although such concern for heirs could in theory lead to radically different outcomes, in reality that would be unlikely, particularly in early modern Europe, where prizes such as glory or victory over enemies of the faith were paramount.[51] And in any case, the fact is that foreign policy was dictated by short term interests and changed greatly from ruler to ruler.[52] The assumption that rulers did not look past their own reigns is thus not at all unrealistic. As for the assumption about alliances, we shall see that it does not cause great problems either.

3. How did the tournament advance military technology?

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. So how do improvements to military technology fit into the model? 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.

Before we incorporate advances in military technology into the model, we need to see how they came about. Most, before the nineteenth century, were the result of learning by doing, no matter what the particularly military technology happened to be—whether it was gunpowder or something else. Rulers fought wars and then used what worked against the enemy. The learning could take place during a war, or afterwards, when losers could copy winners and both sides could 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. In particular, the armies of French King Charles VII (1422-1461) developed a highly effective artillery service during the Hundred Years War that helped drive the English out of the strongholds they occupied in France. The advances, though, did not stop at war's end. During the war, they came primarily in logistics and the organization of sieges. But afterwards, or at the very end, the French also adopted better gunpowder and began using cast iron cannon balls and gun carriages that could hold artillery when it was fired, so that it did not have to be removed and placed on the ground or on a separate mount. Some of the impetus for innovation after the Hundred Years War came from military rivalry with another power—the Burgundians—but the end result was that the French had even more effective artillery when they invaded Italy in 1494 under King Charles VIII. The shock of the invasion in turn prompted a reaction in Italy, where military architects redesigned fortifications so that they could resist artillery barrages and allow defenders to pummel attackers with cannon fire.[53] Similarly, after a disastrous defeat in the Seven Years War (1756-1763, the French redesigned their field artillery to make it lighter and more mobile and more effective on the battle field. Making the guns lighter was a slow process of experimentation, and it was only part of the story, for the mobile artillery only reached fruition during the French Revolution, when it was combined with new tactics and strategy, by leaders such as Napoleon.[54]

The learning extended to tactics and organization and to the manufacture of weapons, with improvements percolating up from officers, soldiers, administrators, artisans, and merchants. 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.[55] The gun founders in early fifteenth century Frankfurt who made some of the world's earliest handguns figured out how to cut the weight and the price of the weapons (which were essentially tiny hand held cannons) by using less metal (Figure 2.2). That innovation may seem obvious to us, but at a time when full sized cannons regularly exploded when tested (Figure 2.3)—that was why they were always tested before being used—the gun makers must have had to experiment to assure themselves that their handguns were safe.[56] How else, when they had no theory to guide them, could they have assured that their guns would not blow up in the holder's arms?

It is true that some of the advances did derive from the sort of experimentation that we might call conscious research. The copper hull sheathing adopted by the British navy in the eighteenth century was an example. The impetus came from the damage that gnawing shipworms did to hulls in tropical waters, particularly in the Caribbean. One remedy—used since the sixteenth century—was to nail an extra layer of planks on the hull, but worms could eat through the planks too. Lead sheathing was tried as well, but it did not hold up and, worse yet, it triggered a chemical reaction that caused iron fittings and nails on the hull and rudder to corrode. At sea, the consequences could be catastrophic: "My rudder was washed from my stern, and the irons on the sternpost broke," reported one commander of a lead sheathed ship in 1675. "I was forced to get my rudder inboard to save it, and drove in the sea three days with my rudder lying on the deck." Experiments with an alternative—copper sheathing—began in the middle of the eighteenth century, and it was soon revealed to have the added advantage of keeping the

hull clean of weeds and barnacles and of increasing a ship's speed. But it too made iron fittings rust, which was not easy matter to resolve since the underlying science was as yet a mystery. But after trying out layers of paper and other substances to separate the copper and the hull, the British navy eventually solved the problem in the 1780s by replacing the iron with a copper alloy that did not react with the sheathing but was strong enough to turn into fittings.[57]

Yet learning by doing dominated, until well into the eighteenth century, and research only took over after 1800. So if we are concerned with advances in early modern Europe, we should focus on learning by doing. 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 $[0, a]$. 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 obtain an innovation x with a probability based on the 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 innovation in their war will come from the 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 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 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.[58] 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.

What happens if successive pairs of different rulers from the same two countries play the game over time, 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. 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 will slow to a halt, as

typically happens with learning by doing.[59] It will also stop if wars are not fought. But if the technology is relatively new—as was the gunpowder technology—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 not slow until the limits to knowledge begin to bind. But that will not happen if these limits change, either through the learning by doing itself or 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 the 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 $k\,E(x)$. 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 under these favorable assumptions technical change will screech to a halt.

Fixed frontiers to knowledge are more realistic for the early modern world, at least up until the eighteenth century.[60] 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.

One additional 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 have the cutting edge technology. Possessing 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 either, 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.[61]

Consider then a ruler who 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.

4. Addressing doubts about the model

This bare bones tournament model is certainly open to criticism. Above all else, it may seem simplistic. 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 more elaborate game might.[62] But that stark pattern does describe many rulers in the early modern world, from emperors in China to kings in western Europe. Second, the model glosses over the knotty 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.[63] As for alliances, sometimes they were determined well in advance of any hostilities and

confirmed by a marriage. Those it would be reasonable to treat as exogenous. The other alliances could simply be considered another means of mobilizing resources, which leaves the model unchanged so long as the average variable cost remains constant.

Another set of problems concern these average variable costs c_i. These costs, which are political, cannot be observed directly. But tax rebellions, or elite opposition or defections when resources were mobilized for war would be evidence that they were high. So too would low tax levels in war time. The reason is that in the equilibrium with war, the ratio c_2 / c_1 of the political costs the two rulers face will (from equation 3) simply equal the inverse ratio z_1 / z_2 of the resources they mobilize. Tax revenues were usually the biggest component of the resources z_i that were marshalled for war; conscription and revenues from the ruler's possessions contributed much less in most cases. (In early modern Europe, Sweden and Prussia would be exceptions here, because the Swedish kings drafted a sizeable number of soldiers, and Prussian rulers drew significant revenue from their own property.) So if two rulers were fighting one another, the one with lower tax revenues would have a higher average variable cost c_i.[64] And even if rulers were not fighting one another, a higher average variable cost would, from equation 3, imply lower taxes in war time, although the lower taxes could also result from a less valuable prize or from differences in an enemy's average variable cost.

One might also worry about the assumption that the average variable costs c_i are constant, for surely they would begin to rise if mobilization grew without bound. The easiest way to overcome that objection is to impose a limit L_i to the resources z_i that can be mobilized at a constant variable cost c_i. In other words, if two rulers go to war, they each face the constraint

$$z_i \leq L_i \qquad (6)$$

on the resources that they can marshal, with L_i being larger in huge countries that can draw upon a bigger population or tax base. Once the constraint binds, a ruler cannot summon any more resources z_i.

Adding this constraint does not change things greatly. The same two equilibria remain, with the only difference being the precise conditions for the equilibria and the expressions for the resources mobilized and the odds of victory.[65] The most interesting case involves the leader of a small country who can summon resources z_1 at low cost c_1 but faces a severe limit L_1 to the amount of z_1 he can marshal. Suppose he faces an opponent with a higher cost of c_2 of mobilizing resources but a much larger upper bound L_2 to what he can do. What happens will then depend on L_1 as well as the other exogenous variables.[66] The small power may even drop out and cut its military spending, despite its lower cost of mobilizing resources, because it would be overwhelmed by its bigger opponent.

That was in fact the situation facing the Netherlands in the early eighteenth century. Thanks to its wealth and its representative institutions, it could collect taxes at relatively low political cost. But continued war against larger powers such as Britain and France, with five or ten times the Netherlands' population, had strained the economy and provoked opposition. Tax hikes were political impossible, because they required the assent of provincial assemblies and local authorities. With tax revenues bumping up

against a "ceiling," the Netherlands adopted a neutral foreign policy and tumbled from the ranks of the great powers.[67]

One might wonder too about what would happen if the fixed cost b and the the variable costs c_i changed over time. Although these variables are fixed and exogenous for each pair of rulers, some of the expense involved in b—for instance, establishing a fiscal system—could rightly be considered as a sunk cost by subsequent rulers. They would therefore face a lower value of b and hence, by inequality (2), have a greater likelihood of going to war. Political and administrative reforms that cut the political costs c_i would, if they remained in place, have a similar effect on subsequent rulers, for they would be able to marshal resources at lower cost. The outcome would be similar if fighting took a toll on the prize P and reduced its value—for instance, by devastating territory that rulers were fighting over. War could actually become more common, although the resources assembled would fall.[68]

Finally, one might worry that because they did not bear the full costs of going to war the rulers in early modern Europe would waste resources. From the perspective of social welfare, they no doubt would, for they could easily damage the economy as a whole in their effort to win. But they would hardly squander their tax revenues or the men under their command, for that would be tantamount to increasing their own costs of mobilizing resources. Self interest would make them use their men and material carefully as they pursued their military goals. By all indications they did exactly that. Military contractors and procurement officials watched the price of equipment carefully, and governments made a special effort to care for veterans, who made armies and navies effective. For one reason, it was simply "cheaper by far to cure a wounded veteran," as

Geoffrey Parker has noted, "than to train . . . a replacement." Charity pushed rulers in the same direction, driving them to ransom captives and to create hospitals for troops and homes for crippled veterans.[69]

5. The model's implications: where will the gunpowder technology be advanced?

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 if inequality (2) holds—in other words, when the value of the prize is higher, when opponents' costs c_i are similar, and when fixed costs b are smaller. 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 if some of the fixed costs are sunk because a a tax bureaucracy was already in place, naval dockyards had already been built, or a 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 require setting up a big invasion force. War will persist if the inequality holds 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, which is guaranteed by (2), is, however, only a necessary condition for sustained productivity growth with the gunpowder technology. It is not sufficient. For that, as we know, three other conditions must hold as well. First, the resources Z spent on war must be large, for otherwise there will be little learning by doing even though the rulers are in the equilibrium with war. Since $Z = P/C$ in the equilibrium with war, a sizeable Z requires a prize P that is large relative to the sum C of the average variable costs of the two rulers.

Second, the warring rulers must use the gunpowder technology heavily. If not, learning by doing with the technology will be minimal. 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.

Third, the rulers must be able to acquire the latest innovations in the gunpowder technology at low cost. If not, they will lag behind leaders who have the cutting edge technology or can easily get it. 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 laggards 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.

These three additional conditions are necessary for advances with the gunpowder technology, and together with inequality (2) they are sufficient. When and where do all four of them hold? Let us consider western Europe first and postpone answering the question for the rest of Eurasia to the next chapter.

For western Europe, inequality (2) was clearly satisfied throughout the early modern period, for the rulers of the principal powers fought relentlessly (Table 2.1). That they did so is hardly a surprise. As we know, they had been raised to fight and cherished the military prize *P* they pursued, be it territory, commercial advantage, victory over enemies of the faith, or Hobbes's glory and reputation. Because their realms were close to one another, they did not usually have to pay (Spain's Armada or its war against the Netherlands being exceptions) for a distant invasion in order to go to war. Proximity thus kept the fixed cost *b* of starting wars low, and it was reduced even more if part of it was the sunk cost of setting up a fiscal system in an earlier reign.

Western Europe's rulers also benefitted from relatively low political costs *C* of mobilizing resources, at least if we limit ourselves to major powers. The crushingly high tax rates relative to GDP (12 percent of GDP in France and 28 percent in Britain in the eighteenth century) in what were poor economies suggest as much. True, some rulers—the Holy Roman Emperors, for example—did face severe obstacles to what they could do, although the Habsburg Emperors could certainly marshal men and money in Austria and their other dynastic holdings. Other states (in addition to the Netherlands, Sweden in the early eighteenth century, and Italian principalities in the mid seventeenth century)

were limited by their size or political constraints and eventually had to drop from the ranks of the principal powers.[70] But western Europe's costs of summoning resources were smaller than in the other major states of Eurasia. Consider, for example, the Ottoman Empire. Its emperors were fighting European states and therefore were were contending for the same prize *P*. But by the eighteenth century, their tax revenues were less than the median for major European powers; less than what was raised by one of their major opponents, the Austrians; and far less than what France, England, or Spain collected.[71] It follows that they faced a higher average variable cost of assembling resources than in Europe.

The same was likely true in China too. The evidence comes from capita tax rates in war time, which were much higher in Europe than in China (Table 2.3). Although the difference could simply reflect a less valuable prize in China or the nature of China's enemies, it is bolstered by claims that tax revenue in China were in fact constrained by the threat of revolt and by elites who could more easily siphon off tax revenue in larger empire.[72] All the evidence therefore implies then that the ratio *P/C* was high in Europe and that major power were mobilizing enormous sums for war.

That leaves two more conditions to be checked: that the rulers of the major western European powers used the gunpowder technology heavily and that they could easily acquire the latest advances in the technology. That they relied almost exclusively on the gunpowder technology is clear. In constrast to China, they did not have to worry about nomads, or even major threats from cavalry forces as in eastern Europe, the Middle East, or South Asia.[73] They could focus on gunpowder, and not on an older technology that had exhausted its potential for improvement via learning by doing.

Some of them did admittedly spend money on a second ancient technology with limited potential for improvement—galley warfare. Galleys, which dated back to classical times, were ideally suited to amphibious warfare in the light winds of the Mediterranean and also important on the Black Sea and the Baltic. Galleys did grow more effective in the Middle Ages, and in the early sixteenth century they acquired ordnance that made it possible to smash ship hulls. But then the limits to improving this aged technology were reached. Only a few guns could be added without taxing the oarsmen, and with little room to store water for the oarsmen to drink, the galleys' range was severely restricted. Furthermore, they were vulnerable to heavily armed sailing ships. But the size of the galley forces was minimal, at least for the major western European powers. Of them, France had perhaps the biggest galley fleet, but even it was dwarfed by the French sailing ship navy, which was far more expensive.[74]

Finally, could rulers in western Europe get hold of the most recent improvements in the gunpowder technology? There too the answer is yes. The barriers to doing so were small. Embargoes could not block the diffusion of the latest weapons, skills, and tactical innovations, since enforcement was difficult in early modern Europe. In the sixteenth century, for instance, the Holy Roman Emperor Charles V could not stop gunsmiths from Nürnberg from peddling handguns to enemy, the King of France; his ban on sales proved ineffective.[75] The major obstacle to diffusion was in fact distance, but the western European states were close enough to eliminate it as an impediment. Markets for military goods and services then helped spread the latest advances, as numerous examples demonstrate. Charles V's son, Spanish King Philip II, recruited talented military architects from his dominions in Italy and skilled gunners from Flanders, France,

and Germany. Two centuries later the French were subsidizing the British iron master William Wilkinson in an effort to acquire British technology for manufacturing cannons.[76] Imitation was perhaps an even more effective means of spreading innovations, particularly after wars were over, when it became clear what had failed and what had worked, and when armies and navies had the money and time to rearm and reorganize. As we have seen, that sort of learning spurred the French to improve their artillery after the Hundred Years War (1337-1453) and even more clearly after their defeat in the Seven Year's War (1756-1763). The same process spread innovative ship designs and naval tactics.[77]

One additional obstacle, besides distance, was that advances often involved a number of complementary skills or reforms, 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 obtained the right to impose heavy penalties on any of them who quit.[78] 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.

Transferring the innovations would have been even slower if they depended on complementary skills, such as navigation or metal working, that were scarce in the civilian economy.

In western Europe, a ruler could at least put such a team together. Experienced soldiers, officers, and artisans and architects sold their services across the continent. The same was true for many civilian artisans. So in general military innovations would spread in western Europe.

All four conditions of the model therefore held in western Europe throughout the early modern period, and we would therefore predict sustained improvements to the gunpowder technology. We could make a similar prediction for the late Middle Ages, for there were active markets for military goods and services, and rulers were fighting for the same valued prize and beginning to use the gunpowder technology heavily (particularly given our broad definition of what this technology was). Furthermore, some of these late medieval rulers had established (often with the help of representative institutions) their realms' first permanent taxation—export duties, salt and hearth taxes, and impositions on taxes—and so presumably faced a lower cost of mobilizing resources.[79] We would therefore expect innovation in fourteenth and fifteenth-century Europe too.

6. Testing the model's implications in early modern Europe

According to the model, western Europeans should have advanced the gunpowder technology from the late Middle Ages on. With all the innovations, the military sector in

western Europe should have experienced sustained productivity growth. Does the historical record agree?

It certainly does, at least according to the military history. Artillery, first used in the late Middle Ages, was soon battering down city walls and triggering a drastic redesign of fortifications and—in reaction—new siege tactics that eventually rendered the task of taking a stronghold far more predictable and made even seemingly impregnable fortresses vulnerable.[80] In the early seventeenth century, King Gustavus Adolphus made field artillery effective, and in the late eighteenth, the French army increased its mobility by cutting its weight, which opened the door to drastic changes in tactics under Napoleon. Handguns, which crop up about 1400, were initially small bore cannons mounted on staves (Figure 2.4); then came matchlocks, fired with a smouldering match (Figure 2.5), and, in the seventeenth century, the more reliable flintlocks. And from the mid sixteenth century on, there were also pistols for the cavalry. At sea, ordnance was first mounted on ships in the fourteenth century. Four hundred years later inventions such as gunports had made it possible to cram 74 guns on board the largest warships, and the naval ships' range, seaworthiness, and ability to sail in inclement weather had all improved. So had tactics, training, and organization, whether in navies or armies. Volley fire (which required extensive drill for muskateers to sustain a barrage, particularly when the themselves were under attack) was but one example. And throughout this whole process, the successful monarchies got better and better at paying for wars and at supplying their armies and navies, as they gradually shifted from hiring private contractors to utilizing their own bureaucracies.[81]

There is also powerful quantitative evidence that the productivity of the technology was climbing, and doing so continuously and at rates unparalleled elsewhere in these preindustrial economies. In the infantry, for example, firepower became critical once handguns replaced bows, and the rate at which French troops could get off shots jumped 10-fold between 1600 and 1750, as bayonets made it possible to replace pike men and matchlocks were supplanted by more reliable flintlocks with ramrods and paper cartridges (Table 2.4).[82] The higher firing rate translated into labor productivity growth of 1.5 percent per year, which rivals overall labor productivity growth rates in modern economies and far exceeds what one would expect even at the onset of the Industrial Revolution.[83] And this yardstick is clearly an underestimate, because it ignores advances in tactics, provisioning, or methods of organization that were an integral part of the gunpowder technology. To take but one example, firing tactics did not stop improving once volley fire was perfected in the early seventeenth century. By the early eighteenth century, troops with flintlocks were divided into platoons that were dispersed throughout a battalion and arranged in a way—some standing, some kneeling—which allowed all members of a platoon to fire simultaneously. A third of the platoons would fire first, and then the other two thirds would follow in succession. The result was greater firepower, better moral since the men were all acting in unison as part of a small group, and—for the same reason—better control as well.[84]

Navies also witnessed sustained productivity growth—hardly a surprise given that it was there that Europe's lead was probably greatest. Measuring naval productivity is hardly easy, because 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.[85]

Yet despite the varied demands made of warships, the evidence is clear that productivity was advancing in early modern European navies. 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 other words, the productivity not just of labor, but of all the factors of production. In the English navy, this index was rising at a rate of 0.4 percent per year between 1588 and 1680, a period when firepower was gaining in importance.[86] 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.[87] One might worry that 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 by the late 1500s it had already begun to emphasize bombardment as an alternative to the boarding that had been the customary goal in naval battles, and the 1588 data in fact come from ships that were already specialized in firepower—the heavily armed flotilla that defeated the Spanish Armada.

Still another stark 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; the relative price of pistols, for instance, fell by a facto of six in England between the mid sixteenth century and the early eighteenth (Figure 2.6). The price of weapons—cannons, muskets, and pistols—also tumbled relative to the cost of the

relevant factors of production. As with the cost of modern computing, the plummetting prices were a sign of productivity growth, and again, an underestimate, because they ignore improvements in tactics, supply, and organization.

We can estimate productivity for weapons manufacturing in early modern France and England, by comparing the price of artillery, muskets, or pistols to index of the cost the factors of production. 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 (Table 2.5). Another way of analysing the prices (comparing the price of weapons to that of a civilian commodity such as spades, which involved a comparable production process) yields an even higher median—1.1 percent per year, which rivals the rates achieved in textiles and iron during the Industrial Revolution (Table 2.6).

The estimates do involve assumptions about market structure in Europe's military sector (Appendix B has all the details), but the evidence suggests that they are perfectly reasonable. And there is little chance the results are statistical flukes.[88] If anything, they (like the firing rate for handguns) are likely to be underestimates. The calculations ignore improvements in quality (such as the move from the matchlock to the more reliable flintlock) that should have increased prices and thus artificially reduced the estimated rate of productivity growth. They also ignore possible technical change in the production of civilian goods, which would have the same effect. And worst of all, they omit the periods when productivity growth was likely to be most rapid—namely, right after the weapons were invented. That is when the costs of production are likely to falling most rapidly thanks to learning by doing, but the prices for weapons that we need for the

calculations do not usually appear in historical records until much later, when weapons sales grew common.[89] The one instance when prices are available that early (for the first handguns produced in Frankfurt) in fact suggests that the resulting downward bias in the estimates is large, for total factor productivity growth turns out to have been 3.0 percent a year between 1399 and 1431, an impressive figure by modern standards and astounding for the end of the Middle Ages.[90]

The gunsmiths of late medieval and early modern Europe were getting better and better at making weapons, while the firepower of infantry and warships was rising inexorably. And those were far from the only advances that match the predictions of our model. The gains from some of the innovations was dramatic. The copper sheathing on eighteenth-century British warships, for instance, raised top speeds by nearly 20 percent and increased the effective size of the fleet by perhaps a third because the vessels spent less time being careened and repaired and more time at sea. The time at sea was also lengthened by changes that were less noticeable but just as important: healthier sanitation and provisions, and Britain's stronger fiscal system, which—in contrast to the French fisc—could afford to keep the ships in commission. And because ships could spend more time at sea, their crews could learn to work together more effectively as a team.[91]

Meanwhile, captains in the British navy were honing their skills as fighters. We can see how they did so, thanks to an analysis by Daniel Benjamin and Anca Tifrea. Between 1660 and 1815, as Britain rose to become the dominant naval power in Europe, her ship captains learned how to become far more accomplished naval warriors, which drastically cut their fatality rate, and presumably the mortality rates of their crew as well. The lower death rates cannot be explained by Britain's naval dominance in the late

eighteenth century, for they had already dropped by 1710, before Britain's lead was overwhelming. Rather, they were the result of what the captains took in from the mistakes of their predecessors, mistakes that taught them how to fight and what strategies to choose—when, for instance, to do battle, and when to flee. If we measure such learning by the number of commanders who had died before a captain took the helm, then this stock of knowledge of past errors turns to be the force driving down the mortality rates, even when we take into account the intensity or amount of fighting that the captain himself ended up being exposed to. Indeed, if one holds this intensity and amount of fighting constant, then the greater knowledge of past mistakes cuts a captain's odds of dying from 16 percent in 1670-90 to a mere one in a thousand in 1790-1810.[92]

Land armies made their troops more effective too. Getting people to follow orders when their lives are in danger is never easy. Maintaining discipline under fire is harder still. To overcome the problem, modern armies train soldiers extensively and work to forge a powerful sense of loyalty within the small groups in which troops fight. The training and commitment to fellow squad members will get soldiers to perform in the midst of battles and overcome what turns out to be a deeply rooted reluctance that humans have to kill at close range. These obstacles—so the evidence suggests—are ancient: they are hardly peculiar to an overly timid modern age.[93] Although early modern armies obviously did not have the benefit of modern studies of group dynamics, they did manage to find similar solutions to the problem. Sixteenth-century Spanish troops, for example, were organized into groups of 10 or so men who lived together and came to depend on one another for help. The soldiers would end up working well together and they would go to extremes to avoid disgracing themselves in the eyes of their comrades.

The Spanish armies also relied on veterans to train the new recruits. Both practices won praise even from Protestant soldiers who fought the Spanish in Europe's wars of religion, and they were eventually imitated by armies elsewhere on the continent.[94] So even when it comes to an intangibles such as group organization, the evidence confirms the model's implications for late medieval and early modern Europe—in particular, the prediction of sustained productivity growth in western Europe's military sector.

7. From military supremacy to conquest

The sustained innovation in Europe, it should be stressed, was in no sense preordained. In many ways it was, as we shall see, an accident of history. Learning by doing would in fact have been possible anywhere before the Industrial Revolution, and the outcome in Europe depended on a host of contingencies that lie outside the tournament model. To begin with, there had to be rulers who prized victory in war and who faced low political costs when they gathered resources to fight. In Europe there always were such rulers (the Hapsburgs, Valois, and Bourbons in the sixteenth and seventeenth centuries; Britain, France, and Prussia in the eighteenth), who could and did devote enormous sums to warfare with gunpowder weapons. If one of these monarchs had somehow annihilated the others and become a European hegemon, then innovation would have halted, or so at least the model predicts. But there would have been little or no innovation either if the rulers of these major European powers had faced stiffer resistance to higher taxes, or if gunpowder had been an ancient technology when they first gained the ability to collect taxes.

These critical factors are exogenous to the model. It cannot explain why some princes in Europe faced less tax resistance, or why gunpowder was not discovered a thousand years earlier. And it certainly cannot explain why there was no hegemon in Europe. To account for these conditions, we ultimately have to turn to history, to the history both of Europe and of the rest of the world.

But before we turn to these contingencies and exogenous factors, one pressing question has to be answered: how did supremacy with the gunpowder technology translate into conquest? The tournament in Europe did push European princes to advance the gunpowder technology and ultimately to achieve supremacy in its use. But most early conquerors were private adventurers, not generals or admirals. They typically had entered into some sort of contract with the crown and they may have even enjoyed a ruler's support. But they were not leading some massive royal invasion force, and many of their men were not even experienced soldiers. So did they get hold of the gunpowder technology, or at least enough of it to help them seize power or extract resources abroad?

The issue is not the technology itself, for we know it allowed the early conquerers to wield power in far away places where Europeans were scarce and where the technology was often the best way to make up for lack of numbers. Transporting huge numbers of Europeans to, say, Latin America or Asia, was out of the question: costs and mortality rates were too high.[95] The gunpowder technology (which substituted physical and human capital for military manpower) was the answer, even if it did have limits. With it, handfuls of Portuguese could extort money from South Asian merchants and hold off besieging armies behind the walls of European style fortifications. In Latin America, small numbers of Europeans could seize the rulers of the Aztec and Inca Empires and

take their place at the top. And in both South Asia and Latin America the technology permitted Europeans to attract native allies and to extort resources by the threat of violence, without ever having many colonists or any sort of an army of occupation. But there is still the fact that a conqueror such as Cortes had no military experience when he embarked for the New World.[96] How did he and the other early conquerors get their hands on enough of the gunpowder technology (and learn enough about how to use it) to tip the military balance in their favor?

It was not because Cortes's men were all soldiers with long experience in European warfare. Although little is known about most of the 2100 or so Europeans who participated in the conquest of Mexico, we do have details about the occupations of 153, and of them, 28 percent had occupations that could loosely be called military (soldiers, sailors, pilots, gunners, and gunsmiths). Perhaps another 10 percent were nobles and thus familiar with arms and horses. But that would still leave a large majority who were in no sense veterans of European wars. The same was true of Pizarro's men, of whom "only a very small minority…had any professional European military experience."[97]

The crux of the matter, though, was that both Cortes and Pizarro had some seasoned troops on their side, and while few of their men may have fought in Europe, many had done so in the new world. The Portuguese in southeast Asia had a similar advantage: Da Gama, Cabral, and Albuquerque were accompanied by men who had fought Muslims in North Africa. As in Europe, the veterans could train and command the novices, and the experience battling together in the new world would teach them the discipline they repeatedly demonstrated on the battle field.[98]

It would in fact have been a great surprise if that had not been the case, at least in Spain. By the end of the fifteenth century, civil war, the campaign to conquer the Muslim Emirate of Granada, and conflict with the French in Italy had given Spain a large number of battle hardened troops and officers. The Spanish monarchy encouraged its subjects to keep handguns and cutting weapons and to use them as members of militias or peace keeping brotherhoods. Laws did little to ban the ownership of weapons; what restrictions there were tended to focus barring arms that could be concealed, such as daggers or, later on, pistols.[99]

Nor was Spain unusual. Service in early modern armies was common enough that if even if Pizarro had been picking western Europeans at random, he would have had better than a 99 percent chance of getting at least one war tested veteran among his 167 men.[100] And most Europeans would have been familiar with the gunpowder technology, even if they had never served in the military, for legislation throughout western Europe did little to discourage the ownership of weapons. Gun ownership was widespread near Nürnberg in the sixteenth-century, and by the seventeenth, French peasants often owned muskets, and city dwellers were firing them off during festivals. Firearms were widespread in seventeenth-century England too, and part of a man's expected contribution to local peacekeeping. Efforts to curtail ownership in England aroused such resistance that a right to possess arms was written into the 1689 Bill of Rights.[101]

So even if the early conquerors were private adventurers, they still had the gunpowder technology in their arsenals. And we know it was immensely useful to them. Why else would Cortes have built the 13 brigantines and had them lugged in pieces some fifty miles across rough terrain for the attack on Tenochtitlan? Why else would the

Portuguese immediately build a fortress after capturing Malacca? Their actions speak louder than anything they could have written.

Not that all the early conquerors were private adventurers. The Portuguese in Asia were not: they were engaged in what swiftly became a government effort, particularly after the Portuguese crown settled on a strategy centered on fortresses and state sponsored trade. The Portuguese in Asia therefore possessed state of the art ships, naval ordnance, fortifications, and navigational knowledge that their monarchy had helped develop, in part because of its own involvement in the European tournament, particularly its rivalry with the kings of Castile.[102]

Over time, the other states reigned in the private efforts, but it did not happen overnight, and for good reason. Within Europe itself, monarchs had long relied on private entrepreneurs to wage war, and they continued to do so well into the seventeenth century, and not just for provisions or war finance, but for mobilizing armies and actual fighting. Privateering let them do the same at sea. Both allowed rulers to take advantage of Europe's huge market for military goods and services and its abundant supply of mercenaries, arms makers, and military contractors [103] A prince could profit from their expertise, and by paying contractors, privateers, and mercenary officers with plunder, he could harness their self interest and perhaps avoid some of the political costs of a brutal jump in taxes. Relying on them, quite simply, would be no different from what a modern company does when it outsources the preparation of its payroll instead of doing it in house. And such outsourcing was all very easy in early modern Europe, where the lines between private and public were blurred.

Private conquest simply extended the practice to other continents. The conquerors raised money from backers and promise shares to the participants, from the foot soldiers to the merchants or officials who outfitted the expedition.[104] By the seventeenth century, the private ventures were being organized as the world's first joint stock companies, which gave them even greater access to funding, by allowing them to sell shares that could be traded on an exchange. The companies pursued trade in Asia and the Caribbean and other parts of the world, but the trade was usually accompanied by military force, either to grab footholds, squeeze out competitors, win a trade monopoly, or protect against other Europeans in what became an intercontinental battle between states and mercantile interests. The companies had the right to conduct military operations, and the biggest ones—the Dutch East India Company and British East India Company—became important arms of their governments' foreign policy. The Dutch Company attacked Portuguese fortresses and shipping, built a fortified capital in what is now Jakarta, and assisted in coordinated Dutch attacks on Spanish and Portuguese interests in Asia and Latin America. As for the British Company, it fought the French in Asia and eventually conquered India.[105] With the help of the private companies, western Europe was exporting warfare with the gunpowder technology overseas.

In Europe then, the gunpowder technology could pass into private hands with relative ease, and private wealth and interests could be tapped to pursue conquest abroad. In Britain, merchants and investors in foreign adventures would profit from a widespread belief that foreign trade benefitted the country and required a stronger navy; they would become a powerful lobby in favor of even more resources for the navy.[106] In China, Japan, and the Ottoman Empire, by contrast, things were not that easy, for there were

obstacles to private use of the gunpowder technology, and barriers to large privately funded and privately led ventures of conquest. As we shall see, these hurdles were also accidents of history, like the unusual and exogenous political conditions that allowed European rulers to spend a fortune on war. But together they made it easier for Europeans to conquer the world.

Table 2.1
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 2.2

Probability That a Major European Sovereign Was Deposed After Losing War

	Fraction of Losing Sovereigns Deposed			
	Excluding Civil Wars		Including Civil Wars	
Period:	1498-1789	1790-1920	1498-1789	1790-1920
Country				
Austrian Dominions	0.00	0.06	0.00	0.12
France	0.00	0.05	0.02	0.09
Great Britain	0.00	0.00	0.03	0.00
Hohenzollern Dominions	0.00	0.07	0.00	0.06
Netherlands	0.00	0.20	0.10	0.33
Spain	0.00	0.13	0.00	0.16
Sweden	0.00	0.13	0.00	0.13

Source: Langer 1968 ; Darby and Fullard 1970 ; Levy 1983 ; Clodfelter 2002 .

Note: Wars are taken from the list in Clodfelter and are dated by when they end. Wars that involved no great powers are excluded, with Levy being the source of the list of great powers and the dates of their being great powers. Being deposed includes being exiled, imprisoned, maimed, executed, or forced to commit suicide. It does not include dying in battle, which would not greatly change the table. Sovereigns lost a war when they ceded territory, or their armies fled, or Clodfelter or Langer said their opponents were clearly victorious. Sovereigns included all monarchs, whether absolute or constitutional. For republics, the sovereign was the parliament or legislative assemblies; if the legislative assemblies shared sovereignty with a president or other executive, then the sovereign was the executive and the legislative assemblies together. During Charles V's reign as Holy Roman Emperor, his holdings as King of Spain are included in the Austrian dominions.

Table 2.3: 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 France, Hoffman and Norberg 1994, 238-239; for England, the European State Finance Data Base that Richard Bonney has assembled (http://www.le.ac.uk/hi/bon/ESFDB/dir.html), data Mark Dincecco has posted at the Global Price and Income Group web site (http://gpih.ucdavis.edu/) and explained in Dincecco 2009 and population figures from Wrigley, Schofield et al. 1989 , Table A3.1; for China, Huang 1998 ; Myers and Wang 2002 ; Liu 2009 , the Global Price and Income History Group web site 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 2.4

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

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

Source: Lynn 1997, 454-472

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

Table 2.5
Estimated rates of total factor productivity growth from of an index of prices relative to the cost of the factors of production: English and French weapons

		Assumed factor shares					*Estimated total factor productivity growth*
Weapon	*Initial–final dates*	*Skilled labour*	*Capital*	*Iron*	*Copper*	*Wood*	*(% per year/t-statistic)*
France							
Artillery	1463–1785	0.5	0.125	0.125	0.125	0.125	0.6/16.35
Muskets	1475–1792	0.5	0.167	0.167		0.167	0.1/0.96
England							
Artillery	1382–1439	0.5		0.25		0.25	1.4/5.37
Muskets	1620–78	0.5	0.167	0.167		0.167	0.6/2.48
Pistols	1556–1706	0.5	0.167	0.167		0.167	0.8/4.08

Source: Bytherne 1543 ; 1785, AN Marine D/3/34 "Compte fonderie d'Indret"; Rogers and Rogers 1866-1902 ; Guyot 1888 ; Levasseur 1893 ; Nicollière-Teijeiro and Blanchard 1899-1948 ; Tout 1911 ; Phelps Brown and Hopkins 1955 ; Beveridge 1965 ; Avenel 1968 ; Clark 1988 ; Rogers 1993 ; Clark 2002 ; nd [1524-1525], BN fonds français 2068 "Prothocolle pour servir d'avertissement" For further details about the sources and how the prices were were calculated, see Hoffman 2011 Table 1.

Notes: The estimates are based on regressions using equation (2) in Appendix B. If lack of data excluded a factor from the regressions, no factor share is shown.

Table 2.6

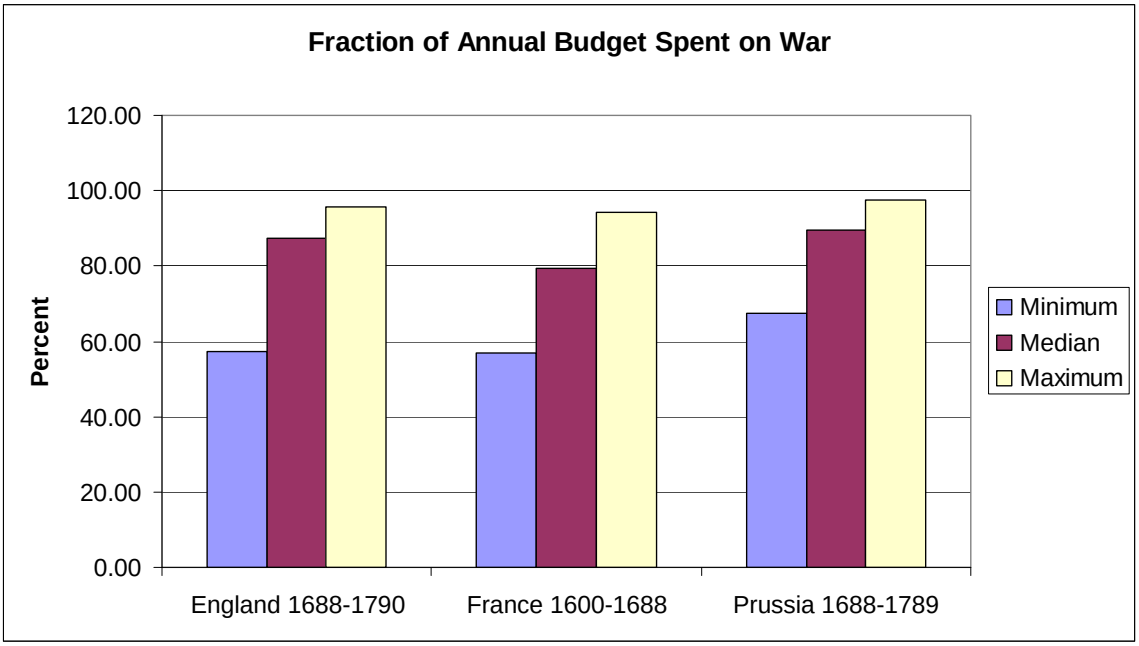
Estimated rates of total factor productivity growth from relative price of weapons and non military manufactured goods

Military good	*Non-military good*	*Period*	*Total factor productivity growth (% per year/t-statistic)*	*Factors of production in addition to skilled labour*	*N*
France					
Artillery	Lathing nails	1463–1785	0.7/4.95	Copper, capital	25
Muskets	Lathing nails	1475–1792	0.4/1.34	Iron, capital	37
England					
Artillery	Spades	1382–1439	2.4/8.65	None	10
Muskets	Spades	1620–78	1.6/3.49	None	7
Pistols	Spades	1556–1706	1.1/4.85	Iron, capital	12

Source: In addition to the sources listed in Table 2.5, they are Guyot 1784-85, vol. 15, sv "Rente" and English spade prices kindly furnished by Greg Clark. For more details about the sources and how the prices were calculated, see Hoffman 2011 Table 2.

Notes: The regressions are based on regressions using equation (3) in appendix B. N is the number of price observations for the military goods; where there were more than 10 observations, the regressions were run with additional factors of production other than skilled labour. The other factors of production were ones whose prices could be found and for which factor shares were likely to be different for the military good and the comparison good.

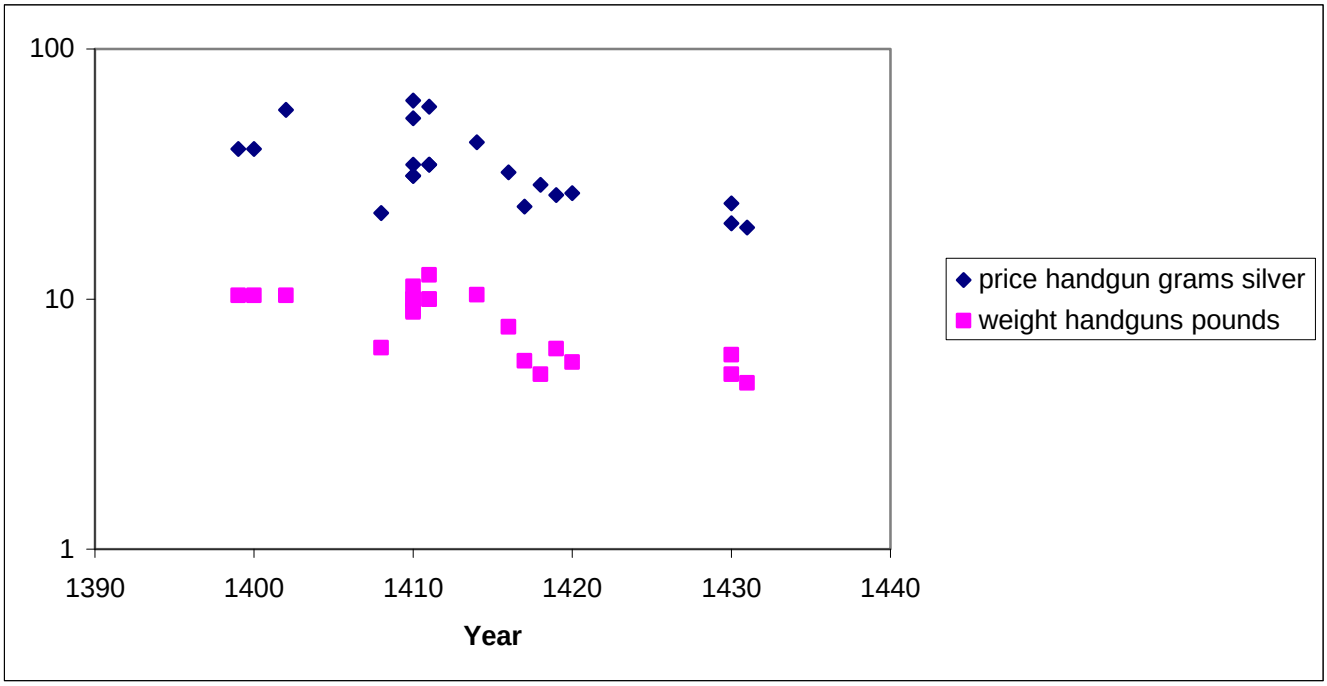
Figure 2.1 Fraction of Annual Budget Spent on War: England, France, Prussia, 1688-1790



Source: govmilexpenditures.xls Mitchell and Deane 1962, 389-391 (Britain); European state finance database http://esfdb.websites.bta.com , consulted May 5, 2011 (data supplied by Richard Bonney and Martin Körner for France and Prussia).

Note: The figures England and France—but not Prussia—include subsidies for allies and some, and some, but not necessarily all, debt payments. Expenditures in the English case are net public expenditures.

Figure 2.2. Price and weight of early handguns in Frankfurt, 1399-1431



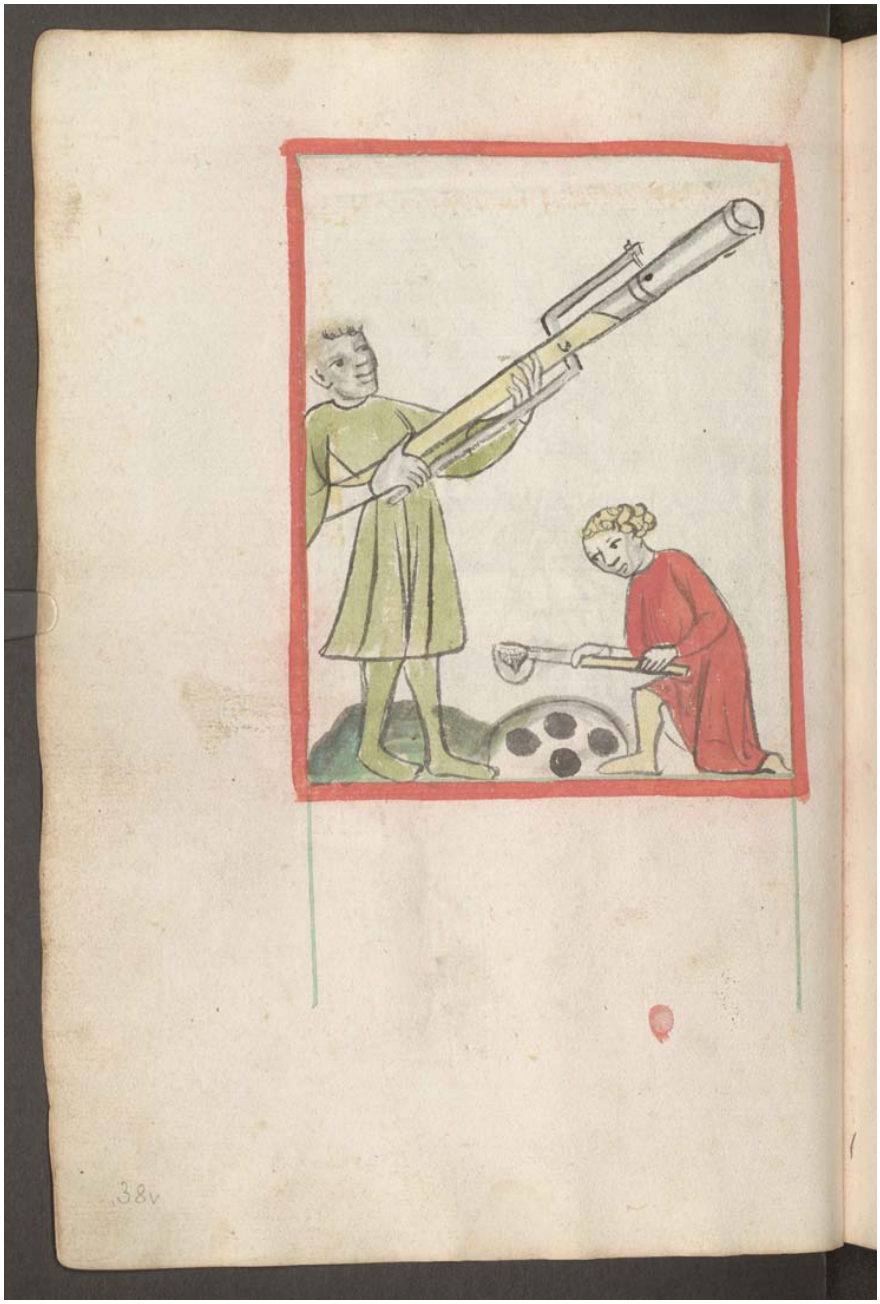
Source: Rathgen 1928

Figure 2.3. Exploding cannon, circa 1411.

Source: Austrian National Library, ms. 3069, fol 29.

Note: The manuscript warns the gunner not to stand beside the cannon but 10 or 20 steps behind it. For more on the manuscript itself, see Leng 2002, 1: 172-178, 195-197; 172:439

Figure 2.4 . Early handgun, circa 1411.

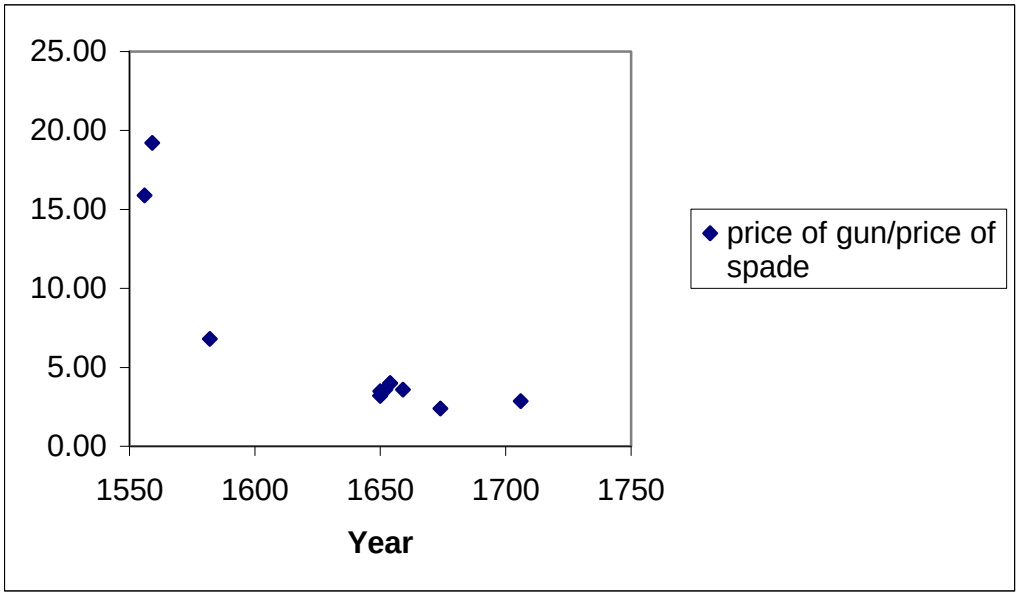


Source: Austrian National Library, ms. 3069, fol 86.

Figure 2.5. Firing a matchlock, 1607.

Source: Gheyn 1971 Figure 10.

Figure 2.6. Price of pistols relative to price of spades: England, 1556-1706.



Source: Rogers and Rogers 1866-1902 (pistol prices); Greg Clark (spade prices).

Chapter 3: Why the rest of Eurasia fell behind

From the late Middle Ages up to 1800, western Europe fulfilled all four conditions required for advancing the gunpowder technology:

1. It endured incessant warfare among western Europe's major powers—proof that inequality 2 in chapter 2 held or, in other words, that its rulers faced similar political costs of mobilizing resources and that they were battling for a prize which was valuable relative to the costs of establishing a fiscal system and a military apparatus.
2. These rulers lavished huge sums on war, a sign that their costs of summoning resources were not only similar, but low.
3. They used the gunpowder technology heavily.
4. They could acquire the latest military innovations at low cost.

Together these four conditions are enough to guarantee sustained improvement in the gunpowder technology, and that is exactly what happened in western Europe.

What about the major civilizations in Eurasia—in eastern Europe, the Middle East, South Asia, and East Asia? Did they meet the same four conditions and do so throughout the early modern period? If so, they should have advanced the gunpowder technology too. But if even one of the four conditions did not apply, then the tournament model implies that they would fall behind. And if these laggards had trouble getting hold of the latest innovations, then the gap between them and the leaders would widen.

It turns out that none of the other major civilizations in Eurasia could satisfy all the four conditions throughout the early modern period. They all failed—Japan, China, Russia, South Asia, and the Ottoman Empire. As the model predicts, they almost all fell behind the western Europeans in advancing the gunpowder technology. The only exceptions (Russia after the late seventeenth century, and the powers battling in Japan before the Tokugawa Shogunate) were temporary and in fact match the model's predictions closely.

The consequences were huge. Although Western Europeans were not conquering huge swaths of land outside the Americas in the sixteenth and seventeenth century, they did use the gunpowder technology to muscle in on the spice trade and get a toe hold in South and South East Asia. They also dominated the trans-Atlantic slave trade. And by the eighteenth century they were seizing hold of India, all without sending large number of troops abroad. That paved the way for even more dramatic expansion in the nineteenth century.

The question then is why the conditions failed to hold elsewhere in Eurasia. That issue lies outside the model, just as it did for western Europe. But the model can at least point us toward an answer. As we shall see, that answer reflected historical contingencies. Events could easily have taken a different turn, and the outcome—western Europe's conquest of the world—was in no way foreordained.

1. The obstacles elsewhere in Eurasia

What then held back Japan, China, Russia, South Asia, and the Ottoman Empire? What kept them from satisfying the requisite conditions and made them lag behind western Europeans in the development of the gunpowder technology? It was certainly not ignorance of the technology or an inability to make weapons. By the sixteenth century, these civilizations all possessed gunpowder weapons, which had in fact been invented in China, and they all had gunsmiths and cannon founders who could manufacture them. Even Japan, where firearms were apparently not introduced until 1543, was soon turning out handguns in sizeable numbers.[107]

So what then were the obstacles? We can see by asking which of the four requisite conditions derived from the tournament model happened to apply to these civilizations and which failed to hold. And we can also ask when the conditions were met. Here, some readers may perhaps fear that even posing such questions is a mistake, because it risks treating Japan, China, Russia, South Asia, and the Ottoman Empire as homogeneous entities. Of course, they were not homogeneous, any more than western Europe was. But the fears are in any case unwarranted, for our model makes no assumption of homogeneity. Indeed, heterogeneity—be it political, economic, or cultural—will in fact play an important role in our story.

Let us start then with the third condition—that the rulers use the gunpowder technology heavily. It was clearly satisfied in sixteenth-century Japan, where warlords enmeshed in a devastating civil war quickly adopted firearms. In short order, they began to use artillery too, and tried, albeit haltingly, to arm ships.[108] In China, by contrast, this

third does not hold, for 97 percent of the time China was engaged in war involving nomads against whom firearms (as we know) long remained impotent (Table 3.1). In confrontations with nomads, the older technology of mounted archers was more effective, along with the fortifications of the Great Wall and the establishment of frontier military colonies, both of which helped defend against nomadic raids. The western Europeans, by contrast, fought no wars against nomads. China's military problems were thus simply different from western Europe's, and as we shall see, China was not alone.

Because nomads posed the biggest threat, China's emperors and officials had no reason to mobilize resources for a navy either, with or without the gunpowder technology. Navies were expensive, and the funds would go to better use if directed against the nomads. That in fact was the main reason why after 1433 the Ming Emperors halted the enormous fleets that had been sailing to South Asia and Africa under the command of Zheng He. The fleets were not voyages of exploration. Rather, they aimed to impress local rulers and extend and enforce China's practice of strategically allocating trade rights in return for tribute and good behavior. But the voyages had to be heavily subsidized. So why pour money into the fleets when the real threat came from nomads inland?[109]

Not that China shunned the gunpowder technology altogether. Handguns and cannons proved useful when fired from the fortifications along the Great Wall, and the gunpowder technology 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 (1644-1911), the nomads remained the new dynasty's chief enemy well into the eighteenth century, and against them the gunpowder technology was still ineffective because it continued to strain supply lines to the breaking point.[110]

Russia, the Ottoman Empire, and the various powers waging war in India faced similar problems with enemies who kept them from focusing on the gunpowder technology. Until the middle of the seventeenth century, the Russians' major land enemy were nomadic Tatars. Firearms helped against them, particularly if deployed from behind fortified lines, but cavalry armed with bows and sabers was a more effective 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. As for India, until the eighteenth century, warfare there too made heavy use of cavalry. In addition, both the Ottomans and Russia had to funnel resources into that other ancient technology with limited potential for improvement via learning by doing—galley warfare, which was ideally suited the Mediterranean, the Black Sea, and the Baltic.[111]

In short, the requirement that rulers rely almost exclusively on the gunpowder technology would work against innovation in the Ottoman Empire. It would lead to the same prediction for India before the eighteenth century, for China, except in the waning days of the Ming Dynasty, and for Russia, at least before the late seventeenth century, when the Tatars ceased being a major threat. Japan, by contrast, would be more fertile ground for innovation, like western Europe.

Japan, however, eventually ran afoul of the first condition—in other words, inequality 2 in chapter 2—which predicts that war will stop if one ruler annihilates his opponents and conquers their realms. Without war, learning by doing stops, and so do advances in military technology. The resources mobilized z_i decline too. Such an outcome never happened in early modern Europe, which was always torn by conflict. But that is precisely what took place in Japan when it was unified in the late sixteenth and early seventeenth century.

Japan had suffered through generations of devastating civil war when three victorious warlords succeeded in consolidating the fragmented country under what became the rule of the Tokugawa Shoguns (1603-1867). By crushing opposition and rewarding loyalty, the Tokugawa then fashioned a regime that eliminated internal strife. Peace made the populace better off, but it left the Shogun with no one else to fight. In terms of our model, it was as though Japan's ruler was in a tournament with no other contestants. He would have had 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 he or the warlords who united the country did not turn to foreign conquests once they had vanquished their domestic enemies. One of the warlords, Toyotomi Hideyoshi, actually did try to invade Korea (and via Korea, China) in 1592 and 1597, but failed, because he "lacked the resources" needed to carry out such an operation—in particular, a large navy, which he and the other warlords had scarcely begun to develop during their civil war. Other Japanese leaders came to realize that an invasion without adequate resources was unrealistic. They were "unenthusiastic" about the operation and "quickly" withdrew from Korea after Hideyoshi

died. They knew, in other words, that successful military competition against foreign powers entailed a large fixed cost (relative to the size of the prize), 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.[112]

As in Tokugawa Japan, the first condition would have also discouraged China from fighting distant wars in which the gunpowder technology might have been more useful than it was against nomads. For much of its history, China was a large unified empire and much bigger than neighboring states. The emperors and the officials who advised them would therefore have found themselves in a situation akin to that of the Tokugawa Shoguns: warfare abroad, including invading Japan, would have required building an effective navy or fighting distant land battles. That would have meant paying a prohibitively high fixed cost *b*, which would have made such wars unattractive.

What about the two other conditions for improving the gunpowder technology: that the ratio *P/C* of the value of prize to the sum of the average variable costs be high, and that rulers be able to acquire the latest innovations at low cost? The requirement that *P/C* be high clearly handicapped the Ottoman Empire by the eighteenth century. As we have learned from their meager eighteenth-century tax revenues, the Ottoman sultans faced a high cost of mobilizing resources after 1700, even though they were fighting European states for the same prize *P*. The ratio *P/C* for the Ottomans was therefore low, and their high cost of mobilizing resources also implied (from expression 5 in chapter 2) that they had little chance of defeating European rulers in the eighteenth century, even if they imported the latest weapons and tactics. A similar conclusion holds for China, for as

we have seen, its tax revenues suggest that it too had high costs of mobilizing resources for war. So China would likely have a low value for *P/C* as well.

Like western Europe, Japan before the Tokugawa Shogunate probably also faced low average variable costs. The evidence is admittedly indirect: the armies Japanese warlords raised were big relative to the population. But that is exactly what one would expect in wartime if *P/C* was large.[113] By the eighteenth century, the Russians likely had a low average variable cost too and a correspondingly high value for *P/C*. They were by then fighting the western Europeans for the same prize, and although their per-capita tax revenues were still lower than in the west, the czars—thanks to the reforms of Peter the Great (1682-1725)—could draft serfs into the military, which cut the average variable costs of fielding a military force.[114] Western leaders, by contrast, had to wait for the wars of the French Revolution to conscript troops on that scale.

Finally, India's leaders were hobbled by high average costs of mobilizing resources and by a lower value of the prize they were fighting for, all of which reduced their *P/C* ratio. The Indian case is in fact a telling one. In the eighteenth century, the subcontinent was convulsed by virtually constant warfare among the leaders and states that arose as the Mughal Empire disintegrated. The unremitting hostilities imply that the first condition was satisfied, and the armies were fighting with gunpowder weapons (condition three) and could easily have acquired leading innovations from one another (condition four) in what was an active market for military goods and services.[115] But the one remaining condition required for advancing the gunpowder technology—that *P/C* be high—failed to hold.

On the one hand, political costs *C* of mobilizing resources were high. Data on tax revenues in India are lacking, but it is clear that the new states which emerged on the subcontinent in the eighteenth century were struggling to gain control of resources that remained in local hands.[116] The administrative and political problems defied easy solution. The kingdom of Mysore, for example, had begun financial reforms in the late seventeenth century and managed to develop what was perhaps the most effective fiscal systems in south Asia. Yet even it had a long way to go. As late as 1725 it still had no regular tax revenue, and attempts to get money out of the hands of local elites and traditional leaders were repeatedly frustrated. Mysore's ruler late the eighteenth century, Tipu Sultan, tried for instance to replace local revenue collectors (most of whom in predominantly Hindu Mysore were influential local Brahmins) because they had long siphoned off funds. But his efforts were frustrated, because the new tax officials, who like Tipu were Muslims, lacked necessary information about land values and revenues.[117]

In addition, the value of the prize *P* was reduced by conflict within powerful Indian families over succession to a throne or rights to rule.[118] Strife of this sort, which had become rarer in western Europe after the late Middle Ages, cut the value of the prize for victors in India, by raising the odds that a prince or other ruler would be unable to enjoy the fruits of winning. The prize was still valuable enough to get the rulers to fight, but not big enough relative to the average variable costs of fighting to get them to mobilize a large amount of resources *Z*. Since they were not raising many resources, the model would predict that their wars would generate little or no innovation.

The Indian case is important, for it shows why unending warfare and highly developed markets for military goods are not enough to advance the gunpowder

technology. If they had been enough, then eighteenth-century India should in fact have been an innovator, not a laggard. Our model, by contrast, predicts the opposite, because with high political costs and strife over rights to rule, the Indian rulers would marshal few military resources and thus fail to innovate.

The model can also help explain why the East India Company became a dominant military power in India and why, as an agent of British foreign policy, it eventually took over much of the subcontinent. The reason was that the Company simply had lower average variable costs of mobilizing military resources than its Indian opponents. It could thus assemble more equipment, more soldiers, and a larger number of skilled officers when it had to fight. Not only could it draw on naval support from Britain and use its own financial system to fund its military ventures, but it had also gotten control of wealthy Bengal and neighboring territory along the Ganges in northeastern 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 meant it had a lower average cost c_i and, from expression 5 in chapter 2, a greater chance of winning wars. It should be no surprise then that the Company conquered much of the subcontinent, simply by hiring away the best officers and their troops, who gave the Company an insuperable edge in discipline and organization.[119]

The only remaining condition is that rulers outside of western Europe be able to acquire innovations at low cost. One of the chief barriers to to doing so, we know, was distance. It alone could hamper the diffusion of the latest skills, weapons, and tactical innovations, even if mercenaries and weapons makers were willing to work for foreign masters. Advances could also be stopped if they involved complementary skills or

reforms. To get the innovation, a ruler would have to acquire the whole package, as the king of Spain did when he obtained the technology of boring solid cannon castings from France. These two obstacles could easily have caused huge technological gaps to open up if learning by doing persisted in one part of Eurasia and halted in another. So even if all rulers could in theory have advanced the gunpowder technology, once some fell behind, they would have had a hard time catching up.

It is true that gunpowder innovations might have spread relatively easily between the warring powers in eighteenth-century India or in Japan before the Tokugawa Shogunate, because the warring parties did not lie that far apart. The problem, however, was the enormous distance between East and South Asia, on the one hand, and western Europe, on the other. As we have seen, western Europe was the only part of Eurasia that satisfied all the other conditions for advancing the gunpowder technology throughout the early modern period. None of the other Eurasian powers met that standard; at one time or another, they all ran afoul of at least one of the conditions. The model therefore implies that western Europe would have been a leader in advancing the gunpowder technology—an implication that is certainly born out by both quantitative and qualitative evidence. But the model also predicts that the Eurasian powers distant from western Europe would fall behind, particularly when they failed to meet the other conditions required for innovation. That prediction would apply in particular to China, India, and to Japan after it was unified under the Tokugawa Shogunate.

Could these distant Asian powers have caught up by importing European innovations when needed? They would all have had an incentive to buy the latest military technology from western Europe if it was more effective militarily, and the Europeans

did in fact export their arms and expertise to places as far away as China.[120] But wholesale transfer of the cutting edge technology would have been hampered by distance alone in South or East Asia. If it was difficult to move a whole team of cannon makers from France to Spain, how much harder would it have been to get them to India or China? The obstacles would have been much higher, because of the risks of ocean travel and the difficulties of getting Europeans to settle in an alien place.

These barriers did clearly slow the transfer of the gunpowder technology to East and South Asia. We can see their effect most clearly in eighteenth and early nineteenth-century India, where they kept rising Indian powers—Mysore, Maratha, and the Khalsa kingdom—from hiring enough European officers. The officers from Europe were essential for instructing troops in western methods of war: without them discipline suffered and coordination between infantry and cavalry collapsed. But the Indian powers simply could not recruit enough mercenary officers from Europe or train enough native replacements. As a result, they were vulnerable to the East India Company, which used its better finances to lure their European officers away. Or worse yet, European officers might simply refuse to work for the Indian powers if it meant fighting against the Company. That was yet another reason behind the Company's conquest of South Asia.[121]

On this score, Russia and the Ottoman Empire would have a somewhat easier time of it, since they were closer to western Europe. Yet even with the imports, we would predict that anemic tax revenues would keep the Ottomans from defeating the Europeans after 1700. The Russians, by contrast, could be expected to do much better, at least after the late seventeenth century. Not only could they import the technology more easily than distant Asian powers, but they could now focus on fighting with gunpowder

weapons and mobilize enormous resources by drafting serfs. Given Russia's size, it would stood a good chance of defeating western European opponents even if they could marshall men, supplies, and money at lower political costs. The reason was that Russia would be much less likely to hit the limit of the resources it could assemble. In other words, it would be much less likely to run up against constraint 6 in chapter 2. As long as it could import the gunpowder technology and keep mobilizing resources, we would expect it to rise in the ranks of the world's powers.

2. Testing the model outside western Europe

What about the model's predictions for the rest of early modern Eurasia? Do they hold up? The evidence that made it possible to measure military productivity in western Europe is lacking elsewhere in Eurasia, but we can at least test the model's implications for the pace of innovation with the gunpowder technology, for patterns of trade in gunpowder weapons and expertise, and for the odds of victory in wars where the technology was effective.[122]

If we begin with Japan, the model predicts improvements to the gunpowder technology until the Tokugawa Shogunate gained power in the early seventeenth century, when warfare and innovation should have stopped and tax collections should have tapered off.

Those predictions match the historical record. Before the Tokugawa, the Japanese had discovered—some twenty years earlier than Europeans—the key tactical innovation of volley fire that allowed infantry soldiers with slow loading muskets to

maintain a nearly continuous round of fire. But once the Tokugawa unified the country, war stopped and so did the innovations.[123] And over time tax revenues did decline as fraction of agricultural output.[124]

A cultural explanation clearly cannot account for this sudden change, for Japanese continued to have a strong attachment to martial values.[125] One might think that this line of argument 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.[126]

Historical evidence also confirms the model's implications for China and eighteenth-century India. Both would have been 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 argument about competition were correct. Both should also have tried to import weapons and expertise from Europe when the gunpowder technology proved useful.

That is exactly what happened. The Chinese had a huge head start in using the gunpowder technology, but eventually the western Europeans caught up and surpassed them. The initial Chinese lead is clear. Gunpowder had first surfaced in Chinese texts in the 9th century, and depictions of artillery survive in China from 12th century. Signs of anything equivalent in Europe do not crop up for a hundred years or more (Figure 3.1). By the late Middle Ages, however, the technological gap between the Chinese and western Europeans had vanished. The Chinese seem to have been no faster at making effective use of siege artillery and they lagged a bit behind western Europeans in putting

cannons on ships. In the early modern era, they they clearly fell behind. Unlike western Europeans, they did not adopt water tight gunports in the early sixteenth century, or replace their matchlocks with the more reliable flintlocks in the late seventeenth century.[127] By the late eighteenth century, the lag struck knowledgeable Western Europeans in China, whose carefully documented observations cannot simply be dismissed as cultural stereotyping or special pleading motivated by a desire to convince people at home that China was a military pushover.[128]

Such examples may of course reflect something besides a technological lag. It might conceivably be relative prices, or the threat posed by nomads, who were China's major enemy. But Chinese officials themselves recognized that European weapons were superior and they did so early on. As the Acting Superintendant of Foreign Trade in Canton observed in his description of an early sixteenth-century Portuguese naval cannon, "with this arm one can sail about at will on the high seas, and no other country's ships can match it."[129] And officials in China actually backed up their words with actions. When the gunpowder technology proved effective against enemies, as it did at the close of the Ming dynasty in the early seventeenth century, they turned to the Portuguese and the Jesuits for weapon designs, gun casting, and military expertise. They did the same under the Qing dynasty, up into the late eighteenth century.[130]

Military leaders in eighteenth-century India followed much the same path. 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, imports of weapons, and mercenary officers who could train native

troops.[131] Like the Chinese, the Indians sought to import the gunpowder technology from western Europe, just as the tournament model predicts.

The resulting flow of military goods and expertise from western Europe to Asia is consistent with Europe having a technological lead. Relative prices support the same conclusion. The evidence is admittedly scanty, but we can at least compare the price of handguns to food in the early seventeenth century in both China and western Europe. We can do the same circa 1800 in Europe and India. In the early seventeenth century, muskets cost three to nine times more (relative to food) in China than England or France. In India, at the dawn of the nineteenth century, they were nearly fifty percent dearer relative to food (Table 3.2).

Such a price difference is just precisely what we would expect if long-run productivity growth in the military sector (at least when it came to using the gunpowder technology) had been more rapid in western Europe than in Asia. It is true that the price gap might have stemmed from a lower relative price of capital in western Europe, since weapons and the gunpowder technology in general were capital intensive. But it could just as easily reflect economies of scale that derived from all the resources lavished on the gunpowder technology in western Europe and all the accompanying learning by doing.[132]

The tournament model's predictions therefore fit the evidence in China and India. What about Russian and the Ottoman Empire? The model implies that Russia and the Ottoman Empire would also have been less likely to advance the gunpowder technology and that both would have imported weapons and military expertise from western Europe, up until the eighteenth century. Then their paths would have diverged. High political

costs c_i would have made the Ottomans drop further back and cut their odds of winning wars, particularly against western powers. The reverse would have happened for the Russians.

In fact, military historians argue that the Ottomans fell behind western Europe in the late seventeenth century, particularly in field warfare. Although the Ottomans had a large artillery industry, they imported expertise from western Europe. By the eighteenth century, they dropped from the ranks of the great powers in Europe and were more likely to lose wars.[133] Russia, by contrast, joined the great powers in the eighteenth century, after importing western officers, shipwrights, cannon founders, and military architects from western Europe. And it increasingly it began to win wars against western European powers.[134]

The divergent paths of Russia and the Ottoman Empire are difficult to square with the argument that military competition alone led to gunpowder innovations because both were frequently embroiled in conflicts. That argument also fails to explain why the arms race, constant war, and markets for military goods and services in 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 cannot be reconciled with any plausible cultural argument. And the model also fits Eurasian evidence about military victories, trends in taxation, and the international flow of military goods and services.

3. Did the gunpowder technology matter?

So we have a deeper understanding of why western Europe led in in advancing the gunpowder technology. Although the tournament model is not the final answer, it does succeed where other explanations do not go far enough (Kennedy's argument about military competition when applied to India) or simply fail (cultural arguments when applied to Japan). And it isolates what what lay behind western Europe's technological lead: political costs of mobilizing resources that were low and similar for major powers; a prize that was valuable relative to these costs and to the fixed cost of establishing a military and a fiscal system; the ease with which innovations could spread; and, last but not least, the effectiveness of the gunpowder technology against rulers' enemies. Those characteristics distinguish western Europe from the rest of Eurasia during the early modern period, and point toward the ultimate causes for western Europe's technological lead.

But did the lead really matter? It certainly helps explain the conquest of the Americas, and Europe's domination of the Atlantic slave trade too. But beyond that, was it really important that western Europeans kept pushing the gunpowder technology on? If we consider only western Europe (and leave aside Russia's move into central Asia, which did make use of forts, artillery, and firearms), then outside the Americas, western Europeans held relatively little territory before Britain began to conquer India in the late eighteenth century (Figure 3.2).[135] What difference did it really make that they were ahead of other Eurasians?

A big difference, contemporaries would say. They could in fact invoke many instances when continued innovation with the gunpowder technology had mattered, because even holding a fortress often depended on it. Consider, for example, what happened in the southeast Asian port of Malacca, after the Portuguese built their fort there in 1511. Over time, they expanded and improved the fortifications, adding bastions equiped with artillery. These improvements helped them defeat the 1568 siege by the Muslim sultan of Aceh, even though they and their allies were outnumbered 10 to 1. Although the Sultan had mounted an invasion with over 200 cannons and over 15 thousand men, his forces had to give up after a month, having suffered (according to the Portuguese) some 3500 casualties—among them, the Sultan's own son. The Sultan's problem was that his troops lacked heavy siege guns and had not yet mastered the European technique of sapping by digging zig zag trenches in order to protect against fire from a fort's defenders. The Portuguese could therefore hold out behind their fortifications, which they continued to work on after 1568. Without the improvements, the Portuguese might eventually have succumbed to Aceh, either in 1568, or in one of the nine other sieges that Malacca withstood.[136] And if the Acehnese had not lagged behind—if they had the latest sapping techniques and siege artillery—then they might have seized the fort in 1568 or in one of the later battles.

Malacca is admittedly just one example, but one could easily cite others: the Dutch fort at Batavia, or the Portuguese town of Chaul, where some 1100 Europeans defeated a siege by 140 thousand Indian troops in 1570-1571, thanks to their ships, better handguns, and hastily constructed fortifications.[137] True, there was more involved in the European victories than technology alone. Help from local allies was often critical.[138]

But allies, it is worth repeating, would not rally to the Europeans' side unless it offered some advantage, and that advantage could not have been Europeans' meager numbers: it could only have been their lead in the gunpowder technology.

The Europeans themselves believed that their technological lead mattered in far away places like southeast Asia, particularly when it came to fortifications. Here their actions speak louder than any words. To the extent that their budgets allowed, they strove to keep their fortifications up to date. In the late sixteenth century, for example, when Italians were Europe's masters of fortification, the Portuguese hired one of them, Giovanni Battista Cairato, as the chief military architect of their Empire and sent him to Asia, where he inspected in Goa, Ormuz, and Malacca, and improved them when necessary. It was not just hostile Asian powers that kept the Portuguese vigilant in Asia. In the seventeenth century, the danger, increasingly, was the threat posed by other Europeans. Malacca, for instance, was attacked repeatedly by the Dutch East India Company, beginning in 1606. With their state of the art artillery and warships that could blockade the Portuguese fort, the Dutch were a far bigger menace than nearby Asian rulers. The Portuguese reaction was to fortify off shore islands and strengthen the defenses of Malacca itself. The Dutch in turn ferretted out information about the fortifications by questionning Portuguese prisoners and spying on Malacca itself. The Dutch finally took Malacca in 1641, after a five month siege and bombardment that severely damaged the fortifications. They then quickly rebuilt Malacca's defenses and undertook further improvements later in the century.[139]

Other western European rulers faced a similar threat to their outposts and commerce abroad. In the Americas, Spain's coastal settlements and its merchants' ships

were attacked by privateers and raiders from England, France, and Spain, beginning in the sixteenth century. The Spanish sent an Italian military engineer to the Caribbean in 1586, although lack of money kept Spain from actually doing much to improve their forts for years. The Dutch in the Americas had to protect themselves against the English, and the British had to send warships to South Asia to push the French out of India.[140] All the western European powers had an incentive to keep the fortifications of their outposts up to date, although their budgets limited what they could do. In short, the battles the Europeans were waging against one another made cutting edge gunpowder technology all the more important, even across the globe.

Admittedly, there were limits to what the Europeans' technological edge could accomplish. Until the nineteenth century, it did not let them conquer Africa or push around the Chinese or the Japanese. The Portuguese and Dutch had to trade on terms set by the Chinese and the Japanese, and what little territory Europeans grabbed hold of in East Asia remained militarily vulnerable. Even retreating Ming loyalists who fled China after the Qing takeover were strong enough to push the Dutch out of Taiwan in 1662.[141] The western Europeans faced limits too in south or southeastern Asia, where their technological lead gained them little territory before the eighteenth century. Virtually all they had, really, were slivers of land and fortified trading ports, in contrast to the huge swaths of land that had been conquered in the Americas.

Still, when combined with armed ships, the forts in south or southeastern Asia did give the Europeans a way to prey upon profitable trade and to ward off attacks by other European powers. It was no wonder then that the forts were were a significant bargaining chip in treaties that settled European wars.[142] Along with the rest of the gunpowder

technology, the forts also got the Europeans a toehold in Asia and, in the eighteenth century, actual colonies in India. And in Africa they helped give the Europeans control of the slave trade. When we add to that all the land conquered in the Americas, it is clear that the technology's economic impact was huge.

Not that it demonstrated Europe had higher incomes or a more developed economies. Nor did it make people better off—far from it. Paying off the Portuguese in order to trade in the Indian Ocean was clearly worse than peaceful maritime commerce without the need of weapons—worse for everyone involved, except perhaps the Portuguese themselves. But the gunpowder technology made it easier for them to specialize in extortion rather than peaceful trade. And that, as we shall see, was far from its only economic consequence.

Table 3.1: Frequency of Foreign War in China and Europe, 1500-1799

Country	Percent of time country is at war against foreign enemies, 1500-1799
China:	
all wars	56
excluding wars against nomads	3
France	52
England/Great Britain	53
Spain	81
Austrian dominions	24

Source: Wright 1942 ; Stearns 2001 ; Clodfelter 2002 and James Kung (personal communication of the figures for China).

Note: Excluding wars against nomads does not change the figures for the western European countries because they did not fight wars against nomads. 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 Chinese sources, and her numbers were similar to Kung's.

Table 3.2 Relative price of handguns in Europe and Asia

Year	Place	Weapon	Price (grams silver)	Food	Price (grams silver/1,000 calories)	Calories/gun (England 1620–21 = 100)	
							Correction for using flour
1619	China	Matchlock muskets	150	Rice	0.108	549	345
1630	China	'Hawk muskets'	374	Rice	0.174	852	535
1601–25	France	Matchlock muskets	86	Wheat flour	0.353	96	96
1626–50	France	Matchlock muskets	117	Wheat flour	0.471	98	98
1620–1	England	Muskets	76	Wheat flour	0.302	100	100
1819	India	Guns	54	Wheat flour	0.426	50	50
1796–1807	Britain	Guns exported to Africa	74	Wheat flour	0.861	34	34

Source: Hoffman 2011 Table 5.

Note: If multiple prices were available, I chose those that biased the results against finding a higher relative price for weapons in China and India. Food was relatively expensive in Europe, particularly processed food such as flour. The correction for flour adjusts the Chinese figures to show what the relative price differences would have been had prices of wheat been used rather than flour. For a detailed discussion of the sources and the assumptions involved in constructing this table, see Hoffman 2011

Early advances in gunpowder technology: China and Europe

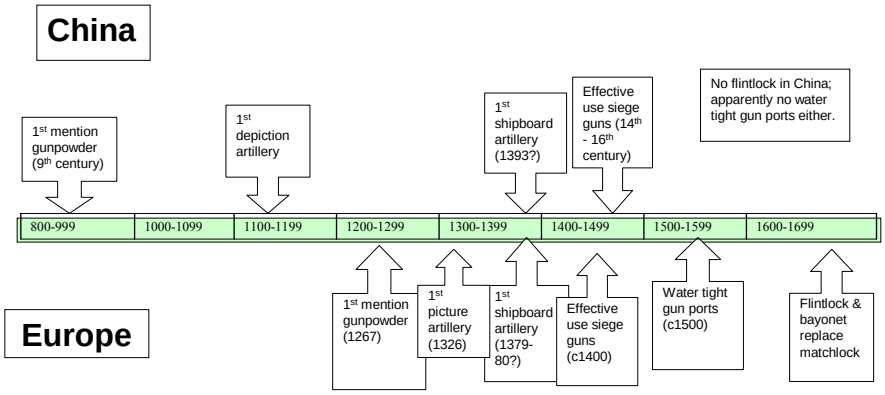


Figure 3.1. Source: Guignes 1808 ; Needham 1954 ; Franke 1974 ; Hall 1997 ; Lynn 1997 ; De Vries 2002 ; Guilmartin 2002 ; Chase 2003 ; Lorge 2005 ; Lorge 2008

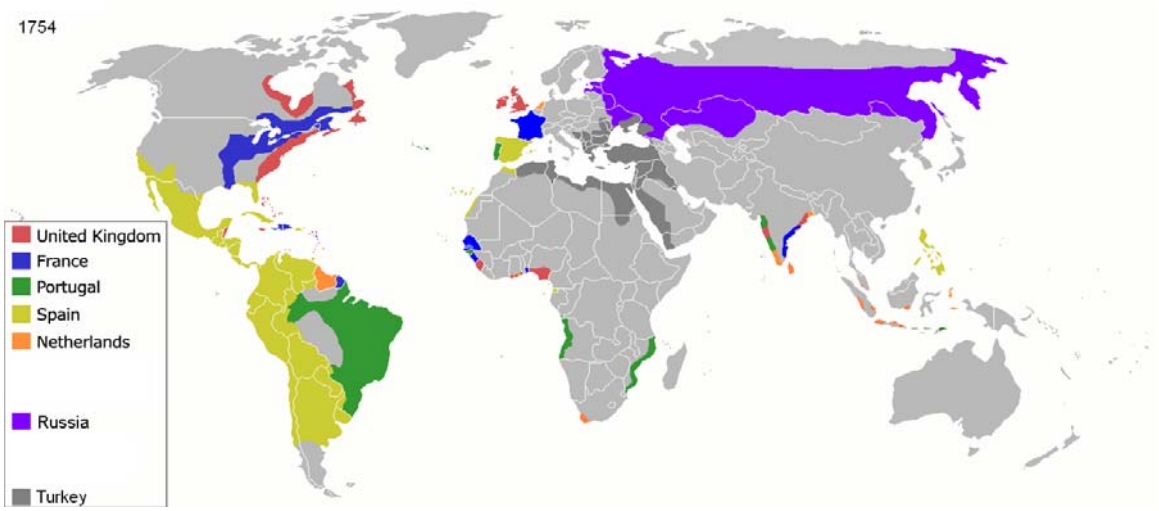


Figure 3.2. Colonisation 1754.
Source: **http://commons.wikimedia.org/wiki/File:Colonisation_1754.png**

Chapter 4: Ultimate Causes: Explaining the Difference between Western Europe and the rest of Eurasia

To advance the gunpowder technology, four conditions have to hold: incessant warfare, massive spending on fighting it, heavy use of the gunpowder weapons, and rapid diffusion of military innovations. In western Europe, all four conditions were satisfied throughout the early modern period. No other part of Eurasia could come close to making that claim.

The model of a repeated tournament explains why these four conditions held in western Europe—and in western Europe alone—by isolating what was distinctive there. In contrast to rulers almost everywhere else in Eurasia (Japan being the only exception), the kings and princes of western Europe's major powers could focus on the gunpowder technology, for they faced no threat from nomads, and unlike the czars in Russia and the Sultans in the Ottoman Empire, they did not have to devote major sums to galley warfare.[143] Furthermore, the prize P they were battling for—be it glory, territory, commercial or strategic advantage, or victory over an enemy of the faith—was valuable relative to the cost b of setting up a fiscal system and military apparatus, at least in the major states. For them, much of this cost was sunk, because the fiscal system and military apparatus had been established by previous rulers. Even if that was not the case, the proximity of most of their enemies meant that they did not have organize an army or navy to fight distant battles or mount invasions, all of which kept b lower than in China or Tokugawa Japan. Their political costs c_i of mobilizing resources were similar and low in western Europe, in contrast to China, India, and the Ottoman Empire in the eighteenth century. As for diffusion of military technology, proximity and the region's highly

developed markets for military goods and services sped advances from one realm to another, as administrators, artisans, and military personnel learned from their mistakes and imitated what worked.

There was one final trait that also distinguished western Europe from the rest of Eurasia. In western Europe, private entrepreneurs could easily take advantage of the widespread familiarity with the gunpowder technology and use it for private expeditions of trade, exploration, and conquest. Few legal or political obstacles stood in their way, and it was not difficult to raise money or to organize partnerships or corporate ventures to fund their undertakings, which played an essential role in Europe's conquest of the world. The same was not true elsewhere in Eurasia. There major hurdles blocked the private use of the gunpowder technology and hampered private efforts to engage in foreign trade, making it much harder for would be entrepreneurs launch expeditions of conquest and exploration.

The next step is to uncover the ultimate causes behind these unusual conditions that marked western Europe off from the rest of Eurasia. We already know one reason why the prize P in western Europe was high relative to the fixed cost b of establishing a fiscal and military system: Europe as a whole was split into separate polities, and the major powers in western Europe were approximately the same size, at least if we compare them to huge states like imperial China or the Ottoman Empire, which were ten times larger than the biggest kingdoms in the West. That also helps explain why military innovations spread rapidly in western Europe, and why the costs c_i of mobilizing resources were similar there, because none of the rulers was a hegemon, who could muster men and material without facing any real constraint. Fragmentation was, in

addition, one of the reasons why western Europe was protected from nomads. Had Europe, like China, been one large empire, then its western edge would have felt the effects of nomad attacks in the east, with Mongol and Tatar invasions and raids in the Middle Ages and sixteenth century. Its rulers would likely have likely have lavished their resources not on the gunpowder technology but on their their cavalry or or on building an eastern wall. Instead, it was Russia, Poland, and Hungary that bore the brunt of the attacks, not the western countries. The question then is why western Europe was fragmented, unlike, say, China.

Fragmentation, though, is only part of the answer, for other parts of early modern Eurasia were also divided into small warring states that fought with gunpowder weapons. Pre-Tokugawa Japan is one example, as is eighteenth-century India. There must therefore be other reasons why in western Europe the prize P was high, b was low, and the c_i*'s* were small and similar.

There in fact are such reasons, and like fragmentation itself, they lie outside the tournament model. Making sense of them requires that we turn to history and to ideas drawn from evolutionary anthropology and experimental economics. That is where we have to seek a deeper understanding of why Europeans conquered the world. In the end, history itself will turn out to be the ultimate cause, where history here means the peculiar chain of past events in each part of Eurasia, including both what happened and what failed to take place. History in this sense will explain the fragmentation of Europe and the unusual values for the exogenous parameters in the tournament model in each part of Eurasia. It will also shed light on why western European entrepreneurs were free to

organize corporate ventures and to use the gunpowder technology in voyages of conquest and, even more important, why their governments gave them an incentive to do so.

Normally, we think of history not as a cause, but as something to be explained. But it can be a cause if past events determine future outcomes or set a society on a path that reinforces itself over time. In western Europe, events had just such an effect: in particular, the centuries of war fought after the collapse of the Roman Empire, when western Europe had warriors and military leaders, but nothing that would qualify as a strong state—in other words, nothing like a state with permanent taxation and a durable fiscal system able to raise appreciable amounts of revenue over the long haul.[144] Elsewhere in Eurasia, lengthy periods of strife like that in medieval Europe usually ended when one of the contending powers vanquished the others and set up a dominant, unified polity. That was what happened when Japan was united under the Tokugawa Shogunate in the early seventeenth century, or (to take the earliest of multiple examples in China) when the Qin state bested its rivals and established the first Chinese imperial dynasty in 221 BC. In Europe, powerful states did eventually emerge from all the turmoil, but not until very late—the late Middle Ages (1300-1500), or the early modern era. In the long intervening period, the lack of strong states and the ongoing warfare unleashed a process of social learning and cultural evolution that splintered western Europe into hostile groups dominated by warlords and devoted to fighting.

Here culture means beliefs and preferences that people acquire not by genetic evolution but by social learning—in other words, by imitating what is common or successful or by avoiding what is frowned upon. Such social learning can spread norms of behavior and determine the parameters that individuals take as exogenous in models

like our repeated tournament. It did just that in western Europe, stamping the region with many of its distinctive features: the huge value that rulers and elites (particularly the nobility) attached to victory in war, or in other words, the large P in the tournament model; the enduring enmities between peoples that made it difficult for anyone to unify western Europe; and even the free rein given private military entrepreneurs in early modern Europe and the low political cost of mobilizing resources in the region's major powers. Some of these traits were obviously not unique to Europe: Ghengis Khan clearly treasured victory too. But when they were combined with the low costs of mobilizing resources that western Europe's major powers finally achieved, they set western Europe apart.

There was a second way in which history shaped future outcomes as well, both in western Europe and the rest of Eurasia.[145] Unlike social learning, which operated over the long run, history's second effect involved the short run, via a contingent turn of events that influenced subsequent outcomes. Military victories, for example, could establish a powerful state, which then gained legitimacy over time, as happened with the Tokugawa Shogunate in Japan and repeatedly in China. Or civil strife could split a young empire apart before it could win the support of elites and change the incentives they faced, as happened with Charlemagne's Empire. Once again, history was the ultimate cause, just as with social learning, because the contingent turn of events affected what occurred later on. But because the path history took was contingent, both in western Europe and in the rest of Eurasia, the outcome was neither preordained, nor dictated inexorably by geography, the distribution of resources, or the commercialization of the economy. Things could easily have turned out differently, and would have likely

done so if Charlemagne's grandsons had not divided the Carolingian Empire, if the Mongols had not swept out of central Asia, if warlords in sixteenth-century Japan had developed navies, or if the Mughal empire had collapsed a century earlier than it did. As we shall see, we might then have had no British Empire, but perhaps a Chinese or Japanese one.

1. Why was Europe fragmented?

The first task is explaining why Europe was fragmented. It was, to repeat, far from the only part of Eurasia that was split into warring political entities. But after the fall of the Roman Empire in the West, Europe was always divided politically, except during the short lived Carolingian and Napoleonic Empires. In other words, it was partitioned for a millennium and a half, from the fifth century on. China, by contrast, was unified under an empire for nearly half of the two millennia between 221BC and 1911.[146]

At first glance, it is actually surprising that Europe was not unified just like China. The existing theory of state size would predict as much, for it implies that all early modern states should have been large, like imperial China or the Ottoman and Mughal Empires. The reason is that all early modern states were, at least by modern standards, autocracies. After all, even the republics or kingdoms with representative institutions had very limited suffrage. But according to the theory, such autocracies should grow in size and take advantage of economies of scale in defense, for their rulers would not have to worry as much as a democratic leader would about disgruntled residents of distant frontier provinces, who might try to secede if they did not get the government posts or the

amount of defense spending they wanted. The implication then is that all states should have been large, particularly when war was common, as in Europe.[147] Yet with the exception of Russia, the states in early modern Europe were all an order of magnitude smaller than China or the Ottoman or Mughal Empires.[148] The small size of the European republics could perhaps be attributed to their representative institutions, which allowed them to mobilize large amounts of per capita tax revenue, but how then does one explain why France or Spain or Prussia did not grow until they had absorbed the rest of the continent?[149]

One possibility is that state size is explained by geography. If geography does determines state size, then it would be easy to understand why state boundaries are often stable provided military technology and transportation costs do not change. Geography has in fact been invoked to explain the striking contrast between Europe and China. The most persuasive version of the argument is due to the physicist David Cosandey and the biologist Jared Diamond.[150] Although they do admit a random element in the formation of state borders, they make geography the ultimate cause behind Europe's political fragmentation and China's long term unity.

Geography, in their view, worked in two ways in China and Europe.[151] First, Europe was more mountainous than China, and because mountain ranges raised transportation costs and thwarted invasions, they created more political boundaries in Europe. Second, Europe had a more irregular coast line than China, and the irregularities–particularly peninsulas–favored the development of smaller states. The claim, as Cosandey explains, is that amphibious invasions were difficult before modern times. A peninsular state could therefore focus its defenses on the neck of the peninsula

(where it might station troops or build fortifications) and avoid the cost of extensive protection of its coastline. It would therefore have an advantage over other states, and it would at the same time reap the benefits of the lower cost of water transport for traded goods.

This argument, at least at first glance, seems persuasive. But upon closer scrutiny it unfortunately does not stand up. Consider first the assertion that Europe was fragmented because it was more mountainous than China. The problem here is the premise that Europe was more mountainous, for it simply turns out to be false. China was in fact more mountainous, even if we limit ourselves to China's historical borders during the Tang (618-907) and Ming (1368-1644) dynasties and leave out more recent high altitude acquisitions such as Tibet. And that result remains the same even if we vary the definition of what mountainous terrain is.

Suppose, for example, that mountainous terrain is defined to be areas over 1000 meters elevation. Then (Table 4.1) only 6 percent of Europe is mountainous versus 33 percent of ancient China. The result is similar if the definition is changed to land with a slope over 15 degrees. And a World Bank classification of mountainous terrain leads to the same conclusion (Table 4.1). China is once again more mountainous than Europe.[152]

Mountain ranges are therefore not the reason China was unified and Europe was fragmented. If mountains were the ultimate cause for unity or fragmentation, then Europe should have had an enduring empire, while China should have split into separate countries. Maps of national borders suggest as much. Major mountain ranges in Europe do divide Spain from France and isolate Italy from northern Europe, but they do not coincide with other national borders in Europe (Figure 4.1). Similarly, mountains do not

define China's national boundaries, except in the west, although they may have affected provincial boundaries (Figure 4.2).[153] We therefore must look elsewhere to explain the different size of states at the two ends of Eurasia.

Does the answer lie with differences in the coastline? Cosandey argues it does, because Europe has a more irregular coastline than China. Measures of the roughness of both coastlines do imply that China's coast is smoother (Table 4.2).[154] But does Europe's jagged coastline actually explain its political fragmentation? If the argument about irregular coastlines is correct, we would expect Europe's peninsulas to have coalesced into unified states at an early date, because the peninsulas could defend themselves at low cost and reap the gains of cheap maritime transport. Italy, however, was not unified until 1870, and the Iberian Peninsula is still divided. Another problem for the argument is that parts of the Chinese coast were irregular too and they would presumably have been breeding grounds for political fragmentation within China.[155]

More important, the fundamental premise of the argument–namely, that amphibious invasions were difficult before modern times–simply turns out to be false. Amphibious raids and invasions were in fact common in the past and frequently successful. In medieval Europe, Muslims raided the coasts of Italy and the Byzantine Empire and took over Sicily and much of the Iberian Peninsula, all with the help of amphibious raids. Vikings attacked in England, France, and the Mediterranean, where they established colonies and muscled their way into control of territory. Their descendants then launched invasions to conquer England (1066) and Sicily (1061-1091). England, as the naval historian N. A. M. Rodger has observed, was successfully invaded eight times between 1066 and 1485, and it was the victim of many other naval landings.

It was simply not all that difficult for skilled marauders to storm ashore or to sail up a river and attack inland. Stopping them required a navy or an army large enough to guard the shoreline and rivers.[156] In other words, it necessitated defending all of a state's borders, and not just the neck of a peninsula. There would therefore be no reason to expect that a peninsula or some other coastal irregularity would have a natural advantage as the boundary of a state.

The jaggedness of the coastline therefore cannot explain why Europe was divided and China usually united. Other simple geographic arguments run into similar problems—for instance, that clamor for irrigation drove political unification. The difficulty here is that the irrigation projects in southern China began before an empire was formed.[157] Also troubling here are similar arguments that could be made about water control in Europe and that should have favored political consolidation there too. A unified polity in Europe, for example, could have maximized the total revenue from tolls on European rivers, an important source of taxes in an era when overland transport was expensive. Separate kingdoms and principalities could not do so, because one prince's tolls could drive down other rulers' tax receipts.

Not that geography was irrelevant, for it did interact with politics and military technology, but in a more complex way than the arguments about mountains and coastlines assume. The bottom line, however, is that geography alone did not determine state size, and it was not the ultimate reason why Europe was divided and China usually an empire. Some rulers—in China in particular—were able to overcome the obstacles of geography and hammer together unified states that endured in time. Others—even with a Charlemagne or a Napoleon on the throne—could not do so. The size of states, a

political outcome, then dictated the nature of each ruler's enemies. Large states like China were more likely to abut thinly populated regions where low rainfall would rule out sedentary agriculture and where herders, hunters, and armed raiders could thrive but be unable to put together any sort of durable state.[158] The large neighboring state would then face the risk of attacks by these nomadic groups, but the ultimate cause behind that threat would not be the low rainfall in a nearby region but rather the size of the state itself, which was the result of politics.

Perhaps the biggest impact geography actually had was not on state size, but on the shipbuilding technology that made it easier for Europeans to launch intercontinental voyages of exploration and intercontinental naval war. By its very location, western Europe had the advantage being exposed to two distinct seafaring traditions, one from the Mediterranean and the other from the Atlantic. In the fourteenth and fifteenth centuries, the Portuguese wedded features of both to create first the caravel and then the carrack, which made it possible to sail further down the African coast and out into the Atlantic. The caravel, which like Mediterranean craft was built over a frame, had rigging that borrowed from both traditions and dimensions that were half way between that of a galley and an Atlantic merchant ship. It was easier to maneuver, a better sailor in adverse winds, and ideally suited for exploring the African coastline. The larger carrack then added more room for cargo and a greater ability to sail with favorable winds once they were discovered. By the time the Portuguese craft reached east Asia, they could outmaneuver Asian vessels, which were made to take advantage of the regular monsoons, and they also found it easier to sail against the wind.[159] Geography had helped the Portuguese build better ships, and the improvements in shipbuilding complemented the

gunpowder technology.

But even these advances reflected much more than Portugal's location or the predictability of the monsoons, for politics was also a powerful impetus behind Portugal's innovations, not just in shipbuilding, but in navigation too. There too enormous progress was made, which, along with better ships, made it easier to explore the African Coast and sail to Asia. The lure behind all of these expeditions was not only the promise of riches but also the chance to continue the armed struggle against the Muslims beyond the borders of the Iberian peninsula. That was one of the paths to glory in western Europe's ongoing tournament, and it gave the Portuguese Crown and Portuguese elites all the more reason to support the voyages and in the process help improve shipbuilding and navigation.[160]

2. Can kinship ties among rulers explain why Europe was fragmented?

If geography cannot tell us why Europe was fragmented and China unified, perhaps ties of kinship among rulers can. Perhaps they kept separate polities alive in Europe and prevented them from coalescing into unified states, as in China, the Mughal and Ottoman Empires, or Tokugawa Japan.

The argument, which at first glance might seem quite persuasive, would begin with the fact that rulers in western Europe were likely to be related to one another, at least from Carolingian times on.[161] In war against their relatives, victorious western European rulers would presumably hesitate to kill or dethrone the losers because they were kin. If we assume that rulers elsewhere in Eurasia were less likely to be kindred, then they

would behave differently in war. When they won, they would tend to eliminate the losers and then absorb their territory and followers. Over time the winners would grow in size, except in western Europe, where they would remain small.

Such a process would be easy to model and it would match at least some of the evidence.[162] It would fit Victoria Hui's comparison of warfare in early modern Europe and warfare during the initial consolidation of China by the Qin Dynasty in 221 BC, and jibe with evidence from the unification of early modern Japan as well, where several losing warlords were killed, died in battle, or committed suicide. It could easily be squared with the growing length of monarchs' reigns in Europe (measured relative to the Muslim World) after the year 700, and with the declining rates of violent death for European kings, which fell from an astronomical 23 to 25 deaths per thousand ruler years in the seventh century (some four times the mortality rate of soldiers in heavy combat today) down to less than 3 deaths per thousand ruler years in the sixteenth century. And one could even come up with an additional reason why victorious European rulers might spare the losers, for from Carolingian times on their clerical advisers placed ever greater emphasis on the Christian virtue of mercy that kings and princes were supposed to show.[163]

For this difference in behavior to matter, however, it has to persist into the early modern period. Otherwise, the winners in Europe's incessant early modern wars should gobble up the losers among the continent's major powers, with unification being the result. There is at least some anecdotal evidence that something along these lines was at work in western Europe. The Emperor Charles the V, whose empire stretched from Hungary to Americas, nearly conquered western Europe, but he spared his major enemy,

the French King Francis I, when he captured him in Italy in 1525. And that is not the only example of a defeated prince who was given a quarter.

Anecdotal evidence, though, is not enough. If victors in war were more likely to spare the losers in Europe than in China–or more generally, in the rest of Eurasia–then that difference in behavior should leave a mark in the early modern period, when we have data on the outcome of wars throughout Eurasia. In particular, rulers in early modern Europe who lost wars to foreign enemies should have been more likely to survive than their counterparts elsewhere in Eurasia who found themselves in a similar predicament. But if we look at what happened to defeated rulers elsewhere in Eurasia, we find that there is no difference between Europe and the rest of the landmass. The test is limited to major powers, but that is precisely where we should see a contrast. And there simply is no such contrast in the data (Table 4.3).[164]

So kinship ties among rulers cannot explain why Europe was fragmented. As for why victorious rulers in both Europe and Asia did not want to take over other large powers they defeated, the answer reflects the limits of preindustrial communications and transportation technology.[165] Winning monarchs would gladly absorb a small realm or incorporate a bit of territory, but ingesting an entire big country risked provoking unmanageable resistance in rebellions and opposition to tax levies. Sending a mobile strike force to repress every act of hostility to their foreign rule would be impossible in a large country, and occupying every town and village would be out of the question. Unless they had overwhelming force that could win over allies (like Cortes and Pizarro in Latin America) or unless they could take over the existing administration (like the Manchus in China), they would be better off extracting concessions from the ruler in

place and then leaving. And on a more general level, the implication is that something else determined state borders, so that modifying them after a military victory was usually just too costly in a large polity.

3. History as a cause of social learning in Europe and of political fragmentation

If geography and kinship ties cannot tell us what distinguished western Europe from the rest of Eurasia, perhaps history can. Perhaps it can explain why Europe was fragmented, why rulers in western Europe found it appealing to fight incessantly, and why at least some of them could mobilize resources at low political cost and do so at precisely moment when the gunpowder technology was militarily advantageous and ripe for improvement via learning by doing. And perhaps it can also reveal why the same conditions failed to hold in Japan, China, India, or the Ottoman Empire.

History can in fact do that. The answers it gives all turn out to depend on peculiar chains of past events, both in western Europe and elsewhere in Eurasia. Some operated over the long run; others, in the short run, via contingent outcomes. One chain of events, which worked over the long run, lay behind Europe's fragmentation and incessant warfare, and behind the high value attached to war there (high, that is, relative to the cost of establishing a fiscal and military system). Other sets of past events explain the low cost of mobilizing effort in western Europe's major powers and the contrasting conditions outside of western Europe. In each case, history set society and local political regimes on a path that reinforced itself over time. Past events also ruled out certain future outcomes or made them much less likely.

Let us start with the first set of events and begin in western Europe, with the barbarian invasions and the collapse of the Roman Empire and their aftermath, in the years between the third and the eighth centuries. Classical authors, somewhat indiscriminately, applied the label "Germans" to the variegated peoples who were as much migrants as invaders when they moved into the western Empire. Whether they came as migrants or invaders, the newcomers were clearly devoted to war, in part because they had been militarized by the Romans themselves, who not only fought the barbarians but hired them to man their army. Through raiding or service in the Roman army, barbarian warriors gained wealth, prestige, or the ability to have more than one wife, and they rallied to leaders in their tribal societies who were victorious in war. The result was the formation of bands of warriors in the fourth and fifth centuries that destabilised the existing barbarian tribes and created new ethnic and cultural groupings from the newcomers and the Roman population, as the western Empire faded away. Western Europe was now fragmented into something new: political units which were not by any stretch of the imagination states with fiscal systems and a monopoly of violence, but which were able to wage war by relying on ethnic and cultural solidarity, hostility to other groups, and loyalty to a personal leader.[166]

Among these groupings, one in particular stood out—the kingdom of the Franks, which was stronger than its neighbors and managed to divert its "military energies away from internal conflict and toward profitable aggression on its borders."[167] Their kingdom expanded through conquest, and in 800, when they controlled most of modern day France, Belgium, the Netherlands, western Germany, and northern Italy, the Frankish King, Charlemagne, established a new western empire with the help of the pope.

Although western Europe was briefly united, Charlemagne's descendents were soon fighting one another, and under his grandchildren the Empire split into three parts. Eventually, western Europe splintered even more, and by 1300, only the western third of Charlemagne's realm (roughly western and central France) remained intact. The other two thirds, though still under the nominal authority of the Holy Roman Emperor, had in fact divided into small principalities (Figure 4.3)

By then the warriors of late antiquity had metamorphized into medieval knights. Fighting, however, was still what they did, and they still battled in military bands led by a leader, or lord. War brought them the greatest honor and gave them a chance to acquire wealth as a reward for military service for their lord. For a knight, the ideal recompense would be an estate—landed wealth that would allow him to marry and have a family. Victorious lords could dream of grander things—of becoming princes or even kings. Spurred on by such prizes, lords and knights devoted mountains of resources to warfare between the tenth and the fourteenth centuries. They scoured Europe to find ideal sites for ever more elaborate castles, first wood and earth and then impregnable fortresses of stone. Even a single knight on horseback required some 50 pounds of iron for his armour and weapons, which might take 10 to 15 days for a forge to produce.[168] The organizing principal was still the same, for these warrior bands and political groups lacked fiscal systems and any appreciable permanent taxation.[169] As before, war was based on loyalty to the leader, solidarity with other members of his retenue, hostility to enemies, and a willingness to fight them. As one revered knight advised in the fourteenth century, "Love and serve your friends, hate and harm your enemies, relax with your friends, exert yourself with all your strength against your foes."[170]

Although the Carolingian Empire was now long gone from what had once been the Frankish heartland—northern France, western Germany, and the area in between—the energies devoted to war were still directed outward, toward the fringes of Europe and the Middle East. Knights from the Frankish heartland fought in northern and eastern Europe and against Muslims in southern Europe and the Middle East between the eleventh and the thirteenth century. They were encouraged by the western Church, which memorialized their exploits and blessed their crusades. In the drive to conquer terrain on the edges of western Europe and beyond, knights from Normandy played a prominent role. They sent their younger sons to fight abroad and won a fearsome reputation for their military prowess and savagery in battle. When the Normans slaughtered a Muslim army from Palermo in 1068, for instance, their leader, the Norman Count Roger, sent the victims' carrier pigeons home with messages inscribed in the dead men's blood, so that their families would swiftly learn the grisly news.[171]

Muslims were not the only ones terrorized by the Normans. Byzantine Christians were too. To drive a band of the Normans out of southern Italy in 1043, the Byzantines raised a huge army and sent the Normans an ultimatum: either accept a truce and leave, or fight. But the Normans not intimidated, even though they were greatly outnumbered. When the Byzantine envoy brought them the ultimatum, one Norman, after admiring the messenger's horse, suddenly knocked it unconscious with his fist. His aim, according to the monk who recounted the story with admiration, was clear—to frighten the Byzantines. His comrades quickly replaced the horse with an even better one, and the envoy carried the Normans' implicit response back to the Byzantine leaders, who dared not reveal what had happened for fear that their army would be terrified and desert. And

the next day the Normans boldly attacked the Greeks and won, despite their small numbers. That brutal incident, and others like it, gained the Normans and the Franks an unsavory reputation for violence and for insatiable greed as well, throughout the Muslim and Greek Christian world.[172]

How, though, could these warrior bands and political groupings wage war without fiscal systems and permanent taxation? How could they get their followers to risk their lives and fight together for a common goal? Making war certainly could bring prizes—wealth, property, glory—that a leader of a warrior band could distribute among his followers, and private rewards of this sort could, as we shall see below, be a powerful incentive to fight. Making war also served to shield all the members of a band from enemies. But it was clearly dangerous. How could a leader keep his followers from shirking and leaving the fighting to others? Shirkers, after all, would still be protected from enemies, and they might, at least indirectly, enjoy the benefits of spoils brought back from war. And that must have been a real problem, at least early on, for the Roman historian Tacitus noted that the barbarians had at least occasional trouble with deserters, cowards, and men who were not warlike.[173] How could leaders overcome such problems and provide what we would call the public good of defense? Were loyalty to leaders, solidarity within one's own group, and hostility to enemies that powerful?

They were, but understanding how western Europe's peculiar history gave them such force requires a detour into experimental economics and evolutionary anthropology. Economists have done numerous experiments to analyze, in an idealized way, precisely the sort of dilemma facing the leaders of the warrior bands and political groupings in medieval Europe. In the typical experiment, ten participants might be given $20 each and

told they can contribute any portion of it toward a public good that will benefit everyone in the group. They interact anonymously by computer and so do not know one another. For each $1 they contribute, they and the other participants will all get $ 0.30, but they can keep any money that they do not contribute. The $0.30 is, like defense, a public good since they will all benefit from it, and money they hold back is equivalent to shirking and letting others do the fighting. If the participants were all to contribute $20, they would each receive $60—the best possible outcome for everyone—but if they are concerned with nothing but their own winnings, then each one has an incentive to give nothing and to let others make contributions. (Doing so is a dominant strategy if the participants play only once, and it is also the equilibrium if participants play a fixed number of rounds.) In other words, everyone has an incentive to shirk, and in equilibrium, no one should contribute anything.

When the experiment is run, however, that is not what happens. At the start, participants actually make substantial contributions, which then diminish if the game is repeated. The average contribution might drop from roughly $10 to under $2 by the tenth round of play. You might think that the participants are inching toward the equilibrium predicted by game theory. But most of them never get to the zero contribution that is the equilibrium, and, worse yet, if the experimenter tells them that he is starting the whole experiment over again—say in round ten—then in round eleven the average contribution jumps again.

Apparently, participants take into account more than just they money they earn. It in fact turns out that they are also concerned about how well the whole group makes out, and they get angry if they sense that they are victims of unfair behavior—for instance, if

their winnings are lower than the average because other participants have contributed little or nothing. They also seem to be learning what strategies work best with their fellow participants, even if the whole procedure is anonymous.[174]

One way to boost the contributions is to harness that anger and let participants punish shirkers by revealing how much everyone contributed in the previous round. Participants will often retaliate against a shirker, even if doing so cuts their individual earnings, and if shirkers are penalized, then contributions will usually rise. Contributions will climb even higher if the punishment makes those who give little feel ashamed of having violated norms of fairness. The outcome will depend, though, on where the experiment is conducted. In some places—among them Boston, Zurich, and Chengdu China—shirkers are targeted, but in others—including Athens and Muscat—the ones punished are actually those who contributed a great deal. In some places, then, penalizing shirkers is legitimate, but in others it is clearly not. But when it is legitimate, shirking can be greatly reduced.[175]

How then do such differences between societies arise? Here the most convincing answer comes from evolutionary anthropologists and allies they have in economics, who invoke cultural evolution. For them, to repeat, culture consists of what an economist would call preferences and beliefs, which are acquired by a process of social learning. In their view, culture accounts for much of the variation between human societies, and in particular, the differences in norms of behavior in the public goods experiments. And it can evolve via social learning, which typically involves imitating what is common or successful or avoiding what is frowned upon.[176]

If they are right—and I believe they are—then their argument can also explain the

willingness of warriors or knights to fight for their leaders or lords in medieval Europe. For the argument to work, all that we would need would be a long period of frequent war between small stateless societies—in other words, just the situation in western Europe at the end of the Roman Empire and during the early Middle Ages (c400-c1000). The war could involve raiding other groups or defending against their attacks. In such a world, a willingness to fight for one's own group and marked hostility to other groups will complement one another and contribute to success in the conflicts, even though both impose costs that would include not only the risk of death or injury in war but also foregone opportunities of trade with other groups. This combination of "bravery" and "belligerence," which has been dubbed "parochial altruism," will then spread via social learning. Victory will bring rewards and encourage emulation of parochial altruism in other societies. As for losing societies, they will disappear or imitate the winners by adopting the same norms of conduct. As a result, warfare will grow more frequent (at least initially) because members of societies with more parochial altruists will know they are likely to defeat societies with fewer. The outcome is not foreordained, because other equilibria are possible, including ones where peaceful dealings among groups predominate. But the slide toward increasing numbers of valiant warriors and growing hostility to other groups is all the more likely if parochial altruists punish shirkers in their own group who fail to fight.[177] The outcome will then be a society of brave warriors who hate their enemies and punish cowards.

That does sound eerily like barbarian society in western Europe from the end of the Roman Empire into the early medieval period. It did splinter into hostile groups devoted to fighting, groups that were dominated by warriors willing to sacrifice their

lives in battle for the benefit of their comrades. Increasingly, the warriors had themselves buried with their weapons—archaeological evidence for the growing importance of warfare among the barbarians.[178] And the barbarians did punish cowards, deserters, and unwarlike men, who, according to Tacitus, were hanged or thrown into marshes with hurdles on their heads. Furthermore, not fighting to the death was considered shameful.[179]

With medieval knights and their lords, the importance of warfare, military valor, and hostility to ones enemies persisted into the High Middle Ages (c1000-c1300). At the same time, medieval western Europe became even more fragmented, as kings and princes bestowed wealth and extensive local political powers on their supporters. Meanwhile, there were even signs that medieval Europe developed a comparative advantage in weapons production, for in the ninth and tenth centuries Frankish swords were exported to eastern Europe and the Muslim World.[180]

Still, one might be skeptical. Apart from Tacitus, the archaeological evidence, and the descriptions of modern historians, the only other support for the argument comes from experiments in the modern world or from models of evolutionary games that are calibrated with evidence from prehistoric societies. Could warfare actually could be organized this way in reality, and not just in a game theoretical model? And would there have been enough time for all the cultural change to take place during the Middle Ages?

There was likely enough time for the cultural evolution to have taken place. The birth of new social groups and the extinction of old ones (so anthropological evidence from New Guinea shows) is rapid enough to bring about cultural change in 500 or 1000 years, and the process can be even faster if groups imitate their successful neighbors.[181]

Western Europe had that much time in the centuries after the collapse of the Roman Empire in the West, for there were no strong states that could fund war in a very different way—namely, by imposing heavy taxes—and there was also no hegemonic conquerer who put the whole process of cultural evolution to an end by establishing the sort of durable empire that was created in China, or in Japan with the Tokugawa Shogunate. All the pieces—a willingness to fight for one's group, hostility to other groups, and enormous value placed on victory in war—could have easily been in place in western Europe by the eleventh century, if not long before.

Furthermore, there are real examples of groups waging war in this way—in the Amazon or ungoverned areas of Pakistan and Africa.[182] Perhaps the best example comes from the Turkana in East Africa, a group of some half a million nomadic pastoralists who camp in dispersed settlements and have no hereditary leadership nor any centralized political or military authority. As the anthropologists Sarah Mathew and Robert Boyd have shown, the Turkana fight defensive wars and go on offensive raids to seize cattle from other ethnic groups, much like the barbarians on the edge of the Roman Empire, whose forays sought livestock and slaves. The Turkana's undertakings are dangerous: 14 percent of Turkana men die in warfare between puberty and the beginning of fatherhood, and 9 percent while they are fathers. Yet no state compels the men to fight, and they do not seem to be motivated by ties of kinship or repeated dealings, for in the raiding parties (their median size is 248 fighters), the men are not relatives or people who interact with one another on a daily basis. Like the barbarians in western Europe, they do have occasional trouble with desertion and cowardice. Their solution is to punish the shirkers. Deserters and cowards may be berated (and presumably shamed) by women, elders, or

men of the same age. Or they may be beaten severely or forced to pay a fine.[183]

The barbarians in western Europe were even harsher, for according to Tacitus they put the shirkers to death. It is entirely plausible then that cultural evolution allowed them, like the Turkana, to wage war even though they as yet had no fiscal system or centralized states. Cultural evolution also split them into hostile groups, made them place an enormous value on war, and got them to fight bravely for their leaders. Gifts of wealth and local political power gave these leaders an additional incentive to make war, but also meant that the authorities at the top of society—kings and princes—had to negotiate with increasingly independent lords.

Cultural evolution at the end of the Roman Empire and during the Middle Ages can therefore explain at least some of western Europe's peculiar features. At the very least, it can explain Europe's enduring fragmentation, the willingness of elites to go abroad to conquer, and the enormous value that kings and aristocrats (particularly nobles) attached to war—what by the early modern period they called glory. This was the particular solution to the problem of providing the public good of security—one equilibrium among other very different ones—that was reached during the centuries when western Europe had not yet developed any powerful fiscal states that could pay for defense with taxes. It was those centuries without strong states—a long run effect of history—that drove western Europe's cultural evolution via social learning. To be sure, the resulting cultural traits were hardly unique to western Europe. Victory and honor on the battlefield were prized in many other places, as early modern Europeans recognized.[184] Furthermore, by themselves, these cultural attributes are not enough to explain why the western Europeans pushed the gunpowder technology so far. For that

western Europe did have to eventually develope strong states capable of mobilizing huge amounts of tax revenue, for without them, it would have remained like the Turkana, who fight a great deal but do not improve military technology. But as we shall see, it did eventually get such states, at just the moment when the gunpowder technology had enormous potential for improvement via learning by doing.

4. A durable empire would have meant a radically different outcome

There were other Eurasian civilizations where elites were not as devoted to martial values as in western Europe and so might thwart a ruler's military adventures. That no doubt left the average person better off, because war usually took a huge toll on the economy and on most people.[185] China at the end of the Ming dynasty is one example of this sort of aversion to martial values. We have already seen Matteo Ricci's admiration for the indifference that he believed the Ming emperor and his officials displayed toward conquest. Ricci also claimed that the military as a whole was held in less esteem in late Ming China, and he was struck that civilians in Chinese cities did not bear arms in public or keep them at home. The contrast with Europe stood out in his mind: "As among us it appears a beautiful thing to see an armed man, so among them it appears bad," Ricci observed with admiration, since in his view the lack of arms spared the Chinese the injuries and deaths that were common in Europe.[186]

Not that imperial China always shunned war—far from it. The Qing Emperor Kangxi (1661-1722) saw military ability as a mark of fitness to rule, and his successor Qianlong (1735-1796) waged a brutal campaign to add territory in the west. But more

often than not the Chinese emperors seemed more concerned with people's welfare (if only to secure their thrones) than with conquest.[187]

The reasons for the emperors' comparatively pacific behavior can be traced back to China's long history of political unification, which produced an outcome strikingly different from that in Europe. One was the empire's huge size, for as we have seen it cut per capita tax revenues and raised the fixed cost of mounting expeditions abroad. Another was the force of the Confucian thought that took a lasting hold among imperial officials—not just when Ricci was there–for it condemned war and urged rulers and officials to attend to people's livelihood.[188] And finally, since the empire provided security, military careers lost their appeal for the Chinese elite. Instead, they pursued scholarship and education, which opened the door to positions in the Chinese bureaucracy.[189] The consequences for China were another example of the long run effect history can have, this time via politics, ideas, and the incentives elites faced.

So why then did no leader or conqueror ever manage to unite western Europe for long enough to keep cultural evolution from sundering it hostile groups that eventually became separate states? Why, in other words, was there never a durable empire in western Europe, at least after the collapse of Rome? Chinese emperors managed to bring long periods of war to halt when they established long lived dynasties in China. And rulers did the same by extending the rule of the Tokugawa Shogunate over all of Japan and by uniting most of India under the Mughal Empire, which gave the subcontinent a seventeenth century of relative peace. So why not in Europe?

What makes that question even more perplexing is that political unification could easily be self reinforcing once it was in place. True, large states (the Mughal Empire

being one example) did sometimes collapse long after they were founded, but there are a number of reasons—besides just the theory of state size—why political unification, if it survived its birth, might ward off future fragmentation. To begin with, if a new empire became effective at settling conflicts and ensuring security, then in the long run it could create incentives to pursue goals other than war, as in imperial China. It could also reduce ethnic differences by education, migration, and imposition of a dominant culture. Historians have advanced arguments of that sort for China, given its long history of repeated unification reaching back to 221 BCE, and quantitative evidence about ethnic and linguistic differences supports their claim. Outside of China, ethnic and linguistic diversity usually reflects variations in soil quality and elevation. The reason is simple: when people in the past learned how to farm different types of land, they built up region specific human capital that was hard to transfer to other areas, making it difficult for them to move. But in China something else was at work, for adjacent regions are more homogenous ethnically than the characteristics of the land would lead one to expect. That something else, it has been suggested, is likely the effort that the Chinese state has invested in cultural homogenization over the years.[190] The cultural homogeneity would in turn help hold the large state together. Early unification would also lend legitimacy to such a state's institutions. The legitimacy would help keep empire intact too, and if an invader did succeed in taking over, it would make it easier to rule the whole realm by relying on existing institutions and ideas, as the Manchus did when they founded the Qing dynasty.[191]

5. Western Christianity worked against Europe's unification

Unification might have taken hold in Western Europe too, if, say, Charlemagne's empire had survived long enough for its rulers to reshape incentives and establish the legitimacy of their reign. Europe would have then ended up just like China.

But there was one more centrifugal force that kept that sort of outcome from happening—namely, western Christianity. Along with hostility between groups that cultural evolution had generated, it help keep western Europe fragmented. By 1500, Christianity was, to be sure, the sole bond that held western Europeans together, but the Reformation and religious wars soon snapped that fragile tie and turned it into a source of violent discord and enduring enmity. Even before then, the papacy kept the Holy Roman Emperor—or any other ruler—from permanently reassembling Charlemagne's empire in western Europe. None of the polities in western Europe managed to subjugate the popes for long, thanks in large part to the Investiture Controversy of the 11th and 12th centuries. In this conflict of ideas and political alliances, the papacy struggled to gain greater independence from the Holy Roman Emperor and other kings and to limit their power over the Church, particularly the rights they claimed to appoint bishops and other officials. In their battles against the Holy Roman Emperors, the popes gained the support of cities and aristocracies in Italy and Germany. They won over reforming monestaries in Germany and got the Normans as allies by recognizing their conquests in Southern Italy. They resorted to divide and rule too, by urging powerful vassels to abandon the emperor's cause and by encouraging urban elites in Italy to drive out the bishops whom the emperor had put in charge of city governments. If necessary, they could also apply

their terrifying spiritual weapons of excommunication or interdict, as Pope Gregory VII did in his struggles with Emperor Henry IV in 1076. With these weapons and supporters on their side, the popes succeeded in keeping the Holy Roman Emperors from getting too powerful and from reuniting western Europe. They worked to keep other rulers from getting too strong too. Pope Innocent III not only excommunicated Emperor Otto IV in 1215; he also put France, England, and Norway under interdict. Conceivably, he himself might have become a European hegemon, but his sudden death and the very different temperment of his successor prevented that from happening.

The rest of Eurasia had no equivalent centrifugal force. There was simply was nothing like the western Church elsewhere in Eurasia—no religion that was powerful, politically autonomous, and equipped with an organized clergy. Japan and China lacked anything like the clergy of western Europe. Islam had no organized priesthood, and Brahmins were not organized in India either. In Russia and the Byzantine Empire, the orthodox Christian clergy was organized, but it was not independent of political authority, so it is not just Christianity itself that was at work here. The Ottoman Sultans exercised considerable control over Islam too—so much control that Islamic commentators on the medieval papacy were astonished by the pope's powers.[192] In short, for accidental reasons, the rest of Eurasia lacked the autonomous religious force that helped keep western European rulers from getting strong enough to unify their corner of the world.

This outcome in western Europe was contingent. Charlemagne's empire, after all, could have survived. If it had, it would have stopped the process of cultural evolution and kept the clergy and the popes politically subservient. The path history took was

contingent elsewhere in Eurasia too, in a way that led to very different values for the exogenous conditions governing the tournament model. While fighting had certainly torn other parts of Eurasia asunder, none of the other major Eurasian powers had suffered through western Europe's millenium of war and political fragmentation. Japan came the closest to sharing western Europe's experience, but by the early seventeenth century it was unified under the Tokugawa Shogunate. India had endured long periods of division too, but by the late seventeenth century nearly all of the subcontinent was united in the Mughal Empire. Unification, whenever it occurred, would likely cut the incentives to spend on war, for a large unified state like China would frighten off smaller adversaries. The only potential opponents would likely then be further away, which would impose a bigger fixed cost (the *b* in the tournament model) of mounting an invasion force or (as in the case of Japan) establishing a navy. With less reason to fight, military spending would diminish, and less would be done to advance the gunpowder technology, even if it was useful. Furthermore, large unified states (China and the Ottoman and Mughal Empires are examples) were more likely to have nomads for neighbors, which would discourage use of gunpowder weapons even when there was war.[193]

While the fragmentation of Europe helps explain why European conquered the world, it was therefore not one of the ultimate causes, because it itself was the offspring of history, as was the enduring unification of China or the Ottoman Empire. Fragmentation was fathered by contingent outcomes which determined how powerful the clergy would be or whether a region would become an empire or be divided into warring polities. It was sired, in other words, by the lasting effect that short run historical change can have. But if contingency was its father, then its mother was history working over the

long run, via cultural evolution during the centuries of war after the fall of Rome. The same mix of short and long run historical causes nurtured political unification elsewhere in Eurasia. Decades of life under an empire—itself born of contingency—could shape military technology, ideas, and political incentives, and even turn rulers and elites away from war, as happened, for example, in China. Centuries of war could have the opposite effect and reinforce political fragmention.

6. Why some Eurasian states could mobilize resources at low political cost

If history is then the ultimate cause behind Europe's fragmentation and the high value of the prize *P* that early modern rulers and elites were fighting for in the European tournament, then we still have to explain how some monarchs in western Europe managed to mobilize resources at low political cost. And we have to understand why why the rulers in China and in eighteenth-century India and Ottoman Empire faced much higher costs when they marshalled men and money for war.

The western European monarchs who succeeded in assembling resources at low political cost did so at the end of the Middle Ages or in the early modern period itself, when they gained rights to levy appreciate amounts of permanent taxation. The achievement was a contingent outcome, for not all western European rulers cleared this fiscal hurdle, and some were simply left with little ability to levy taxes. That was true, for instance, of the Holy Roman Emperor, although the family that provided the Emperors throughout most of the early modern period (the Habsburgs) did have considerable tax revenue from the lands where they were princes and kings.

The reason why some rulers made it over the hurdle, while others did not, can be traced back to a particular turn of events that set polities on a different path of development—in other words, to history operating in the short run. The kings of France, for example, gained the right to impose permanent taxes during the Hundred Years War (1337-1453), which pitted them against the kings of England in an interminable battle to see who would rule France. At the outset of the war, the French kings could only raise money when a war was being fought; even a truce would bring tax collection to a stop. But that changed after a disastrous French defeat in 1356, when King John II of France was taken prisoner by the English. Peacetime taxes were collected to pay for his ransom, and his son, who became king Charles V in 1364, managed to get the levies increased and made permanent in the 1360s. He did so by tailoring the taxes to suit the powerful nobility and, even more important, by showing that he could use the money effectively to provide the public good of security. In particular, he and his emissaries dealt ruthlessly with widespread brigandage by bands of furloughed soldiers who ravaged the countryside during periods of peace or truce. Protection against the brigands convinced his subjects that it was worth paying peacetime taxes. To judge from the city of Montpellier, where useable records survive, the annual amount collected per household may have jumped 21 fold between 1320-1333 and 1368-1370.[194]

Getting such an outcome elsewhere in western Europe was also a contingent process. In Brandenburg Prussia, the Great Elector Frederick William increased his revenues by allying with the nobility and by using an army raised during war with Sweden and Poland in 1655-1660 to cow those who might want to reduce taxes once the war was over.[195] Yet when he and other western European rulers did manage to mobilize

resources at low cost, they still had to negotiate with influential elites. That was true even for an absolute monarch such as Louis XIV. Furthermore, their tax revenues, though high by the standards of early modern Eurasia, were limited by concessions made to the elites, which usually involved limits on what could be collected in a given region, or the need to get some sort of consent (often in an court or a representative body, such as an estate) to impose new levies. The concessions put a ceiling on overall tax revenues, which could vary greatly province to province.

The one country in Europe that managed to escape the shackles of this fiscal particularism before the nineteenth century was England, which had something close to uniform taxation. Its tax revenues were then boosted even higher by the Glorious Revolution—a contingent outcome—which gave Parliament control of the purse and the ability to audit expenditures and hold ministers responsible. Parliament could then shape foreign policy and vote spend generously for wars it considered important. In particular, when the Whigs were in power, they could vote huge sums to battle against what they saw as an ominous threat from France.[196]

History also explains the very different cost of mobilizing military resources in other parts of Eurasia and why in particular it loomed so large in imperial China, in the eighteenth-century Ottoman Empire, and in eighteenth century India. For China it is clear why the political cost was so high. It reflected, we know, the empire's size. But the ultimate cause behind the empire's huge size was history—the history of repeated unification under dynasties that managed to rule long enough to make the empire self reinforcing, even when invaders such as the Mongols or the Manchus took over.

The high cost of mobilizing resources in India and in the Ottoman Empire can be

traced back to the contingencies of their political histories. In India, the Mughal Empire itself was decentralized, even at the height of its power. With a meager bureaucracy and emperors who continued to travel with the army and the court, it relied on local power holders to collect taxes even before it disintegrated in the eighteenth century, and it granted them considerable autonomy. Although European kings had once done the same, their control over tax revenues increased beginning in the late Middle Ages, at least in the states that succeeded in imposing permanent taxation. In India, by contrast, the local powers gained the upper hand in the eighteenth century, which caused the Mughal Empire to fall apart. The polities that emerged did try to establish their own fiscal systems, but their progress, as we have seen, was slow. Mysore, which was further along than the others, could still not pry money loose from local elites, and when Mysore's ruler in the late eighteenth century tried to appoint new tax officials, their lack of information about local revenues and wealth kept them from being effective. Before Mysore and the other Indian polities could get working fiscal systems set up, the East India Company took over much of the subcontinent. The Company began, as we know, by conquering the wealthy province of Bengal thanks to the gunpowder technology and to the troops and British naval support that it had deployed to fight the French in South Asia. Revenue from Bengal then funded its other conquests, and its victories were cemented by bargains with local elites that gave the company more tax revenue than native rulers could collect.[197]

Local elites gained the upper hand in the Ottoman Empire as well, but not until the eighteenth century. In the sixteenth century, the Ottoman Sultan seemed far more powerful than the rulers of France, at least to a knowledgeable observer like Machiavelli,

for unlike the French kings, the Sultan was not hemmed in by the rights of local elites.[198] But by the 1700s, the local leaders who collected taxes, served as provincial administrators, or took on military commands were defying imperial orders, pocketing growing amounts of the tax revenue, or even defecting to the enemy. The Sultan could threaten them with execution or loss of their family property, but in the end they would likely be pardoned because the Sultan had no way to replace them.[199] Western Europe's chief monarchs had not been that weak since at least the early seventeenth century.

Perhaps the Empire's weakness derived from the halt to Ottoman expansion in the seventeenth century, which left the Sultan with no more new land rights to award to the leaders of his large cavalry forces. Or perhaps it reflected the growing autonomy of the janissaries, the military slaves who supplied him with increasingly important infantry. Common in the Middle East, the military slaves had originally provided disciplined and loyal soldiers who posed no threat to a Muslim ruler's power. But with military slaves, a Muslim ruler also had less reason to negotiate with elites than the weaker rulers in the medieval West. In the long run, Muslim rulers such as the Ottoman Sultans therefore never got the permanent tax levies that the negotiation ultimately gave their western counterparts. Even worse, by the eighteenth century the janissaries—had become an entrenched group that actually limited the Sultan's powers.[200]

As these disparate outcomes suggest, there was no simple way to predict whether a ruler would gain the capacity to mobilize resources at low political cost. There was, as Charles Tilly stressed, no unique route to that ability, for the path toward toward it was influenced in a complex fashion by many forces, including international relations and domestic political economy.[201] Getting there could be shaped by long series of events, as

with the long periods of unification in imperial China, or by contingent outcomes in the middle of an enduring conflict, as in late medieval France. The achievement was, in short, the result of history, operating over the short or the long run.

Quantitative evidence points in the same direction, or so a recent econometric analyis of early modern tax revenues in western Europe, Poland, Russia, and the Ottoman Empire implies. Some of these states increased their per capita tax revenues between 1500 and 1800, but in others tax revenue stagnated or fell. To explain the variations (as the authors of the study, Sivanc Karaman and Sevket Pamuk, point out), the vast literature on state building has stressed three factors: warfare, whether the economy was agrarian or urbanized, and whether the political regime was representative or authoritarian. The relationship between these factors and the ability to levy high level of taxation, however, was far from simple, because the three interacted in a complex manner. Political regimes with representative institutions did manage to collect more tax revenue in wartime, but only in urbanized economies. Authoritarian regimes could impose heavy taxes in wartime too, but only in agrarian economies. And although the econometric analysis does leave some room for doubt, it suggests that the effect politics had on tax revenues was causal and independent of war and the nature of the economy.[202]

That sort of complicated interaction is consistent with Tilly's argument that there was no unique path toward a state's gaining the ability to marshall huge amounts of resources at low political cost. But it also allows politics more of an independent causal role than in Tilly's work and does not reduce it to a variable dependent on war and domestic political economy alone. Granting politics an independent causal role would also fit Mark Dincecco's research on tax revenues in Europe in the years 1650-1913. He

too finds that war and urbanization affected tax revenues, but they cannot explain all the variation in what the fisc collected. Per-capita taxes also jumped—and independently of the effects of war and urbanization—during bouts of political change, as, for example, when the revolutionary government in France centralized the fiscal system.[203] But if tax revenues are determined, at least in part, by war and political outcomes, then history is one of the ultimate causes behind a state's ability to levy taxes, for it shaped political regimes and also triggered wars. A contingent event, such as the resolution of a political crisis, could vault a polity into a new realm of higher tax revenues, as in France during the Hundred Years War, or in England after the Glorious Revolution. And it could work over the long run too. If, say, an empire survived long enough, then it would be likely to persist, and its very size could then diminish per capita tax revenue, as in China.

By the early modern period then, a millennium of war and ensuing cultural evolution had therefore split western Europe into small, hostile states, whose rulers and elites were engrossed in the fight for glory and the other prizes of battle. Some leaders, though not all, emerged from the process able to mobilize enormous resources at low political cost, and in combatting one another, they all relied heavily on the gunpowder technology, for they were shielded from nomads by Russia, Poland, and Hungary. In short, all the conditions singled out by the tournament model were satisfied in western Europe and satisfied just when the gunpowder technology was new and ripe for improvement for learning by doing.

This outcome was a product of history, as were the strikingly different outcomes elsewhere in Eurasia. The only thing left to explain then is why western European entrepreneurs were encouraged to go abroad and conquer, while their counterparts

elsewhere confronted obstacles when they tried to do the same. Again the ultimate cause will be history.

7. Incentives for conquistadores and military entrepreneurs

By 1500, there was a long tradition in western Europe of harnassing private initiatives to make war and a long tradition too of private efforts to conquer territory abroad. In the Middle Ages, lords hired mercenaries, while knights set out to the frontiers of Europe and beyond to win estates or defeat the enemies of the faith. The practice was understandable in a world where contending lords did not yet rule over states with fiscal systems and permanent taxation and therefore lacked the means to establish standing armies. It helped lords and rulers organize military undertakings against enemies and it reinforced the martial values prized by European elites. It therefore complemented the process of cultural evolution that parochial altruism had triggered.

Reliance on private initiatives and rewards persisted into the early modern period, when it spawned tax farming and military innovations and helped translate advances in military technology into conquest in other parts of the world, as private entrepreneurs launched expeditions of trade and colonization. It is true that other parts of Eurasia relied on private initiatives of this sort too—the Ottoman Empire, for instance, had tax farmers, and mercenaries were common in India—but outside of western Europe the private efforts were limited or ran into obstacles. Often the reason was that rulers there had established fiscal systems much earlier than in western Europe and could therefore hire

officials instead of engaging in what we might today call the "outsourcing" of government and the military to mercenaries and private contractors. In short, they ruled states that were simply more developed than in western Europe. The result was that rest of Eurasia lacked the same history of huge personal rewards that drew entrepreneurs to the military sector or to conquest abroad at the dawn of the age of exploration.

Why, though, did kings and princes in western European continue to rely on private contractors after they set up their own tax systems? Finding out why is important, because without all the entrepreneurs, western Europeans might never have set out to conquer or trade, no matter how far they had pushed the gunpowder technology.

In part, rulers persisted in using private contractors because they had proved successful in the recent past and continued to do so. During the Hundred Years War, English soldiers furloughed during periods of truce during the Hundred Years War were hired in Italy, where in the 1360s they introduced the long bow and novel tactics with the lance into the warfare among city states that already had fiscal systems. The mercenaries were clearly cutting edge professionals, even though Machiavelli later railed against them.[204] Using them also allowed rulers to take advantage of the abundant supply of military entrepreneurs that western Europe's war and lengthy history of political underdevelopment had created over the long run. The entrepreneurs would take on the risks and quickly provide troops, supplies, and—most important of all—credit in an era when even states with permanent taxes could have trouble borrowing, which was essential for funding the explosion of expenses that came with the onset of war.[205]

One danger for kings and princes was that a major military contractor would disobey. Such a threat drove the Holy Roman Emperor to assassinate his chief

entrepreneur during the Thirty Years War, the military commander Wallenstein, and eventually rulers reduced the importance of the military entrepreneurs, as they centralized fiscal systems, constructed bureaucracies, and gained the ability to borrow, to maintain standing armies, and to better monitor subordinates. Although the entrepreneurs did not completely disappear, increasingly they were replaced by royal officials and commissioned officers. Even so, personal financial rewards continued to play a role as a powerful incentive for military and civilian personnel, for the border between the private and the state remained fuzzy in the early modern world. In France, Michel Le Tellier and his son Louvois, who presided over the war department under Louis XIV, amassed a mammoth fortune as they helped their king build a more effective and much bigger army.[206] An even better example comes from the British navy, the dominant seagoing force in the eighteenth century, which made systematic use of personal financial incentives.[207] In a sense, the monarchs in Britain and France were simply changing their contracts with the suppliers and soldiers who furnished military goods and services. Since they now had bureaucrats who could monitor behavior at lower cost, it paid to integrate the suppliers and soldiers into their armies and navies. But their new contracts still spurred them on with personal rewards.[208]

Continued reliance on personal financial rewards—even for government officals—helped created clusters of complementary skills that contributed to western Europe's growing lead in the gunpowder technology. The skills, which ranged from navigation and ship design to cannon founding, added to western Europe's lead with the gunpowder technology, and they were available throughout the continent, for as we have seen, short travel distances and porous borders could not halt the flow of military goods

and services, even if it meant supplying an enemy king in wartime. Personal rewards were an essential part of the process, along with the rest of the money spent military goods and services. For Jean Maritz, the Swiss cannon founder who perfected the technique of boring cannons for the French, the remuneration meant that he died with the fortune not of a successful artisan, but of a wealthy merchant or noble, one that put him in the top 1 percent of the wealth distribution in the French province where he made his home.[209] John Harrison, whose invention of the marine chronometer made it possible to measure longitude accurately at sea, was motivated by a government prize established in the aftermath of a 1707 naval disaster brought on by navigational errors.[210]

The personal rewards had another important consequence, for they gave western Europeans all the more reason to go abroad and conquer. There were of course other motives at work. The Portuguese, as we have seen, wanted to continue the struggle against the Muslims; the medieval admonition to conquer abroad still swayed behavior; and as for Columbus, he could draw inspiration from an intellectual tradition that depicted the lands he was sailing for as the richest part of the globe.[211] But windfalls from far away places, particularly early on, did a huge amount to stimulate interest in foreign expeditions. When the treasures sent back by Cortes reached Spain in 1520, they "created a sensation" and incited other Spaniards to search the Americas for wealth. Pizarro's ransom had a similar impact. The riches delighted Spain's rulers, and the discovery of silver in Mexico and Peru in the middle of the sixteenth century pleased them even more, for the avalanche of bullion that the mines yielded (thanks to the new process of extracting silver with mercury) could fund their wars.[212] Without these initial strokes of good luck, voyages of conquest might well have subsided, or so the record of

earlier human exploration suggests.[213] Windfalls continued to impress Europeans for centuries. When in 1744 Captain George Anson brought 32 wagons full of treasure back to London from a Spanish Galleon he had captured in the Pacific, he was paraded through the streets as a national hero—and eventually promoted to First Lord of the Admiralty—even though only 10 percent of his original crew had survived the harrowing four-year voyage.[214]

Spain's and Portugal's profits in turn encouraged other European states to support rival ventures of trade, private conquest, and privateering, with the private efforts culminating in the Dutch and British East India Companies. The two trading companies, as we have seen, were important arms of their governments' foreign policies and could raise huge sums in Europe's burgeoning capital markets.[215] The employees of both companies traded on their own as well, and their personal profits were an added motive behind Britain's creation of a territorial empire in India. Having the Company fight the French, in what was the South Asian Indian theater of the Seven Years War, did clearly fit the goals of British foreign policy and also protected the Company's earnings. Having it take over Bengal, however, was another matter, which provoked debate back in London. Yet before the debate was resolved in the late 1760s in favor of a territorial empire, the Company's men in India had already taken the first step by using their own army (and British naval forces sent to fight the French) against the ruler of Bengal. Their aim was to protect both the Company's business and their own private profits from his attacks. They then employed their military forces to take over Bengal, and eventually other territory too, with the support of the British government.[216]

The private ventures and incentives made eminent sense for conquest and

exploration, and for preying on trade in far away places. Travel and communication were too slow for even the most powerful states to monitor what was happening half way around the world. Relying on private incentives was often the best way to get such things done. Even the Portuguese empire (which exercised more state control from the very beginning than did Spain) made room for considerable amounts of private trade.[217] An even better way to harness private incentives was to make distant conquest or preying on trade into a corporate venture, with private investors and captains who would be richly rewarded with a share of the profits when they succeeded. The conquistadors turned to that sort of organization, as did (on a much grander scale) the Dutch and English East India Companies.[218]

Western European rulers did regulate the private ventures and limit entry. A would be Spanish conquistador, for example, needed a royal charter. But the obstacles to private undertakings were generally much smaller than in the rest of Eurasia. Merchants in China, for instance, were often barred from conducting overseas trade during the Ming and Qing dynasties. In Tokugawa Japan, there was a crack down on would be pirates, a ban on building large ships, and foreign trade was choked almost to death. By 1640, "all but a few Japanese had been prohibited on pain of death from going abroad."[219] Although the prohibitions could not completely stop overseas trade or travel (Chinese merchants, after all, could be found throughout South East Asia), they did make the undertakings much harder for the Chinese and Japanese. And while western European governments would often intercede on behalf of their merchants abroad, Chinese emperors would not.[220]

One additional hurdle confronted would be explorers outside of western Europe:

they had a harder time getting access to the technology that made it possible for small groups to conquer or prey on trade abroad—the gunpowder technology. In western Europe, as we know, gun ownership was widespread, and conquistadores had no problem buying firearms and recruiting men familiar with their use. That was not necessarily so in the rest of Eurasia. China and the Ottoman Empire restricted private gun ownership and trade in firearms, and Tokugawa Japan banned the export of weapons. Laws of this sort were never perfectly enforced, but when in place they would discourage other Eurasians from despoiling foreign traders or trying to set up colonies by force.[221]

Why did states outside western Europe enact such prohibitions? The bans on travel and trade in imperial China and Tokugawa Japan were adopted by relatively strong rulers who aimed to reinforce their domestic security and to control foreign policy. The incentives to preserve their policy then lasted long enough for it to become the foundation of their successors' dealings with the outside world—an example of history working in the short run via decisions that then have lasting effects. In China, for instance, the restrictions on trade date back to the first Ming Emperor, who barred most maritime traffic in 1372 in order to keep his subjects from challenging his rule by allying with people outside China. His ban then became a "cornerstone" of Ming maritime policy, and while the restrictions were lifted in 1567, they were reimposed later in the dynasty and in the Qing dynasty too.[222] In Japan, Toyotomi Hideyoshi, one of the country's unifiers, initiated the restrictions on trade in the late sixteenth century, and they were reinforced in the seventeenth century by the first Tokugawa shoguns. The aim was to strengthen the sovereignty of Japan's rulers and their mastery of foreign affairs. The policy also had the advantage of keeping regional lords (daimyo) from gaining too much

wealth and power from foreign trade.[223] As for the prohibitions against gun ownership and trade in firearms in China, the Ottoman Empire, and Tokugawa Japan, they likely had similar origins.[224]

European princes would have balked at enacting similar measures, for several reasons. Restricting gun ownership would upset the nobility, and banning armed private expeditions would mean spurning western Europe's abundant supply of military entrepreneurs, among them its many privateers.[225] And although outlawing trade might impose losses in a huge state such as China (with horses, a strategic good, being a particular example), the cost of foregone trade would be even higher in the smaller states of western Europe. Finally, the long tradition of conquest abroad in western Europe had created a powerful vested interest (part of historians call mercantilism) in foreign expeditions, particularly in states with thriving port cities and powerful merchants, such as Britain and the Netherlands.

One final advantage that western European traders and conquerors had (at least relative to their counterparts in the Ottoman Empire) was that Islamic law simply made it difficult to establish anything like the Dutch East India Company—the world's first joint stock company with an independent legal existence and an indefinite life span. An undertaking of that scale was simply too big and too risky for short lived partnerships, the only legal vehicle readily available to Ottoman merchants and entrepreneurs. The hang up here derived (so Timur Kuran has argued) from Islamic commercial law. Its limitations were certainly not planned. Rather, they were the result of two historical contingencies: first, the accident of what happened to be spelled out in the Koran and was thus difficult to change; and second, the virtues of a legal tradition that worked well for

the short term trading ventures of medieval merchants but could not easily cope with the sort of long distance expeditions of trade and raiding undertaken by the Dutch, which involved huge amounts of fixed capital in the form of docks, storehouses, and fortresses. Islamic partnerships had to be dissolved and liquidated whenever a partner died; unlike corporation, they had no independent existence of the parties involved. Liquidation was relatively easy for a short term medieval trading venture, but it was impractical when capital was invested for years and raised from scores of investors, and when it might mean selling off assets such as a fortress thousand of miles away. As a result, Ottoman business ventures had to be small and short lived, and they could not mobilize large amounts of fixed capital.[226] Those restrictions ruled out the private ventures undertaken by the Dutch East India Company or the by the British East India Company during its conquest of India.

None of these obstacles to trade, travel, or the use of guns was perfect. Private efforts to conquer or prey upon trade were still possible elsewhere in Eurasia. But they confronted barriers that were much higher than in western Europe. And then there was one more historical contingency that may have discouraged other Eurasians from doing what da Gama, Columbus, Cortes, or Pizarro did—what might call western Europe's economic inferiority complex at the dawn of the early modern period. Western Europeans were convinced that other parts of the world were wealthier—particularly Asia or the southern latitudes that were Columbus's goal.[227] Although Columbus brought little tangible wealth back, da Gama returned with encouraging news, even if some of it was based on misconceptions. Cortes's gold and Pizarro ransom gave even more reason to explore and conquer. And by the middle of the sixteenth century, the discovery of

silver mines stoked the envy of all of Spain's rivals.

Other Eurasians would not have suffered from the same delusions as the western Europeans. They produced or traded in the silks, spices, and other luxury goods that Europeans lusted after. They thus had less reason to believe that other parts of the known world were wealthier. More important, their own experience of long distance travel would only confirmed that belief. Between 1405 and 1433, for example, the Ming emperors dispatched seven huge fleets under the commander Zheng He to overawe rulers from southeast Asia to Africa and collect tribute from them. The expeditions brought back some exotic goods such as ostriches and giraffes back to China, but no windfall of gold or silver—nothing like Cortes's gold or Pizzaro's ransom—and even the exotic goods failed to impress the emperors. The fleets in fact had to be subsidized, and that was one reason why they were finally halted. Why, after all, spend money on the fleets, when the real military problem was with nomads to the north?[228] One might think that the Chinese were simply sailing in the wrong direction and that they should have tried to cross the Pacific. But sailing from Asia to Latin America would have been challenging, because it was radically different from the well known monsoon trading routes followed by Zheng He. The Spanish did not master the eastward voyage across the Pacific until 1564; even then mortality rates were at least 30 percent per trip and sometimes as high as 75 percent. Furthermore, the Chinese simply had none of the accidental windfalls that encouraged exploration and conquest in western Europe, and attempting a Pacific crossing would be unlikely to produce one.[229]

In short, while rulers in western Europe relied on entrepreneurs in war and conquest, similar private undertakings were by and large discouraged in other parts of Eurasia. If, say, the Ottoman Sultan did not seek territory abroad, his subjects would have trouble doing it for him, for there would be too many obstacles in their way. The same would be true for China and Japan. There too conquest would have to be a government enterprise. A ruler might decide to enlarge his realm, as the Qianlong Emperor did when he wiped out the nomads and added territory to China's west, but otherwise there would be no conquest abroad. Interested private parties would have a hard time even lobbying for conquest because of all the hurdles blocking their path. Western Europeans faced no such barriers, and they were in fact encouraged by rulers who were battling religious enemies or one another in the western European tournament, particularly when it spilled out into Asia, the Americas, and distant waters.

That contrast helps account for part of the difference between western Europe and the rest of Eurasia, and it was a product of history. History also explains why the exogenous conditions governing the tournament model were so different in western Europe, or in other words, why it was the only part of early modern Eurasia that satisfied the four conditions needed for advancing the gunpowder technology: incessant warfare, massive spending on fighting it, heavy use of the gunpowder weapons, and rapid diffusion of military innovations. Those conditions held when rulers fought for a prize P that was large relative to the fixed cost b of setting up a fiscal system or military; when the political costs c_i they faced to mobilize military resources were similar and low, and

their realms of roughly the same size; and when other countries were nearby but distant from nomads or seas where galley warfare dominated.

How did history have such an impact? Some of its consequences were worked out over the long run via peculiar chains of events that set each part of Eurasia on a different path of political development or cultural evolution: the succession of long lived empires in China; the unification of Japan and the establishment of the durable Tokugawa Shogunate; the decentralization of the Mughal Empire and (by the 1700s) of the Ottoman Empire; and, last but not least, the centuries of war in western Europe after the fall of Rome, without anything that would qualify as a strong state. But history also acted in the short run via contingent outcomes with unforseen long term consequences: the Reformation, the windfalls of treasure from the New World, the bans on trade adopted to reinforce new rulers' security in China and Japan, the Ottoman Sultan's decision to rely on janissaries, and the timing of the Mughal Empire's collapse. Perhaps the most remarkable of these freighted contigencies was what came in the wake of the Investiture Controversy. It made western Europe the only part of Eurasia with an organized and politically autonomous clergy, over which stood a pope who could work to prevent rulers from growing too powerful. Along with cultural evolution, this unique feature of western Christianity (and not of Christianity in general) helped keep western Europe fragmented.

None of these outcomes was foreordained. In the Ottoman Empire, the janissaries were advantageous initially because they allowed the Sultans to form a loyal and disciplined military force. But if the Sultans had not relied on the janissaries, perhaps they would have negotiated with elites from the outset and in the long run gotten more tax revenue. The importance of cavalry and galleys in the wars they fought would still

have kept from forefront of the gunpowder technology, but they might have done a better job of holding their own against the Europeans in the eighteenth century. Similarly, if the Mughal Empire had collapsed earlier, then Mysore and the other powers that took its place might have had the time to develop fiscal systems that would raise tax revenue at low political cost. With that revenue, they might have stopped the East India Company. Without such a fiscal system, Mysore still almost defeated the East India Company, and it might have even won if it had used territorial concessions to keep one of the other Indian powers—the Maratha Confederacy—from allying with the British. Such a loss might in turn have convinced the Company to abandon the fight and to limit itself to much less territory in India.[230]

Different outcomes were possible elsewhere too. What would have happened if one of Charlemagne's grandsons had killed his brothers and managed to hold the Carolingian Empire together? If it had remained intact, the European Emperors might have kept the popes under their thumbs and then had to contend with nomads from the east and galley warfare on the Mediterranean. Clearly, the course of world history would have changed. Or what if the warlords in pre-Tokugawa Japan had constructed sizeable navies, which could have been redeployed for invading Korea? With a lower fixed cost for a foreign invasion, Tokugawa Japan might then have been launched on a path of foreign conquest.[231]

But the most intriguing counterfactual concerns China. Although early unification did perhaps incline the Chinese Empire toward remaining intact, there were times when China could plausibly have remained divided. The most convincing scenario involves imagining what would have happened if China had not been conquered by the

Mongols in the thirteenth century. Considering the course of history without a Mongol conquest seems much more realistic than imagining (as several authors have) what would have happened if voyages like Zheng He's had continued.[232] That counterfactual is implausible, for it ignores the incentives facing the Ming Dynasty, which was threatened by nomads and therefore had little reason to waste money on further nautical expeditions.

But a world without a Mongol conquest was a real possibility. Forging an empire like the Mongols' demanded a rare charismatic leader like Ghengis Khan, and even after the Mongol Empire coalesced, it was unstable and could easily have disintegrated before China had been conquered. In the early thirteenth century, before the Mongols took over, East Asia was split into three hostile powers locked into a military equilibrium: the Western Xia and the Jin to the north, and the Southern Song to the south and along the coast. If the Mongols had not shattered this equilibrium (and no other nomadic mega Empire had taken their place), then China might well have remained divided, and the Southern Song would have continued to prosper. Since fighting with the Western Xia and the Jin would not have stopped, the Southern Song would have persisted in developing their commercial taxes and their navy, which had helped them survive a Jin invasion and would have protected both inland waterways and their coastal capital.[233] Over time one could easily imagine merchant elites in prosperous Southern Song cities lobbying (like their mercantile counterparts in western Europe) for urban fortifications and for a powerful ocean going navy to protect their burgeoning overseas trade. At that point the gunpowder technology would become immensely attractive, at least along the seaboard.

What would the outcome have been? Militarily, the Southern Song state would have been large by European standards, and it would not have been free of threats from nomads. Hence the Southern Song could not have specialized in the gunpowder technology: like the Ottomans and the Russians, they would have had to divide their effort between the gunpowder technology and the older means of dealing with nomads. But their incentive to use gunpowder would have been much stronger, and with substantial commercial tax revenues, they would not have faced overwhelming political costs in pushing the technology further than the Ming ever did. Alternatively, they could (like the Russians) simply buy the latest version of the technology from the Europeans their merchants traded with. And it would have been much easier for Chinese merchants to establishing maritime trading centers abroad.

The end result would likely have been a much stronger state by 1800, one that might have held off the Europeans and the Japanese, or at least negotiated with them on more equal terms. And it could have provided much more security internally. Would China have also industrialized faster? Seaborn trade might have encouraged industrialization, but there was too little of it to have much of an effect in state as big as the Southern Sung.[234] And China would still lack England's cheap coal. Yet one could imagine a different path to industrialization, one based on a textile industry like that found in the early United States. The ongoing warfare and fortification of cities along the coast would have already raised wages and thereby encouraged industrialization, if Jean-Laurent Rosenthal and R. Bin Wong are correct.[235] Waterpower could substitute for coal as a source of power, as in the early American textile industry, and the textile machines might be imported from England by merchants eager to sell in the large domestic market,

or to the Jin and the Western Xia. Although textile manufacturing might need protection to prosper, Chinese merchants could get it from their stronger state, and in the meantime agglomeration economies along the coast could spur industrialization of other sectors of the economy. Such a Southern Song China might not have been the first to industrialize, but it would likely have joined Japan, the United States, and continental Europe in having an industrial revolution not in the twentieth century, but in the 1800s.[236]

Table 4.1: Mountainous terrain in China and Europe

	Percent mountainous	
Mountainous if:	China	Europe
Elevation > 1000 meters	33.28	6.28
Slope of terrain > 15 degrees	30.93	2.71
Classified as mountainous by World Bank study	37.40	10.60

Source: Yang 2011 . See appendix C for a detailed discussion of the data.

Note: For the measurements of elevation and slope, China is defined as the modern provinces of Heilongjiang, Jilin, Liaoning, Hebei, Shandong, Jiangsu, Anhui, Henan, Shanxi, Shaanxi, Gansu, Sichuan, Chongqing, Hubei, Zhejiang, Jiangxi, Hunan, Guizhou, Yunnan, Guangxi, Guangdong, Fujian, Taiwan, and Hainan. That is approximately the boundary of the Tang (618 - 907) and Ming (1368 - 1644 AD) Dynasties. This definition, it should be noted, omits the modern provinces of Inner Mongolia, Xinjiang, Qinghai, and Tibet, so that they are not included in the calculation. The World Bank study, which is based on China's modern boundaries, does include Inner Mongolia, Xinjian, Qinghai, and Tibet, but a sensitivity analysis suggests that removing these four provinces would not make Europe more mountainous than China. Europe, for elevation and slope, was defined to be Ireland, United Kingdom, Portugal, Spain, France, Belgium, Switzerland, Italy, Netherland, Germany, Denmark, Poland, the Czech Republic, Austria, Slovenia, Croatia, Slovakia, Hungary, Bosnia and Herzegovina, Serbia, Montenegro, Albania, Macedonia, Greece, Bulgaria, Romania, Moldova, Ukraine, Belarus, Lithuania, Latvia, Estonia, Norway, Sweden, Finland, Luxemburg, Monaco, Andorra, Liechtenstein, and San Marino. Because the World Bank study had no data for Luxemburg, Monaco, Andorra, Liechtenstein, and San Marino, they were omitted from the calculations based on the World Bank classification, but the resulting error is minimal since these five small countries constitute less than 0.06 percent of Europe's area. For details see appendix C.

Table 4.2: Measures of the irregularity of China's and Europe's coastline

Landmass	China	Europe
Degree of concavity (area of landmass divided by area of its convex hull)	0.68	0.60
Probability that a line segment between two points in the landmass cuts across the shoreline	0.06	0.41

Source: Schropp 2012 . See appendix C for a detailed discussion of the data.

Note: The two measures work as follows: if a landmass has an irregular coastline, its degree of concavity is lower, and the probability that a line segment between two points in the landmass cuts across the shoreline is higher. Because this probability will depend on the depth of the interior of landmass, it was estimated by creating artificial shapes that have the same shoreline as China or Europe but equivalent interior depths. As for the degree of concavity, the convex hull of a landmass is the smallest convex shape containing it. For a definition of what a convex shape is and an explanation of why the two measures work, see appendix C.

Table 4.3: Results of a probit analysis of the probability that a ruler is dethroned after a military defeat: Eurasia, 1500-1789.

Marginal effect on the probability that a ruler is dethroned of a unit change in	Estimates from Probit (Standard Errors)
Losing a war	0.294 (0.039)
Losing a war*being a big power in western Europe	-0.070 (0.013)
Losing a war*being a non western big power	-0.058 (0.014)
Having a civil war	0.053 (0.025)
N	595
Test of hypothesis that there is no difference in the likelihood of survival of great powers in western Europe and great powers elsewhere in Eurasia	p = 0.49

Source: Clodfelter 2002, Langer 1968, Levy 1983, Darby and Fullard 1970.

Note: Each observation is a war outcome for a particular country. The data includes all wars throughout the world that are listed in Clodfelter, ended before 1790, and involved at least one big power. Many of these wars involved smaller states or were fought outside of Eurasia. The big powers here are defined as any of the western European states that were ever listed as great powers in Levy, plus China, the Ottoman Empire, Persia, the Mogul Empire, and Russia. The marginal effect of each explanatory variable was calculated under the assumption that the other explanatory variables were set equal to their mean value.

Figure 4.1: Mountain ranges and borders in modern Europe. Steep areas (those with slope over 25 degrees) are dark, and if they fall on national boundaries they are highlighted. Source: Yang 2011

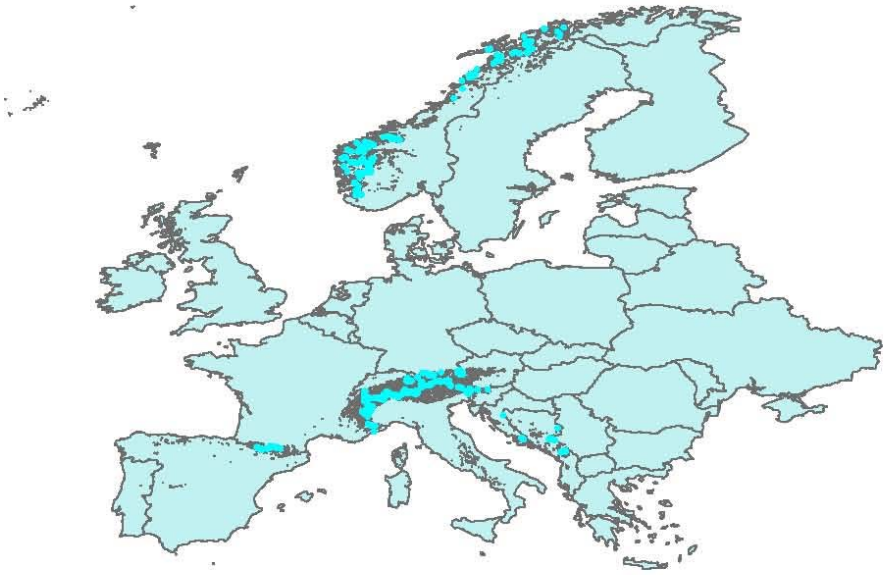


Figure 4.2: Mountain ranges and borders in ancient China. Steep areas (those with slope over 35 degrees) are dark, and if they fall on imperial or provincial boundaries they are highlighted. Note that the implicit definition of steepness is more restrictive for China. Source: Yang 2011

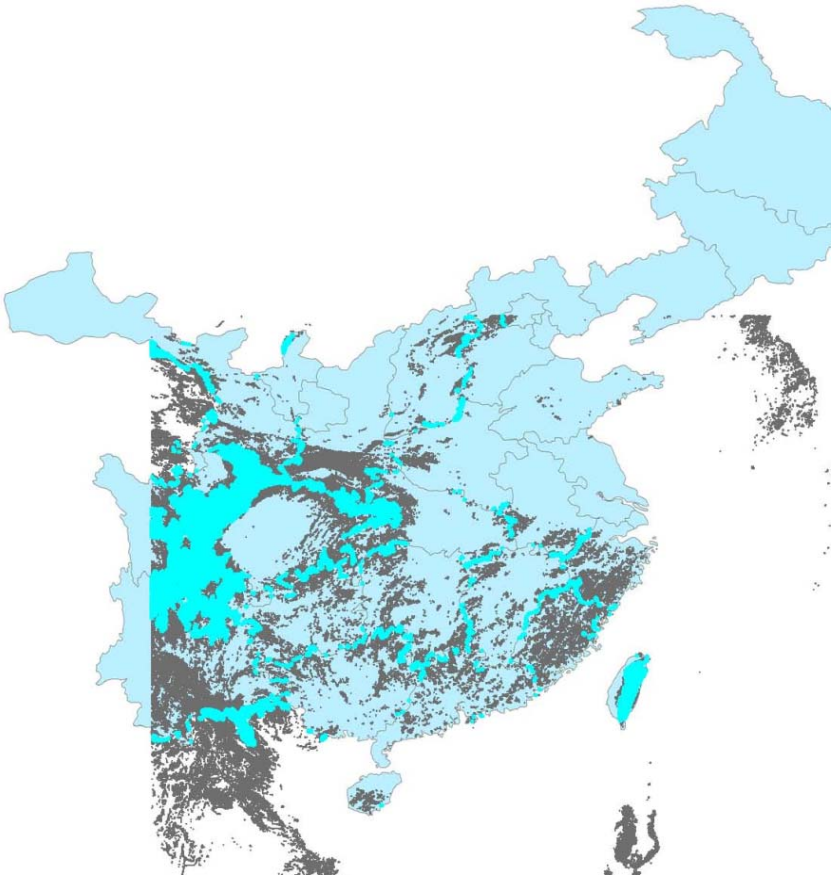


Figure 4.3: Europe in 1300

Chapter 5: Technological Change and Armed Peace in Nineteenth-Century Europe

After 1815, the incessant warfare that had bedeviled Europe for centuries virtually disappeared. Diplomats at the Congress of Vienna had fashioned a coalition that discouraged armed conflicts within Europe, until late in the century. The European powers fought in the rest of the world, and their military rivalries within Europe lived on. But the only wars they waged on the continent itself were short and relatively bloodless, allowing the continent to bask in peace (albeit an armed one) until the onset of World War I.[237]

With warfare subsiding within Europe, did the tournament fade away too, and with it the advances in the gunpowder technology that had been sustained since the late Middle Ages? It might seem so. Nonetheless, military technology continued to evolve. Rifled handguns and artillery replaced smooth bore muskets and cannons, and armored battleships and steam powered gunboats took the place of sailing ships—advances that gave the Europeans an even bigger edge in colonial wars.[238]

An extension of our model can explain why, an extension that takes into account three critical things that changed in the nineteenth century. The first were the different incentives that rulers and political leaders faced when they considered going to war. Glory—a military goal that could not easily be divided up—diminished in importance among rulers' ambitions, as did another indivisible goal—trade monopolies. It because much easier therefore to negotiate peaceful settlements to disputes, and there was more reason to do so, for the devastating experience of the Napoleonic wars made it clear that defeat would could now impose huge penalties on losers and even threaten their very existence.[239] Sovereigns themselves had for the first time to face the risk that military

defeat might topple them from the throne or bring their powers to an end (Table 2.2). The downside to war became even clearer later in the century, as foreign policy came under control of statesmen or legislative leaders who stood to lose more from hostilities than any Old-Regime monarch. They had to heed the sentiment of legislators or the people, and although they could exploit public opinion—by, say, fanning nationalist demands—it could turn on them, force their hand, or even topple them from power after a catastrophic loss, as happened to Napoleon III in 1870.

The second major change in the nineteenth century were political and administrative reforms that cut the political cost of mobilizing resources. During the Napoleonic Wars, states centralized their fiscal systems more thoroughly than ever before, and later in the nineteenth century representative assemblies gained a voice in fiscal decisions. Cumulatively, the reforms made it easier to raise taxes and hence diminished the political cost c_i that each state faced when it sought revenue for military spending or assembled men and supplies for war.[240] Nationalism and conscription had the same effect. As a result, the total cost of mobilizing military resources ($C = c_1 + c_2$ in the model) fell in Europe. The lower cost C in turn offset, at least partially, the effect of the new incentives leaders faced, which reduced the value of the prize P they were fighting for. As a result, although nineteenth-century statesman were more likely to negotiate peaceful settlements, they could marshal more resources $Z = P/C$ when the hostilities actually broke out, and even in peacetime they would, as we shall see, spend large sums on the military.

One final difference distinguished the nineteenth century, a critical one. It was now clear that military technology could be advanced not just via learning by doing

during wars, but by research and development, research and development that could be undertaken in peacetime by the military itself or by private entrepreneurs eager for military contracts. Although some research had always been 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 grew easier still in the nineteenth century, with the growth of engineering know how during the Industrial Revolution.[241] It relaxed the limits that available knowledge imposed on technological change and meant that innovation could potentially be sustained forever.

These three changes ensured that the gunpowder technology would continue to advance despite a century of relative peace in Europe. Innovation even accelerated at the end of the nineteenth century, when Europe's military rivalries intensified during the build up to World War I. Adding to Europe's military might was the transformation of her civilian economies, which magnified the prowess of European forces both at home and in far away colonies. Telegraphs and newly constructed railroads could now direct huge armies, speed them to battle and keep them supplied. Spreading industrialization, by boosting GDP, let countries to devote increasing sums to their armies and navies, even when the military's share of the government's total budget declined. And medical advances such as quinine helped Europeans survive the devastating diseases of tropical Africa. With all this military power in their hands and the medical advances at their disposal, and with the diplomatic revolution doing nothing to discourage colonial wars, the Europeans found it much easier to conquer distant territory, and they expanded their

empires in Africa, Australia, and Asia. If we add their erstwhile colonies in the Americas, the Europeans had, by 1914, taken over some 84 percent of the globe.

1. Continued improvements in military technology

What then is the evidence for continued productivity growth in the military sector of the economy during the nineteenth century? We should look at it first, before we start tinkering with our model to take into account the century's economic and political changes. At first glance, one might think that measures of productivity growth would be easy to assemble, for government statistics are far more abundant for the nineteenth century, particularly after governments established statistical officies and ministries began issues periodic reports. The trouble, however, is that the new and improved gunpowder technology was better in so many dimensions that a simple comparison with an older version of the technology from, say, the eighteenth century is extremely difficult. How, for example, do we compare a smooth bore eighteenth-century flintlock musket with a World War I breech loading rifle, which not only fired more rapidly but had a longer range and much greater accuracy? The problem looms even larger for other weapons or for navies. How, for instance, does the flintlock stack up against a machine gun, or a wooden ship of the line against an armored battleship with rifled artillery that fired explosive shells and steam power that made it faster and more manouverable? And how do we assess the huge improvements in supply and transportation made possible by railroads?

The comparisons we can make, such as the rate of fire for handguns (which was one of our labor productivity measures for early modern Europe), will clearly understate the magnitude of the technological change and therefore underestimate the rate of productivity growth. If we limit ourselves to this single imperfect measure (Table 5.1), then the labor productivity of infantrymen increased at a rate (under 1.1 percent annually) that was a bit slower between 1750 and 1911 than it had been during the preceding 150 years (1.5 percent annually between 1600 and 1750, according to Table 2.4). But the firing rate ignores a host of other improvements, such as the useful range of handguns, which had jumped by a factor of 5 over the nineteenth century—a growth rate of 1.5 percent per year.

A more accurate index of productivity would take into account both the range and the rate of fire, plus other measures of a weapon's performance too. Such a yardstick does exist; it amounts to a theoretical estimate of how lethal a particular weapon is, at least under ideal circumstances. If it is used to gauge effectiveness of military labor, then the labor productivity of an infantryman with a handgun climbed 1.6 percent per year between 1750 and 1903 (Table 5.1). World War I era machine guns—a more capital intensive weapon—were deadlier still, although they required a crew of more than one man. The implied labor productivity growth might have reached 2.0 percent per year over the nineteenth century. It was even higher for field artillery. The best field cannon of the late eighteenth century (the one that Gribeauval devised in France in the disastrous aftermath of the Seven Years War) gave Napoleon a great advantage, but it paled by comparison to the rifled, breech loading 75mm guns deployed at the end of the nineteenth century. They yield labor productivity growth rates of as much as 5.1 percent annually

for nearly a century and a half (Table 5.1). That result and the others derived from this lethality index are all comparable to or higher than long run labor productivity growth rates in advanced modern economies.[242]

Theoretical effectiveness, it is true, did not always mean victory on the battlefield. Military success obviously depended on a host of other factors, from tactics, strategy, and organization to the size and behavior of the enemy's forces. A 75mm gun, for instance, could cut down charging infantry, yet it was of little use once troops had dug into trenches—a great drawback, it turned out, in the opening days of World War I.[243] Tactics in particular took time to work out. But if tactics were right, then a new weapon could devastate troops who carried outmoded equipment and had not yet adjusted their own manner of fighting. In the 1866 Austro Prussian War, for example, rapid fire from Prussians' breech loading rifles slaughtered the poor Austrian troops. Unlike the Prussians, the Austrians had to stand to load their muzzle loading rifled muskets, which not only slowed them down but also made them easy targets.[244]

The contest between new and old could be just as lopsided at sea. In the Crimean War, the Russian navy wiped out the Turkish fleet at the Black Sea port of Sinope by firing new explosive shells instead of traditional solid cannon balls.[245] And when the new weapons were matched with the transportation technology of the Industrial Revolution—so Daniel Headrick has shown—the Europeans could wield power in territory that had long been beyond their reach. In China, steam powered gun boats helped the East India Company bully its way into trade concessions during the Opium War by choking off supplies to Beijing. And railroads, steamboats, and better weapons (including machine guns by the end of the nineteenth century) made possible conquest in

parts of North and South America where guerrilla warfare waged by decentralized Native American societies had defied Europeans from the age of the conquistadores on.[246]

The gunpowder technology, in short, grew even more effective in the nineteenth century, widening the military gap between those who had cutting edge weapons and supply systems and those who did not. The haves now included not just the Europeans, but European-Americans in newly independent colonies like the United States, and also countries that adopted the technology and industrialized rapidly, such as Japan. What then explains the acceleration of technical change in the military sector?

2. Technological change and armed peace: a model

An extension of our model can answer this question, by taking into account the three changes that put a distinctive stamp on nineteenth-century European politics, diplomacy, and technology. (Extending the model does require a little more simple theory, but it is always explained in words, and readers who want to skip over it entirely can simply leap ahead to the closing paragraphs of this section.) The first was the shift in the incentives that rulers and political leaders faced. Napoleon had changed the rules of war. Defeat now carried the risk that a sovereign would be deposed (Table 2.2) or that a country would lose its independence.[247] At the same time, glory receded in importance as a goal rulers and leaders pursued, having succumbed to Enlightenment attacks and to the devastating experience of the Napoleonic era. One sign of glory's waning hold was the diminishing frequency with which the word (or its French equivalent, *gloire*) appeared in books (Figure 5.1 and 5.2), particularly when it was yoked to the word for war (Table

5.2). As it shrank in importance, the prize *P* at stake in conflicts may have dropped in value too, and it may have declined even more as foreign policy came under the control of statesmen and political leaders who stood to gain less and lose more in war than any Old-Regime monarch. But the key difference was that negotiating peaceful settlements had grown easier, for with glory reduced to insignificance and the older indivisible goal of defeating enemies of the faith having faded away even earlier, the prize could now be divided up. Yet another indivisible goal—gaining a trade monopoly—also faded away in the nineteenth century, as protectionism receded and mercantile companies lost their role as proxy navies.[248] Negotiation and peace were therefore much more likely outcomes than before 1815, at least within Europe itself. In fact, if we set colonial wars aside, then the amount time western Europeans spent fighting and the combat deaths they suffered both dropped by nearly 80 percent between 1650-1815 and 1816-1913 (Table 5.3).

Not that Europeans abandoned wars and military spending entirely in the interval between the Napoleonic Wars and World War I. They continued to fight colonial wars, particularly at the end of the century, and they used force (or the threat of force) to put down or discourage civil disturbances, which rocked Europe more than once during nineteenth century.[249] And wars were still fought within Europe, as Table 5.3 makes clear. What reigned after 1815 was not a complete respite from war within Europe, but rather an armed peace with occasional interruptions, an armed peace backed up by continued military spending.

To incorporate the changed incentives into the model, we again assume that pairs of rulers or statesmen are selected and thrust into the same sort of repeated tournament we analyzed earlier. As in the original model, each pair engages in the tournament only

once, with the tournament determining whether they are bellicose during their reigns or time in office. Now consider two of these rulers or statesmen who have paid the fixed cost *b* and are willing to go to war. Let them them go ahead and mobilize their resources z_i as in the original model. But then modify the model to allow them to negotiate over dividing the prize *P* before they actually start fighting.[250] If they can both agree to a division, they can split the prize *P* accordingly, but if not, they have to battle one another, as in the original model, with the winner receiving a prize $dP\ (0 < d < 1)$ that is reduced by the damage and losses caused by war. If their agreement can be 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 the 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 amount of resources *Z,* which in equilibrium will equal *dP/C,* and they will coexist in 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 European history fairly closely.

The second major change in the nineteenth century stemmed from political and administrative reforms that cut the political cost c_i of mobilizing resources. During the Napoleonic Wars, western European states pushed centralization of their fiscal systems further than ever before, and later in the century representative assemblies gained a voice in fiscal decisions. On average, the reforms boosted a country's real per capita tax revenues substantially, even if after we factor in the effects of economic growth and of the higher taxation that war and foreign threats triggered—indeed, by over 62 percent.[251] The reforms, in short, made it easier to raise taxes and hence diminished the political cost

c_i of mobilizing resources and the total cost C. Nationalism and conscription had a similar impact. The lower total cost C could in turn offset both the effect of glory's waning hold on leaders, which would diminish the prize P, and the consequences of the damage done by war, which would reduce the effective size of prize even further, to dP. As a result, although the nineteenth-century statesman in charge of foreign policy would therefore be more likely to negotiate peaceful settlements, they could marshal substantial resources $Z = dP/C$ when hostilities actually broke out or even during an armed peace.

The evidence on ninteenth-century military spending bears out that conclusion. If we cast aside debt payments, which represented money devoted to past wars, then British and French expenditures on the army and navy in the relatively peaceful period between the 1820s and the 1860s were roughly the same as or even considerably greater than they had been in the equally peaceful 1780s (Table 5.4). Thereafter their spending climbed to still higher levels at the end of the century, as an arms race took hold of Europe and as rising incomes and tax revenues made sizeable spending increases possible.[252] And those figures do not take into account the manpower that nineteenth-century states could commandeer by conscription, for unlike their Old-Regime predecessors, they did not have to hire hords of mercenaries or privateers.

The final distinctive feature of the nineteenth century was that military technology could now be advanced not just via learning by doing, but by research and development. Some research, of course, had always been was done, but it grew more common in the eighteenth century, as the Enlightenment encouraged the collection and appreciation of useful knowledge. That made it possible to improve the gunpowder technology without

actually fighting. And the task became even easier in the nineteenth century, with the growth of engineering know how during the Industrial Revolution.[253]

When, for instance, the French navy added steam warships in the 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 led both the British and French navies to adopt 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.[254] 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.[255]

Before we see how this research and development were carried out, let us consider the effect it and more useful knowledge would have on our model. More useful knowledge (particularly from the Industrial Revolution) would relax the limit a to what learning by doing could do, but the model also has to incorporate decisions about research itself, which made it possible to innovate even in peace time. Imagine then our two nineteenth-century rulers or statesmen who mobilize military resources z_i to use either in fighting or in 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 and development of 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 constant returns to scale and common to all rulers, 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 $c_i (w_i , r_i)$ is the average variable cost 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, with the two rulers still mobilizing $Z = z_1 + z_2 = dP/C$ for the military if they are in an armed peace or actually at war. If the cost r_i of researching and developing the new technology declines for both rulers (as was likely after the Enlightenment and the Industrial Revolution), then C will fall too, making it even easier to devote resources to the military.[256]

How will innovation be affected? In the original model, innovation was only possible with war, 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 only the share $s = r_i y_i / c_i (w_i , r_i) z_i$ of spending on the improved technology 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 will be $F^{z}(x)$. 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, although the expected value of innovation will be greater with war because $F^{Z}(x)$ stochastically dominates $F^{sZ}(x)$.

With this modification, what would the model lead us to expect for innovation in the nineteenth century? On the one hand, the lack of actual fighting—in other words *s* in the model—will exert a drag on military innovation if *s* is small, by putting an end to learning by doing. The substitute for learning by doing will be spending on improved technology, and we can calculate a rough estimate for it by computing the portion of the military budget that goes for acquiring ships, arms, and military equipment. (The acquisitions may of course include some spending on the existing technology.) In the nineteenth century, however, that fraction of the budget was not large. In France, for instance, it amounted to only 6 percent of the total defense budget in the years 1820-1864.[257] The rest of defense expenditures went for on going operations, and while a tiny part of ongoing operations might also go for development of the improved technology (for instance, for training troops to use new weapons), most would presumably involve the existing technology. At the same time, the diminished prize *dP* would dull the incentives to mobilize resources for armies and navies.

On the other hand, there were powerful forces that worked in the opposite direction, against any sort of technological slow down. Higher incomes and the lower political cost *C* of levying taxes offset the effect of the reduced prize *dP* and meant that political leaders could assemble just as many resources $Z = dP/C$ as Old Regime

monarchs had. In fact, they could mobilize far more than that as the century wore on (Table 5.4).[258] Their high level of military spending could then counteract the drag that the lack of actual fighting exerted on military innovation. What was undoubtedly a lower cost r_i of researching and developing the improved version of the gunpowder technology would have the same effect by cutting C. Most important of all, the advances in science and engineering during the Industrial Revolution would shift the support of the distribution F and relax the constraint imposed by the old limits to knowledge a. Without such a shift, technical change would eventually halt, according to our model. But if the distribution shifted—so the model suggests—then either learning by doing or research and development could sustain permanent technical change.[259] The armed peace in the nineteenth century could then generate as much innovation as in the past, or—thanks to the advances in knowledge—even more.

That in fact was what happened. Despite passing less time on the battlefield, the leaders of the major European military powers were still competing in an repeated tournament in the nineteenth century, and their resources were still pushing the gunpowder technology forward. They kept their eyes glued on their rivals, with the French fretting about the Germans, and the British worrying whenever the French navy flexed its muscles, and they sought to replace outmoded weapons systems with better technology. They continued to spend heavily on the military and were eager to acquire weapons and ships that would help them outdo potential opponents in Europe's nineteenth-equivalent to the Cold War. Although they could not devote the bulk of their budgets to acquiring new weapons, the money they did spend on researching and developing better versions of the gunpowder technology kept technological change

going, and even accelerated it in the arms build before World War I, because the money was coupled with the explosion of engineering and scientific know how during the Industrial Revolution.[260] The know how, so the model implies, was critical here, for it made up for the loss of learning by doing in war and released innovation from the limits imposed by the existing store of knowledge.

3. Nineteenth-century military research and development

How then was the research on new weapons carried out? And how were the improvements to the gunpowder technology developed and put into practice? Some of the research, and even more of the development, was done directly by the government. But many of the advances came from private enterpreneurs, who made a number of the big discoveries that pushed the gunpowder technology ahead in the nineteenth century, from Dreyse's breech loading rifle to Maxim's machine gun and Krupp's rifled steel cannons.[261]

Military research itself was not entirely new. In the sixteenth century, King Philip II of Spain ran experiments to test military inventions and rewarded the inventors whose inventions were promising.[262] But the experimentation grew more common and much more effective when the Enlightenment spurred the systematic collection of useful knowledge. As we have seen, eighteenth-century experiments with remedies against shipworms led the British Navy to a solution—copper sheathing and fittings for hulls—that boosted the speed of ships by perhaps 20 percent and magnified the effective size of the fleet by as much as a third.[263] And at the end of the eighteenth century, the physician

Gilbert Blane's drew on statistical evidence to argue for cleanliness and better diet in the British Navy. His efforts (and those of others) cut shipboard mortality and thereby gave the British navy an edge because it could keep experienced crews at sea longer.[264]

The scientific knowledge and engineering know how of the Industrial Revolution made research and development even more effective. European states eagerly sought to take advantage of developments in manufacturing, metallurgy, and transportation during the Industrial Revolution in order to bolster their armies and navies. When, for example, the United States perfected the mass production of handguns with interchangeable parts, the British government sent emissaries to America to study and then import the tools and procedures the Americans were using. The virtues of this American system of manufacturing were clear, for parts that could be interchanged on the battlefield would greatly reduce the cost and difficulty of supplying an army. But it required thorough inspections when the guns were being made, plus new gauges, jigs, and tools for working metal and wood. It also meant taking the manufacturing process, which had been in the hands of skilled artisans, and breaking it down in small steps done by specialized machines. To adopt the American methods, the British government constructured a new arsenal at Enfield in 1854, filled it with American machinery, and brought back Americans to help train British workers.[265]

For the private entrepreneurs who improved the gunpowder technology, the chief incentive was a lucrative government contract. Alfred Krupp, who pioneered rifled steel cannons, eagerly sought out contracts from the German government. Other technologically advanced firms did the same in Britain and France.[266] Foreign sales of armaments or military technology became important as well for the big military

contractors such as Armstrong-Whitworth, Krupp, Vickers too, particularly at the end of the nineteenth century.[267]

But it was not just a tiny number of huge companies or great inventors that were chasing after profits from innovation. Consider, for instance, what happened in Britain, in the aftermath of the Crimean War. In one of the last battles of the war, in October 1855, three armored French ships—floating artillery batteries—managed to demolish Russian fortifications at Kinburn, even though they were being pelted by Russian guns. Their success convinced the French navy to build an ambitious number of ironclad warships, and by 1860 France had 15 of them launched or under construction. Fearing that the French might use their ironclads to invade, the British (who like other European powers could learn of their neighbors military innovations from diplomats, official investigations, and intelligence sources) decided to act. Their navy committed to building its own ironclads in 1858, and it tested various types of armor to see what worked best. But even before then it was receiving proposals for ways to "shot-proof" ships from private entrepreneurs and inventors: 6 of them in 1857; 21 in 1858, when the British navy decided to construct armored ships; and over 590 in the following four and a half.[268] The explosion of interest was understandable. Since contracts to build armored ships were large, they offered the prospect of sizeable rewards from any innovation that could serve as the design for a huge production run. Entrepreneurs and inventors responded accordingly, as they did elsewhere when demand was high in the industrializing economies of the eighteenth and nineteenth centuries.[269]

Big firms did come to dominate the European arms industry by the end of the century, with research that led to dramatic advances. They also sold weapons abroad

and, particularly in the case of British firms Armstrong-Whitworth and Vickers, exported armament technology to countries such as Japan, Italy, or Russia. As in the past, innovation was international, and there were relatively few obstacles to the diffusion of cutting edge technology. Armor plate provides a typical example. By the end of the nineteenth century, the wrought iron that protected the French and British ironclads in the 1860s had been superseded by hardened steel with over twice the resistance to artillery fire, in a process that involved firms, inventors, and military officers in Britain, France, Germany, and the United States. The steel armor, introduced in 1876 by the big French firm Schneider, was initially combined with wrought iron to keep it from cracking when struck by artillery shells. Further innovation soon made the wrought iron unnecessary. Better ways of hardening the surface of the steel while keeping its interior ductile eliminated the cracking, and the addition of nickel (pioneered by Schneider in 1889) and chromium made the steel tougher still. By 1893 the huge Krupp family firm devised an improved process of heat treating and hardening nickel chromium steel that became the norm throughout western Europe. A layer of that armor offered the same protection as over two times as much wrought iron.[270]

The innovations that advanced the gunpowder technology in the nineteenth century did not all come from private entrepreneurs, though. Military officers also played an enormous role. In France, the artillery officer Henri-Joseph Paixhans introduced the explosive shells that could be fired in a flat trajectory during naval combat. His experiments showed that they were far more devastating to wooden sailing ships than solid cannon balls, and that convinced the French navy to begin adopting them in 1827. Other advanced navies gradually followed suit, while those that lagged behind,

such as the Turkish fleet at Sinope, risked devastation.[271] The equally innovative French officier Dupuy de Lôme, who persuaded the French navy to build its ironclad warships after the Crimean War, worked out the design and specifications for France's new armored fleet.[272] His campaign in turn spurred the British to follow suit.

Officers and government officials were even more effective at developping new technology, making it work in practice and devising tactics and strategy that took advantage of the innovations.[273] They also created appropriate supply systems. Without this further development, and without suitable tactics, strategy, or supply, new weapons could prove useless or—worse yet—backfire. Officers and officials of the Prussian Army were particularly successful in getting all these ingredients right in the late nineteenth century. Under the direction of perceptive leaders such as Helmuth von Moltke, the Prussian Army worked out how to adapt strategy to the railroad and how to use rail lines efficiently to deliver troops and supplies. It also devised the right tactics for new weapons: for instance, waiting to fire with the new breech loading rifles, which the Prussians deployed with such success against the Austrians in 1866.[274] The efforts of Moltke and other European officers and officials ended up reinforcing the undertakings of the private entrepreneurs, a complementary relationship with centuries of history in western Europe. Together, they pushed the gunpowder technology to new levels of destructiveness.

4. What the innovations meant for conquest and imperialism

Although Europe basked in relative peace between 1815 and the start of World War I, the rest of the world (and in particular for the regions that became new European colonies) was not so fortunate. The nineteenth-century diplomatic coalition discouraged fighting within Europe itself, but imperial wars were another matter, and by the last decades of the century, a race to add colonies was on, driven by lobbying and the widespread conviction among Europe's leaders and elites that they were engaged in mercantilist competition in which colonies were essential to their nations' success.[275] Thanks to the military innovations that the tournament produced (rifles and steam gunboats are prime examples, as Daniel Headrick has shown) it was now much easier to build or enlarge empires abroad. In the past the gunpowder technology had been ineffective against societies that lacked cities or had no centralized government, such as the central Asian nomads or the plains Indians in the Americas. But by the second half of the nineteenth century, it no longer had the limitations. At the same time, medical advances allowed Europeans to survive tropical diseases such as malaria that had previously ravaged troops and officials in Africa. In 1823-36, some 97 percent of British troops in West Africa died or were obliged to leave the army. By 1909-13, the mortalities rates had plummetted over 98 percent, and they dropped almost as much for Europeans in French West Africa and in other tropical climates. Defeating disease opened the door to colonizing of parts of the world such as the interior of Africa that had long been off limits.[276] And the gunpowder technology was, if anything, even more

capital intensive, so that a small number of Europeans could conquer and hold territory in these new colonies.

Victory in these colonial campaigns still demanded the right tactics and strategy. Otherwise, the Europeans could still lose, as the British did in in 1879 in the battle at Isandlwana against the Zulus. Winning also depended on the ability to supply and transport troops. Difficulties supplying troops undercut whatever advantage the gunpowder technology might have given the British in Afghanistan. Furthermore, their tactics proved ill suited for the rugged environment and for the sort of guerrilla war the Afghans were waging. Eventually, the British decided that they could never conquer and hold Afghanistan.[277]

In Africa, by contrast, there was little to hold the Europeans back. The same was true for the interiors of India, of Australia, and of southeast Asian islands. With a dominant military technology in their hands, the Europeans seized control of most of Africa and pushed their colonies in Australia and South and Southeast Asia inland (Figure 5.3). And against states that could still put up too much resistance to make conquest possible, they could still use the gunpowder technology to extract major trade concessions. They did so in China, and the Americans, who shared the technology, pried similar concessions out of Japan. The gunpowder technology had finally conquered the world.

Table 5.1

Labor Productivity Growth: The European Infantry After the Eighteenth Century

Measure of labor productivity	Flintlock to rifle: firing rate (1)	Flintlock to rifle: range (2)	Flintlock to rifle: lethality (3)	Flintlock to machine gun: lethality (4)	Field artillery: lethality (5)
Period	1750-1911	1800-1911	1750-1903	1750-1918	1765-1898
Labor productivity growth rate (percent/year)	0.3-1.1	1.5	1.6	1.4-2.0	4.4-5.1

Source: 1911, sv "rifle" 23: 332-333; Hughes 1974, 16; Dupuy 1984, 93; Dupuy 1985, 19-31; Lynn 1997, 454-472, 561; and the following web sites (all consulted February 3, 2013): http://en.wikipedia.org/wiki/Vickers_machine_gun ; http://en.wikipedia.org/wiki/Canon_de_12_Gribeauval ; http://en.wikipedia.org/wiki/Canon_de_75_mod%C3%A8le_1897 http://fr.wikipedia.org/wiki/Canon_de_75_Mod%C3%A8le_1897

Note: Column 1 assumes a firing rate of 2 shots per minute in 1750 and 3 to 12 shots per minute in 1911. Column 2 assumes a usable range of 120 yards in 1800 (according to a Napoleonic era test described in Lynn, p. 561) and 600 yards in 1911. Column 3 uses Dupuy's lethality index for a 1903 Springfield rifle and assumes that his calculation for an eighteenth-century flintlock comes from the year 1750. Column 4 assumes that Dupuy's lethality calculation for a World War I machine gun concerns a Vickers machine gun with a crew size of either 3 or 8 people. Column 5 use Dupuy's lethality index for an 18th century Gribeauval and an French 75mm gun, assuming that they concern the years 1765 and 1898 and that the crew sizes were between 5 and 15 in 1765 and 6 in 1898.

Table 5.2

The frequency with which glory and war appear in the same sentence: French books 1500-1999

Century	Number of times glory and war appear in the same sentence	Rate at which they appear in the same sentence (occurences per 10,000 words)
1500-1599	17	0.05
1600-1699	240	0.11
1700-1799	177	0.04
1800-1899	142	0.02
1900-1999	94	0.02

Source: ARTFL database of French texts (artflx.ucchicago.edu) consulted August 5, 2011.

Note: The table is the result of a search for the French words “gloire” (glory) and “guerre” (war) in the same sentence in the ARTFL database, which consists of classic French texts from the Middle Ages to the present. The number of texts before 1600, however, is limited.

Table 5.3 War deaths and frequency of war in western Europe, 1650-1913

Period	Total years of war per century	Military deaths per year (thousands)
1650-1815	115	41
1816-1913	26	9

Source: Dincecco, 2009, Appendix Table 1, which is based on Clodfelter.

Note: The wars considered include all wars listed in Clodfelter which were fought at least part in western Europe and which involved at least one of Austro Hungary, Belgium, Britain, Denmark, France, Italy, the Netherlands, Portugal, Prussia, Spain, and Sweden. Coastal and naval campaigns were excluded, as were colonial wars. The total years of war per century was calculated by summing the length of all the wars fought in each period and then dividing by the length of the period. Since more than one war could be going on in any given year, the total years of war could exceed the length of the period. The length of each war was set equal to one plus the starting year minus the ending year. Deaths before the nineteenth century are subject to considerable uncertainty.

Table 5.4 Average annual military spending Britain and France, 1780-1864

	Annual military spending in million grams of silver (Military debt excluded)	
Years	Britain	France
1780-89	1262	645
1820-24	1193	1233
1835-44	1084	1715
1855-64	2811	3195

Source: The French spending data are taken from Marion 1914-1931, 1: 455-461, for the 1780s, and from Corvisier and al 1997, 2: 428 thereafter. The British spending data come from Mitchell and Deane 1962, 389-391, for the 1780s, and thereafter from the Correlates of War 4.0 material capabilities database (accessed April 6, 2012 at www.correlatesofwar.org), which is described in Singer, Bremer et al. 1972 ; Singer 1987 . Silver conversions are from the silver value of the pound data file and the Paris price data file at the Global Price and Income History Group website gpih.ucdavis.edu (accessed July 28, 2008).

Note: Silver conversions were done using the market price for silver in nineteenth-century Britain; otherwise the mint price was used. If we include colonial wars, then France had 4 years with war in the 1780s and again in 1820-24, and 10 years with war in 1835-44 and again in 1855-64. The figures for Britain were 4 years with war in the 1780s, 2 years with war and 1820-24, and 10 years for war in 1835-44 and again in 1855-64. Ignoring colonial wars reduces these numbers greatly.

Figure 5.1

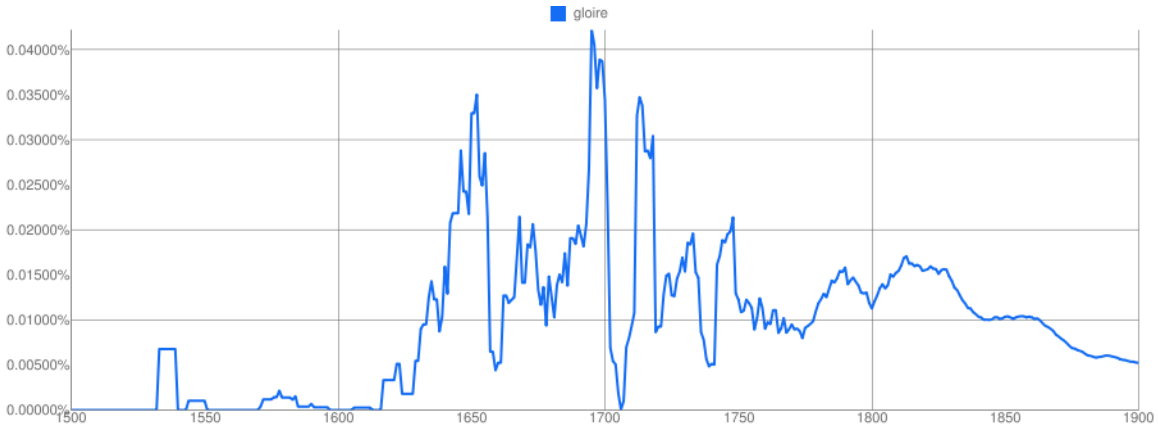
The frequency of the word “glory” in British English, 1500-1900

Source: Google Ngram search conducted August 5, 2011.

Note: The search was restricted to works published in the United Kingdom. The frequency with which glory appears is normalized by the number of works published per year. The results were smoothed using a 7-year moving average centered on the year in question, and the search process excluded occurences in fewer than 40 books, which cut the number of occurences before the mid seventeenth century. The data are subject to optical character recognition errors, particularly before 1800.

Figure 5.2

The frequency of the word “gloire” (glory) in French, 1500-1900

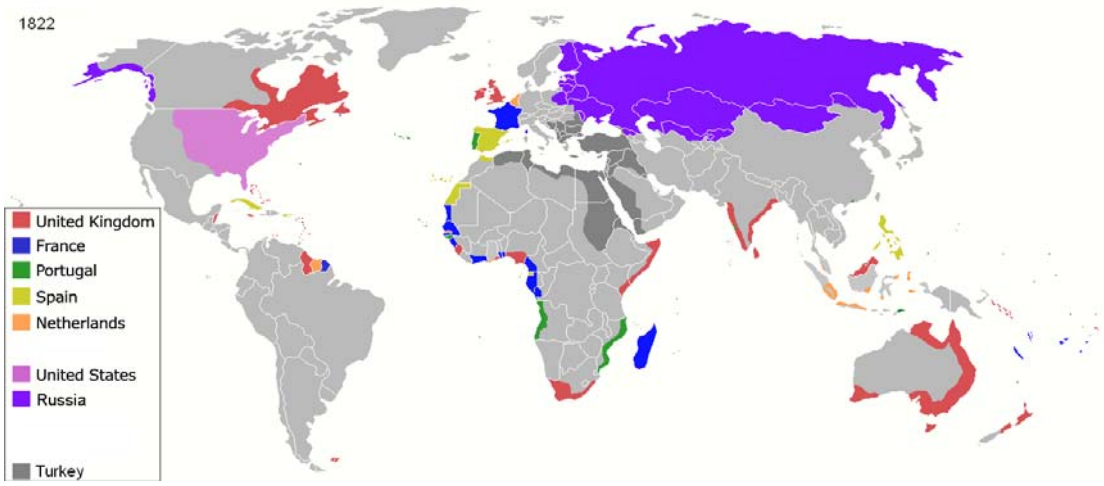


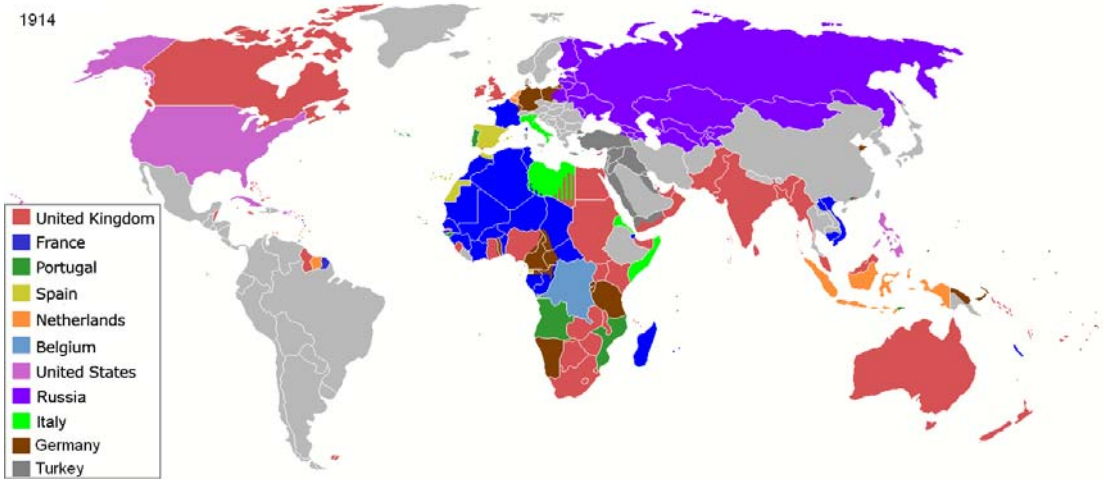
Source: Google Ngram search conducted August 5, 2011.

Note: The search was restricted to works in French; the other search criteria and search limitations (in particular, the low number of occurences before the middle of the seventeenth century because of limited data) are as in Figure 5.1.

Figure 5.3

European colonies, 1822 and 1914





Source: http://upload.wikimedia.org/wikipedia/commons/7/7d/Colonisation_1822.png and http://upload.wikimedia.org/wikipedia/commons/e/e2/Colonisation_1914.png

Conclusion: The Price of Conquest

After World War I, the growth of Europe's colonial holdings halted, and by 1938 the European colonial empire had actually shrunk by 1 percent.[278] Having an empire, although it was still acceptable, began to run into resistance, both from western critics of colonialism and from indigenous nationalists opposed to European domination. Even more important, there was simply not much more territory the Europeans could profitably conquer. The case against colonialism gathered strength after World War II. Western Europe's military power had collapsed, its political leaders were concentrating on economic recovery and domestic social spending, and opposition to empire (bolstered by the Cold War) waxed louder, both at home and in the colonies themselves. By the late 1970s, the European empires had virtually disappeared.

How then did the Europeans end up taking over so much of the world? The gunpowder technology was essential. It allowed a handful of armed Portuguese to build fortified toeholds in South and Southeast Asia and then profit by muscling in on the spice trade and by selling protection to Asian merchants. It won conquistadores allies in Mexico and helped them seize control of the Aztec and Inca Empires. From that apex of political power, the Europeans could then extract resources from the natives, without ever having many colonists or any sort of an army of occupation. And by pushing the technology further than anyone else in Eurasia, they could, by the eighteenth century, topple the Ottoman Empire from the ranks of the great powers and begin the conquest of India.

Thanks to the Industrial Revolution, their military lead widened even further in the nineteenth century, when they gobbled up Africa and, along with their former colonists in America, finally succeeded in bullying China and Japan into making trade concessions. But their lead was already evident in 1800, when Britain alone had just begun to industrialize and when real wages in much of the rest of Europe were no higher than in Asia.[279] By then the Europeans had already already grabbed 35 percent of the globe and they had long been exporting weapons and military expertise to Asia, Africa, and the Middle East. Without the gunpowder technology, none of the conquests, either before or after 1800, would have been possible.[280] Disease alone would not have let them take over the Americas, and it would have been no help all in Asia, where everyone had acquired the same immunity as the Europeans.

1. Why Europeans conquered the world

Why then was it the Europeans—and in particular the western Europeans—who led the way with the gunpowder technology? For Victor David Hanson, the ultimate cause is a distinctive western military culture, one that sprang to life in ancient Greece and persisted into the modern age and that stressed adaptability, discipline, an egalitarian infantry, and fighting to annihilate in defense of democracy.[281] But the notion of culture at work here seems to be more a result than a cause. It was behavior chosen or followed in certain situations, rather than the fundamental preferences and beliefs that explain why military men acted in a particular way. And even as a description of behavior, it seems wrong, particularly if it is to be stretched (as Hanson's argument requires) to cover Greek

hoplites, early modern conquistadores, and British imperial forces. Adaptability and fighting to annihilate are not by any means peculiar to the West, and it is hard to argue that Cortes, Pizarro, da Gama, or their men were battling for democracy. Like the merceneries who filled western European armies in the early modern period, they sought money and a chance to improve their station in life. Glory and a desire to defeat enemies of the faith may have also spurred them on, but not democracy.[282] Finally,if western military culture was so much better, why did early modern Europeans have such esteem for Japanese warriors? Their admiration went beyond mere talk, for they even sought to hire the Japanese as mercenaries.[283]

A better argument—and the most appealing one historians have devised—invokes military competition in western Europe. Europe's persistent military rivalries (so Paul Kennedy's lucid formulation goes) launched an arms race, and its competitive markets fostered innovation and kept one country from conquering the others and bringing the military competition to a halt. That is certainly a good first step, but as we have seen, it leaves too much unexplained. Competitive agricultural markets did not stimulate innovation in early modern Europe; what was peculiar about the military sector? And why did markets and persistent military rivalries not have the same effect in eighteenth-century India? Why, in short, did the same conditions not vault the Indians to the forefront of the gunpowder technology?

The answer comes from a simple model of a tournament played repeatedly by different pairs of rulers. The model isolates four conditions that were necessary and sufficient for advancing the gunpowder technology: incessant warfare, massive spending on it, heavy use of gunpowder weapons, and rapid diffusion of military innovations. In

western Europe, all four conditions were satisfied throughout the early modern period. No other part of Eurasia could come close to making that claim, and the tournament model singles out the reasons why. First of all, in contrast to rulers in eastern Europe and much of the Middle East and Asia, the monarchs of the major western European powers could focus on the gunpowder technology. They did not battle nomads or engage in much galley warfare, both of which would have undercut the technology's appeal. They primarily fought one another, and against other western European powers, the gunpowder technology worked well. Second, the prize they were fighting for—glory, territory, commercial advantage, or victory over enemies of the faith—loomed much larger relative to the cost of setting a fiscal system and military apparatus than in other parts of Eurasia. The political costs they faced when mobilizing resources for war were also similar and low, in contrast to China, India, and the Ottoman Empire in the eighteenth century. And military innovations spread rapidly, because military markets were highly developed and distances between countries were relatively small.

Everything therefore favored heavy spending on the gunpowder technology in western Europe. The model would therefore predict rapid innovation via learning by doing with what was a relatively new technology that had enormous potential for being improved, even if the underlying scientific knowledge and engineering know how did not change. And that is precisely what happened in western Europe, as rates of productivity growth in the military sector (as measured by prices and the performance of weapons) were sustained at high levels from late Middle Ages on—a surprising result in what were preindustrial economies. But because the four conditions did not hold elsewhere, the rest of Eurasia fell behind, even though the gunpowder technology had been invented in

China and was used with proficiency, at least initially, in the Middle East, and in South and East Asia.

The model explains all that and it has other virtues as well. It can make sense of why Japan suddenly fell behind in the seventeenth century, why Russia joined the major powers in the eighteenth century and the Ottoman Empire dropped out, and why the powers in India could wage war constantly in the eighteenth century without advancing the gunpowder technology on their own. In other words, it yields a new understanding of why states rise and fall and a new narrative for world history. And it can isolate what was critical for the widening European lead in the 1800s, despite a century of virtual peace in Europe itself: it was the useful knowledge and engineering know how generated by the Enlightenment and the Industrial Revolution. Along with medical advances and easier transport on railroads and steam ships, the widening military lead made it much easier for Europeans to expand their empires even further in the late ninteenth century.

By revealing what advanced the gunpowder technology, the model also points us toward the ultimate cause for the striking differences between western Europe and the rest of Eurasia. That ultimate cause was history: the peculiar chain of past events that shaped subsequent outcomes and determined the distinctive values of the model's exogenous parameters in each part of Eurasia.

As a cause, history worked over both the short and long run, with political history playing a premier role. If we examine western Europe first, the collapse of the Roman Empire was critical. It meant living without anything like a state for centuries, during which western Europe split into mutually hostile groups that coalesced around military leaders and developed their own ethnic identities. That long run process of cultural

evolution was first of the two historical forces that fragmented Europe. The second was western Christianity, the only religion in Eurasia that was politically independent and had a powerful, organized clergy. Its most stunning effects were felt over a shorter time span. Not only did it divide Europe further during the Reformation, but even earlier, in the aftermath of the investiture controversy, its leaders, the popes, succeeded in keeping secular rulers from growing strong enough to conquer and unify western Europe. The fragmentation these two centrifugal forces generated in turn sped the diffusion of military innovations and isolated western Europe from nomads, making gunpowder the technology of choice. It was all the result of history—not an outcome dictated (as Jared Diamond and others have argued) by the geography of western Europe. And at least in the case of the popes' ability to keep rulers in check, one could argue that the outcome was contingent. It was clearly not something inherent in Christianity itself, for the orthodox clergy in eastern Europe and the Middle East, for instance, never achieved the same political autonomy.

The other conditions required to advance the gunpowder technology were also the result of Western Europe's history. The cultural evolution after the collapse of the Roman Empire meant that rulers in western Europe attached a high value to military victory. The result was that Europe was plagued by unending war, for the prize rulers were fighting for was worth far more (at least by the early modern period) than the costs involved in establishing an army, navy, and fiscal system. In midst of the ongoing fighting, some rulers succeeded in creating states that could mobilize resources at low but relatively similar political costs. Creating such states was also a contingent outcome, realized in the short run via political alliances between rulers and elites that then took

hold. Some rulers in western Europe failed to clear this hurdle. Those who did became the leaders of the great powers that pushed the gunpowder technology forward from the late Middle Ages on.

In the rest of Eurasia, history put political development—and hence fiscal and military development too—on a very different path. In East Asia, unification under the Tokugawa brought Japan's own period of unending hostilities to a close, thanks to a political settlement that gave the daimyo local autonomy but kept them from challenging the shogun, who had control of foreign policy. By adding the fixed cost of invasion or distant naval operations to any military adventures, Japan's unification halted a process of innovation with the gunpowder technology that resembled the one underway in Europe.

In China, unification within a large empire had a similar effect. It raised the political costs of mobilizing resources as well, and the centuries under an emperor who provide security created long run incentives to pursue more peaceful and rewarding goals than war. Most important of all, because Chinese empire was so large, the major military threat it faced came from nomads from the Asian steppes. Against them, the gunpowder technology was long of little value, and there was little reason to spend on it or advance it. And by the time it did prove useful, distance from the leading centers of the technology in western Europe (a major obstacle to technological diffusion, at least before the nineteenth century) kept the Chinese from quickly catching up.

Again, the root cause at work here—the early and recurrent unification of China—was not the result of geography, despite what Jared Diamond and others have claimed. It was in fact a consequence of history, and that history could have taken a

different path. If, for instance, the Mongols had never conquered China (a far more plausible counterfactual scenario than speculating about what would have happened had voyages like Zheng He's continued), then China might have remained divided. The likely outcome would probably have been a much stronger state in China, one that could have resisted European bullying, and earlier industrialization too. Although China would probably not have been the first economy to industrialized, it could well have done so in 1800s and not had to wait until the twentieth century.

Like China, the Ottoman Empire and the powers in India could not focus on the gunpowder technology either, which kept them from being at the forefront of the gunpowder technology. And as in China, distance from western Europe slowed diffusion of the latest gunpowder weapons to India, despite the numerous European mercenaries employed there. More important, in the eighteenth century both the Ottoman Emperors and the powers in India faced high political costs when they tried to mobilize resources for war. The underlying reasons were, once again, historical. The Mughal Empire had relied on local elites to collect taxes. The powers that succeeded it did the same, even though they tried to establish centralized fiscal systems. In the eighteenth century, local elites gained the upper hand in the Ottoman empire too. Again, the outcomes might have been different, if, say, the Mughal Empire had collapsed earlier, if Ottoman expansion had not halted, or if instead of relying on janissaries, the Ottoman Sultans had opted to negotiate with elites and (like rulers in western Europe) offered them political concessions in return for higher taxes.

History also explains one final critical trait that distinguished western Europe from the rest of Eurasia and proved critical for Europe's conquest of the world. In

western Europe, private entrepreneurs could easily take advantage of the widespread familiarity with the gunpowder technology and put it to use in private expeditions of trade, exploration, and conquest. Gun ownership was licit and widespread in western Europe, and few legal obstacles stood in the way of entrepreneurs eager to launch expeditions of foreign trade, raiding, or conquest. Furthermore, they could easily raise money or organize partnerships or corporate ventures to fund their undertakings. The private efforts began with the conquistadores and proved ideal for organizing distant voyages of conquest and raiding. They culminated with the Dutch and English East India companies, which mobilized Europe's burgeoning financial markets to support not just foreign trade but raiding and conquest abroad in Britain's and the Netherlands' ongoing mercantile and military competition against their European rivals. In the process, the western Europeans exported their style of fighting and their incessant mercantilist wars to the four corners of the globe. It all made eminent sense when the Europeans were confronting one another around the world and when it was just too expensive to send huge armies abroad.

Reliance on private military entrepreneurs was nurtured during the long period when Europe had no major states that were able to collect sizeable tax revenues and nothing like a bureaucracy that could organize armed forces. Europe's lengthy history of political underdevelopment created an abundant supply of willing military entrepreneurs, who ranged from arms makers and privateers to contractors able to organize and fund entire armies. When powerful states did finally appear in Europe, they had little reason to reign the entrepreneurs in. Curtailing private conquest abroad was equally difficult. The private ventures, which reached back to the Middle Ages, had spawned powerful groups

of merchants and nobles with an interest in foreign military expeditions. Stopping them would cause trouble. So would efforts to ban gun ownership and private trade in weapons, which could also be traced back to the centuries Europe spent withoutstrong states. Without such states, weapons were necessary for security, but when Europe's rulers were finally mighty enough to provide it themselves, they would have balked at disarming influential elites, particularly nobles who were as devoted to war as the European monarchs themselves.

Elsewhere in Eurasia, would be entrepreneurs faced many more obstacles if they wanted to trade or conquer territory abroad. The reasons, again, can be traced back to each region's peculiar history. Bans on international travel and trade in Tokugawa Japan and Ming China were adopted by rulers who were strong by European standards, and who sought to control foreign policy and to bolster their own domestic security. Their measures—contingent outcomes—then became a cornerstone of subsequent foreign policy. Prohibitions against gun ownership and trade in firearms in China, the Ottoman Empire, and Tokugawa Japan likely had similar origins in political decisions by relatively powerful states. And in the Ottoman Empire, yet another contingent outcome—the provisions of Islamic commercial law—kept merchants from organizing and funding the large commercial ventures that trade and conquest in distant lands required.[284] None of these hurdles was impossible to clear (there were Chinese merchants and traders, after all, throughout southeast Asia), but each one did impose heavy costs on non Europeans who might want to trade or establish colonies in far away places.

2. A balance sheet of world conquest and the military revolution

Did western Europeans end up profiting from the conquest of the world and all the advances to the gunpowder technology? They certainly won the spoils of raiding and colonization, beginning with the silver from Latin America and the sugar and coffee that slaves produced. They gained New World crops as well such as maize and potatoes. But the Europeans also paid a price, though far less than the slaves or the Native Americans, who perished not just from disease but from the conquerors' devastation of their whole society. Much of the American silver simply helped fund more of the wars that European princes pursued without bearing the costs of the military adventures. Mercantilist battles to control trade with their distant acquisitions simply added yet another cause for war among western Europe's rulers. And although their incessant fighting did give birth to the military innovations, it went far beyond what average Europeans would have wanted to guarantee their own security. All the war also came with heavy costs. Arming ships added substantially to the price of transportation, and land war imposed an even heavier toll: not just crushing taxes, but epidemics and violence at the hands of soldiers who were unrestrained by discipline before the late 1600s and whose ravages could cut agricultural productivity by 25 percent for a generation.[285] Nor was nineteenth-century colonialism much better, for while it involved no hostilities within western Europe itself, it did in all likelihood take a toll on average Europeans. The British Empire, for instance, generated no profits, at least in the years 1880-1912. It in fact required a subsidy and ended up simply redistributing income from middle class taxpayers to the upper classes.[286]

So even in Europe itself there was little that could offset all the harm that the conquest of the world did, at least if we consider the welfare (or even more narrowly the income) of the average person. Outside Europe the damage done was immeasurably greater. Besides the horrors visited upon the slaves and the Native Americans, and the atrocities committed in nineteenth-century colonies such as King Leopold's Belgian Congo, there is plausible econometric evidence that the slave trade still keeps Africa poor, and equally persuasive evidence that the Spanish conquest causes poverty today in Latin America.[287] The root of the problems, so research suggests, lies with with the bad institutions and the unequal distribution of wealth that empire often fostered. Inequality created political incentives that blocked institutional reform and worked against mass education and the acquisition of human capital. Some would argue that scarce human capital is the real obstacle here, not institutions, because in the long run human capital transforms institutions. If so, then the human capital that the Europeans brought along in their colonial ventures may have ultimately promoted economic growth in ex colonies; technology, crops, and livestock they carried might conceivably have done the same. But these positive effects, if they did finally materialize, took a long time to arrive, particularly in colonies with large indigenous populations.[288] And even if they did lead higher incomes in the distant future, that still does not compensate for all the harm that the conquest did to human welfare.

3. War, the Industrial Revolution, and the Great Divergence

There is, however, one unexpected benefit that the conquest and all the war in Europe brought into the world, a benefit that may atone, albeit only partially, for all the evil they did: together, the conflict and empire building helped trigger the British Industrial Revolution. Other scholars—notably Patrick O'Brien—have made such a claim, and, thanks to his work, and to research by Robert Allen, Ronald Findlay, Kevin O'Rourke, and others, we can see how war, despite all the harm that it did, could paradoxically have touched off the world's first episode of sustained economic growth.[289]

It was not that the great inventors of the Industrial Revolution were all toiling for the military sector. In fact, only 13 percent of them had any sort of connection with the military, less than one might expect in an economy where spending on the army and navy could exceed 25 percent of GDP.[290] Rather, victory in wars of the late seventeenth and eighteenth centuries stimulated the British economy by winning Britain a large share of Europe's intercontinental trade. The trade in turn created jobs in London and other cities, drawing in migrants and ultimately raising wages and agricultural productivity as farmers responded to demand. When combined with Britain's cheap coal and capital and skilled machinery makers, the high wages gave inventors an incentive to find ways to substitute inexpensive, energy consuming machines for labor that was so dear. They did so by inventing spinning machines and steam engines, putting Britain, and eventually the rest of western Europe, on the path toward sustained economic growth.

War may have even made the rest of western Europe ripe for industrialization. Since the Middle Ages, the incessant fighting in western Europe had drawn

manufacturing out of the countryside, where it could take advantage of cheap seasonal labor, and into cities, where wages were higher because of the cost of transporting food but industry was protected by walls. But the higher wages meant that labor saving machines would be profitable earlier in western Europe than, in, say, China, where the empire provided more security from war, at least away from the areas subject to attack by nomads, and where manufacturers could take advantage of lower rural wages.[291]

Without Britain's victories in the wars of the seventeenth and eighteenth centuries and the jolt they gave the British economy, the Industrial Revolution would have been delayed for decades or more. Conceivably, it would have been held up for 50 or 100 years, and economic growth throughout the world would have been stalled for just as long. Had that happened, we might still be living in the final days of horse drawn carriages. The reason is that if Britain had lost the wars and with it its West Indies and Asian trade, then its urbanization and its wage levels would both suffer. In such a scenario, Allen's empirical model implies that British wages in 1800 would still be mired back at the level where they had been in 1700 and that British urbanization in 1800 would be back at the level of 1750.

Worse yet, the whole Industrial Revolution would have been postponed by as much as a century, because no other economy could have taken Britain's place as the engine of economic growth via mechanization and industrialization. If, for instance, France had won the wars and captured the amount of trade Britain had in 1800, then French urbanization in 1800 would have risen but only by 7 percent. And French wages in 1800 would have climbed by only 2 percent—not enough to launch industrialization in France. The problem is that in the empirical model the invigorating effect of

intercontinental trade is spread out over an economy's entire population and reduced if the population is large. France's much bigger population (nearly three times that of Great Britain) would greatly dilute the stimulus that any trade won in war would give the French economy. Nor could one hope that trade might ignite early industrialization in East Asia. Japan's population in 1800 was roughly the same as France's, and China's was much larger. Even British levels of trade would have had little effect with populations that big.[292]

The economic benefits Britain derived from its victories were further magnified because Britain concentrated on naval conflict and avoided land battles on its own soil. It therefore escaped much of the damage done by war.[293] Since Britain escaped most of the collateral damage from war and reaped most of the benefits, its military triumphs could therefore trigger the Industrial Revolution, which does atone, although only in part, for all the harm Europe's wars and conquests did.

We should be careful, however, not to give warfare too much credit, for it was not the ultimate cause behind Britain's success. Other factors, such as readily accessible coal, helped Britain industrialize, and its political institutions gave it the revenue and financial credibility needed to finance its wars and win most of them. Those political institutions—early centralization, ministerial responsibility, and Parliamentary control of the purse—were the product of Britain's history, making it the second ultimate cause behind the Industrial Revolution.[294] War merely ushered history's creation into the world.

History—and in particular political history—is then one of ultimate causes behind the European conquest of the world. It was also one of the ultimate causes behind the

"great divergence" that saw western European incomes rise above those elsewhere in Eurasia. Here too it was not the only cause: others, from accessible coal to government policies or the movement to acquire useful knowledge in the eighteenth century, also played a role. But history was critical. It could launch a lengthy process of cultural evolution that has nothing to do with Max Weber's claims and yet set western Europeans apart from other Eurasians as far back as the Middle Ages.[295] But it also worked in the short run, creating states that could mobilize enormous resources for war at low political cost, as in Britain in the eighteenth century. The political history here depended the support that elites such as warriors, merchants, or nobles gave to their rulers, but it cannot be reduced to social groupings alone: politics played an independent role. And it was, above all else, contingent, and could have been reversed, at least at certain pivotal moments, virtually everywhere in Eurasia.

Appendices

Appendix A: Extensions of the tournament model

1. Constraints on the rulers' resources.

Initially, we assumed that the rulers in the tournament model faced no constraints on the resources z_i that they could mobilize at a constant variable cost c_i. Eventually, however, they would run into limits to available resources, and the costs c_i would rise. The simplest way to take those limits into account is to impose the constraint $z_i \leq L_i$ (inequality 6 in chapter 2) on both rulers and to assume that the costs c_i remain constant until the constraints bind. If neither constraint binds, nothing in model is changed. If one or more of the constraints do bind, then the same two subgame perfect equilibria remain, with the only difference being the precise conditions for the equilibria and the expressions for the resources mobilized and the odds of victory, which now depend on the L_i as well as the other exogenous parameters.

The most interesting case occurs when the constraint binds on ruler 1, who has a lower cost c_1 of mobilizing resources, but not on ruler 2. We might think of ruler 1 as being the leader of a small country with representative institutions, such as the Britain, while ruler 2 is on the throne of a larger country such as France with a higher cost c_2 of mobilizing resources but no binding constraint on the amount of resources he can assemble. There will be war if in equilibrium both rulers enter the tournament; that will happen if the following two inequalities hold:

$$P + c_2 L_1 - 2 (P c_2 L_1)^{\wedge 0.5} \geq b \qquad (1)$$

$$(P c_2 L_1)^{\wedge 0.5} - c_1 L_1 \geq b \qquad (2)$$

Inequality (1) guarantees that ruler 2 will have nonnegative expected earnings if there is war; inequality (2) does the same for ruler 1.

In the equilibrium with war, the probability that ruler 2 wins, which had been given by expression 5 in chapter 2, will now be $1 - (L_1 c_2 / P)^{\wedge 0.5}$ and it will decrease as L_1 and c_2 rise. The total resources mobilized in the war will now be $Z = (P L_1 / c_2)^{\wedge 0.5}$ which will grow as P and L_1 increase but fall as c_2 increases. It will determine the distribution of innovations $F^Z(x)$.

What would happen if we allowed the same two rulers to play a two-stage game and save resources for later conflict? Depending on the discount rate, the size of the constraints, and value of the prize in each stage, we can end up with an equilibrium where ruler 1 sits out the first stage (giving ruler 2 the prize without opposition) but then saves resources in the hopes of winning in stage 2.

2. Armed peace[296]

In chapter 5, we allowed pairs of leaders who have paid the fixed cost b and mobilized their resources z_i to negotiate over dividing the prize P before they actually start fighting. We assume that the division can be enforced by the threat of the resources

they have mobilized, with leader 1 offering a share of the prize to leader 2, who then decides whether or not to accept the offer. If they can both agree to the division, they split the prize P accordingly, but if not, they have to battle one another, as in the original model, with the winner receiving a smaller prize dP $(0 < d < 1)$ that is reduced by the damage and losses caused by war.

Because $d < 1$, in equilibrium they will reach an agreement in order to spare themselves the damage done by war. There will be no actual fighting, but the two leaders will still mobilize resources, provided that $dP \geq b(1 + c_2 / c_1)^2$. (That is simply inequality 2 of chapter 2 with a prize reduced to dP, and it is the condition they both pay the fixed cost and decide not to sit on the sidelines.) Their peace will therefore be an armed one, and the total resources they mobilize with be $Z = dP/C$.

3. Research and development with an armed peace

In chapter 5, we assumed that military resources $z_i = f(x_i, y_i)$ are produced by spending taxes on x_i units of the existing military technology (each at a cost w_i) and y_i units of research on and development of 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. We assumed the production function f was constant returns to scale and common to all rulers, and that each ruler took his w_i and r_i (which may vary from country to country) as given.

What happens then in our modified tournament where leaders can negotiate an armed peace to avoid the damage done by war? If a leader decides to pay the fixed cost b

in our modified tournament, he 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. To do so, he will want to minimize the cost of producing the resources z_i that he mobilizes, for otherwise he would be playing a dominated strategy. Because the production function is constant return to scale, his minimized cost will equal $c_i (w_i , r_i) z_i$ where $c_i (w_i , r_i)$ is the average variable cost of z_i. The two leaders will choose the same level of resources z_i as in the original model with a prize were dP, and all the equilibrium remain unchanged, with the two leaders still mobilizing $Z = z_1 + z_2 = dP/C$ for the military if they are in an armed peace. By the envelope theorem, each leader's cost $c_i (w_i , r_i)$ of mobilizing resources will be an increasing function of w_i and r_i, so it and the total cost C will fall if the r_i of researching and developing the new technology declines for both rulers.

Appendix B

Using prices for artillery and handguns to measure productivity growth in the military sector (as we did in chapter 2) is possible provided four assumptions hold: first, each of these military goods is each produced by cost minimizing firms that are small relative to the size of their markets; second, entry into these product markets is open; third, markets for the factors of production are competitive; and that the firms have U-shaped short run average cost curves.

These are not unreasonable assumptions for early modern England, France, and Germany, as I show with abundant supporting evidence in Hoffman 2011 . Factor markets were competitive, and weapons production in these countries was, for the most part, in the hands of a large number of small scale contractors and independent craftsmen. Furthermore, entry into the weapons business did seem to be open, at least in the long run. Craftsmen and contractors moved their production from city to city and even entered the business from other fields or migrated from country to country. While there were some signs of fleeting collusion or high prices in England and France when their rulers wanted to nurture the native arms industry, they seem to have been temporary, because major weapons buyers (this was true in particular of governments) would go elsewhere if they thought prices were high.

Under these assumptions, it will be difficult for weapons producers to collude, and free entry will drive them to produce at minimum average cost. That will be the outcome even if there is a monoposonist buyer. The long run industry supply curve will then be flat, and the price of producing the military goods will equal their marginal and

average cost. We can then measure the rate of productivity growth by regressing the logarithm of the price p of the military good on the logarithms of the costs of the factors of production, with all costs and prices measured relative to the cost of one of the factors of production such as skilled labor. In other words,

$$\ln (p/w_0) = a - bt + s_1 \ln (w_1/w_0) + \ldots + s_n \ln (w_n/w_0) + u \quad (1)$$

where a is a constant, $b > 0$ is the rate of total factor productivity growth, u is an error term, w_0 is the skilled wage, and s_i and w_i are the factor shares and prices of factors of production other than labor.

Unfortunately, we can rarely run such regressions, because there are few years when we can measure both the price of the military good and the cost of all the factors of production. But we can at least calculate p/w_0 for a large number of years and compare it with long run averages of the relative prices w_1/w_0 through w_n/w_0. If p/w_0, the relative price of military goods relative to skilled labor, falls more rapidly than the relative prices of the other factors of production, then we have evidence of total factor productivity growth in the military sector, and we can estimate how large the rate of productivity growth must have been.

One simple way to do that is to make an educated guess at the factor shares s_i which would leave only the regression coefficients a and b to be estimated. Indeed, if we regroup the terms $s_i \ln (w_i/w_0)$ on the left side of equation 1, we have

$$\ln (p/w_0) - s_1 \ln (w_1/w_0) - \ldots - s_n \ln (w_n/w_0) = a - bt + u \quad (2)$$

The term on the left side of the inequality sign is simply an index of the price of the military good p relative to the costs of the factors of production, where these costs are calculated from long term averages.[297] We could then regress this index on time to estimate the rate of total factor productivity growth *b*. That is what we did for Table 2.5.

Another way of analyzing the price data leads to the same results—comparing the price *p* of our military good with that of a civilian commodity which involved a comparable production process. If the civilian commodity was made with similar factors of production and similar factor shares, and if the same economic assumption held for it too (small firms, open entry, U-shaped short run average cost curves, competitive factor markets, and a Cobb-Douglas production function), then equation 1 would apply to its price *q* too, and the logarithm of *p/q* would be:

$$ln\ (p/q) = c - dt\ + e_1\ ln\ (w_1/w_0)\ + \ldots + e_n\ ln\ (w_n/w_0) + v \qquad (3)$$

Here *c* is a constant, *d* is the rate of total factor productivity growth for the military good minus that for the non military good, *v* is an error term, and the e_i's are differences in the factor shares for the two goods. We could therefore regress *ln (p/q)* on time and on the available factor costs $ln\ (w_i/w_0)$ for which we have long run averages and come up with an estimate for *d*, the rate of total factor productivity growth for our non military good less that for our non military good. The estimate will be biased if some of the variables $ln\ (w_i/w_0)$ are omitted from the regression, but if the e_i's are small, then the bias will be small too and may be either positive or negative.[298] If production of the non-military good does not experience any technical change, then *d* will be close to the rate of

productivity growth *b* for the military good. If there is technical change in production of the military good, the *d* we get from equation (3) will underestimate productivity growth for the military good. That is what we did in Table 2.6. For further discussion and the source of the prices and wage figures used in both Tables 2.5 and 2.6, see Hoffman 2011 .

Appendix C

The data for Table 4.1 were gathered by Lili Yang as part of a Caltech undergraduate summer research fellowship project that I directed; she then used the same data to write an impressive Caltech E11 research paper (Yang 2011) for me. In her paper, Yang employed ArcGIS software and other statistically analysis tools to analyze geographic data sets, including GTOPO30 elevation data (US Geological Survey). See for further paper for details.

The data for Table 4.2 also came from an impressive summer undergraduate research fellowship project and E11 paper that I directed, this time by Eric Schropp (Schropp 2012). Schropp calculated the two measures of the irregularity of China's and Europe's coastlines: the degree of concavity of the Chinese and European landmasses, and the probability that a line segment between two points in each landmass would cut across the shoreline. The degree of concavity is simply the ratio of the area of the landmass divided by the area of its convex hull, where the convex hull is the smallest convex shape containing the land mass (essentially, the smallest shape without holes or indentations). The degree of concavity will be smaller the more irregular the coastline is because the convex hull will have to expand in order to include coastline irregularities. As for the probability that a line segment between two points in each landmass will cut across the shoreline, it will be larger when there are more irregularities, because it will be more common for line segments to run across inlets and bays. This probability does depend on the depth of the interior of landmass, it was estimated by creating artificial shapes that have the same shoreline as China or Europe but equivalent interior depths. For further details about both measures and the data used, see Schropp 2012 .

Appendix D

The conclusion estimates what would have happened if Britain had not won the wars that gave it the lion's share of intercontinental trade in the eighteenth century; it also estimates what would have happened if France had won the wars and the associated trade. The estimates take the model in Allen 2009, 130-131 and the data used in Allen 2003 to calculate counterfactual scenarios. The calculations involve solving the system of linear equations in Allen's model for a reduced form that expresses the endogenous variables in terms of the exogenous ones. The counterfactuals then estimate the impact in 1800 of changes to one of the key endogenous variables—international trade per capita. For Britain, two counterfactuals were estimated: one assumed that in 1800 Britain had lost all of its trade with Asia and the West Indies; the other that Britain's trade in 1800 had been reduced to the level in 1750-51. In both scenerios I supposed that the slave trade and Britain's trade with the United States in 1800 remained unchanged. The French counterfactual assumed that France had as much total trade in 1800 as Britain did.

Abbreviations

AN Archives nationales (Paris)

BN Bibliothèque nationale (Paris)

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[1] Lewis 2001 ; McCormick 2001 ; Kennedy 2004

[2] Coupland 1995 ; Lamouroux 1995 ; Clark 2009 ; Smith 2009

[3] Headrick 1981, 3

[4] Headrick 1981, 3; Parker 1996, 5

[5] See Crosby 2004 ; Diamond 2005 for two masterful accounts of the role of disease, and much more.

[6] Diamond 2005

[7] Hemming 1970, 28-30; Hassig 2006 ; Livi-Bacci 2006 ; Headrick 2010, 108

[8] Livi-Bacci 2006

[9] Livi-Bacci 2006 .

[10] Hemming 1970, 36-45, 73, 190-191; Lockhart 1972, xiii, 10-15; Brooks 1993 ; Guilmartin 1995a ; Clodfelter 2002, 33; Hassig 2006 ; Headrick 2010, 108. The figures for the daily wages of a Castillian laborer (35.10 maravedis per day in Leon) come from the Global Price and Income History Group at gpih.ucdavis.edu ; I have assumed 250 days of work per year. In defending Cuzco, the conquistadors did have help from native allies.

[11] Headrick 1981 ; Headrick 2010

[12] For the military revolution, see the seminal work of Geoffrey Parker and the ensuing debate in Black 1991 ; Rogers 1995 ; Parker 1996 . For the importance of piercing and cutting weapons in the gunpowder technology through the sixteenth century (for lances) and beyond (pikes until the end of the seventeenth century and swords into the eighteenth century), see Gheyn 1971 ; Kist 1971 ; Hale 1985, 50-55; Parker 1996, 17-18; Lynn 1997, 180-182,383, 456-158,490-199; Frye 2011 . Including everything that makes men and equipment effective is not what most military historians would do. But it is how an economist would calculate the productivity, with the men and equipment simply being labor and capital. The non military example of desk top computers may help here. I could be writing with a 1981 desktop computer that cost me $4,800 in today's dollars, but I am far more productive with the modern equivalent, which is far more powerful and cost only $2,000. The improvements to the computer hardware, however, account for only a portion of the higher productivity. The rest comes from better ways of making use of

computers—improved programs, internet search engines, and so on—which are the civilian equivalents of tactics and organization.

[13] Irwin 1962 ; Boxer 1969, 44-62; Diffie and Winius 1977, 224-227, 243, 249-260, 287-294; Manguin 1988 ; Subrahmanyam 1993, 67-98; Guilmartin 1995b ; Subrahmanyam 1997, 109-112, 205-116, 252-268; and Birch 1875-1884, 1: 5-6, 2:101-102, three: 134-136, four: pagetwentyfour. There was opposition to the strategy of relying on forts, which was Albuquerque's. On the early history of the fortification of Malacca, Manguin corrects the account given in Irwin.

[14] Hemming 1970 ; Lockhart 1972, 22-24; Guilmartin 1995a ; Headrick 2010, 113-115.

[15] Gardiner 1956, 35-44, 62-71; Cortés, Elliott et al. 1971, 103; Hassig 2006

[16] Gardiner 1956 ; Cortés, Elliott et al. 1971 ; Lockhart 1993, 186-193; Hassig 2006, 134-135, 153-157

[17] For nuanced and intelligent formulations of this argument, see Black 1998, 60-61; Kamen 2004, 121-122

[18] Gardiner 1956, 116-128, 154-155; Hassig 2006, 83-89, 123, 148-160

[19] Hassig 2006, 83-89

[20] Diffie and Winius 1977, 256-260; Guilmartin 1995

[21]Thornton 1988 ; Kamen 2004, 121-122; Headrick 2010, 111-123, 170. In the 1570, as Kamen points out, there were only some 25,000 Spanish households in Latin America.

[22] Rogers 1995 ; Parker 1996

[23] 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

[24] The quality of Asian cutting and piercing weapons could be quite high, if we judge from the comments of western observers. See, for instance, the official history of the Jesuit mission to the east, Maffei 1590, 558, which claimed that Japanese swords and daggers could "cleave asunder Europe iron almost without losing their edge." For the Jesuit humanist Maffei, see Lach 1965, 1, part 1: 323-326.

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

[26] 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 take their place on the firing line. For volley fire in Europe and Japan, see Parker 1996, 18-19, 140-141, but also Lamers 2000, 111-115.

[27] 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."

[28] Kennedy 1987, 16-24

[29] Hoffman 2010 and Carlo Cipolla's pioneering study Cipolla 1965 .

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

[31]For 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 ; and the conclusion below.

[32] Machiavelli 1977, 247;Skinner 1978, 244-248; Hale 1985, 91-96.

[33]Elia and Ricci 1942, 1: 66. Ricci's remarks cannot simply be dismissed as an instance of the dismissive stereotyping that was common among westerners in China, because as this and other passages make clear, he admired the emperors' avoidance of war. Nor was Ricci trying to persuade readers (as some westerners did) that China would be easy to invade. For similar remarks by a European clergyman a century later, see Comentale 1983 .

[34] For Great Britain, the estimate comes from Kennedy 1987 Table 2, which shows that military expenditures reach 27 percent of GDP during the Seven Years War and 28 percent during the wars of the French Revolution and Napoleon. For France, following Mathias and O'Brien 1976 Table 5, I assume that taxes are 12 percent of GDP and that military expenditures (including paying debts run up in previous wars) equal 100 percent of tax revenues, which is the upper range of the expenditures figures for the end of the Old Regime in Marion 1914-1931, 1: 455-461. Although there are as yet no reliable GDP figures for eighteenth-century China, we can compare per capita tax rates with daily wages. Per-capita tax rates for China, Britain, and France in the 1770s will be given below, and they can be converted to days of unskilled labor at wage rates in Beijing and London in Allen, Bassino et al. 2005 and wages from Philip T.

Hoffman's Parisian database at http://gpih.ucdavis.edu/Datafilelist.htm . If the military absorbed 100 percent of the taxes in China but only 50 percent of taxes in Britain and France (an unlikely assumption that minimizes the difference between China and the European countries), then military spending relative to wages was 2.40 times higher in France than in China and 3.22 times higher in Britain.

[35] Brzoska 1995 , Table 3.

[36] Glete 1993 ; Parrott 2001b, 126-127; Landers 2003, 316-325. Although the figures are uncertain, data in Landers suggest that peak mobilization in armies under the Roman Empire ranged between between 1 and 2 percent of the population—more than in the Middle Ages. Early modern states could match that, and in some cases (Sweden, the Netherlands) exceed it.

[37]Hoffman and Norberg 1994, Table 1, p. 238; Hoffman and Rosenthal 1997, Table III.1; Tiberghien 2002 ; Bonney 2007 . The Versailles calculation compares the upper bound estimate for the costs of creating the palace and its grounds (100 million livres) to total tax revenus during the 53 years of construction.

[38] Harding 1991, 28-30; Finer 1997, 3: 1344, 1350-1356; Lynn 2000 ; Rodger 2004, 242 (the source of the quote), 257. As Finer points out, Parliament and the king generally cooperated in the eighteenth century. 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.

[39] No threat drove French King Charles VIII to invade Italy in 1494, but rather dynastic aspirations and perhaps the aspiration to use the invasion as a stepping stone for a glorious crusade. That was likely far more than his subjects wanted—or so one recent historian (Labande-Mailfert) concludes. See Mattingly 1971, 133-137; Labande-Mailfert 1975, 180-220, 527-528 for details.

[40] Louis-XIV and Sonnino 1970, 124; Machiavelli 1977, 247; Hale 1985, 22-34; Cornette 1993, 152-176; Corvisier and al 1997, 1: 383-387.

[41] Lynn 2000 ; Bell 2007, 29-35 (the source of the quotation); Monluc 1864, 13-15, 40-44; Cornette 1993, 294; Parrott 2001a, 313-317; Drevillon 2005 .

[42] Hobbes 1651, 61-62; Hale 1985, 22-24

[43] Brito and Intriligator 1985 ; Powell 1993 ; Fearon 1995 ; Jackson and Morelli 2011

[44] Jackson and Morelli 2011

[45] Anisimov 1993, 244-245

[46] Mattingly 1968, 156. For the impact of past religious strife, see Fletcher and Iyigun 2010

[47] The model below is adapted from Fullerton and McAfee 1999, and ; Garfinkel and Skaperdas 2007 .

[48] For a review of the conflict literature, see Garfinkel and Skaperdas 2007 . The insightful model of Jackson and Morelli 2009 can explain complex patterns of war 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.

[49] If losers pay a penalty *d* that they can avoid by sitting out the war, then the model is identical, but with the prize raised to $P + d$ and the fixed cost *b* described below increased to $b + d$. If the penalty only applies when the ruler sits out the war and fails to defend his realm against attack, then the only difference is that the fixed cost decreases to $b - d$.

[50] Garfinkel and Skaperdas 2007 .

[51] For instance, if the tournament were repeated among successive generations of two families, then one possible equilibrium would have the king of country A letting the king of country B win without opposition in even rounds and the reverse happening in odd rounds. The result would be perpetual peace because kings would win the prize without ever mobilizing resources or fighting. Such an equilibrium would be impossible, however, with early modern prizes such as glory or victory over enemies of the faith, for to win them, rulers had to fight. It is true that those prizes had lost their importance by the nineteenth century. That opened the door to different equilibria, as we shall see in chapter 5.

[52] Mattingly 1968 ; Lynn 2000, 185-186.

[53] The account of technical change during and after the Hundred Years War is taken from Hall 1997, 115-122 . For fortifications, see Parker 1996, 9-13; Hall 1997, 159-163

[54] Alder 1997 ; Parker and al 2005, 194-198

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

[56] For examples of cannons exploding when tested, including one in Frankfurt in 1377, see Rathgen 1928, 20; Leng 2002, 304-315, 342-344. Although handguns first appeared in the fourteenth century, their numbers only begin to grow in the early fifteenth century: Hall 1997, 95-96; McLachlan 2010

[57] Lavery 1987, 56-65 (the source of the quotation); Rodger 2004, 221, 303, 344-345, 375. Copper prevents the growth of microorganisms, weeds, and barnacles, which slowed ships down.

[58] Fullerton and McAfee 1999

[59] Lucas 1993

[60] Mokyr 2002

[61] 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.

[62] See, for example, Jackson and Morelli 2009 .

[63] As Fullerton and McAfee show, that someone designing such a tournament can attain any level of Z (and hence any expected value of innovation) at lowest cost by with only two contestants.

[64] Of course if the difference between their average variable costs was too large, then the two would not go to war, because inequality (2) would fail to hold. For conscription in Sweden, see Parker 1996, 48-53

[65] For details, see Appendix A.

[66] See Appendix A for details, including what happens if we add a second stage to the game, so that one contestant can save resources for later rounds.

[67] Levy 1983 ; de Vries and van der Woude 1997, 97, 109-126; Hoffman, Rosenthal et al. 2007, 27; Dincecco 2009 ; Dincecco 2011, 51-54. The quotation is from de Vries and van der Woude, p. 111.

[68] Suppose the toll the war takes is dz_i $(0 < d < 1)$, which is proportional to the resources expended. Then the model is the same, but each ruler's cost of mobilizing resources is raised to $c_i + d$. The ratio of their costs will therefore decrease, making war more likely, while the total resources assembled will fall.

[69] Parker and al 2005, 72-75; Hoffman 2011, 42-44

[70] For Sweden and the Italian principalities, see Hanlon 1998, 7; Lynn 2000, 186

[71] Pamuk and Karaman 2010 . At issue here are the figures for total revenues collected, but the Ottomans also levied much less on a per capita basis.

[72] Huang 1970 ; Huang 1998 ; Brandt, Ma et al. 2011 ; Sng 2011 .

[73] For nomads and threats from mounted cavalry, see chapter 3.

[74] Pryor 1988 ; Glete 1993, 114-115,139-146, 310, 501-530, 576-579, 706-712; Guilmartin 2002, 106-125. In 1695 France had 46 galleys, with a total displacement of perhaps 15 thousand tons, and 156 armed sailing ships, with a total displacement of 208 thousand tons, and its galley fleet virtually disappeared in the eighteenth century. Minor powers such as Venice did have large galley fleets.

[75] Willers 1973, 237-301

[76] 1782 ; 1785 ; Maggiorotti 1933-1939 ; Goodman 1988, 126-129; Chaloner, Farnie et al. 1989, 19-32

[77] Bruijn 1993, 59-62, 88-89; Black 1998, 107, 127

[78] Alder 1997, 39-46; Minost 2005 .

[79] Guenée 1971, 167-176, 254-257

[80] Vauban 1740 ; Ostwald 2002

[81] For an outstanding account of the technological change, see Parker 1996 and the pioneering book by Cipolla 1965 ; other sources for this paragraph include Rathgen 1928 ; Redlich 1964-1965 ; Willers 1973 ; Black 1991 ; Glete 1993 ; Rogers 1993 ; Corvisier and al 1997 ; Hall 1997 ; Lynn 1997 ; Lynn 2000 ; Parrott 2001b ; Guilmartin 2002 ; Landers 2003 ; Parker and al 2005 .

[82] For the importance of infantry firepower, see Williams 1972, xcvi-xcvii; Parker 1996, 16-17; Lynn 1997, 464-465, 489

[83] Over the period 1600-1750, labor productivity growth in agriculture—the biggest sector of preindustrial economies—never exceeded 0.5 percent per year in nine economies examined in Stephen Broadberry s.v. "Labor Productivity" Mokyr 2003, 3: 250-253, and it was usually much less or even negative. According to the same source, at the outset of the Industrial Revolution (1760-1800), output per worker in Britain as a whole increased only 0.2 percent per year, while output per working hour actually declined 0.2 percent per year.

[84] Chandler 1970 ; Lynn 1997, 485-489.

[85] Guilmartin 1974, 253-254; Guilmartin 1983 ; Glete 1993, 58-61, 158-159.

[86] Capital here is computed from displacement, and labor from crew sizes for the English navy, using the size of the crew for the English navy as a whole. The data are taken from Glete 1993, 186, 195, 205; Martin and Parker 1999 . F factor shares (0.496 for capital and 0.503 for labor) come from 1744 construction and crew labor costs in Boudriot and Berti 1994, 146-152. Seventeenth century data on costs

from BN Ms Colbert 62 1646-1649 fols. 388-399, 419-420 (1640-1683) yields similar factor shares (0.460 for capital and 0.540 for labor). For firepower, see Glete 1993 ; Martin and Parker 1999, 33-36; Guilmartin 2002 .

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

[88] For the assumptions, evidence in support of them, and reasons why the productivity figures are not likely to be statistical flukes, see appendix B and Hoffman 2011 .

[89] For the rapid initial rate of productivity growth due to learning by doing, see Lucas 1993

[90] Hoffman 2011, Table 4. The evidence comes from a regression of the relative price of the early handguns on the cost of the factors of production; the underlying data come from Rathgen 1928, 68-74.

[91] O'Brien and Hunt 1993 ; Rodger 2004, 209, 221, 344-345, 374-375, 424-425; O'Brien 2008 ; O'Brien and Duran 2010

[92] Benjamin and Tifrea 2007, 981-984.

[93] Field 2010

[94] La Noue 1587, 315-322, 352-357; Williams 1972, xcii, c-civ; Lynn 1997, 14-16, 440-443 (similar practices in seventeenth-century French armies); Parrott 2001a, 42-43; Kamen 2004, 163-164

[95] Even in the eighteenth century, the mortality rate aboard ships sailing from the Netherlands to Southeast Asia was over fifteen times what it was for adults (aged 15-59) in late seventeenth-century Breslau. It was much higher too than the mortality rates in other life tables that fit early modern Europe: Riley 1981 .

[96] Cortés, Elliott et al. 1971, li-lii. For the small number of Europeans in Latin America and Asia, see Subrahmanyam 1993, 217-224; Kamen 2004, 42-44, 95-96

[97] Gongora's study of the founders of Panama finds that perhaps half had military background, but he adopts an extremely broad definition of military: Gongora 1962, 79-82; Lockhart 1972, 20-22, 37-39; Grunberg 1993 ; Grunberg 1994 .

[98] Gardiner 1956, 95-100; Díaz del Castillo 1963, 15-43, 57-84 (his experience fighting before the conquest of the Aztec Empire); Lockhart 1993, 20-23; Grunberg 1994 ; Guilmartin 1995b ; Guilmartin 1995a . For an example of discipline on the battlefield—one among many--see Díaz del Castillo 1963, 148-149

[99] Lockhart 1972, 20-23; Grunberg 1994 ; Guilmartin 1995b ; Guilmartin 1995a ; Kamen 2004, 7, 15-17, 23-28, 163-166. Laws in a 1640 compilation of Spain's laws did not prohibit the of weapons, save those

that could be concealed or in cases where they owner was Muslim or a recent convert to Christianity. Laws from the reigns of Ferdinand and Isabella also obliged subjects to arm themselves with cutting weapons and practice the use of artillery: Spain [Laws 1640, 1: 319; 312: 121-124, 292-293, 352-353; 313: 313-314

[100] If European armies recruited 1 percent of the population (a low figure, at least in wartime), and male adults were 30 percent of the population, then then there would be only a 0.3 percent chance of getting no veterans in a groups of 167 men chosen at random.

[101] Jourdan, Isambert et al. 1966, 10: 805-808; 811: 170-171; 812: 377-378, 910-912; 813: 866-867; 819:222; 827: 410-412; Willers 1973, 27-28; Bercé 1976, 105-111; Goubert 1986, 41-42; dewald 1987, 26; Baulant, Schuurman et al. 1988 ; Malcolm 1992 ; Malcolm 1993 ; Malcolm 2002 . The French legislation did prohibit students and journeymen from bearing arms (1478) and barred non nobles from carrying swords and crossbows (1487); it also banned firearms in general (1546, 1548, 1679), but it excepted nobles, soldiers, urban militia, and people living near borders.

[102] Diffie and Winius 1977, 185-187, 198, 220-223, 301; Glete 1993, 108-109; Subrahmanyam 1993, 47-51, 67-73, 97-98; Guilmartin 1995b ; Subrahmanyam 1997 ; Guilmartin 2002, 77-83; Guilmartin 2007 ; Disney 2010

[103] Redlich 1964-1965 ; Hanlon 1998 ; Hillmann and Gathmann 2008 ; Parrott 2012 . To get a sense of how abundant the supply was, there were (according to Redlich) some 400 military entrepreneurs active in Germany at the peak of the 30 Years War.

[104] Díaz del Castillo 1963, 15-17, 27, 44-50; Bethell 1984-2008, 176-178; Kamen 2004, 95-106

[105] Boxer 1965, 86-105, 187-220; Boxer 1969, 106-115; Chaudhuri 1982 ; Neal 1990 ; Subrahmanyam 1993, 144-147, 169; Gelderblom, de Jong et al. 2010 As Neal shows, the returns on the British and Dutch East India Companies' shares testify to the close link between their commercial and military goals: both companies profited, for instance, when the French were defeated in the Seven Years War.

[106] Glete 1993, 179-180; O'Brien 1998 ; Rodger 2004

[107] Brown 1948 ; Parker 1996, 140, 230-231

[108] The Japanese still had a long way to go to join the front ranks of the gunpowder technology. Their artillery production was limited, they had trouble putting artillery on ships, and they had yet to improve

their fortifications to bring them up to European standards: Brown 1948 ; Lamers 2000, 155-156, 166; Swope 2005 and Philip Brown (personal communication).

[109] Hucker 1974 ; Chan 1988 ; Dreyer 2007 . For China's strategic use of trade, see Lee and Temin forthcoming . There were other reasons not to spend on a seagoing navy as well. A seagoing navy was not needed to protect the Ming capital—Beijing, after 1421—and fortresses and watch towers could deal with coastal pirates.

[110] Needham 1954, v. 5, part 7: 398-407; Franke 1974 ; Atwell 1988 ; Lorge 2005 ; Perdue 2005 .

[111] McNeill 1964 ; Esper 1969 ; Hellie 1971 ; Parry and Yapp 1975 ; Guilmartin 1988 ; Pryor 1988 ; Glete 1993, 114-115, 139-146, 310, 706-712; Lynn 1997, 528-529; Gommans and Kolff 2001 ; Guilmartin 2002, 106-125; Gommans 2003 ; Paul 2004 ; Agoston 2005, 191, 202-203, and chapter 2.

[112] Brown 1948 ; Smith 1958 ; Reischauer, Fairbank et al. 1960, 1:614-615; Berry 1982, 207-217; Berry 1986 ; Hall and McClain 1991, 75-76, 277-279; Brown 1993 ; Parker 1996, 140-143; Lamers 2000, 155-156, 166; Guilmartin 2002, 182-190; Chase 2003, 175-196; Berry 2005 ; Swope 2005 ; Lorge 2008, 68, 81-86

[113] Finer 1997, 3: 1088.

[114] Hellie 1971 ; Pintner 1984

[115] 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.

[116] Stein 1984 ; Washbrook 1988 ; Alam and Subrahmanyam 1994 ; Barua 1994 .

[117] Subrahmanyam 1989 ; Roy 2011b, 72-73, 167

[118] Gommans 2003

[119] Marshall 1987, 45, 80-90, 115-123; Alavi 1995 ; Gommans and Kolff 2001 ; Cooper 2003 ; Gommans 2003 ; Roy 2010 ; Roy 2011b . One other advantage the East India Company came from late eighteenth-century legislation that made the Company a credible ally for powers in India: Oak and Swamy 2012

[120] Hoffman 2011 .

[121] Roy 2011b, 77, 95-130, 168-169

[122] For the difficulty finding data on factor costs and relative prices for military goods elsewhere in Eurasia, see Hoffman 2011

[123] Parker 1996, 18-19, 140-143; Chase 2003, 175-196; Berry 2005 .

[124] Smith 1958

[125] The Japanese attachment to martial values was apparent to European observers. The Portuguese admired the Japanese samurai, and the sixteenth-century history that Jesuits commissioned of their mission to Asia said of Japan "it is to arms—truly above all else—that the Japanese are devoted" Maffei 1590, 558; Diffie and Winius 1977, 395-396. For Maffei, see Lach 1965, 1:323-326

[126] For the source of the story (Noel Perrin's Giving up the Gun) and a review that sets the facts straight, see Totman 1980 .

[127] Guignes 1808, 20; Needham 1954, v. 4 part 3, v. 5 parts 6 and 7; Franke 1974, 188-192; Hall 1997, 42-56; Lynn 1997, 456-465; De Vries 2002, 396; Guilmartin 2002, 44-61, 92-97; Chase 2003, 31-32, ; Lorge 2005, 100-107; Lorge 2008, 72-75. Artillery was used in sieges in China as early as 1359, but it may not have been effective until as late as the sixteenth century.

[128] Guignes 1808, 20-36. Guignes, a merchant and diplomat who spoke Chinese, admired other things in China, and as was typical for the Enlightenment, he backed up his observations with data. For another eighteenth century example, see Cipolla 1965, 117.

[129] Needham 1954, v. 5, part 6: 369-376.

130 Josson and Willaert 1938 ; Needham 1954, v 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.

131 Kolff 1990 ; Gommans and Kolff 2001 ; Gommans 2003 ; Roy 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; Parthasarathi 2011, 206-213; Roy 2011b

[132] For an overview of the relevant trade literature here, see Helpman 1999

[133] Levy 1983 ; 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).

[134] Cipolla 1965 ; Hellie 1971 ; Levy 1983 ; Pintner 1984 ; Anisimov 1993 ; Kotilaine 2002 ; Paul 2004 Russia did develop an arms industry during the seventeenth and eighteenth centuries, but arms 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).

[135] For the use of gunpowder technology in Russia's expansion, see Black 1998, 70; Hellie 2002 ; Witzenrath 2007 ; Perdue 2009, 90; Stanziani 2012, 27-28, 110-116

[136] Do Couto 1673, 67-84; Irwin 1962 ; Manguin 1988 ; Parker 1996, 122

[137] Diffie and Winius 1977, 298-299; Parker 1996, 122-123, 131, 227

[138] Subrahmanyam 1993, 133-136

[139] Maggiorotti 1933-1939, 3: 273-275; Irwin 1962 ; Hanlon 1998, 73-74, 90-92, 227. After 1580, Portugal was ruled by the kings of Spain, and Cairato was a Spanish subject.

[140] Hoffman 1980 ; Bethell 1984-2008 ; Kamen 2004, 258-263; Parker and al 2005, 146-147

[141] Shepherd 1993, 57, 91; Wills 1998

[142] Chaudhuri 1982 ; Disney 2009, 2: 146-147, 168-170; Coclanis 2010

[143] Minor powers such as Venice did have large galley fleets, but for even for the major power with the largest number of galleys—France—the galley fleet was dwarfed in size by the regular sailing navy.

[144] Guenée 1971, 167-180, 254-257; 1977-, sv "Steuer, Steuerwesen"; Collins 1991, 154

[145] For additional ways in which history influences outcomes, see Greif 2006 and David 1994 for path dependence and the way it allows history to affect institutions.

[146] Imperial China did change in size, particularly when it expanded during the Qing dynasty (1644-1912).

[147]Alesina and Spolaore 2003 , especially p. 106. The precise dimensions of such a state would presumably depend on military technology and on the costs of transportation. It might be small when transport costs were high and defense fortifications were effective, as in medieval Europe, and large in defense against nomads. But military technology and transportation costs are themselves affected by state size. A large state is more likely to abut areas vulnerable to attacking nomads, and it can cut transport costs over a wide area by assuring security. Cf. Dudley 1991 .

[148] Qing dynasty China measured some 14.7 million square kilometers in 1790, according to Turchin, Adams et al. 2006 ; France, the biggest country in western Europe, only 0.5 million in the late eighteenth century. The comparison leaves aside colonies, which would have made the Spanish Empire even bigger than Qing China. China's dimensions under the Ming dynasty were smaller—the Chinese empire

measured some 6.5 million square kilometers in 1450—but even so it was still orders of magnitude larger than any contemporary European realm. So were the Ottoman and Mughal Empires.

[149] In a era of high transportation costs, it was easier to monitor delegates in a smaller state and therefore easier for smaller states to have representative institutions. In early modern Europe, states with representative institutions could raise more tax revenue per capita, even if we take into account differences in wages, urbanization, and the cost of fighting wars. See Hoffman and Norberg 1994 ; Dincecco 2009 ; Stasavage 2010 ; Dincecco 2011 ; Stasavage 2011

150. Kennedy 1987, 16-23; Cosandey 1997 ; Lang 1997 ; Diamond 2005, 454-456, 496.

151. Rainfall and river systems may have also played a role. Lang 1997 notes that irrigation and water control favored large state in China. The argument is essentially that a large state can take advantage of economies of scale and internalize externalities in providing the water control infrastructure. But Lang also observes that this advantage cannot be the ultimate explanation for China's unity, because the infrastructure was locally developed and locally maintained in much of China.

152. Yang 2011 . The historian John K. Fairbank reached a similar conclusion (Fairbank 1974, 3) as did the political scientist Hui 2005 in her comparison of warfare and politics during the initial unification of China and the early modern military revolution in Europe.

[153] Yang 2011

154. A measure that Cosandey devised points in the same direction: Cosandey 1997, 299-307. For an explanation of his measure and the merits of the measures used in Table 4.2, see appendix C

155. See, for example, Hucker 1974, 275-276; Deng 1997, 4-8.

156. Coupland 1995 ; Kennedy 1995 ; Rodger 2004, lxv

[157] Lang 1997

[158] Barfield 1989 ; Turchin 2009

[159] For the technological changes, I am indebted to Headrick 2010, 12-25, and, for the comparisons with Asian ships, I have drawn upon Needham 1954, v. 4, part 3: 508-514; Reischauer, Fairbank et al. 1960, 2: 13-14.

[160] Disney 2009, 2, 27-43; Headrick 2010, 20-21.

[161] Bartlett 1993, 39-43

162. The simplest model would be a two stage game, in which victory allowed the winner in the first stage to gain the prize a second time without opposition by killing off the loser in the first stage. For such a model, see Appendix A.

[163] Hui 2005 ; Anton 2006 ; Eisner 2011 ; Blaydes and Chaney 2013

164. Results are similar if one excludes colonial wars or if the variables are recoded by a secondary school student. One might worry about the endogeneity of losing a war and the interaction terms involving it, but an instrumental variables estimate (with the start and end date of the wars, and designation as a great power by Levy as instruments) leads to the same conclusion.

[165] For an insightful analysis of these limits and their interaction with military technology, see Dudley 1991 . Unfortunately, the technologies he singles out cannot explain the differences between western Europe and China, because they were in use in both. Furthermore, Dudley may exaggerate the role heavy cavalry played in fragmenting medieval Europe, at least according the research of Bernard Bachrach; see Parker and al 2005 .

[166] The account here is drawn primarily from Geary 1988, especially pp. 43-80, 112-113, 226-231, and from Bartlett 1993, 45-47; van Dam 2005 ; Wormald 2005 .

[167] Fouracre 1995, 99-100.

[168] Bartlett 1993, 39, 45-51, 60-84; De Charnay and Kaeuper 2005, 22, 34-35, 40-41, 47-50

[169] Medieval princes did eventually collect revenue from tolls, coinage, and the exercise of justice, and they might also get exceptional contributions to fund war. But they did not have permanent excise or property taxes.

[170] De Charnay and Kaeuper 2005, 70

[171] Bartlett 1993, 39-43, 48-51, 85-105, 243-260. The story about the carrier pigeons is from Bartlett 86-87 and Malaterra 2007, 2:41-42.

[172] Bartlett 1993, 85-90; Malaterra 2007, 1:9

[173] Tacitus 1970, 12:11 which speaks of punishing "transfugas...ignavos et imbelles".

[174] For a lucid overview of the experiments and the various ways economists have tried to make sense of the what happens, see Arifovic and Ledyard 2012 . Their explanation for the participants' behavior, which fits the experimental data, assumes participants have utility functions that are linear in three terms: their

own payoff, the average payoff to the group, and the amount by which their payoff is less than the average payoff to the group, which captures the participants' disutility (anger at unfair outcomes in my words) when they feel they are being taken advantage of. The weights of the three terms are exogenous random variables. The other part of their explanation is that experimental subjects also learn by randomly trying out new strategies and evaluating old ones. With their model, cooperation can then emerge endogenously in the public goods experiments. For more on the experiments and for the role that emotions play in subjects' behavior, see Bowles and Gintis 2011 .

[175] Herrmann, Thöni et al. 2008 ; Bowles and Gintis 2011, 24-29

[176] Henrich 2004 ; Boyd and Richerson 2006 ; Bowles and Gintis 2011

[177] Henrich and Boyd 2001 ; Boyd and Richerson 2006 ; Choi and Bowles 2007 ; Lehmann and Feldman 2008 ; Mathew and Boyd 2008 ; Boyd, Gintis et al. 2010 ; Bowles and Gintis 2011 . One worry here is how punishment can started if there are only a small number of altruists in a society who will punish shirkers. But that is not a problem if the altruists can coordinate their efforts and take advantage of likely economies of scale in the provision of the public good of defense. For skeptical views about the role of punishment, see Dreber, Rand et al. 2008 ; Ohtsuki, Iwasa et al. 2009 ; Rand, dreber et al. 2009 .

[178] Geary 1988, especially p. 74.; Fouracre 1995

[179] Tacitus 1970, 12.; Geary 1988, 52-57

[180] McCormick 2001, 732-733

[181] Soltis, Boyd et al. 1995 ; Boyd and Richerson 2006, 209-210

[182] Barth 1956 ; Lindholm 1981 ; Gray, Sundal et al. 2003 ; Fratkin 2006 ; Beckerman, Erickson et al. 2009 ; Mathew and Boyd 2011 .

[183] Mathew and Boyd 2011 ; see also Gray, Sundal et al. 2003 ; Fratkin 2006 .

[184] Military values were held dear in both India and Japan; as the sixteenth-century Jesuit history of missionary activity in Japan remarked, "It is to arms--truly above all else--that the Japanese are devoted" (Armis vero apprime dedita gens est): Maffei 1590, 558; Gommans 2003, chapter 2

[185] For the costs imposed by early modern war, see chapter 6.

[186] Elia and Ricci 1942, 1: 50, 66-70, 168. For other early modern observers from the West who remarked on how rare it was to see weapons in China, see Boxer 1953, 146, 271. Ricci's admiring observations

were—to repeat—in no way instances of the sort of stereotyping that was common among early westerner visitors to China. In particular, unlike some westerners, he was not trying to persuade readers that China would be easy to invade. For the rare criticisms of this sort in sixteenth century Europe itself, see Dewald 1996, 35.

[187] Perdue 2005, 203, 239, 284-299, 530-531; Waley-Cohen 2006

[188] Hsiao 1979, 9-21, 148-153

[189] Fairbank 1974, 2-9

[190] Elvin 1973, 21, 69, 83; Gernet 1987 ; Hui 2005 ; Michalopoulos 2008, (for ethnolinguistic diversity). As Michelopoulos shows, in China adjacent regions with the same soil quality and elevation are 89 percent similar ethnically, far more than the 71 percent one would expect.

[191] Fukayama 2011, 149

[192] Strayer 1971, 321-328; Gernet 1987 ; Downing 1993, 34-35; Lewis 2001, 178; Fukayama 2011, 167, 263-267, 280

[193] Turchin 2009

[194] Henneman 1976 . The tax figures are from p. 263, and are sums actually collected. The difference, as Henneman shows, was not due to currency manipulation.

[195] Carsten 1954, 189-201, 266-276

[196]For this and the previous paragraph, see Brewer 1989 ; O'Brien and Hunt 1993 ; Hoffman and Norberg 1994 ; Hoffman and Rosenthal 2002 ; O'Brien 2008 ; Cox 2009 ; Dincecco 2009 ; Pincus 2009 ; Dincecco 2011 ; Cox 2012 ; Pincus 2012 ; Pincus and Robinson 2012

[197] For India, see chapter 3 and Cohn 1960 ; Cohn 1961 ; Stein 1984 ; Marshall 1987, 45-145; Washbrook 1988 ; Subrahmanyam 1989 ; Alam and Subrahmanyam 1994 ; Gommans 2003, chapter 3 and 4; Vaughn 2009, 396-573; Fukayama 2011 ; Parthasarathi 2011, 56-57; Roy 2011b, 20, 39-40, 72-73, 167; Swamy 2011 ; O'Brien 2012 . For Europe, see Guenée 1971, 148-150

[198] Machiavelli 1977, 129; Fukayama 2011, 214-215

[199] Sahin 2005 ; Pamuk 2012

[200] Pamuk 2008 ; Fukayama 2011, 192, 214-218, 223-228; Blaydes and Chaney forthcoming

[201] Tilly 1990

[202] Karaman and Pamuk 2011 . The major econometric issue in the paper for Karaman and Pamuk is the endogeneity of their explanatory variables, but they make a persuasive case for instrumental variable estimates that lead to the same conclusions.

[203] Dincecco 2009 ; Dincecco 2011

[204] Mallett 1974, 36-38, 196-197; Parrott 2012 . For early development of the city states' fiscal systems, see Guenée 1971, 168-180

[205] Redlich 1964-1965 ; Parker 1996, 64-67; Hanlon 1998, 241-260; Parrott 2012

[206] André 1942 ; Corvisier 1983 ; Lynn 1997 ; Parrott 2012, 122, 264-306. As Parrott points, the French deemphasized mercenaries and private suppliers before the other major powers in Europe, because it was associated with the anarchy of the Wars of Religion. But even the French did not abandon them completely.

[207] Rodger 2004 ; Benjamin and Thornberg 2007 ; Benjamin and Tifrea 2007 ; Benjamin 2009

[208] Brauer and van Tuyll 2008, 117-118

[209] The cannon founder, Jean Maritz, left an estate of 1.4 million *livres* when he died near Lyon in 1790 after having given his two daughters dowries of 125 thousand *livres* each. Although rich Parisian nobles and financiers were certainly much richer than Maritz, the size of his daughters' dowries would put him in the top 1 percent of Lyon's wealth distribution, on a par with local nobles and above successful merchants. Marriage contracts are a good indicator of wealth in Lyon since 95 percent of the population had one. In the 1780s, only 1.1 percent of the marriage contracts (89 of 8021 contracts in the *enregistrement*) had dowries over 100 thousand livres. Garden 1970, 213, 357-358, 737; Minost 2005, 264

[210] Rodger 2004, 172

[211] Cortés, Elliott et al. 1971, L; Diffie and Winius 1977, 196-198; Wey Gomez 2008 ; Disney 2009, 2: 1-2, 17

[212] Cortés, Elliott et al. 1971, xxv, 40-46; Lockhart 1972, 13; Grunberg 1993 ; Kamen 2004, 82-89, 98,109-110, 285-286. On war funding, see also Drelichman and Voth forthcoming .

[213] Diamond and Keegan 1984 ; Keegan and diamond 1987

[214] Williams 2000, 201-207, 222-223; Rodger 2004, 238-239, 260-261

[215] Boxer 1965, 86-87; Boxer 1969, 106-115; Chaudhuri 1982 ; Findlay and O'Rourke 2007, 230-256

[216] Boxer 1965, 201-206; Marshall 1987, 75-106, 135; Vaughn 2009, 396-573

[217] Disney 2009

[218] For the conquistadors, see Bethell 1984-2008, 176-188

[219] Berry 1982, 133-134; Hall and McClain 1991, 50-51, 66-67, 195-198, 261-262; Toby 1991, xxiii-xxv

[220] Geiss 1988, 491-505; Toby 1991, xiii-xx, 11-13; Wills 1993 ; Deng 1999, 117-138; So 2000, 126-127; Dreyer 2007, 40, 175, 184.

[221] Boxer 1953, 146; Cipolla 1965, 118; Toby 1991, 11-13; Chase 2003, 87-89, 151-154, 183, 195. By contrast, gun ownership seems to have been widespread in parts of India.

[222] Elvin 1973, 217-218; Langlois 1988, 168-169 (the source of the quote); Deng 1999, 117-118; So 2000, 126-127

[223] Berry 1982, 149-150; Hall and McClain 1991, 66-70, 198; Toby 1991, xiii-xxxviii; Ferejohn and Rosenbluth 2012

[224] In Japan, Hideyoshi disarmed peasants both to promote peace and to end popular uprisings. Since daimyo still had arms, the policy had the added advantage of preventing resistance to their local powers: Berry 1982, 102-106. Chinese emperors apparently limited access to guns both to prevent uprisings and to avoid making it evident that westerners had superior technology: Cipolla 1965, 117-118; Waley-Cohen 1993 .

[225] For privateering, see Hillmann and Gathmann 2008

[226] Kuran 2010 . The corporation itself was accident; originally, it was created by the western Church to manage long lived religious institutions at a time when western European political powers were weak. The corporation might never have arisen in western Europe, if the Church had not been politically independent or if powerful states had arisen in medieval Europe. On this important point, see Goldstone forthcoming .

[227] Subrahmanyam 1993, 64-66, 238-244; McCormick 2001, 584-587, 708-716; Freedman 2008, 140-145; Wey Gomez 2008 ; Disney 2010

[228] Chan 1988, 232-236, 275, 302-303; Gungwu 1998, 319-326; Dreyer 2007 . For the exotic goods and evidence that the emperors were unimpressed, see Dreyer, pp. 157-163, who quotes the Xuande emperor's reaction when he received the tribute after the final voyage: "We do not have any desire for goods from distant regions, but we realize that they [are offered] in full sincerity." The emperor's blasé reaction to the

exotic goods may of course simply have been reflected the attitude that the Son of Heaven was supposed show when presented with objects from abroad.

[229] Chaunu 1951 ; Diamond and Keegan 1984 ; Keegan and diamond 1987 ; Headrick 2010, 39-41

[230] Roy 2011b, 93, 105, 128-130, 170

[231] Brown 1948 ; Hall and McClain 1991, 277-279; Lamers 2000, 155-156, 166; Swope 2005 ; Lorge 2008, 68, 81-86

[232] For examples, see Needham 1954, 4, pt. 3: 487, 503, 533; McNeill 1984, 42-48. See also the excellent discussion in Morris 2010 .

[233] For this and the following paragraph, see Di Cosmo 1999 ; Ai 2009 ; Davis 2009b ; Davis 2009a ; Jing-shen 2009 .

[234] Suppose that the Southern Sung had gained an amount of additional trade equal to total British intercontinental trade in 1800 and that their population was only 75 million. (The population would likely have been much larger than that, but a low population magnifies the effect of trade.) Even in this optimistic scenario, wages would have only risen by 1 percent, according to the model that Robert Allen estimated using European evidence: Allen 2003 ; Allen 2009, 130-131. That would not have been enough to have stimulated mechanization.

[235] Wong and Rosenthal 2011

[236] The result might of course have been different still. Without the Mongols, the plague might not have reached western Europe. Britain would then had no new draperies and perhaps even no Industrial Revolution either.

[237] See Schroeder 1994, vii-ix, 391-395, 574-581, 799-803 and the discussion of Table 5.3 below.

[238] Headrick 2010 .

[239] Schroeder 1994, ix, 578-581, 799-803; Bell 2007, 232, 237, 307-309

[240] Dincecco 2009 ; Dincecco 2011 .

[241] Mokyr 2002 .

[242] Average labor productivity growth in the American economy as a whole was 2.14 percent per year between 1959 and 2006: Jorgenson, Ho et al. 2008, Table 1

[243] Stevenson 2005, 149

[244] Showalter 1976, 76-96, 105-113, 121-130; Dupuy 1985, 8-10; Clodfelter 2002, 205-207

[245] Baxter 1933, 69-70; Clodfelter 2002, 200

[246] Headrick 2010, 170, 177, 199-206, 257-292. The Spanish, for example, found late eighteenth-century firearms useless against the Comanches who raided the northern reaches of their American empire: Hämäläinen 2008

[247] Schroeder 1994, vii-ix, 391-395, 578-581, 799-803; Bell 2007, 57-80, 212-217, 232-250, 307-309.

[248] Findlay and O'Rourke 2007, 388-402; Solar forthcoming .

[249] For England and France, which were major colonial powers, the years per century that they spent fighting dropped by much less after 1815 (by 37 and 45 percent respectively) if we take into account colonial wars. Without colonial wars, the respect declines were 77 and 75 percent, which is close to the average in Table 5.3. As for the time spent fighting civil wars and disturbances, it did not increase dramatically in the years 1816-1913, at least according to the sources used to construct Table 5.3, but it remained important.

[250] The extension to the model here is adapted from Garfinkel and Skaperdas 2007 , which contains more realistic variations; see also McBride and Skaperdas 2007 . For the technical details, see appendix A.

[251] Dincecco 2009 ; Dincecco 2011 .

[252] Eloranta 2007

[253] For useful knowledge and the Enlightenment, see Mokyr 2002 ; Mokyr 2005 .

[254] Baxter 1933, 11-16; Lavery 1983-1984, 1: 155; Glete 1993, 443-455; Gardner 1995 ; Corvisier and al 1997, 2: 490-492. The results of the Crimean War (1853-1856) did play a role in winning over the final skeptics.

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

[256] For the technical details, see appendix A.

[257] Corvisier and al 1997, 2: 428.

[258] Eloranta 2007 .

[259] Suppose, for instance, that successive pairs of political leaders are in a repeated tournament, that the equilibrium for each round is an armed peace, that their research spending yields a best innovation *w,* and that it also shifts the support of the distribution *F(x)* from which the leaders in next round draw their

innovations *x* to *[w, w + a]*. If the same process continues under successive pairs of leaders, then the armed peace will continue, and the rate of technical change per round will be *E(x)*, the expected value of *x* after one round.

[260] Baxter 1933 ; van Creveld 1989, 223; Corvisier and al 1997 ; Eloranta 2007

[261] van Creveld 1989, 220-221.

[262] Goodman 1988 .

[263] See chapter 2.

[264] Blane 1785 ; Rodger 2004, 281, 307-308, 399-400.

[265] Ames and Rosenberg 1968 ; Smith 1977

[266] Showalter 1976 ; Köhne-Lindenlaub 1982 ; Corvisier and al 1997, 2:498; Mokyr 2003, John Singleton, sv "Arm Industry," 1: 159-167

[267] Trebilcock 1973

[268] Baxter 1933, 98-133, 165-181.

[269] With large markets made possible by transport improvements such as the Erie Canal, nineteenth-century America is a prime example: Sokoloff 1988 ; Romer 1990 ; Romer 1996 .

[270] 1911, sv "Armour Plates," 2: 578-582; Trebilcock 1973 ; Mokyr 2003, John Singleton, sv "Arms Industry," 1: 159-167.

[271] Baxter 1933, 4, 17-21, 69-70.

[272] Baxter 1933, 4, 40, 60-64, 92-133Baxter, 4, 40, 60-64, 92-133.

[273] Showalter 1976 ; van Creveld 1989, 220-221; Corvisier and al 1997, 2: 497-498.

[274] Showalter 1976, 76, 95-96, 105-130

[275] Kennedy 1987, 195-197, 211; Schroeder 1994, 18, 574-575; Engerman 2006 .

[276] Headrick 1981 ; Headrick 2010, 111-123, 170-187, 196-228, 250-292.

[277] Clodfelter 2002, 248, 252-253; Headrick 2010, 158-162, 216, 308-309.

[278] Broadberry and O'Rourke 2010, 2: 136 (Table 136.132).

[279] Allen, Bassino et al. 2011

[280] Here I disagree with Stanziani 2012

[281] Hanson 2002

[282] Birch 1875-1884, 3: 169-187, 258; Díaz del Castillo 1963 ; Stern 1992 ; Grunberg 1993 ; Lockhart 1993 ; Grunberg 1994 ; Subrahmanyam 1997 ; Disney 2010 . The Aztecs clearly adapted their tactics in fighting the conquistadores, and the Incas fought to kill. And those are hardly the only counterexamples to Hanson's argument.

[283] For an instance in which westerners hired the Japanese as mercanries in 1595, see Reischauer, Fairbank et al. 1960, 2:26. Western admiration of the Japanese devotion to war appears in Francis Xavier's letters and in the Jesuits' sixteenth-century history of their mission in Asia Maffei 1590, 558; Lach 1965, v. 1 part 2: 664, 669.

[284] Kuran 2010

[285] Gutmann 1980 ; Hoffman 1996, 185-186; Lynn 1997, 415-434; Engerman 2005 ; Solar forthcoming

[286] Davis and Huttenback 1986 .

[287] Hochschild 1999 ; Nunn 2008 ; Dell 2010 .

[288] Engerman and Sokoloff 1994 ; Acemoglu, Johnson et al. 2001 ; Acemoglu, Johnson et al. 2002 ; Acemoglu and Robinson 2006 ; Glaeser, Ponzetto et al. 2007 ; Austin 2008 ; Acemoglu and Robinson 2012 ; Easterly and Levine 2012

[289] Allen 2003 ; O'Brien 2006 ; Findlay and O'Rourke 2007, 308-310, 339-345, 350-352; O'Brien 2008 ; Allen 2009 ; O'Brien 2010 .

[290] Military spending reached 27 percent of GDP in the Seven Years War and 28 percent of GDP in the Napoleonic Wars: Mathias and O'Brien 1976 ; Kennedy 1987, Table 2. The data on inventors come from taking the list in Allen 2009, Appendix A and looking the 79 inventors up in the Dictionnary of National Biography and Wikipedia.

[291] Rosenthal and Wong 2011

[292] For details about all the calculations here see appendix D.

[293] O'Brien 2006

[294] North and Weingast 1989 ; Cox 2009 ; Dincecco 2009 ; Dincecco 2011 ; Cox 2012 ; Pincus and Robinson 2012 . That war is not an ultimate cause would fit the econometric evidence in Acemoglu, Johnson et al. 2005 , who find that in Europe intercontinental trade boosted urbanization, their proxy for

economic growth. It did so both directly and by bringing about institutional change. War, however, had no direct effect once trade and institutions were taken into account.

[295] For an example of the sort of cultural causation I would argue against, see Landes 1999

[296] The extension to the model here is adapted from Garfinkel and Skaperdas 2007 which contains more realistic variants than the one presented here.

[297] The expression on the left of the equality sign is just:

$$ln\ (p/(w_0\hat{}s_0)*\ (w_1\hat{}s_1)*...*\ (w_n\hat{}s_n))$$

where $s_0 = s_1 + ... + s_n$ is the factor share of labor and the factor shares s_i (for $i > 1$) are positive numbers whose sum is less than 1. For the other assumptions involved see Hoffman 2006 .

[298] See Hoffman 2006 for details.